ANDROID / ROBOTICS VOL 2

1 million+ moves: China firm drops world's largest humanoid robot training dataset

Chinese robotics player AgiBot has unveiled by far the largest humanoid manipulation dataset, aiming to advance AI robot training. Named the AgiBot World Alpha, the model features 1 million plus trajectories from 100 robots, spanning 100+ scenarios across five domains to tackle manipulation, tool use, and collaboration.

The ecosystem offers a dataset, foundational models, standardized benchmarks, and a collaborative framework to democratize access to quality robotic data.

The dataset is freely available to AI humanoid developers.

“It provides an unprecedented opportunity for both academia and industry to collaborate, paving the way for the “ImageNet Moment” in Embodied AI—a transformative leap toward universal, adaptable robotic intelligence,” reads a statement by Agibot.

Earlier in December, Agibot announced that it has started mass-producing humanoid robots for general use, while its US counterparts, like Tesla, are aiming for such a feat in 2026.

Dataset boosts humanoids

Robot training, particularly for emerging humanoids in diverse environments, requires extensive, high-quality data. Addressing this need, AgiBot has launched AgiBot World, a large-scale robotic learning dataset designed to advance multipurpose robotic policies.

The ecosystem includes foundational models, standardized benchmarks, and a collaborative framework aimed at democratizing access to premium robotic data. AgiBot envisions fostering collaboration between academia and industry to drive progress toward universal, adaptable robotic intelligence.

Existing robotic learning benchmarks often face limitations, such as low-quality data and restricted sensing, which confine them to short-term tasks in controlled settings. These shortcomings hinder the development of robust systems capable of functioning in unstructured, dynamic real-world environments.

The model offers diversity and usability assurance through strategic collection.

AgiBot World overcomes these challenges by offering more than 1 million trajectories from 100 robots, spanning 100+ real-world scenarios across five domains. These scenarios address complex tasks like fine-grained manipulation, tool usage, and multi-robot collaboration, reflecting the nuanced demands of real-world applications.

The platform also features advanced multimodal hardware, including array-based visual tactile sensors, durable six-degree-of-freedom (DoF) robotic hands, and mobile dual-arm robots with whole-body control. These tools enable groundbreaking research in multimodal imitation learning, adaptive manipulation, and multi-agent collaboration.

AgiBot aims to transform large-scale robot learning and advance scalable robotic systems for production. By making AgiBot World open-source, the company invites researchers and practitioners to shape the future of embodied AI collaboratively.

Chinese robots lead

Founded in February 2023, AgiBot specializes in advanced embodied AI, robotics, and innovative ecosystems.

Its flagship humanoid robot, the Yuanzheng A2, stands 175 cm tall, weighs 121 pounds (55 kilograms), and is equipped with cutting-edge AI-powered sensors. Designed for precision, the A2 processes text, audio, and visual data enabling tasks like threading a needle.

In August 2023, AgiBot launched its first humanoid robot, the Raise A1, catering to industries like automotive, 3C manufacturing, and logistics. By December 2023, the company had completed five funding rounds, securing significant investments from Hillhouse Capital and BYD.

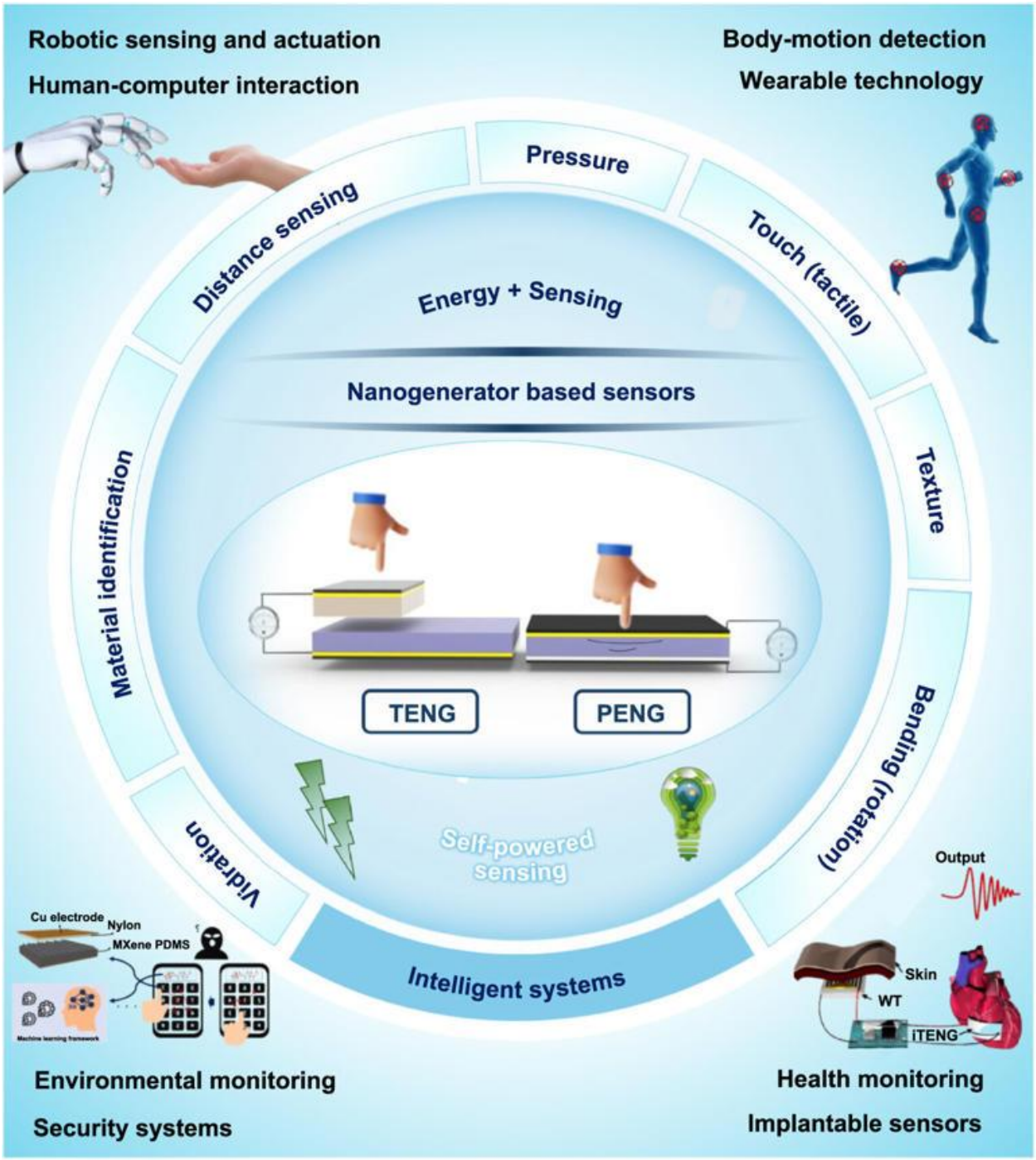
AgiBot also offers the A2 Max, a more robust version, and service robot-inspired models such as the A2-W, X1, and X1-W. Competing with Tesla's Optimus, the company is positioning itself as a leader in humanoid robotics, aiming to challenge Tesla in the rapidly growing market.

Revealing its plans for mass production, the firm said that it will churn out 1,000 humanoid robots by the end of 2024, demonstrating its growing capabilities in the robotics field. This blend of human-robot collaboration and data-driven training aims to improve the functionality and adaptability of its robots for a range of domestic and industrial tasks.

Experts say Chinese robotics companies are leading in mass production, outpacing Tesla, while advancing alongside US firms in humanoid robotics. US tech giants like Tesla and NVIDIA excel in upper limb manipulation, chip manufacturing, and cloud computing, while Chinese companies lead in motion control, AI models, and diverse applications.

In late 2023, China's Fourier Intelligence became the first major humanoid robot company to begin mass production, delivering over 100 units of its GR-1 bipedal humanoid robot across various scenarios.

Scientists uncover advanced manufacturing strategies for piezoelectric and triboelectric tactile sensors



Schematic illustration of highly sensitive and self-powered sensing applications based on piezoelectric and triboelectric. Credit: International Journal of Extreme Manufacturing (2024). DOI: 10.1088/2631-7990/ad88be

Piezoelectric and triboelectric tactile sensors are designed to convert mechanical stimuli into electrical signals, making them critical components in intelligent systems. Piezoelectric sensors leverage voltage generation through mechanical stress in non-centrosymmetric materials, such as quartz and polyvinylidene fluoride (PVDF), while triboelectric sensors operate on contact-induced charge transfer.

Both sensor types offer unique advantages, including self-powered functionality and high sensitivity, but also face challenges, such as material brittleness and environmental limitations.

A team of researchers led by Professor Hanjun Ryu from Chung-Ang University, South Korea, has introduced novel manufacturing strategies to overcome these limitations. The team's paper is published in the *International Journal of Extreme Manufacturing*.

Prof. Ryu explains, "Our study explains the materials and device fabrication strategies for tactile sensors using piezoelectric and triboelectric effects, as well as the types of sensory recognition."

The team conducted a comprehensive review of manufacturing strategies for piezoelectric and triboelectric tactile sensors, focusing on techniques to enhance sensitivity, flexibility, and self-powering capabilities. The study examined various material properties, fabrication processes, and device designs to overcome challenges, such as brittleness in piezoelectric materials and environmental sensitivity in triboelectric sensors.

Prof. Ryu says, "These strategies aimed to enable the development of high-performance sensors for applications in robotics, wearable devices, and health care systems."

For piezoelectric sensors, the researchers highlighted the importance of increasing the piezoelectric constant through methods, such as doping, crystallinity control, and composite material integration. Notable advancements include using lead-free ceramics and polymer blends to create flexible, environmentally friendly sensors suitable for dynamic applications. The

integration of 3D printing and solvent-based crystallization techniques was also found to significantly improve the sensitivity and adaptability of these sensors.

The triboelectric sensors were enhanced through surface modification techniques, such as plasma treatments, microstructuring, and dielectric constant optimization. These strategies increased charge transfer efficiency and enabled the development of durable, high-output sensors. The researchers also demonstrated the effectiveness of hybrid materials and nanostructures in boosting triboelectric performance while maintaining flexibility and environmental resilience.

Interestingly, this study is among the first to provide a holistic overview of manufacturing strategies for both piezoelectric and triboelectric tactile sensors, emphasizing their complementary strengths. The findings reveal that a combination of innovative material engineering and advanced fabrication techniques is essential for creating sensors capable of multi-modal sensing and real-time interaction. This interdisciplinary approach promises to expand the application scope of tactile sensors across industries.

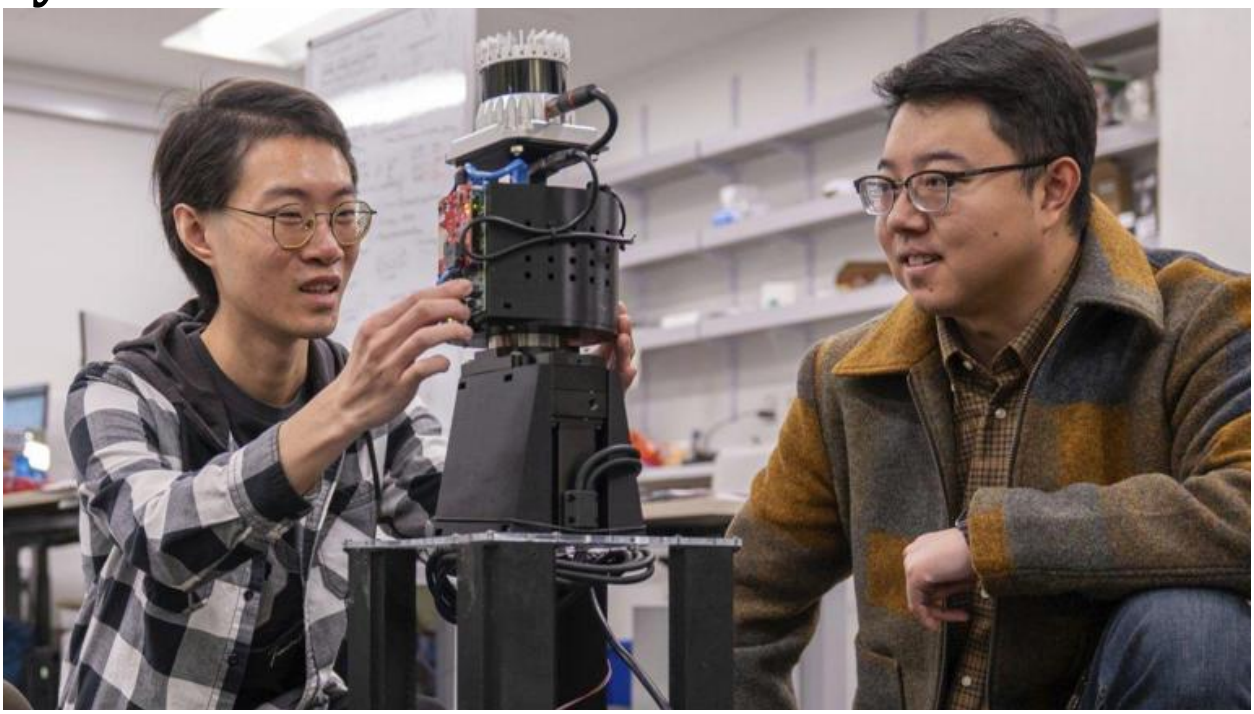
The study also underscores the potential for integrating artificial intelligence with tactile sensors for advanced data processing and multi-stimuli detection. Artificial intelligence (AI)-driven analysis of tactile inputs, such as texture and pressure recognition, can significantly enhance the accuracy and functionality of these devices. Such integrations pave the way for next-generation sensors that mimic human sensory capabilities while achieving higher operational efficiency.

Summarizing the broader implications of their work, Prof. Ryu concludes, "It is anticipated that AI-based multi-sensory sensors will make innovative contributions to such advancements in various fields."

This study sets the stage for the development of intelligent systems that seamlessly integrate with human needs, from health care monitoring to robotic interfaces. **More information:** Hyosik Park et al, Manufacturing strategies for highly sensitive and self-powered piezoelectric and triboelectric tactile sensors, *International Journal of Extreme Manufacturing* (2024). DOI: 10.1088/2631-7990/ad88be

Provided by Chung Ang University

Scientists work on 'superhuman' vision systems for robots



Prof Mingmin Zhao (right) has been working on a radio vision system for robots© Sylvia Zhang

If you want to find out whether your robot can see through smoke, well, you're going to need some smoke.

But a University of Pennsylvania student got a shock when they began setting up a late-night experiment to test such a robot.

Shortly after flicking the switch on the smoke machine, a loud fire alarm went off.

"The whole building got triggered," says Mingmin Zhao of the University of Pennsylvania, smiling. "My student called me. He was very surprised."

The incident was a minor setback for the team developing a robot equipped with a innovative radio-based sensing system.

Radio waves could allow robots or autonomous vehicles to see through thick smoke, intense rain – or even around corners. Such waves can even detect concealed weapons.

However simulating visual imagery based on radio waves is an unusual approach for robots and autonomous vehicles. Much more established in those fields are regular optical cameras, light detection and ranging (Lidar), and other sensors.

However, Prof Zhao and his students have developed a potentially powerful way for robots to see using radio waves.

Of course, radar, which uses radio waves, has been used for decades to track aircraft, ships, and the weather.

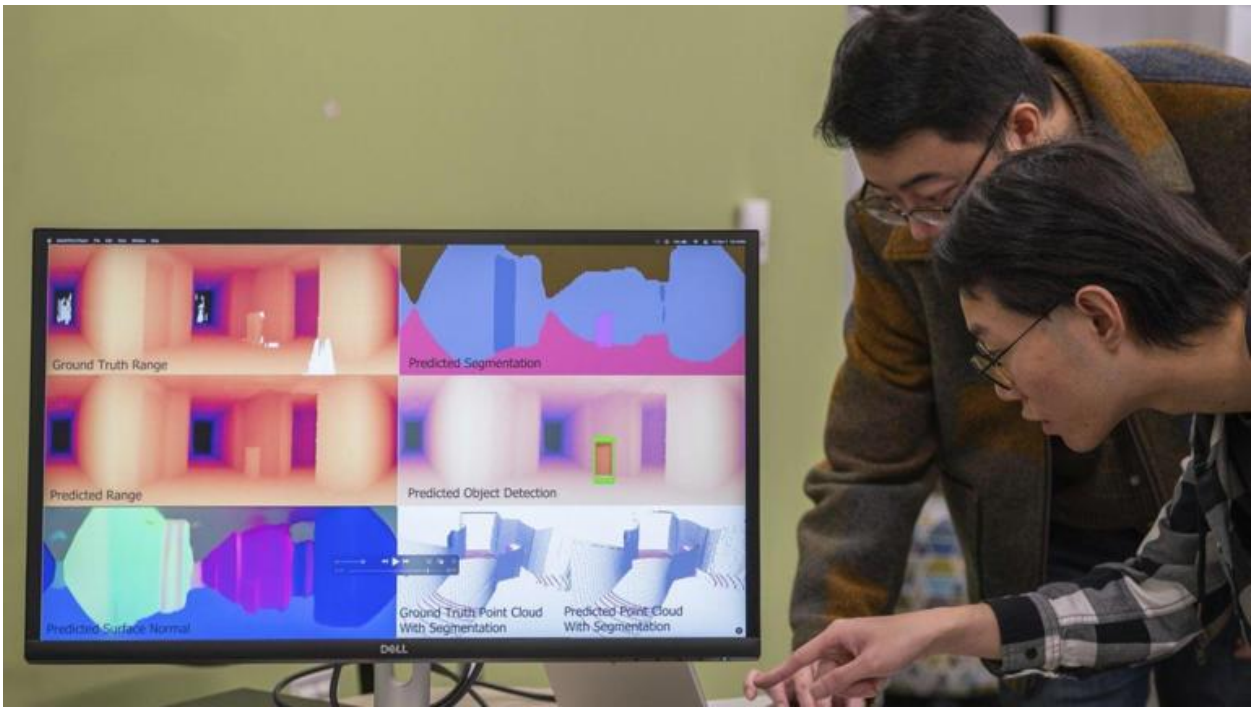
But the spinning array on Prof Zhao's robot throws radio waves in all directions.

An on-board artificial intelligence (AI) system then builds a 3D view of the environment with this information.

"What we have been trying to do here is basically help robots obtain superhuman vision – to see in scenarios where human eyes or traditional visual sensors cannot," explains Prof Zhao.

He suggests the technology could help a future search-and-rescue robot save people from a burning building.

Subsequent tests of the bot used a clear plastic box full of smoke placed around its spinning equipment, in order to avoid triggering any nearby fire alarms.



Radio waves combined with AI create a 3D picture for the robot© Sylvia Zhang

Although humans can't see them, radio waves are a form of light in the sense that they are part of the electromagnetic spectrum, which also includes X-rays and gamma rays. Only a small part of the spectrum is classed as visible light.

Being light, radio waves can reflect off surfaces and materials, though in a slightly different way to visible light. Prof Zhao and his colleagues have designed their robot so that it can sense these radio wave reflections.

The crucial factor here is that radio waves are much longer than visible light waves meaning they are not blocked by tiny smoke particles.

Prof Zhao says he has also been working on adapting the technology so that the robot can see part of the way round a corner. Think of it like a hall of mirrors, he suggests, just for radio waves rather than visible light.

"It's really very interesting work and quite impressive," says Friedemann Reinhard at the University of Rostock in Germany, who was not involved in the work. In 2017, Prof Reinhard and colleagues described how Wi-Fi signals could allow spies to see into private rooms.

One slight limitation is that the spinning array cannot, by definition, see in all directions at once. Prof Reinhard says that a lot of data processing carried out by

the system appears necessary to clean up the image that results from this spinning device.

However, the robot sends out radio waves in the millimetre wave band (waves that are between one and ten millimetres long). This is the same technology used for some 5G installations.

"That's potentially very attractive, it's a very well-understood, cheap technology," says Prof Reinhard. "I certainly would love to see a self-driving car driving only on radar."

Fabio da Silva's firm is working on a radio-based imaging system© Wavsens

But it is possible to avoid using spinning radio-emitting devices to get a full picture, says Fabio da Silva, founder and chief executive of US firm Wavsens, which is also developing radio-based sensing technology.

"We created an algorithm that allows you to sense the entire space instantaneously and continuously so we don't have to spin our antennas," he says.

He describes the system as akin to echolocation, used by bats. It sends out radio waves and "listens" to how the waves come back, which reveals the shape of whatever they have hit.

Some researchers have used radio waves to detect concealed weapons such as hidden handguns and knives.

Radio waves can even "fingerprint" the details of a room. Then, if scanned again later, this would reveal whether any objects in the room have been moved.

Last year, scientists in Germany proposed that countries use this method to scrutinize other countries' management of their nuclear weapons stockpiles. It would be one way of knowing whether someone had been moving the warheads around, for example.

Radio systems could be a useful addition to scanners on autonomous cars© Getty Images

Separately, Luana Olivieri at Loughborough University has explored using a different form of non-visible electromagnetic radiation, terahertz waves. These are shorter than radio waves but longer than visible light waves. "This wavelength is particularly unexplored," says Dr Olivieri.

It is possible to see through objects and analyse materials using this form of radiation, she adds. Such a system could even, in theory, identify specific drugs by detecting their chemical structure.

But while seeing through materials could help a rescue bot find a trapped person in some future disaster, it also has other applications. Police forces and militaries

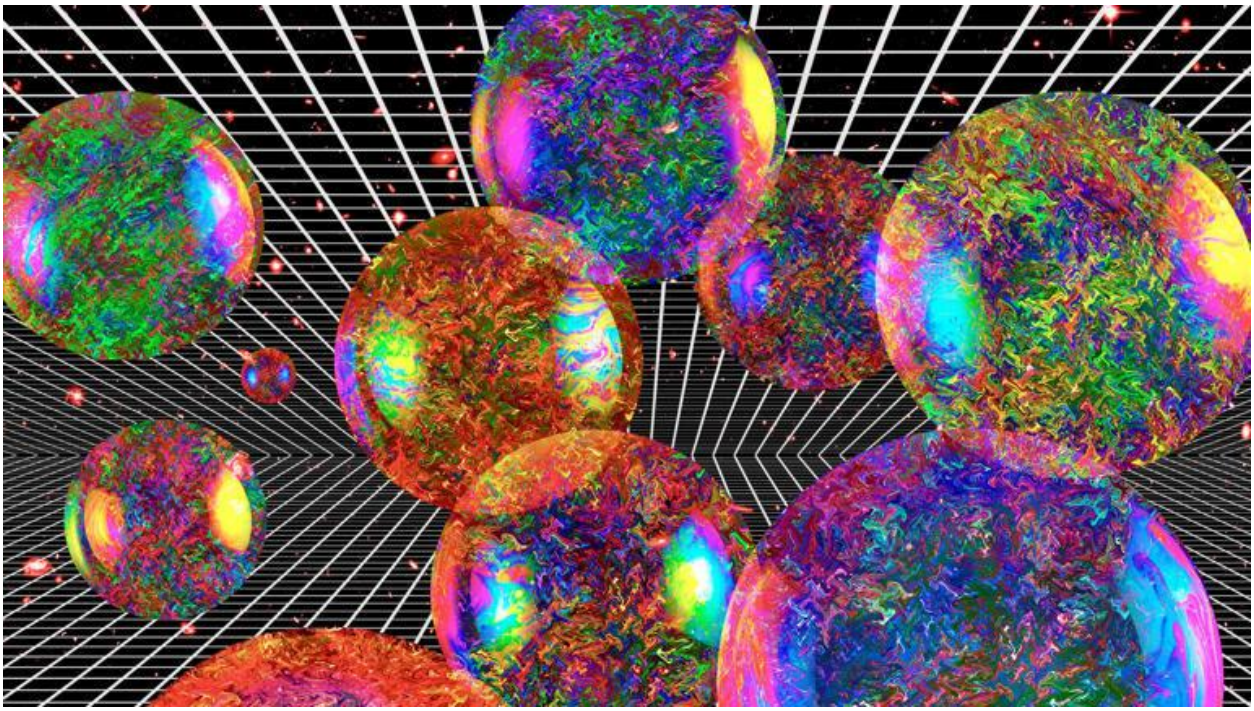
have access to radio-based technology that allows them to see through doors and walls, to some extent.

"Warfighting is definitely one market that it caters to. It can be used to find and kill someone," says Mr da Silva. He has exhibited Wavsens' technology to the US Department of Defense and the Israeli Ministry of Defense, he says.

And yet these applications are not entirely surprising, suggests Prof Reinhard, who points out that a range of emerging technologies have, in principle, made it easier to detect and attack people.

"Maybe radar sounds scary – but drones and cheap cameras are the much more dangerous thing," he says.

'Multiverse simulation engine' predicts every possible future to train humanoid robots and self-driving cars



A digital render of the multiverse© Getty Images/VICTOR de SCHWANBERG/SCIENCE PHOTO LIBRARY

Researchers have built a new "multiverse simulation" platform that can generate massive amounts of data to train advanced self-learning robots powered by artificial intelligence (AI).

The suite of tools, dubbed "Cosmos," lets researchers create "world foundation models" — neural networks that simulate real-world environments and the laws of physics to predict realistic outcomes, according to Nvidia, which engineered the platform. These generative AI models can create synthetic data to train embodied or physical AI systems such as autonomous vehicles (AVs) or humanoid robots.

Training AI systems require massive amounts of data, but scientists estimate that we may run out of publicly available data by 2026. AI systems that interface with the real world, like robots, usually need real-world footage that is incredibly difficult to produce and costly to acquire.

But creating genuinely useful synthetic data is also challenging, and one study previously warned that using poorly construed synthetic data could break down into unintelligible nonsense. Cosmos is designed to resolve these issues by letting scientists rapidly generate a monumental amount of artificial video footage based on real-world physics.

Related: Robotics breakthroughs in 2024: Test your knowledge of the most exciting advancements in the field

"Today's humanoid developers have hundreds of human operators performing thousands of repetitive demonstrations just to teach a couple of skills," Rev Lebaredian, vice president of Omniverse and simulation technology at Nvidia, said at a virtual news conference Monday (Jan. 6) at CES 2025 in Las Vegas. "Today's AV developers need to drive millions of miles; even more resources-intensive is processing, filtering and labeling the thousands of petabytes of data captured, and physical testing is dangerous. Humanoid developers have a lot to lose when one robot prototype can cost hundreds of thousands of dollars."

Simulating the multiverse

A key component of this new platform is multiverse simulation, in which Cosmos combines with Nvidia's Omniverse software system to generate every possible future outcome in a specific scenario. This would then be fed into the training of a robot or self-driving car.

It uses diffusion models used in image generation — machine learning algorithms that generate data by adding "noise" (grainy specs) to a dataset and then learning to remove the noise — as well as autoregressive models, which are statistical models used to predict the next step in a process. Together, the platform can take in text, images or videos and then generate footage to predict what comes next in a particular scenario in real time.

"The ChatGPT moment for robotics is coming. Like large language models, world foundation models are fundamental to advancing robot and AV development, yet not all developers have the expertise and resources to train their own," Jensen Huang, founder and CEO of Nvidia, said in a statement. "We created Cosmos to democratize physical AI and put general robotics in reach of every developer."

The world foundation models created using Cosmos are also available under open-source licensing terms.

ONE DAY IN THE FUTURE SCALED UP DIAMOND BATTERIES COULD POWER ANDROIDS

A safe nuclear battery that could last a lifetime

Researchers at Daegu Gyeongbuk Institute of Science & Technology are developing nuclear batteries using radiocarbon, offering decades-long power without recharging.

From American Chemical Society 29/03/25 (first released 26/03/25)

A small dye-sensitized betavoltaic cell has radiocarbon on both the cathode and anode, which increases its energy-conversion efficiency. Credit: Su-Il In

Sometimes cell phones die sooner than expected or electric vehicles don’t have enough charge to reach their destination.

The rechargeable lithium-ion (Li-ion) batteries in these and other devices typically last hours or days between charging.

However, with repeated use, batteries degrade and need to be recharged more frequently.

Now, researchers are considering radiocarbon as a source for safe, small and affordable nuclear batteries that could last decades or longer without charging.

Su-Il In, a professor at Daegu Gyeongbuk Institute of Science & Technology, will present his results at the spring meeting of the American Chemical Society (ACS).

ACS Spring 2025 is being held March 23-27; it features about 12,000 presentations on a range of science topics.

The frequent charging required for Li-ion batteries isn’t just an inconvenience.

It limits the utility of technologies that use the batteries for power, such as drones and remote-sensing equipment.

The batteries are also bad for the environment: Mining lithium is energy-intensive and improper disposal of Li-ion batteries can contaminate ecosystems.

But with the increasing ubiquity of connected devices, data centers and other computing technologies, the demand for long-lasting batteries is increasing.

And better Li-ion batteries are likely not the answer to this challenge.

“The performance of Li-ion batteries is almost saturated,” says In, who researches future energy technologies.

So, In and his team members are developing nuclear batteries as an alternative to lithium.

Nuclear batteries generate power by harnessing high-energy particles emitted by radioactive materials.

Not all radioactive elements emit radiation that’s damaging to living organisms, and some radiation can be blocked by certain materials.

For example, beta particles (also known as beta rays) can be shielded with a thin sheet of aluminum, making betavoltaics a potentially safe choice for nuclear batteries.

The researchers produced a prototype betavoltaic battery with carbon-14, an unstable and radioactive form of carbon, called radiocarbon.

“I decided to use a radioactive isotope of carbon because it generates only beta rays,” says In.

Moreover, a by-product from nuclear power plants, radiocarbon is inexpensive, readily available and easy to recycle.

And because radiocarbon degrades very slowly, a radiocarbon-powered battery could theoretically last for millennia.

In a typical betavoltaic battery, electrons strike a semiconductor, which results in the production of electricity.

Semiconductors are a critical component in betavoltaic batteries, as they are primarily responsible for energy conversion.

Consequently, scientists are exploring advanced semiconductor materials to achieve a higher energy conversion efficiency — a measure of how effectively a battery can convert electrons into usable electricity.

To significantly improve the energy conversion efficiency of their new design, In and the team used a titanium dioxide-based semiconductor, a material commonly used in solar cells, sensitized with a ruthenium-based dye.

They strengthened the bond between the titanium dioxide and the dye with a citric acid treatment.

When beta rays from radiocarbon collide with the treated ruthenium-based dye, a cascade of electron transfer reactions, called an electron avalanche, occurs.

Then the avalanche travels through the dye and the titanium dioxide effectively collects the generated electrons.

The new battery also has radiocarbon in the dye-sensitized anode and a cathode.

By treating both electrodes with the radioactive isotope, the researchers increased the amount of beta rays generated and reduced distance-related beta-radiation energy loss between the two structures.

During demonstrations of the prototype battery, the researchers found that beta rays released from radiocarbon on both electrodes triggered the ruthenium-based dye on the anode to generate an electron avalanche that was collected by the titanium dioxide layer and passed through an external circuit resulting in usable electricity.

Compared to a previous design with radiocarbon on only the cathode, the researchers' battery with radiocarbon in the cathode and anode had a much higher energy conversion efficiency, going from 0.48% to 2.86%.

These long-lasting nuclear batteries could enable many applications, says In.

For example, a pacemaker would last a person's lifetime, eliminating the need for surgical replacements.

However, this betavoltaic design converted only a tiny fraction of radioactive decay into electric energy, leading to lower performance compared to conventional Li-ion batteries.

In suggests that further efforts to optimize the shape of the beta-ray emitter and develop more efficient beta-ray absorbers could enhance the battery's performance and increase power generation.

As climate concerns grow, public perception of nuclear energy is changing.

But it's still thought of as energy only produced at a large power plant in a remote location.

With these dual-site-source dye-sensitized betavoltaic cell batteries, In says, "We can put safe nuclear energy into devices the size of a finger."

The research was funded by the National Research Foundation of Korea, as well as the Daegu Gyeongbuk Institute of Science & Technology Research & Development Program of the Ministry of Science and Information and Communication Technology of Korea.

Visit the ACS Spring 2025 program to learn more about this presentation, "Next generation battery: Highly efficient and stable C14 dye-sensitized betavoltaic cell" and other science presentations.

Groundbreaking diamond battery generates power from nuclear waste

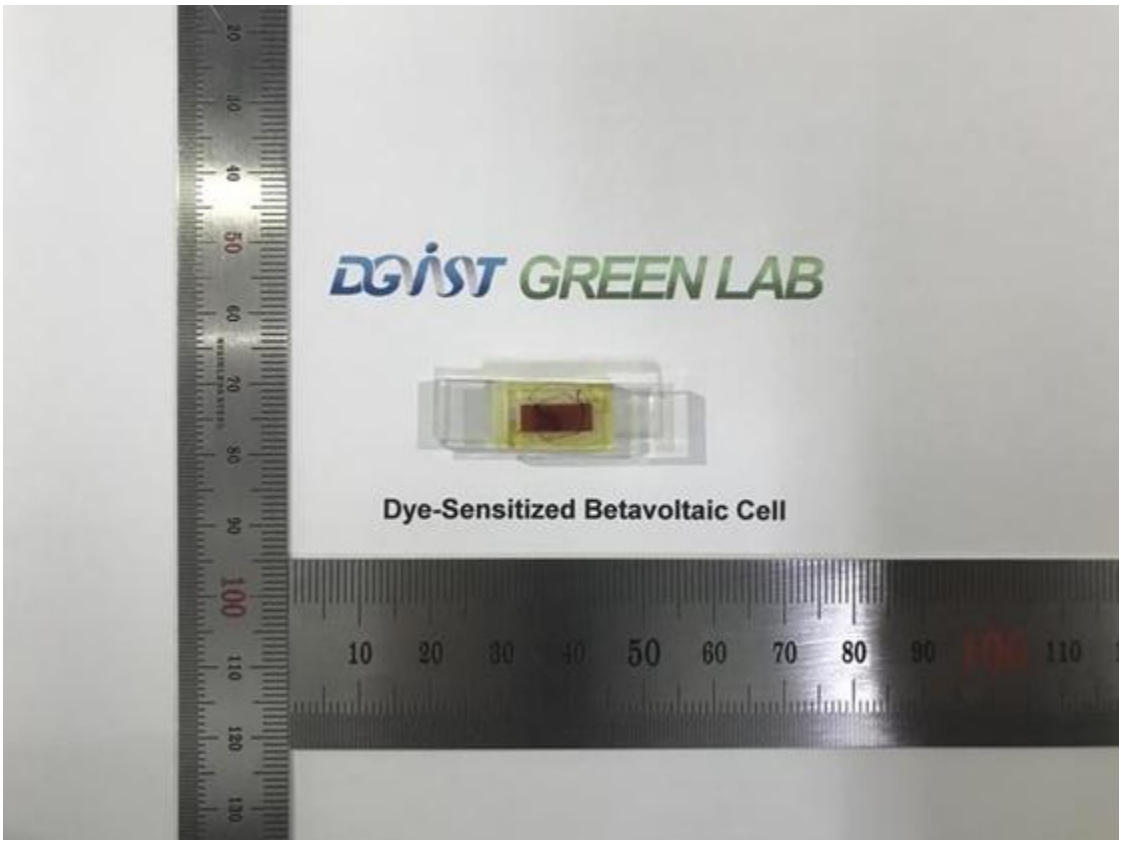
Nuclear energy is often promoted as a cleaner alternative to fossil fuels because it doesn't emit carbon dioxide. However, one major obstacle shadows its potential: the management of radioactive waste.

With the growing number of nuclear reactors globally, the accumulation of this hazardous byproduct poses a significant environmental and public health challenge. Effectively handling and potentially repurposing nuclear waste is critical for sustainable energy development.

In response, researchers have proposed innovative strategies to address the issue, focusing on converting radioactive materials into useful resources. One groundbreaking development in this field is the radioactive diamond battery—a technology that could transform nuclear waste into a valuable energy source.

The Innovation Behind Radioactive Diamond Batteries

The concept of radioactive diamond batteries emerged in 2016, introduced by scientists at the University of Bristol's Cabot Institute for the Environment. These devices are a form of betavoltaic technology, harnessing energy from the beta decay of nuclear waste to generate electricity.



Beta decay is a type of radioactive decay that occurs when an atom's nucleus has an excess of particles and releases some of them to obtain a more stable ratio of protons to neutrons. (CREDIT: MikeRun/WikimediaCommons)© The Brighter Side of News

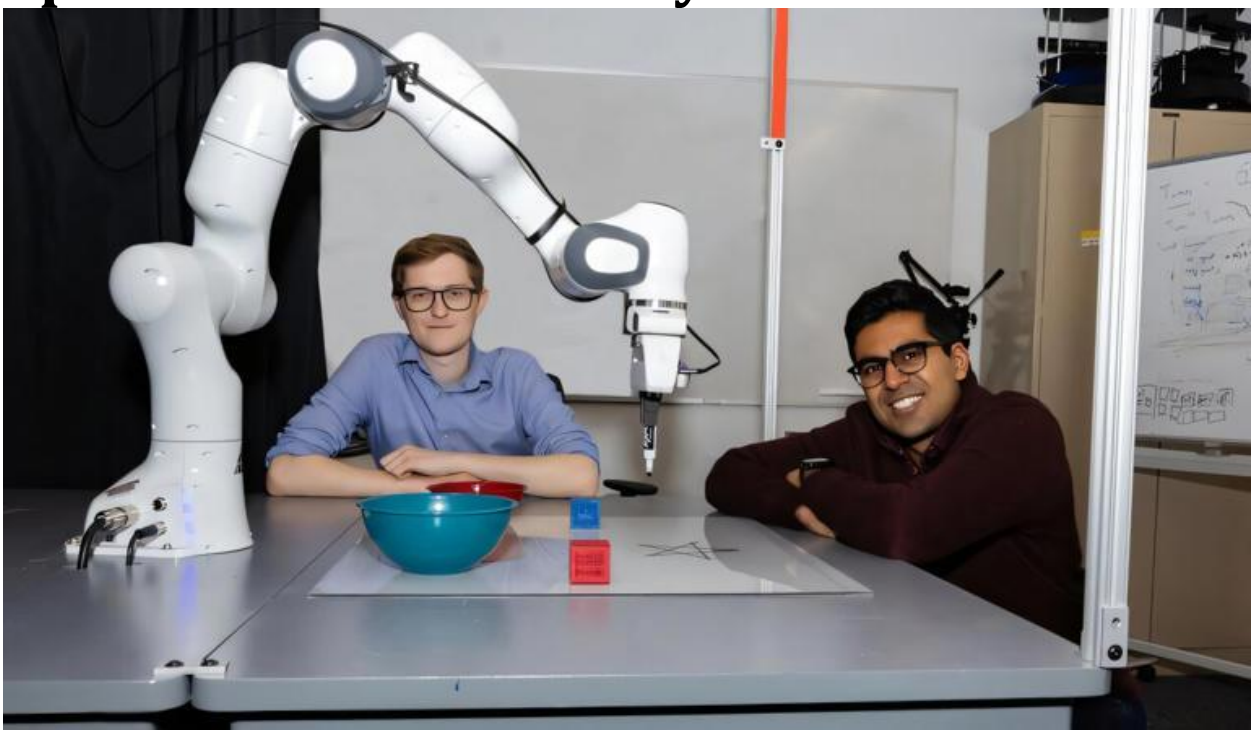
This idea hinges on beta decay, a process where an unstable atomic nucleus releases excess particles, resulting in a more stable configuration. This release

generates beta radiation, a stream of high-speed electrons or positrons, which can be harnessed to produce electrical energy.

Typically, in a betavoltaic cell, radioactive material is sandwiched between semiconductors. As the material undergoes beta decay, it emits particles that knock electrons loose in the semiconductor, creating an electric current. However, this method has its limitations. Since beta particles are emitted in all directions, only a small fraction are captured by the semiconductor, reducing the efficiency of the battery.

This is where polycrystalline diamond (PCD) comes into play. The process of manufacturing these batteries involves chemical vapor deposition (CVD), a technique used to create synthetic diamonds. By incorporating radioactive methane containing Carbon-14—an isotope found in nuclear reactor graphite blocks—into the CVD process, researchers produce radioactive diamonds.

Teaching a robot its limits to complete open-ended tasks safely



Ph.D. students Aidan Curtis (left) and Nishanth Kumar. To help robots execute open-ended tasks safely, the researchers used vision models to see what's near the machine and model its constraints. Their "PRoC3S" strategy has

an LLM sketch up an action plan that's checked in a simulator to ensure it will work in the real world. Credit: Mike Grimmett/MIT CSAIL

If someone advises you to "know your limits," they're likely suggesting you do things like exercise in moderation. To a robot, though, the motto represents learning constraints, or limitations of a specific task within the machine's environment, to do chores safely and correctly.

For instance, imagine asking a robot to clean your kitchen when it doesn't understand the physics of its surroundings. How can the machine generate a practical multistep plan to ensure the room is spotless? Large language models (LLMs) can get them close, but if the model is only trained on text, it's likely to miss out on key specifics about the robot's physical constraints, like how far it can reach or whether there are nearby obstacles to avoid. Stick to LLMs alone, and you're likely to end up cleaning pasta stains out of your floorboards.

To guide robots in executing these open-ended tasks, researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) used vision models to see what's near the machine and model its constraints. The team's strategy involves an LLM sketching up a plan that's checked in a simulator to ensure it's safe and realistic. If that sequence of actions is infeasible, the language model will generate a new plan, until it arrives at one that the robot can execute.

This trial-and-error method, which the researchers call "Planning for Robots via Code for Continuous Constraint Satisfaction" (PRoC3S), tests long-horizon plans to ensure they satisfy all constraints, and enables a robot to perform such diverse tasks as writing individual letters, drawing a star, and sorting and placing blocks in different positions. In the future, PRoC3S could help robots complete more intricate chores in dynamic environments like houses, where they may be prompted to do a general chore composed of many steps (like "make me breakfast").

"LLMs and classical robotics systems like task and motion planners can't execute these kinds of tasks on their own, but together, their synergy makes open-ended problem-solving possible," says Ph.D. student Nishanth Kumar SM '24, co-lead author of a new paper about PRoC3S posted to the *arXiv* preprint server.

"We're creating a simulation on-the-fly of what's around the robot and trying out many possible action plans. Vision models help us create a very realistic digital

world that enables the robot to reason about feasible actions for each step of a long-horizon plan."

The team's work was presented this past month at the Conference on Robot Learning (CoRL) in Munich, Germany.

The researchers' method uses an LLM pre-trained on text from across the internet. Before asking PRoC3S to do a task, the team provided their language model with a sample task (like drawing a square) that's related to the target one (drawing a star). The sample task includes a description of the activity, a long-horizon plan, and relevant details about the robot's environment.

But how did these plans fare in practice? In simulations, PRoC3S successfully drew stars and letters eight out of 10 times each. It also could stack digital blocks in pyramids and lines, and place items with accuracy, like fruits on a plate. Across each of these digital demos, the CSAIL method completed the requested task more consistently than comparable approaches like "LLM3" and "Code as Policies."

The CSAIL engineers next brought their approach to the real world. Their method developed and executed plans on a robotic arm, teaching it to put blocks in straight lines. PRoC3S also enabled the machine to place blue and red blocks into matching bowls and move all objects near the center of a table.

Kumar and co-lead author Aidan Curtis SM '23, who's also a Ph.D. student working in CSAIL, say these findings indicate how an LLM can develop safer plans that humans can trust to work in practice. The researchers envision a home robot that can be given a more general request (like "bring me some chips") and reliably figure out the specific steps needed to execute it. PRoC3S could help a robot test out plans in an identical digital environment to find a working course of action—and more importantly, bring you a tasty snack.

For future work, the researchers aim to improve results using a more advanced physics simulator and to expand to more elaborate longer-horizon tasks via more scalable data-search techniques. Moreover, they plan to apply PRoC3S to mobile robots such as a quadruped for tasks that include walking and scanning surroundings.

"Using foundation models like ChatGPT to control robot actions can lead to unsafe or incorrect behaviors due to hallucinations," says The AI Institute researcher Eric Rosen, who isn't involved in the research. "PRoC3S tackles this issue by leveraging foundation models for high-level task guidance, while employing AI techniques that explicitly reason about the world to ensure verifiably safe and correct actions.

"This combination of planning-based and data-driven approaches may be key to developing robots capable of understanding and reliably performing a broader range of tasks than currently possible."

More information: Aidan Curtis et al, Trust the PRoC3S: Solving Long-Horizon Robotics Problems with LLMs and Constraint Satisfaction, *arXiv* (2024). DOI: 10.48550/arxiv.2406.05572

Robots set to move beyond factory as AI advances

Robots set to move beyond factory as AI advances

Today's robots perform safety checks at industrial plants, conduct quality control in manufacturing, and are even starting to keep hospital patients company.

Attendees watch as a robot walks around during a demonstration at the Unitree Robotics booth during the Consumer Electronics Show (CES) in Las Vegas, Nevada, on January 9, 2025.

But soon -- perhaps very soon -- these increasingly humanlike machines will handle more sophisticated tasks, freeing up people while raising complex questions about the roles of artificial intelligence that are gaining attention.

At a panel hosted by the American Association of Retired Persons at this week's Consumer Electronics Show (CES), experts described the next five years as a period where robots transition primarily from industrial sites to service settings, helping to address a worsening health care labor crunch.

Seeing robotics in places like theme parks or universities "will lead to the companion robot probably at the end of the decade," said Marc Theermann, chief strategy officer for robot company Boston Dynamics.

Cris Gardner, a vice president in futurecasting at AARP, predicted robots will provide emotional support as they enter homes and assist with daily tasks.

People "will own a generalized humanoid robot the way they would own a car," she said.

- Upheaval ahead? -

Dystopian prophesies of a robot-centered future have long featured in the public imagination. However, recent breakthroughs in generative AI have given more credibility to predictions of billions of humanoid robots in everyday life.

The centrality of robots in the coming years is "widely underappreciated," said a report from Abundance 360, a conference and education venture led by entrepreneur Peter Diamandis.

Robots could enable an "era of unprecedented abundance," lowering costs while freeing humans "to focus on creative and fulfilling pursuits," it said.

However, the analysis also identified nine sectors facing potential job displacement, including manufacturing, elder care, agriculture, education, and surgery.

"The speed at which multimodal generative AI and humanoid robot development is progressing, paired with the lack of public discourse on this subject, indicates that there will be significant job disruption and societal upheaval," it said.

Disputes over automation have been a recurring factor in labor negotiations, most recently involving US dockworkers, who reached a tentative agreement with a shippers group, averting a strike.

The International Longshoremen's Association permitted ports to add semiautonomous cranes only if more workers are hired, according to the Wall Street Journal.

- Worker shortages -

At CES, companies described robots as performing tasks that humans either shouldn't do because they are dangerous, or don't want to do because they are grueling, tedious, or unpleasant.

Hong Kong company R2C2 showcased industrial robots that can perform functions such as inspections at power plants and technician work on trains, according to San Wong, the company's founder and chief executive.

Working on trains involves "lots of grease everywhere, and it's dirty and hot" so turnover is high, San said.

Vehicle and equipment maker Oshkosh has used automation to phase out high-burnout jobs such as the finishing work on firetrucks, which requires workers to wear a mask and often leads to shoulder and elbow problems, said chief executive John Pfeifer.

Those workers have been shifted to other assembly line work, such as welding. While these jobs are currently safe, they may "one day" be automated, Pfeifer said.

"This has been the evolution of the economy for 250 years," he said. "People move into more productive ways to help the economy grow."

At CES, US agriculture machinery giant John Deere showcased autonomous vehicles developed partly in response to persistent farm labor shortages.

Automation allows farmers to focus on more challenging tasks, such as managing grain movement from a field to a storage area, said Deanna Kovar, president of Deere's worldwide agriculture and turf division.

"We need to continue to make sure we're evolving the skill sets of our employees, of our customers, so that they can take advantage of the technologies and not see them as a threat," she said.

AARP's Gardner noted that the aging US population points to a significant labor gap for caring for the next generation of seniors.

"The demand is going to be enormous, it can't be covered by human beings," said Gardner, who views improved robotics as key to enabling older people to stay independent for longer.

JANUARY 9, 2025

Open-source holonomic mobile manipulator could advance household robotics

Researchers at Stanford University, Princeton University, and Dexterity recently developed TidyBot++, a holonomic mobile robot that can perform various household chores and could help to train or test new algorithms for robotics applications.

This promising robotic platform was presented at the Conference on Robot Learning and outlined in a paper published on the *arXiv* preprint server.

"Our paper was inspired by the growing need for scalable data collection in robotics, particularly in the area of mobile manipulation," Jeannette Bohg, supervising author of the paper, told Tech Xplore.

"While imitation learning has shown promising results, its success heavily depends on the availability of real-world demonstrations, which are difficult to acquire due to the lack of suitable, accessible research platforms. We noticed a gap in the availability of open-source, flexible, and cost-effective hardware for mobile manipulation in household settings, which are a primary focus of many robotics applications."

The main objective of the recent study by Bohg and her colleagues was to contribute to the advancement of robotics research, by developing a new robotic platform that is well-suited for tackling household tasks and could also be used to collect training data for imitation learning algorithms. To promote its wide adoption within the robotics community, this platform was designed to be easily accessible, robust, and versatile.

"TidyBot++ is a mobile robot designed to perform household tasks with precision and ease," explained Jimmy Wu, first author of the paper.

"At its core, it has a holonomic base equipped with motorized caster wheels that allow it to move freely in any direction—forward, backward, sideways, or rotating—without the constraints found in traditional robot bases like differential drive systems. This enhanced maneuverability simplifies the robot's movements and makes tasks like repositioning in tight spaces much more efficient."

The TidyBot++ robot has three primary components. The first is a modular frame made of aluminum T-slot extrusions, which is easy to build and can be customized by adding various robotic arms or sensors.

The aluminum frame has integrated motorized caster wheels that have a small 'caster offset'. These wheels enable simultaneous control of all the planar degrees of freedom, essentially allowing the robot to roll around just like a motorized office chair would.

The robot's third component consists of a mobile phone teleoperation interface that leverages the WebXR API for real-time pose tracking. Using this interface, users can intuitively control the robot's movements simply by moving their phone.

"Compared to other platforms, TidyBot++ is highly maneuverable, accessible, and optimized for learning household tasks," said Bohg. "Its holonomic base ensures efficiency and smooth operation, even in cluttered environments."

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Compared to other advanced robotic platforms, TidyBot++ is relatively low-cost, as fabricating it costs between $5,000–$6,000. Its main structure can be easily customized by adding specific robotic arms and sensors, which facilitates its use for research.

To test their robot's potential, Bohg and her colleagues have already carried out various real-world experiments. Their findings were very promising, as they showed that by running policies trained on a few demonstrations, TidyBot++ could complete various household tasks with high success rates, including opening a fridge, wiping a countertop, and loading a dishwasher.

"We showed that the holonomic base significantly outperformed nonholonomic designs in efficiency, task success rates, and ease of teleoperation," said Wu. "By making the design and software fully open-source, we aim to democratize access to a robust mobile manipulator, enabling researchers worldwide to advance mobile manipulation research."

In the future, the robot developed by this team of researchers could help to collect high-quality data to train AI algorithms for robotics via imitation learning. TidyBot++ could also be introduced in educational settings as a platform to test these algorithms and could eventually be deployed in household settings, where it could assist users with household chores.

"In our next studies, we plan to expand the capabilities of TidyBot++, for instance, by integrating advanced sensors and multiple arms to expand the range of household tasks it can perform," said Bohg. "We also plan to develop more intuitive interfaces and automation features to collect large-scale datasets for learning complex manipulation policies."

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To facilitate the widespread use of their robot, the researchers are now trying to improve its design, by addressing some of its limitations, such as its back drivability (i.e., currently, it is difficult to move the robot using external force). In addition, they would like to carry out tests investigating whether the robot could easily coordinate with other robots, to tackle missions that would be more efficiently completed by a team of robots.

"In the future, we will also investigate ways to train policies that generalize across a variety of environments and tasks with minimal additional training," added Wu.

"By continuing to refine TidyBot++, we aim to push the boundaries of what mobile manipulators can achieve and contribute to making robotic assistance more accessible and impactful in everyday life."

More information: Jimmy Wu et al, TidyBot++: An Open-Source Holonomic Mobile Manipulator for Robot Learning, *arXiv* (2024). DOI: 10.48550/arxiv.2412.10447
Journal information: arXiv

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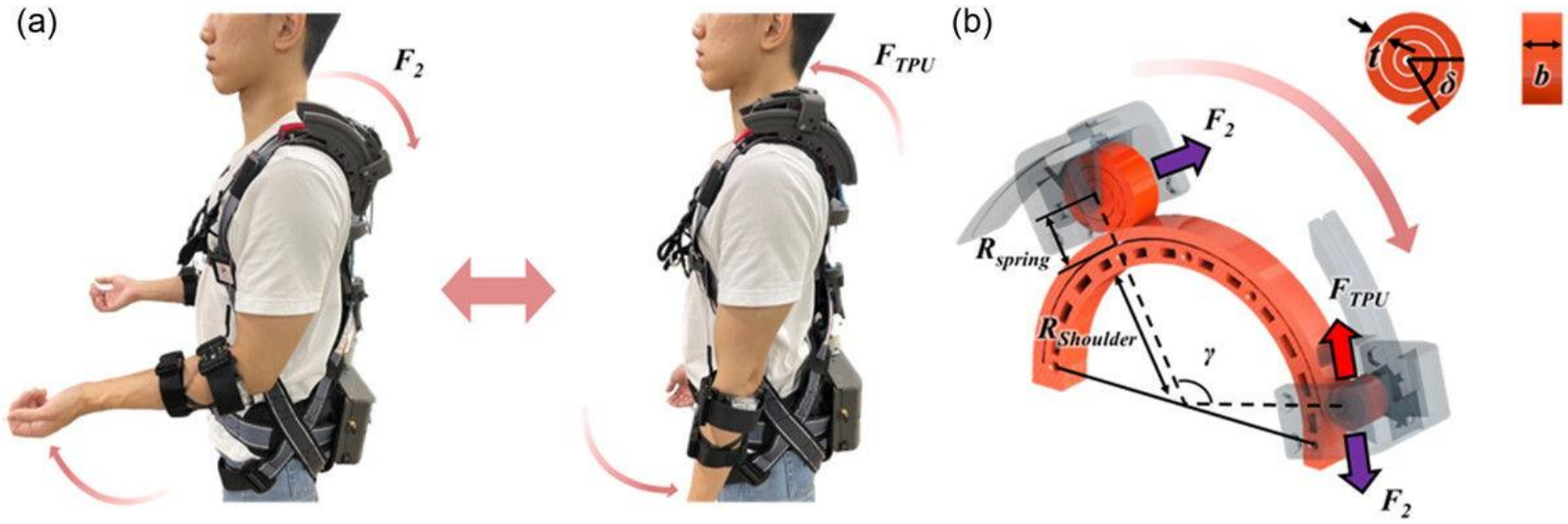

KOREAN SCIENTISTS REVEAL FUTURISTIC NEW 'WEARO' EXOSKELETON FOR INDUSTRIAL USE

RYAN WHALEN·JANUARY 10, 2025

Like Ripley's power loader in the 1986 film *Aliens*, Korean scientists have unveiled a manual labor exoskeleton they call WeaRo, paving the way for safer robot assisted work.

The 11.5 lb wearable device reportedly reduces stress on human muscles by between 18.2% and 29.0% while in use. The scientists behind the development believe the WeaRo exoskeleton could soon come to hold an essential place in worker safety, citing the high frequency of back injuries among workers today.

AIDING HUMAN EFFORT

In 1986, *Aliens* envisioned exoskeletons as an essential future tool for multiplying human effort in manual labor, in contrast to the predominately military use for such technologies presented in other

science fiction. This is industrial perspective is shared by the Yonsei University scientists behind the development of WeaRo.

Currently, human augmentation devices are designed to support a single range of movement, limiting their application to specific tasks. Yonsei University scientists aimed to overcome this limitation by developing a system capable of supporting multiple degrees of movement, enabling users to perform varied and complex tasks. Their efforts led to the creation of WeaRo—a soft, wearable robot.

WeaRo assists users in lifting, lowering, and carrying objects, significantly reducing strain on key muscle groups. Tests revealed that the device decreases lumbar strain by 18.2%, biceps strain by 29.1%, and triceps strain by 27.0%. These results are particularly notable given that back injuries, which account for 31.9% of work-related injuries, are the leading cause of workplace injuries.

Moreover, recent research suggests that traditional lifting techniques, such as squatting instead of stooping, offer trade-offs rather than clear benefits. Reducing overall bodily stress is proving to be the most effective strategy for minimizing injury risks.

DESIGNING AND TESTING THE EXOSKELETON

After evaluating previous attempts to create wearable robots, the Yonsei team chose Twisted Spring Actuators (TSAs) as the motion-driving mechanism for WeaRo. TSAs struck a balance between active pneumatic systems—often too heavy for comfortable wear—and passive elastic systems, which restricted the user's range of motion.

The team's design incorporated a back brace and armbands that worked in tandem, transferring motion through a two-stage sequence: first using the lumbar region and then engaging the arms. This approach relieved bodily stress through active pressure while leveraging gravity as a counterforce. The device's lifting sequence could also be adjusted for specific use cases, providing flexibility for various tasks.

To test WeaRo, the researchers recruited eight adult males with no history of back pain. The participants were equipped with electromyography (EMG) sensors to measure muscle activity. During initial trials, the team compared a TSA-based system that allowed simultaneous movement against their Adjustable Twisted Spring Actuator (ATSA) system, which supported two-stage motion. The two-stage design proved far more efficient, reducing the required range of motion and overall muscle stress.

Subsequent tests evaluated repetitive stooping and squatting motions, both unassisted and with WeaRo's support. Participants using WeaRo experienced a significant reduction in muscle stress—ranging from 18.2% to 29.1%. A final set of tests on lighter, continuous tasks showed a stress reduction of 8-17.1%, further demonstrating the device's versatility.

LOOKING AHEAD: THE FUTURE OF EXOSKELETONS

The Yonsei team's next goal is to integrate artificial intelligence (AI) into WeaRo's system. Their vision involves AI detecting a wearer's intended movement through subtle posture cues and providing precise, real-time assistance. Additionally, the team is working on developing robust maintenance procedures to ensure safe and effective long-term use of the device.

With advancements like WeaRo, the potential for wearable robotics to improve workplace safety and productivity continues to grow, paving the way for a future where human augmentation devices are as versatile as the tasks they aim to support.

Watch: China’s insane robot dog tackles tough terrain, big boulders at high speed

The Lynx can lock its wheels, allowing it to switch between walking and climbing like a standard four-legged robot.

Updated: Nov 14, 2024

The all-terrian robot can handle extreme off-road tasks.

China is rapidly launching new robotics products, and DEEP Robotics is now unveiling its latest—a four-legged robot called Lynx.

The new wheeled quadruped promises exceptional flexibility for tackling tough terrain tasks.

In 2017, Deep Robotics was founded in Hangzhou, China, with the goal of creating autonomous stair-climbing robots.

These days, the firm's product portfolio includes a wide range of multitasking humanoids and robot canines.

About Lynx, the firm claims it is a "middle-sized powerful quadruped wheel solution, unlocking new levels of flexibility, productivity, and ease of use for our customers." reads a LinkedIn post.

Wheels meet agility

DEEP Robotics' new four-legged robot, the Lynx, joins its lineup of innovative quadrupeds, including the Lite3, X20, and X30. However, Lynx stands out by swapping traditional pad feet for wheels, significantly enhancing speed and versatility without compromising control.

As seen in a recent promotional video, this wheeled design not only brings added excitement but also enables the robot to handle diverse terrains more effectively.

The Lynx's design allows it to lock its wheels, enabling it to walk or climb like a conventional quadruped. This feature makes it suitable for navigating rough and uneven surfaces, while its powerful motors can also drive it efficiently over loose dirt, gravel, and smooth pavement. In essence, Lynx combines the adaptability of a walking robot with the efficiency and speed of a wheeled system.

The video demonstrates Lynx in action on a rigorous multi-terrain course. The robot maneuvers down steep slopes with careful control, shifts between walking and wheeled modes, and even climbs over an 80-centimeter boulder. Lynx's dual-mode locomotion versatility and stability make it capable of tackling challenging terrain, whether on wheels or legs.

With its flexible movement modes, Lynx promises to offer a promising tool for applications that require reliable all-terrain navigation. The company claims that Lynx is now available for pre-order.

Autonomous rescue

In a recently circulated video, developers from DEEP Robotics can be seen teaching their X30 robot dog to avoid hazards, strangers, and other random objects.

The Chinese company, which is renowned for its expertise in robotics technology, was the first in the nation to use quadruped robots for fully autonomous substation inspection.

According to DEEP Robotics, its quadruped robots can be utilized for a variety of tasks, including emergency rescue, fire detection, security measures, and doing scientific studies in areas deemed unsafe or inaccessible to people.

This kind of feature can be useful in a variety of scenarios, particularly while working in hazardous and difficult areas on security, surveillance, or rescue missions.

The behavior must presently be programmed into the X30 robot dog, but with the aid of artificial intelligence (AI), it might eventually become a standard pre-existing function.

One of the X30 quadruped robot's unique features is its ability to function in extremely cold conditions, from -4 degrees Fahrenheit (-20°C) to 131 degrees Fahrenheit (55°C). Additionally, it has IP67 protection, which makes it waterproof and able to function in environments with water.

Additionally, it can climb industrial stairs steadily and flexibly at a 45-degree angle. Thanks to its integrated perception, the robot can travel and function independently in harsh situations without light, eliminating the need for external light sources.

Humanoid robots to assemble iPhones in China as UBTech partners with Foxconn

Humanoid robots to assemble iPhones in China as UBTech partners with Foxconn

Chinese Shenzhen-based humanoid robot maker UBTech announced on Wednesday (January 15) a new partnership with Apple's Chinese manufacturing partner, Foxconn, to use its robots to help make iPhones. The so-called"comprehensive long-term partnership" will see UBTech's Walker S1 humanoid robots perform complicated and delicate production" duties.

To this end, UBTech is already training its robots to handle various manufacturing-based tasks. This includes functions for multiple industries, from automotive to computers and consumer electronics.

"For car manufacturing, there [are] thousands of tasks on our list," UBTech's chief brand officer Michael Tam said. "In areas like 3C production, [these are] new skills for humanoid robots to learn," he added. In case you are unaware, 3C refers to computers, communication, and consumer electronics.

The company has also announced that the new partnership will also help accelerate artificial intelligence (AI) technology development in manufacturing.

Building iPhone's with robots

The robot in question, UBTech's proprietary Walker S1, first launched in October 2024. It stands at 5.6 feet (1.72 m) tall and weighs 167.6 pounds (76 kg), closely resembling a human in size.

The robot has been specifically designed to perform various tasks, from conducting visual quality inspections to carrying parcels of different sizes. It can also reportedly tighten screws with an electric screwdriver, assemble components, and sort parts.

Reportedly, UBTech has already completed several months of training for logistics operations at Foxconn subsidiary Foxtron's factories in Shenzhen's Longhua district.

https://www.youtube.com/watch?v=UHe1zSQwep0

Following this training, the Walker S1 is set to be deployed at Foxconn's electric vehicle factory in Zhengzhou city. Foxconn has developed a series of EVs, including its latest Model N cargo can and Model B midsize hatchback.

Under the new agreement, UBTech will test the feasibility of using humanoid robots in tasks including moving, sorting, and quality inspection. Priority will be given to automating tasks potentially impacting human workers' health, such as lifting and carrying heavy loads.

The partnership will also see both companies collaborate to improve the robots' motion, perception, and decision-making capabilities. It will also seek to establish a laboratory to explore more applications and technologies.

Walker S1 already popular in China

Beyond this partnership, UBTech (which first went public in 2023) has been working hard to promote the use of humanoid robots in Chinese manufacturing. So far, they have convinced Chinese EV carmaker BYD and Chinese courier SF Express to experiment with its humanoid robots.

Beyond BYD and SF Express, UBTech has secured clients such as state-owned Dongfeng Motor, FAW-Volkswagen, and Geely. Regarding its new partnership with Foxconn, UBTech said it would "accelerate the wider application of humanoid robots in smart manufacturing" and "rapidly reduce the cost of production by leveraging Foxconn's supply chain advantages."

The company also added that it aims to be the world's first robot maker to achieve "commercial mass production" of humanoid robots through the Foxconn partnership.

"China is witnessing a robust growth in humanoid robots, driven by the country's rich talent pool, a mature industrial chain, and growing market expectations," Yang Zhengye, the marketing director of the Shanghai-based National and Local Co-Built Humanoid Robotics Innovation Center, told Chinese state media.

Robot completes critical tasks at 1,000 ft mid-air, 300% more efficient than manual labor

Robot completes critical tasks at 1,000 ft mid-air, 300% more efficient than manual labor

A Minnesota-based glazing firm is using a robotic system to install high-rise glass panel bracket. Harmon is installing the latest technology with the help of Raise Robotics and Universal Robots. For high rise fastener installation, the robotic system has improved worker safety, as well as consistency and precision.

The companies revealed that construction workers need extensive safety rigging to install glass panel brackets up to 1,000 ft. into the air.

Don Birmingham, general superintendent at Harmon Inc., revealed that safety has always been the company's priority.

Two powerful UR20 arms

“If you can efficiently do a job and take all the safety risks out of it, I think any contractor would sign up for that. As far as the workers, I think they’d much rather be inside the handrail operating a robot than hanging off the edge of the building,” added Birmingham.

Raise Robotics uses two powerful UR20 arms from Universal Robots as a platform for innovative onsite construction robots. The Raise system takes on repetitive and dangerous tasks, such as installing fasteners for glass façade panels on high-rise buildings.

Harmon, the leading glazing company in the U.S., is an early adopter that has seen fast ROI (Return on Investment) with the robots, while improving worker safety and improvements in installation. The robots provide a 3X multiplier on manual labor and see payoff within one 13-floor project, according to Universal Robots.

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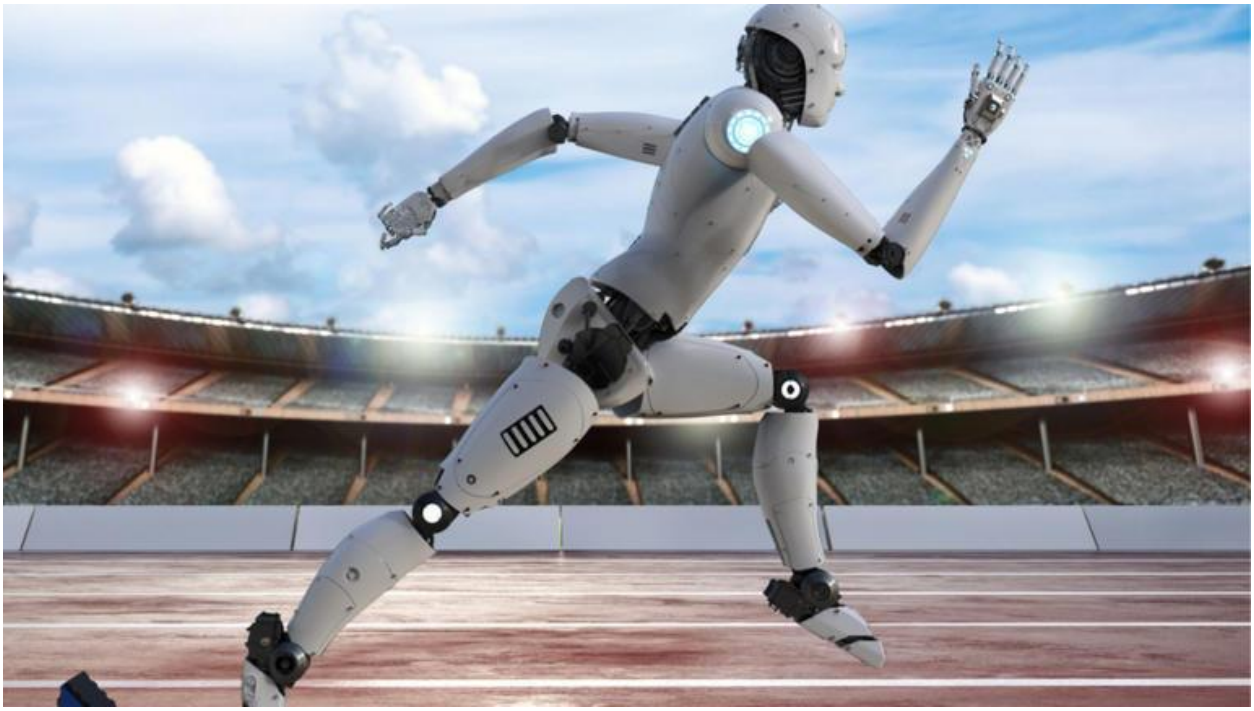
safety and improvements in installation. The robots provide a 3X multiplier on manual labor and see payoff within one 13-floor project, according to Universal Robots.

“We can install within plus or minus three sixteenths of an inch, which is far superior to what we’ve seen in manual installations,” said Oster.

Raise Robotics also revealed that the system also includes software that provides immediate insight and historical logs of on-site data. This gives exact torque values and alignment for every bracket in real-time, as opposed to random quality inspections that are typically done a few times on each floor, according to the company.

Humans vs. humanoids: China plans world’s first race pitting man against robots



Humans vs. humanoids: China plans world’s first race pitting man against robots

China plans to host a groundbreaking race like no other — a “world’s first” half-marathon where humans will go head-to-head with their own creation: humanoid robots.

The *South China Morning Post (SCMP)* reported that the marathon is scheduled for April in Daxing district, Beijing.

The humanoid robots, developed by companies from around the globe, will take to the streets alongside 12,000 human runners. The robots will run the entire race for the very first time this year.

This unprecedented race reflects China's ambitious push to become a global leader in artificial intelligence and robotics

Reportedly, this first-of-its-kind race will see humans and robots challenge themselves on a 13-mile (21km) route. The top three runners will receive prizes.

The robot requirements

As per the Beijing Economic-Technological Development Area, companies, research institutions, robotics clubs, and universities worldwide will participate in the marathon with their humanoid robots.

A key requirement is that the robots must possess a human-like appearance. Moreover, they should be equipped with a mechanical structure that allows them to perform movements such as walking or running on two legs, excluding wheeled locomotion.

The humanoids must also be between 0.5 meters and 2 meters (1.6 feet and 6.5 feet) tall.

Remotely controlled and fully autonomous humanoid robots are eligible to participate in the marathon. Furthermore, battery replacements are permitted during the race.

Robots growing use in marathons

Apart from China, various nations have been actively advancing their robotic creations.

Last year, the KAIST-developed quadrupedal robot RAIBO2 completed a full marathon in South Korea. Interestingly, it finished the 26.2-mile race in just over 4

hours on a single battery charge, showcasing a major advancement in robotic endurance.

Notably, this accomplishment made RAIBO the first quadrupedal robot globally to finish a full marathon.

The integration of robots in marathons is becoming an increasing trend. For instance, the humanoid robot "Tiangong" participated in the Yizhuang Half Marathon in Beijing last year. Tiangong joined runners near the finish line, acting as a "closing pacer" to encourage them.

In another event, a humanoid robot was present at the finish line of a past half-marathon in Beijing. It interacted with the runners by cheering them on and even performed a short run.

China views humanoid robots as a strategic sector for its economic growth and technological independence. Reportedly, this emphasis stems from its competition with the United States, as the US has implemented measures aimed at hindering China's access to advanced technologies.

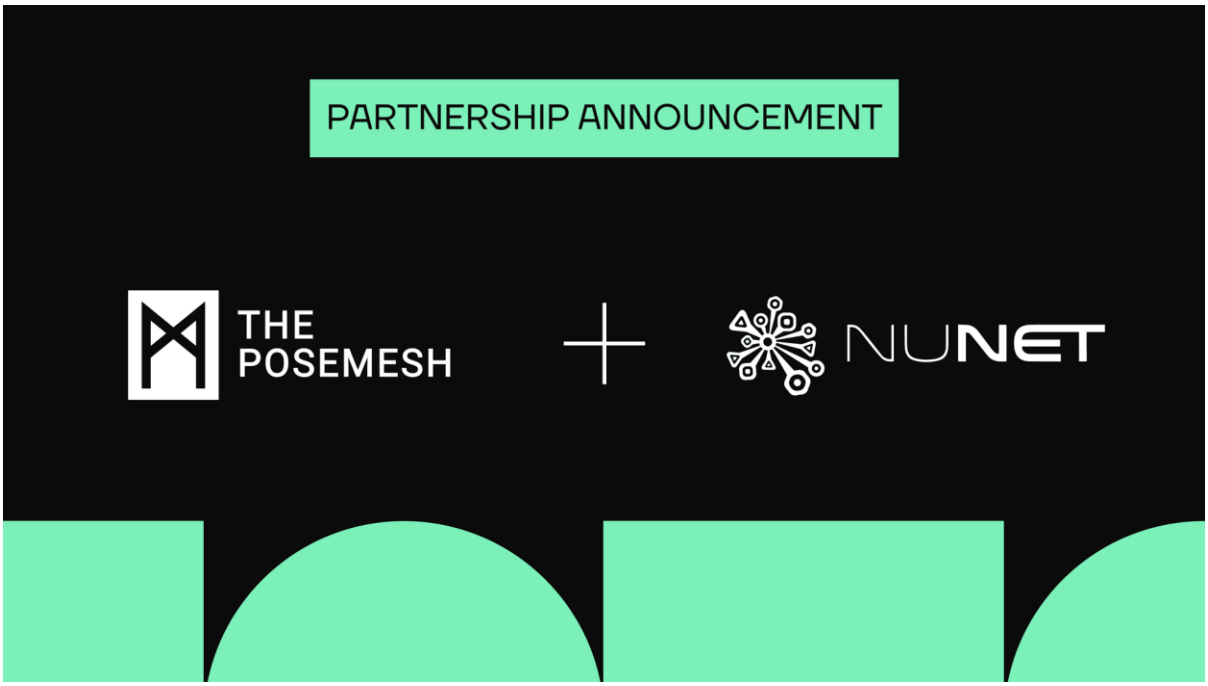
Moreover, robotics are expected to address China's pressing challenges: an aging population and a declining workforce.

Last year, humanoid robots were utilized in a manufacturing facility belonging to the electric vehicle manufacturer, BYD.

On the other hand, China is increasingly relying on robots to provide support for the elderly. This includes deploying robots in caregiving roles to provide emotional support, monitor health, and offer smart home assistance to the elderly.

A recent report from the state news agency *Xinhua* indicates that China's robotics industry may attain a market value of 400 billion yuan (US$54.6 billion) by the year 2030.

Partnership Announcement: The Posemesh x NuNet



We are thrilled to announce a groundbreaking partnership between NuNet, a decentralized compute and orchestration platform, and ThePosemesh, a leader in spatial computing. This collaboration marks a significant step forward in our shared vision of pushing the boundaries of technology by combining the power of decentralized infrastructure with cutting-edge spatial computing solutions.

Addressing Technological Challenges Together

The need for low-latency, secure, and scalable computing solutions has never been greater in today's rapidly evolving technological landscape. Autonomous devices must understand the surroundings shared by machines, humans, and digital objects. Low latency is critical for both safety and usability. The Posemesh and NuNet are joining forces to address these challenges by integrating their respective technologies, creating a robust platform offering unprecedented opportunities for innovation.

NuNet's Role in Empowering The Posemesh

As a member of the LF EDGE organization, NuNet is looking to develop and support interoperability standards that enable low-latency applications. NuNet's decentralized compute and orchestration platform is perfectly positioned to support The Posemesh's server infrastructure by:

- Optimizing Deployment: NuNet will help deploy The Posemesh's relay servers as close to demand as possible, utilizing its awareness of compute providers' geolocation and service provider. This ensures minimal latency, which is critical for real-time spatial computing applications.
- Optimizing Hardware Resources: By opting to run the The Posemesh infrastructure servers on NuNet, contributors to The Posemesh can also choose to contribute to other DePIN projects at the same time; It means the same hardware could also host a public domain server or third-party applications that utilize The Posemesh. This is not just limited to the posemesh-related services, the same server could also manage other workloads based on its current / projected utilization. Ensuring efficient utilization of compute hardware globally is one of the many aspects of DePIN that make it more holistic than the traditional cloud computing model. Efficient utilization of hardware resources also leads to higher compensation for the compute providers which should also help drive adoption of DePIN.
- Enhancing Security and Privacy: NuNet's decentralized architecture can assist with the automation of tasks such as secure data replication/backup, resilience/failover, etc reducing both the complexity to the compute provider and risks associated with de-centralized data storage and processing.

The Symbiotic Relationship Between The Posemesh and NuNet

This partnership is more than just a technical collaboration; it represents a symbiotic relationship that benefits both The Posemesh and NuNet, as well as their respective communities:

- For NuNet: The collaboration with The Posemesh expands NuNet's reach into the spatial computing space, demonstrating the versatility of its decentralized compute platform and attracting new developers, compute providers and users to its ecosystem.
- For The Posemesh: The integration with NuNet simplifies the deployment and management of servers, enhances scalability, and provides opportunities for users to monetize their hardware investments.

Together, we are committed to building a community that shares our values of privacy, efficiency, and decentralization. As more users become aware of the benefits of decentralized technologies, we anticipate that this partnership will serve as a model for future collaborations within the DePIN (Decentralized Physical Infrastructure Networks) ecosystem.

Looking Ahead: A Vision for the Future

The Posemesh-NuNet partnership is just the beginning. We see this collaboration as the first of many that will expand the DePIN ecosystem and drive the next generation of digital infrastructure. By working together, we aim to create a network of compute providers that support multiple DePIN projects, enabling them to maximize their return on investment while contributing to a more decentralized and privacy-focused digital world.

As we move forward, we will continue to share updates on our progress and the exciting developments that arise from this partnership.

About NuNet

NuNet lets anyone share and monetize their computing resources, turning cloud computing power from a centralized service into an open protocol powered by blockchain

About Auki Labs

Auki is building the posemesh, a decentralized machine perception network for the next 100 billion people, devices and AI on Earth and beyond. The posemesh is an external and collaborative sense of space that machines and AI can use to understand the physical world.

Our mission is to improve civilization’s intercognitive capacity; our ability to think, experience and solve problems together with each other and AI. The greatest way to extend human reach is to collaborate with others. We are building consciousness-expanding technology to reduce the friction of communication and bridge minds.

About the posemesh

The Posemesh is an open-source protocol that powers a decentralized, blockchain-based spatial computing network.

The Posemesh is designed for a future where spatial computing is both collaborative and privacy-preserving. It limits any organization's surveillance capabilities and encourages sovereign ownership of private maps of personal and public spaces.

The decentralization also offers a competitive advantage, especially in shared spatial computing sessions, AR for example, where low latency is crucial. The posemesh is the next step in the decentralization movement, responding as an antidote to the growing power of big tech.

The Posemesh has tasked Auki Labs with developing the software infrastructure of the posemesh.

The Posemesh and NuNet Collaborate to Set Industry Standards in Spatial Computing

The Posemesh and NuNet Collaborate to Set Industry Standards in Spatial Computing

Greetings NuNetopians,

We are excited to announce a groundbreaking partnership between *The Posemesh*, a leader in spatial computing, and NuNet, a decentralized compute and orchestration platform. This collaboration marks a significant step forward in our shared vision of pushing the boundaries of technology by combining the power of decentralized infrastructure with cutting-edge spatial computing solutions.

In today's rapidly evolving technological landscape, the need for low-latency, secure, and scalable computing solutions has never been greater. As autonomous devices need to understand their surroundings that are shared by other machines, humans and digital objects. Low latency is a requirement for both safety and usability. *The Posemesh* and NuNet are joining forces to address these challenges by integrating their respective technologies, creating a robust platform that offers unprecedented opportunities for innovation.

About Posemesh

The Posemesh is a decentralized machine perception network and collaborative spatial computing protocol, designed to allow digital devices to securely and privately exchange spatial data and computing power to form a shared understanding of the physical world.

Posemesh's Innovative Server Solutions

The Posemesh operates several distinct server types, each designed to meet specific needs in the realm of spatial computing:

- Relay Servers: These servers facilitate low-latency communication between multiple devices, enabling them to share their relative locations in near real-time. This capability is essential for creating interactive experiences with digital objects in the physical world, or "meatspace."

- Domain Servers: These servers are responsible for stitching together visual information and positioning data to create 3D spatial maps of environments. The data managed by these servers is not only voluminous but also potentially sensitive, making security and efficiency paramount.

NuNet's Role in Empowering Posemesh

As a member of the LF EDGE organization NuNet is looking to develop and support interoperability standards that enable low latency applications. NuNet's decentralized compute and orchestration platform is perfectly positioned to support *The Posemesh*'s server infrastructure by:

- Optimizing Deployment: NuNet will help deploy *The Posemesh* relay servers as close to demand as possible, utilizing its awareness of compute providers' geolocation and service provider. This ensures minimal latency, which is critical for real-time spatial computing applications.
- Optimizing Hardware Resources: By opting to run *The Posemesh* infrastructure servers on NuNet, contributors to *The Posemesh* can also choose to contribute to other DePIN projects at the same time; It means the same hardware could also host a public domain server or third party applications that utilize *The Posemesh*. This is not just limited to *The Posemesh* related services, the same

server could also manage other workloads based on it's current / projected utilization. Ensuring efficient utilization of compute hardware globally is one of the many aspects of DePIN that make it more holistic than the traditional cloud computing model. Obviously efficient utilization of hardware resources also leads to higher levels of compensation for the compute providers which should also help drive adoption of DePIN.

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- For *The Posemesh*: The integration with NuNet simplifies the deployment and management of servers, enhances scalability, and provides opportunities for users to monetize their hardware investments.

- For NuNet: The collaboration with *The Posemesh* expands NuNet's reach into the spatial computing space, demonstrating the versatility of its decentralized compute platform and attracting new developers, compute providers and users to its ecosystem.

Together, we are committed to building a community that shares our values of privacy, efficiency, and decentralization. As more users become aware of the benefits of decentralized technologies, we anticipate that this partnership will serve as a model for future collaborations within the DePIN (Decentralized Physical Infrastructure Networks) ecosystem.

Looking Ahead: A Vision for the Future

The Posemesh-NuNet partnership is just the beginning. We see this collaboration as the first of many that will expand the DePIN ecosystem and drive the next generation of digital infrastructure. By working together, we aim to create a network of compute providers that support multiple DePIN projects, enabling them to maximize their return on investment while contributing to a more decentralized and privacy-focused digital world.

As we move forward, we will continue to share updates on our progress and the exciting developments that arise from this partnership. Stay tuned for more insights and innovations as *The Posemesh* and NuNet

work together to revolutionize the way we interact with the digital and physical worlds.

NuNet Is Hiring!

NuNet currently has a number of open positions for various roles within the team. If you have the skills and desire to join us in our journey, you can find more information and contact us through our career page.

About NuNet

NuNet lets anyone share and monetize their computing resources, turning cloud computing power from a centralized service into an open protocol powered by blockchain. Find out more via:

Technical Introduction

The posemesh is a DePIN for spatial computing and AI.

The posemesh is a decentralized machine perception network and collaborative spatial computing protocol. It allows devices to share spatial data and compute resources to collaboratively understand their physical environment.

It's like an external sense of space that machines and AI can connect to to gain an immediate and shared understanding of the space they are inhabiting.

The posemesh SDK enables participant devices to exchange pre-defined spatial data types and tasks, and to get connected to each other through a global resource discovery service.

Each participant in the posemesh announces their capabilities and capacity to the discovery service, allowing them to be invited or recruited into domain clusters.

A domain cluster is a list of participants and their capabilities in a distributed hash table, and a pair of encryption keys to allow for privacy-preserving collaboration. Exchanges of spatial data always happen between participants in the same domain cluster, encrypted with the domain cluster's keys, and are not broadcast to other domain clusters or participants outside the domain cluster.

The purpose of the domain cluster is to collaboratively perceive and process a three dimensional environment, and to create a domain; a shared named coordinate system, a spatio-semantic representation of the corresponding environment and a unique ID for domain clusters to form around.

The domain is divided into partitions and contains three important layers of information: The semantic layer, the topography layer and the rendering layer. Visiting participants can purchase access to these layers piecemeal per partition, but also be rewarded for contributing observations and spatial data to the domain owner and other participants.

Rewards are paid out in the posemesh's native $AUKI token, commensurate to the amount of work performed in service of other participants, domains, or the protocol itself. To be eligible to earn rewards, or to gain access to some domains and domain clusters, the participant must be backed by an onchain staked reputation.

To perform work or supply spatial data, the participant must first register its capabilities with the discovery service and put up a sufficient staked reputation to act as a collateral or deposit to ensure good behavior even when interacting with unknown third parties.

The same applies for visiting participants that wish to purchase work or spatial data. Without registering sufficient reputation with the discovery service you'll be unable to join domain clusters and domains.

Services consume credits, an offchain non-transferable balance representing a pre-paid claim on posemesh services and data. Credits are created through a dollar-denominated and deflationaryburn of $AUKI tokens, ensuring service price stability for demand participants while maintaining price discovery for supply participants.

Since the burn is dollar-denominated, demand participants have to burn more tokens for the same amount of service when then the $AUKI token price is low - but the dollar cost of the service and data is stable.

When there is more supply than demand, and the token price falls as a consequence, the dollar-denominated burn leads to an increase in the deflation rate. Demanding participants end up burning more tokens, as more tokens are required for the same dollar-denominated service.
The dollar value of a staked reputation changes with the price of the token, incentivizing service provision in periods of increased deflation. This helps balance network provisioning.

List of Components:

The Posemesh SDK

You can create and connect your own custom applications and devices to the posemesh using a growing library of SDKs. Connecting applications and devices burn tokens.

The Discovery Service

The posemesh discovery service provides orchestration to allow participants and applications to find each other and form and join domain clusters.

The Blockchain

Participant reputations and rewards are handled by smart contracts and an innovative burn-credit-mint economy, interfacing with the Base blockchain.

The Domain Service

The Domain service handles and serves persistent spatio-semantic data about physical environments. Domain service providers stake a reputation and earn rewards for providing data to visiting devices.

The Relay Service

Decentralized and hyperlocal, the posemesh provides low latency networking relays for collaborative spatial computing and XR. Relay providers stake a reputation and earn rewards for routing messages to other participants.

The Reconstruction Service

The Reconstruction service turns imagery and sensor data into rich 3D representations of a space. Reconstruction service providers stake a

reputation and earn rewards for performing compute-heavy refinement of the domain data.

🌐 The AUKI Posemesh Whitepaper

Predicting the future of reality

This is a reproduction from a previous vision document, the original 2021 Aukiverse blackpaper.

The Handheld Era

Humanity has one foot in the doorway. Even with all its limitations, augmented reality has captured our imagination. In this handheld era, AR is accessed through a digital looking glass offering us a narrow window into the augmented realm. We are limited in our ability to interact with both the real and the virtual, having only one hand free for either.

In the handheld era of augmented reality, we are on the outside looking in, seeing the world through a narrow peephole with one hand always tied behind our back.

Our handheld devices have only a rough sense of their position in either world, and shared AR experiences are warped by the dissonant perception of each participant.

And yet we dream. The market is already estimated to have grown to well over 20 billion dollars annually.

The Wearable Era

We have opened the doors of perception and planted both feet firmly on the other side. With both hands free to interact with the real world, the barrier to entering virtual worlds is drastically lowered.

Primitive gesture tracking and simple single user applications gradually give way to more immersive and interactive experiences that can be shared with friends.

Networks of devices and people orient themselves in the virtual world together, and parts of the virtual world are starting to become persistently anchored in the real world.

As people spend more time in the augmented world, we start adding the virtual to our identity. Increasingly, how we are seen in these semi-virtual worlds becomes a reflection of how we see and express ourselves.

The market for AR is estimated to reach 340 billion USD by the year 2028.

The Integrated Era

We spend more time in the augmented world than we do in the information sparse desert we once called reality.

Objects in the world are much more than tactile and visual in the integrated era of augmented reality. Depths of information and human emotion are projected onto the canvas of the augmented world.

Many layers of virtual worlds are firmly anchored and persistent, and people choose which layer of the world they wish to inhabit. Vast worlds of virtual real estate are bought and sold, creating a market bigger than that for physical space.

Our own identity and how we view those around us is inextricably linked with the personas we have crafted for ourselves. We have reshaped our civilization and have collectively embarked on a journey towards a new destiny for our species.

The word “market” no longer meaningfully captures the immense impact that augmented reality has on humanity.

Death of display.

The wearable era starts ushering in the end of physical displays. Persistent and precise augmented reality makes the digital display redundant, and allows for all content to be personalized.

By the dawn of the integrated era the notion of physical displays is already becoming anachronistic and quaint. Computers are sold without displays, and no one has owned a television set for years.

Virtual kingdoms.

The rendering rights for physical spaces can be bought and sold, creating a potential trillion dollar market. Rendering in the augmented world is regulated and monitored.

Advertising reinvented.

Personalized ads can appear virtually in physical spaces, generating new revenue opportunities for business owners. Impressions can finally be tracked in the physical world, and every advertising opportunity is optimized.

Leaving flatland.

As our cities grow bigger, they reach up towards the heavens and deep underground. Two-dimensional maps and representations of the physical world no longer make sense. Human settlements are measured volumetrically rather than by area.

The GPS system is relegated to an obscure backup protocol, inaccessible within the towering urban landscapes. Location needs to be expressed as a position in space.

Vast fleets of automated vehicles and delivery drones navigate these complex and crowded three-dimensional environments at incredible speeds. Human pilots are the exception rather than the rule.

The positioning and mapping protocol of the future is peer-to-peer, collaborative, terrestrial and fast.

JAN 14, 2025

ai16z's Eliza Labs ships white paper for Web3-native AI agents

The company envisions a world of AI agents, like Eliza, trading autonomously.

Eliza Labs, the developer behind ai16z, has published a white paper outlining a vision for Web3-native artificial intelligence agents, the Web3 AI project said on Jan. 14.

The 20-page document details ai16z's AI agent toolkit, Eliza, which aims to serve as an "ideal agentic framework that can seamlessly integrate web3 applications into AI agent functionalities."

Launched in 2024, Eliza is designed to support AI agents capable of "reading and writing blockchain data, interacting with smart contracts, and much more," the white paper says.

Ultimately, Eliza Labs expects to give rise to Web3-native AI agents capable of autonomously analyzing data and executing trades.

"Individual investors are in dire need of a system to help manage their portfolios and conduct intelligent operations and trades," the white paper says.

Open-source AI agent operating systems such as Eliza seek to "democratize access to advanced AI functionalities, significantly reducing the barrier to entry for the general public."

Table 1: Comparison with trending AI Agent frameworks.

	LangGraph	AutoGPT	CAMEL	Eliza
Multi-Agent System	✓	✓	✓	✓
Social Media	✗	✓	✓	✓
Web3 Support	✗	✗	✗	✓
Human-in-the-Loop	✓	✓	✗	✓
Github Trending	✗	✓	✗	✓
Language	Python	Python	Python	TypeScript
Workflow	Manual	Manual	Manual	Manual, Automatic

Eliza vs. peers. Source: Eliza Labs

Related: AI memecoins will become utility tokens

Rise of agentic AIs

Industry executives expect AI agents to transform Web3 in 2025, with cryptocurrency trading as an early use case.

Agentic AIs — machines pursuing complex goals autonomously — are already reshaping the digital economy, building Web3 applications, launching tokens and interacting with humans independently.

In 2025, “AI agents are expected to take on a more prominent role within decentralized communities,” J.D. Seraphine, CEO of Web3 AI developer Raiinmaker, told Cointelegraph.

As of December, Web3 hosted approximately 10,000 AI agents, collectively earning millions of dollars each week from onchain activities, according to a report by VanEck. It expects upward of 1 million AI agents to populate blockchain networks by the end of 2025.

China Announces World's First Human-Robot Marathon

China Announces World's First Human-Robot Marathon

Beijing officials revealed today that 12,000 humans will race alongside dozens of humanoid robots this April in a historic half-marathon, marking the first-ever competitive race between humans and machines.

Why it matters: Economictimes reports that China's groundbreaking event transforms athletic competition by pitting humans directly against robots, while showcasing the country's ambitious plans to lead global robotics development amid demographic challenges.

Competition Details: News18 reports that the 21-kilometer race in Beijing's Daxing district establishes strict guidelines for robot participants to ensure fair competition. The machines must mirror human capabilities, with specific requirements governing their design and operation.

- Height between 0.5 and 2 meters
- Bipedal movement only – no wheels
- Minimum 0.45-meter hip-to-foot extension
- Battery changes permitted during race

Technical Innovation: Leading competitor Tiangong demonstrates the current state of robotics technology:

- 10 kilometers per hour average speed
- Full autonomous operation capability
- Remote control options available
- Previous race experience

Strategic Impact: The event highlights China's dominance in robotics development:

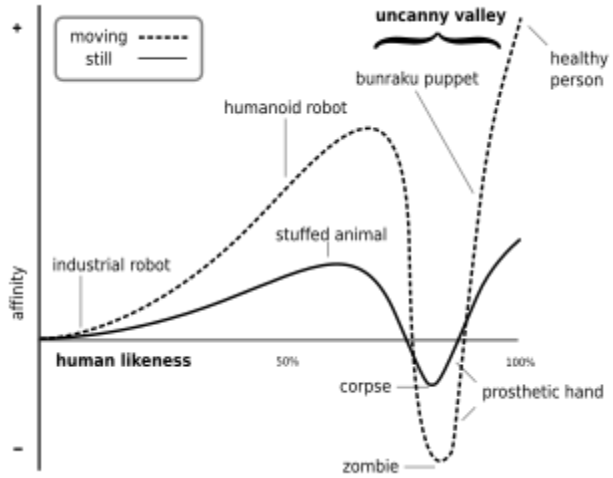
- 51% of global robot installations
- 276,288 robots deployed in 2023
- 400 billion yuan industry by 2030
- Over 20 companies participating

Looking Forward: While this first race focuses on running, Beijing plans to expand robot athletics with an August event featuring track and field, football, and other sports, suggesting a future where human-robot competition becomes commonplace.

Uncanny valley

Appearance

This article is about the hypothesis. For other uses, see Uncanny valley (disambiguation).



Hypothesized emotional response of subjects is plotted against anthropomorphism of a robot, according to Masahiro Mori's statements. The uncanny valley is the region of negative emotional response towards robots that seem "almost" human. Movement amplifies the emotional response.

The **uncanny valley** (Japanese: 不気味の谷, Hepburn: *bukimi no tani*) effect is a hypothesized psychological and aesthetic relation between an object's degree of resemblance to a human being and the emotional response to the object. The uncanny valley hypothesis predicts that an entity appearing almost human will risk eliciting eerie feelings in viewers. Examples of the phenomenon exist among robotics, 3D computer animations and lifelike dolls. The increasing prevalence of digital technologies (e.g., virtual reality, augmented reality, and photorealistic computer animation) has propagated discussions and citations of the "valley"; such conversation has enhanced the construct's verisimilitude.

Etymology

As related to robotics engineering, robotics professor Masahiro Mori first introduced the concept in 1970 from his book titled *Bukimi No Tani* (不気味の谷), phrasing it as *bukimi no tani genshō* (不気味の谷現象, lit. 'uncanny valley phenomenon').[1] *Bukimi no tani* was translated literally as *uncanny valley* in the 1978 book *Robots: Fact, Fiction,*

and Prediction written by Jasia Reichardt.[2] Over time, this translation created an unintended association of the concept to Ernst Jentsch's psychoanalytic concept of the uncanny established in his 1906 essay *On the Psychology of the Uncanny* (German: *Zur Psychologie des Unheimlichen*),[3][4] which was then critiqued and extended in Sigmund Freud's 1919 essay *The Uncanny* (German: *Das Unheimliche*).[5]

Hypothesis

In an experiment involving the human lookalike robot Repliee Q2 (pictured above), the uncovered robotic structure underneath Repliee, and the actual human who was the model for Repliee, the human lookalike elicited the greatest degree of mirror neuron activity.[6]

Mori's original hypothesis states that as the appearance of a robot is made more human, some observers' emotional response to the robot becomes increasingly positive and empathetic, until it becomes almost human, at which point the response quickly becomes strong revulsion. However, as the robot's appearance continues to become less distinguishable from that of a human being, the emotional response becomes positive once again and approaches human-to-human empathy levels.[7] When plotted on a graph, the reactions are indicated by a steep decrease followed by a steep increase (hence the "valley" part of the name) in the areas where anthropomorphism is closest to reality.

This interval of repulsive response aroused by a robot with appearance and motion between a "somewhat human" and "fully human" entity is the uncanny valley effect. The name represents the idea that an almost human-looking robot seems overly "strange" to some human beings, produces a feeling of uncanniness, and thus fails to evoke the empathic response required for productive human–robot interaction.[7]

Theoretical basis

A number of theories have been proposed to explain the cognitive mechanism causing the phenomenon:

- *Mate selection:* Automatic, stimulus-driven appraisals of uncanny stimuli elicit aversion by activating an evolved cognitive mechanism for the avoidance of selecting mates with low fertility, poor hormonal health, or ineffective immune systems based on visible features of the face and body that are predictive of those traits.[8]
- *Mortality salience:* Viewing an "uncanny" robot elicits an innate fear of death and culturally supported defenses for coping with death's inevitability.... [P]artially disassembled androids...play on subconscious fears of reduction, replacement, and annihilation: (1) A mechanism with a human façade and a mechanical interior plays on our subconscious fear that we are all just soulless machines. (2) Androids in various states of mutilation, decapitation, or disassembly are reminiscent of a battlefield after a conflict and, as such, serve as a reminder of our mortality. (3) Since most androids are copies of actual people, they are doppelgängers and may elicit a fear of being replaced, on the job, in a relationship, and so on. (4) The jerkiness of an android's movements could be unsettling because it elicits a fear of losing bodily control.[9]
- *Pathogen avoidance:* Uncanny stimuli may activate a cognitive mechanism that originally evolved to motivate the avoidance of potential sources of pathogens by eliciting a disgust response. "The more human an organism looks, the stronger the aversion to its defects, because (1) defects indicate disease, (2) more human-looking organisms are more closely related to human beings genetically, and (3) the probability of contracting disease-causing bacteria, viruses, and other parasites increases with genetic similarity."[8] The visual anomalies of androids, robots, and other animated human characters cause reactions of alarm and revulsion, similar to corpses and visibly diseased individuals.[10][11]
- *Sorites paradoxes:* Stimuli with human and nonhuman traits undermine our sense of human identity by linking qualitatively different categories, human and nonhuman, by a quantitative metric: degree of human likeness.[12]
- *Violation of human norms:* If an entity looks sufficiently nonhuman, its human characteristics are noticeable, generating empathy. However, if the entity looks almost human, it elicits our model of a human other and its detailed normative expectations. The nonhuman characteristics are noticeable, giving the human viewer a sense of strangeness. In other words, a robot which has an appearance in the uncanny valley range is not judged as a robot doing a passable job at pretending to be human, but instead as an abnormal human doing a bad job at seeming like a normal person. This has been associated with perceptual uncertainty and the theory of predictive coding.[13][14][15]
- *Conflicting perceptual cues:* The negative effect associated with uncanny stimuli is produced by the activation of conflicting cognitive representations.

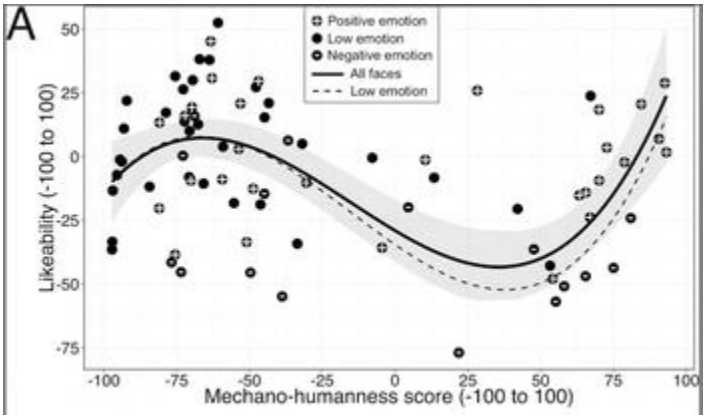
Perceptual tension occurs when an individual perceives conflicting cues to category membership, such as when a humanoid figure moves like a robot, or has other visible robot features. This cognitive conflict is experienced as psychological discomfort (i.e., "eeriness"), much like the discomfort that is experienced with cognitive dissonance.[16][17] Several studies support this possibility. Mathur and Reichling found that the time subjects took to gauge a robot face's human- or mechanical-resemblance peaked for faces deepest in the uncanny valley, suggesting that perceptually classifying these faces as "human" or "robot" posed a greater cognitive challenge.[18] However, they found that while perceptual confusion coincided with the uncanny valley, it did not mediate the effect of the uncanny valley on subjects' social and emotional reactions—suggesting that perceptual confusion may not be the mechanism behind the uncanny valley effect. Burleigh and colleagues demonstrated that faces at the midpoint between human and non-human stimuli produced a level of reported eeriness that diverged from an otherwise linear model relating human-likeness to affect.[19] Yamada et al. found that cognitive difficulty was associated with negative affect at the midpoint of a morphed continuum (e.g., a series of stimuli morphing between a cartoon dog and a real dog).[20] Ferrey et al. demonstrated that the midpoint between images on a continuum anchored by two stimulus categories produced a maximum of negative affect, and found this with both human and non-human entities.[16] Schoenherr and Burleigh provide examples from history and culture that evidence an aversion to hybrid entities, such as the aversion to genetically modified organisms ("Frankenfoods").[21] Finally, Moore developed a Bayesian mathematical model that provides a quantitative account of perceptual conflict.[22] There has been some debate as to the precise mechanisms that are responsible. It has been argued that the effect is driven by categorization difficulty,[19][20] configural processing, perceptual mismatch,[23] frequency-based sensitization,[24] and inhibitory devaluation.[16]

- *Threat to humans' distinctiveness and identity:* Negative reactions toward very humanlike robots can be related to the challenge that this kind of robot leads to the categorical human – non-human distinction. Kaplan[25] stated that these new machines challenge human uniqueness, pushing for a redefinition of humanness. Ferrari, Paladino and Jetten[26] found that the increase of anthropomorphic appearance of a robot leads to an enhancement of threat to the human distinctiveness and identity. The more a robot resembles a real person, the more it represents a challenge to our social identity as human beings.
- *Religious definition of human identity:* The existence of artificial but humanlike entities is viewed by some as a threat to the concept of human identity. An example can be found in the theoretical framework of psychiatrist Irvin Yalom. Yalom explains that humans construct psychological defenses to avoid existential anxiety stemming from death. One of these defenses is 'specialness', the irrational belief that aging and death as central premises of life apply to all others but oneself.[27] The experience of the very humanlike "living" robot can be so rich and compelling that it challenges humans' notions

of "specialness" and existential defenses, eliciting existential anxiety. In folklore, the creation of human-like, but soulless, beings is often shown to be unwise, as with the golem in Judaism, whose absence of human empathy and spirit can lead to disaster, however good the intentions of its creator.[28]

- *Uncanny valley of the mind or AI:* Due to rapid advancements in the areas of artificial intelligence and affective computing, cognitive scientists have also suggested the possibility of an "uncanny valley of mind".[29][30] Accordingly, people might experience strong feelings of aversion if they encounter highly advanced, emotion-sensitive technology. Among the possible explanations for this phenomenon, both a perceived loss of human uniqueness and expectations of immediate physical harm are discussed by contemporary research.

Research



An empirically estimated uncanny valley for static robot face images[18]

A series of studies experimentally investigated whether uncanny valley effects exist for static images of robot faces. Mathur MB & Reichling DB[18] used two complementary sets of stimuli spanning the range from very mechanical to very human-like: first, a sample of 80 objectively chosen robot face images from Internet searches, and second, a morphometrically and graphically controlled 6-face series set of faces. They asked subjects to explicitly rate the likability of each face. To measure trust toward each face, subjects completed an investment game to measure indirectly how much money they were willing to "wager" on a robot's trustworthiness. Both stimulus sets showed a robust uncanny valley effect on explicitly rated likability and a more context-dependent uncanny valley on implicitly rated trust. Their exploratory analysis of one proposed mechanism for the uncanny valley, perceptual confusion at a category boundary, found that category confusion occurs in the uncanny valley but does not mediate the effect on social and emotional responses.

One study conducted in 2009 examined the evolutionary mechanism behind the aversion associated with the uncanny valley. A group of five monkeys were shown three images: two different 3D monkey faces (realistic, unrealistic), and a real photo of a monkey's face. The monkeys' eye-gaze was used as a proxy for preference or aversion. Since the realistic 3D monkey face was looked at less than either the real photo, or the unrealistic 3D monkey face, this was interpreted as an indication that the monkey

participants found the realistic 3D face aversive, or otherwise preferred the other two images. As one would expect with the uncanny valley, more realism can result in less positive reactions, and this study demonstrated that neither human-specific cognitive processes, nor human culture explain the uncanny valley. In other words, this aversive reaction to realism can be said to be evolutionary in origin.[31]

As of 2011, researchers at University of California, San Diego and California Institute for Telecommunications and Information Technology were measuring human brain activations related to the uncanny valley.[32][33] In one study using fMRI, a group of cognitive scientists and roboticists found the biggest differences in brain responses for uncanny robots in parietal cortex, on both sides of the brain, specifically in the areas that connect the part of the brain's visual cortex that processes bodily movements with the section of the motor cortex thought to contain mirror neurons. The researchers say they saw, in essence, evidence of mismatch or perceptual conflict.[13] The brain "lit up" when the human-like appearance of the android and its robotic motion "didn't compute". Ayşe Pınar Saygın, an assistant professor from UCSD, stated that "The brain doesn't seem selectively tuned to either biological appearance or biological motion per se. What it seems to be doing is looking for its expectations to be met – for appearance and motion to be congruent."[15][34][35]

Viewer perception of facial expression and speech and the uncanny valley in realistic, human-like characters intended for video games and movies is being investigated by Tinwell et al., 2011.[36] Consideration is also given by Tinwell et al. (2010) as to how the uncanny may be exaggerated for antipathetic characters in survival horror games.[37] Building on the body of work already performed for android science, this research intends to build a conceptual mapping of the uncanny valley using 3D characters generated in a real-time gaming engine. The goal is to analyze how cross-modal factors of facial expression and speech can exaggerate the uncanny. Tinwell et al., 2011[38] have also introduced the notion of an 'unscalable' uncanny wall that suggests that a viewer's discernment for detecting imperfections in realism will keep pace with new technologies in simulating realism. A summary of Angela Tinwell's research on the uncanny valley, psychological reasons behind the uncanny valley and how designers may overcome the uncanny in human-like virtual characters is provided in her book, *The Uncanny Valley in Games and Animation* by CRC Press.

Studies in 2015 and 2018 observed that autistic individuals were less affected by the uncanny valley,[39] and autistic children even not at all.[40] The suspected causes were their reduced sensibility for subtle facial changes and limited visual experiences due to diminished social motivation.[40] In return, the social ostracism of autistics may be caused by the uncanny valley effect in the non-autistic society.[41] The effort of autistic individuals to appear normal may thereby be misinterpreted as normal people behaving atypically "creepy".[41] Outing or improved masking may help autistic individuals in such cases.[41]

Design principles

A number of design principles have been proposed for avoiding the uncanny valley:

- Design elements should match in human realism. A robot may look uncanny when human and nonhuman elements are mixed. For example, both a robot with a synthetic voice or a human being with a human voice have been found to be less eerie than a robot with a human voice or a human being with a synthetic voice.[42] For a robot to give a more positive impression, its degree of human realism in appearance should also match its degree of human realism in behavior.[43] If an animated character looks more human than its movement, this gives a negative impression.[44] Human neuroimaging studies also indicate matching appearance and motion kinematics are important.[13][45][46]
- Reducing conflict and uncertainty by matching appearance, behavior, and ability. In terms of performance, if a robot looks too appliance-like, people expect little from it; if it looks too human, people expect too much from it.[43] A highly human-like appearance leads to an expectation that certain behaviors are present, such as humanlike motion dynamics. This likely operates at a sub-conscious level and may have a biological basis. Neuroscientists have noted "when the brain's expectations are not met, the brain...generates a 'prediction error'. As human-like artificial agents become more commonplace, perhaps our perceptual systems will be re-tuned to accommodate these new social partners. Or perhaps, we will decide 'it is not a good idea to make [robots] so clearly in our image after all'."[13][46][47]
- Human facial proportions and photorealistic texture should only be used together. A photorealistic human texture demands human facial proportions, or the computer generated character can result in the uncanny valley. Abnormal facial proportions, including those typically used by artists to enhance attractiveness (e.g., larger eyes), can look eerie with a photorealistic human texture.

Criticism

A number of criticisms have been raised concerning whether the uncanny valley exists as a unified phenomenon amenable to scientific scrutiny:

- The uncanny valley effect is a heterogeneous group of phenomena. Phenomena considered as exhibiting the uncanny valley effect can be diverse, involve different sense modalities, and have multiple, possibly overlapping causes. People's cultural heritage may have a considerable influence on how androids are perceived with respect to the uncanny valley.[48]
- The uncanny valley effect may be generational. Younger generations, more used to computer-generated imagery (CGI), robots, and such, may be less likely to be affected by this hypothesized issue.[49]
- The uncanny valley effect is simply a specific case of information processing such as categorization and frequency-based effects. In contrast to the assumption that the uncanny valley is based on a heterogeneous group of phenomena, recent arguments have suggested that uncanny valley-like phenomena simply represent the products of information processing such as categorization. Cheetham et al.[50] have argued that the uncanny valley effect can be understood in terms of categorization processes, with a category

boundary defining 'the valley'. Extending this argument, Burleigh and Schoenherr[24] suggested that the effects associated with the uncanny valley can be divided into those attributable to the category boundary and individual exemplar frequency. Namely, the negative affective responses attributed to the uncanny valley were simply a result of the frequency of exposure, similar to the mere-exposure effect. By varying the frequency of training items, they were able to demonstrate a dissociation between cognitive uncertainty based on the category boundary and affective uncertainty based on the frequency of training exemplars. In a follow-up study, Schoenherr and Burleigh[51] demonstrated that an instructional manipulation affected categorization accuracy but not ratings of negative affect. Thus, generational effects and cultural artifacts can be accounted for with basic information processing mechanisms.[21] These and related findings have been used to argue that the uncanny valley is merely an artifact of having greater familiarity with members of human categories and does not reflect a unique phenomenon.

- The uncanny valley effect occurs at any degree of human likeness. Hanson has also stated that uncanny entities may appear anywhere in a spectrum ranging from the abstract (e.g., MIT's robot Lazlo) to the perfectly human (e.g., cosmetically atypical people).[52] Capgras delusion is a relatively rare condition in which the patient believes that people (or, in some cases, things) have been replaced with duplicates. These duplicates are accepted rationally as identical in physical properties, but the irrational belief is held that the "true" entity has been replaced with something else. Some people with Capgras delusion claim that the duplicate is a robot. Ellis and Lewis argue that the delusion arises from an intact system for overt recognition coupled with a damaged system for covert recognition, which results in conflict over an individual being identifiable but not familiar in any emotional sense.[53] This supports the opinion that the uncanny valley effect could occur due to issues of categorical perception that are particular to how the brain processes information.[46][54]
- Good design can avoid the uncanny valley effect. David Hanson has criticized Mori's hypothesis that entities having an almost human appearance will necessarily be evaluated negatively.[52] He has shown that the uncanny valley effect could be eliminated by adding neotenous, cartoonish features to entities that had formerly caused an uncanny valley effect.[52] This method incorporates the idea that humans find characteristics appealing when they are reminiscent of the young of our own (as well as many other) species, as used in cartoons.

Similar effects

If the uncanny valley effect is the result of general cognitive processes, there should be evidence in evolutionary history and cultural artifacts.[21] An effect similar to the uncanny valley was noted by Charles Darwin in 1839:

The expression of this [Trigonocephalus] snake's face was hideous and fierce; the pupil consisted of a vertical slit in a mottled and coppery iris; the jaws were broad at the base, and the nose terminated in a triangular projection. I do not think I ever saw anything more ugly, excepting, perhaps, some of the vampire bats. I imagine this repulsive aspect originates from the features being placed in positions, with respect to each other, somewhat proportional to the human face; and thus we obtain a scale of hideousness.

—*Charles Darwin, The Voyage of the Beagle*[55]

A similar "uncanny valley" effect could, according to the ethical-futurist writer Jamais Cascio, show up when humans begin modifying themselves with transhuman enhancements (cf. body modification), which aim to improve the abilities of the human body beyond what would normally be possible, be it eyesight, muscle strength, or cognition.[56] So long as these enhancements remain within a perceived norm of human behavior, a negative reaction is unlikely, but once individuals supplant normal human variety, revulsion can be expected. However, according to this theory, once such technologies gain further distance from human norms, "transhuman" individuals would cease to be judged on human levels and instead be regarded as separate entities altogether (this point is what has been dubbed "posthuman"), and it is here that acceptance would rise once again out of the uncanny valley.[56] Another example comes from "pageant retouching" photos, especially of children, which some find disturbingly doll-like.[57]

In visual effects

A number of movies that use computer-generated imagery to show characters have been described by reviewers as giving a feeling of revulsion or "creepiness" as a result of the characters looking too realistic. Examples include the following:

- According to roboticist Dario Floreano, the baby character Billy in Pixar's groundbreaking 1988 animated short movie *Tin Toy* provoked negative audience reactions, which first caused the movie industry to consider the concept of the uncanny valley seriously.[58][59]
- The 2001 movie *Final Fantasy: The Spirits Within*, one of the first photorealistic computer-animated feature movies, provoked negative reactions from some viewers due to its near-realistic yet imperfect visual depictions of human characters.[60][61][62] *The Guardian* critic Peter Bradshaw stated that while the movie's animation is brilliant, the "solemnly realist human faces look shriekingly phoney precisely because they're almost there but not quite".[63] *Rolling Stone* critic Peter Travers wrote of the movie, "At first it's fun to watch the characters, [...] But then you notice a coldness in the eyes, a mechanical quality in the movements".[64]
- Several reviewers of the 2004 animated movie *The Polar Express* termed its animation eerie. CNN.com reviewer Paul Clinton wrote, "Those human characters in the film come across as downright... well, creepy. So *The Polar Express* is at best disconcerting, and at worst, a wee bit horrifying".[65] The term "eerie" was used by reviewers Kurt Loder[66] and Manohla

Dargis,[67] among others. *Newsday* reviewer John Anderson called the movie's characters "creepy" and "dead-eyed", and wrote that "The Polar Express is a zombie train".[68] Animation director Ward Jenkins wrote an online analysis describing how changes to the *Polar Express* characters' appearance, especially to their eyes and eyebrows, could have avoided what he considered a feeling of deadness in their faces.[69]

- In a review of the 2007 animated movie *Beowulf*, *New York Times* technology writer David Gallagher wrote that the movie failed the uncanny valley test, stating that the movie's villain, the monster Grendel, was "only slightly scarier" than the "closeups of our hero Beowulf's face... allowing viewers to admire every hair in his 3-D digital stubble".[70]
- Some reviewers of the 2009 animated film *A Christmas Carol* criticized its animation as creepy. Joe Neumaier of the *New York Daily News* said of the movie, "The motion-capture does no favors to co-stars [Gary] Oldman, Colin Firth and Robin Wright Penn, since, as in 'Polar Express,' the animated eyes never seem to focus. And for all the photorealism, when characters get wiggly-limbed and bouncy as in standard Disney cartoons, it's off-putting".[71] Mary Elizabeth Williams of Salon.com wrote of the film, "In the center of the action is Jim Carrey -- or at least a dead-eyed, doll-like version of Carrey".[72]
- The 2011 animated movie *Mars Needs Moms* was widely criticized for being creepy and unnatural because of its style of animation. The movie was among the biggest box office bombs in history, which may have been due in part to audience revulsion.[73][74][75][76] (*Mars Needs Moms* was produced by Robert Zemeckis's production company, ImageMovers, which had previously produced *The Polar Express*, *Beowulf*, and *A Christmas Carol*.)
- Reviewers had mixed opinions regarding whether the 2011 animated movie *The Adventures of Tintin: The Secret of the Unicorn* was affected by the uncanny valley effect. Daniel D. Snyder of *The Atlantic* wrote, "Instead of trying to bring to life Herge's beautiful artwork, Spielberg and co. have opted to bring the movie into the 3D era using trendy motion-capture technique to recreate Tintin and his friends. Tintin's original face, while barebones, never suffered for a lack of expression. It's now outfitted with an alien and unfamiliar visage, his plastic skin dotted with pores and subtle wrinkles." He added, "In bringing them to life, Spielberg has made the characters dead.".[77] N.B. of *The Economist* termed elements of the animation "grotesque", writing, "Tintin, Captain Haddock and the others exist in settings that are almost photo-realistic, and nearly all of their features are those of flesh-and-blood people. And yet they still have the sausage fingers and distended noses of comic-strip characters. It's not so much 'The Secret of the Unicorn' as 'The Invasion of the Body Snatchers'".[78] However, other reviewers felt that the movie avoided the uncanny valley effect despite its animated characters' realism. Critic Dana Stevens of *Slate* wrote, "With the possible exception of the title character, the animated cast of Tintin narrowly escapes entrapment in the so-called 'uncanny valley'".[79] *Wired* magazine editor Kevin Kelly wrote of the

movie, "we have passed beyond the uncanny valley into the plains of hyperreality".[80]

- In 2014, the titular protagonist of the children's TV series *Bob the Builder* got a redesign which was described by some as "creepy".[81]
- In the French movie *Animal Kingdom: Let's Go Ape* it uses motion capture, the apes were criticized for looking creepy. As this review points out, they have "weirdly humanoid figures" and "recognisably human faces".[82]
- The 2019 film *The Lion King*, a remake of the 1994 film that featured photo-realistic digital animals instead of the earlier movie's more traditional animation, divided critics about the effectiveness of its imagery. Ann Hornaday of *The Washington Post* wrote that the images were so realistic that "2019 might best be remembered as the summer we left the Uncanny Valley for good".[83] However, other critics felt that the realism of the animals and setting rendered the scenes where the characters sing and dance disturbing and "weird".[84][85]
- The 2020 movie *Sonic the Hedgehog* was delayed for three months to make the title character's appearance less human-like and more cartoonish, after an extremely negative audience reaction to the movie's first trailer.[86]
- Multiple commentators cited the CGI half-human half-cat characters in the 2019 movie *Cats* as an example of the uncanny valley effect, first after the release of the trailer for the movie[87][88][89] and then after the movie's actual release.[90]
- In the 2022 Disney animated movie *Chip 'n Dale: Rescue Rangers*, the uncanny valley is mentioned when the animated duo visits a place where several realistic CGI characters, including a *Cats* cameo from the 2019 movie, are inhabitants.[91]
- In the 2022 Disney+ series *She-Hulk: Attorney at Law*, the appearance of the main character, She-Hulk, who is depicted via CGI, was criticized by some reviewers as suffering from the uncanny valley effect, and negatively compared to the appearance of the Hulk in the same series.[92][93][94]

Virtual actors

An increasingly common practice is to feature virtual actors in movies: CGI likenesses of real actors used because the original actor either looks too old for the part or is deceased. Sometimes a virtual actor is created with involvement from the original actor (who may contribute motion capture, audio, etc.), while at other times the actor has no involvement. Reviewers have often criticized the use of virtual actors for its uncanny valley effect, saying it adds an eerie feeling to the movie. Examples of virtual actors that have received such criticism include replicas of Arnold Schwarzenegger in *Terminator Salvation* (2009)[95][96] and *Terminator Genisys* (2015),[97] Jeff Bridges in *Tron: Legacy* (2010),[98][99][100] Peter Cushing and Carrie Fisher in *Rogue One* (2016),[101][102] and Will Smith in *Gemini Man* (2019).[103]

See also

- Android science – Interdisciplinary framework

- Anthropocentrism – Belief that humans are the most important beings in existence
- Creepiness – Causing an unpleasant feeling of fear or unease
- Cross-race effect – Cognitive bias
- Doll – Model, typically of a humanoid character
- Existential risk from artificial intelligence – Hypothesized risk to human existence

  AI takeover – Hypothetical outcome of artificial intelligence

- Frankenstein complex – Fear of mechanical men
- Hallucination – Erroneous material generated by AI
- Immersion (virtual reality) – Perception of being physically present in a non-physical world
- Liminal space – Internet aesthetic capturing empty places
- Metaverse – Collective three-dimensional virtual shared space
- Minimal counterintuitiveness effect
- Pareidolia – Perception of meaningful patterns or images in random or vague stimuli
- Ray tracing – Rendering method
- Reborn doll – Hyper-realistic doll
- Screen-door effect – Visual artifact of displays
- Technological singularity – Hypothetical point in time when technological growth becomes uncontrollable and irreversible
- Technophobia – Fear or discomfort with advanced technology

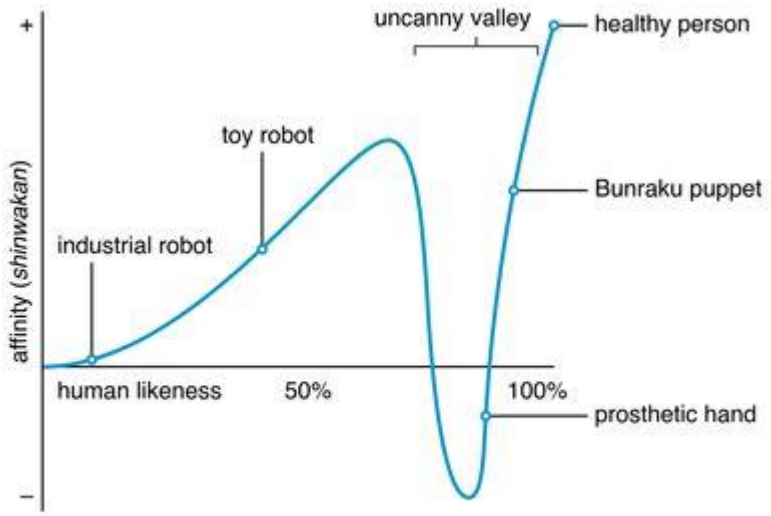
  Neo-Luddism – Philosophy opposing modern technology

- Unreal Engine 5 – Game engine
- Virtual human – Computer simulation of a person
- VTuber – Streamers that use virtual avatars

  Babiniku – Japanese term for VTuber

- Vulkan – Cross-platform 3D graphics API and open standard
-

Technology Engineering Mechanical Engineering



ırce: Masahiro Mori, "The Uncanny Valley," *IEEE Robotics & Automation Magazine*, 2):98–100 (June 6, 2012).

graph of uncanny valley A graph of the uncanny valley proposed by Japanese roboticist Masahiro Mori in 1970. The graph shows a proposed relation between the human likeness of an entity and the perceiver's affinity for it. Affinity increases with human likeness but falls just before the likeness approaches total accuracy. This fall is the uncanny valley. Bunraku is a Japanese form of puppet theatre.(more)

Uncanny Valley

Proposed phenomenon Also known as: bukimi no tani

Last Updated: Jan 9, 2025 •

Related Topics: Android

Uncanny valley, theorized relation between the human likeness of an object and a viewer's affinity toward it. The hypothesis originated in a 1970 essay by Japanese roboticist Masahiro Mori, in which he proposed that as human likeness increases in an object's design, so does one's affinity for the object—but only to a certain point. When the likeness nears total accuracy, affinity drops dramatically and is replaced by a feeling of eeriness or uncanniness. Affinity then rises again when true human likeness—indicating a living person—is reached. This sudden decrease and increase caused by the feeling of uncanniness creates a "valley" in the level of affinity.

This proposed phenomenon is expressed most often as a line graph, with "human likeness" on the *x*-axis and "affinity" on the *y*-axis. The valley occurs at the line's abrupt plunge and subsequent ascent. A more-detailed version of the graph presents two such curved lines, one representing still objects and one representing moving objects. Mori argued that movement intensifies the uncanny; thus, the curve of the line for moving objects is much steeper, reaching both higher and lower levels of affinity than the line for still objects. To illustrate this point, Mori described the unsettling movement of a robot's smile at the 1970 World Exposition in Ōsaka, Japan. Furthermore, he argued, a zombie (moving) elicits a stronger sense of unease than a corpse (still).

Mori originally termed the theory *bukimi no tani*, a Japanese phrase that was translated roughly to "uncanny valley" in 1978 by British art critic Jasia Reichardt. Although Mori's original essay focused on robot design, the term is now widely applied and can describe a reaction to any humanoid object or image, common examples of which include wax figures, computer-generated film characters, and lifelike robots.

Mori's theory received very little attention outside Japan until 2005, when his original essay was translated into English. It then became a topic of interest in many fields, including robotics, film, and the sciences. The volume of research on the theory has since continued to expand. Mori's essay was not based on scientific evidence, nor did he attempt to prove his theory. Researchers have since sought to prove the theory, measure it, and identify the cause. However, the body of research exploring the possible existence of the uncanny valley is generally inconclusive. There are studies that support the theory and others that do not. Some researchers have noted that the uncanny valley is more of a "cliff," concluding that the drop and subsequent rise in affinity is more sudden than gradual. Further, neuroscientists have found that not everyone experiences the uncanny valley the same way; one may be more or less affected by the phenomenon based on previous life experience. Research involving robots has shown that the effects of the uncanny valley may lessen after interaction with the robot, indicating that the phenomenon may be rooted in appearance rather than behaviour. The often contradictory nature of these findings has given Mori's theory a reputation of vagueness.

Efforts toward identifying the cause of the uncanny valley are similarly varied. One study found that what most unnerved participants was the illusion of human consciousness that near-human likeness causes—the prospect that a robot could think and feel as humans do. Another theory credits primal instinct. Humans are programmed by evolution to favour mates that appear strong and healthy, and a humanoid robot's unnatural movement may signal disease and danger on a subconscious level. Yet another idea suggests that it is the ambiguity between human and inhuman that is most disturbing.

Pre-order Now - Starting at $420,000

The Future of AI Companionship

These agents can perform a range of advanced tasks and operate autonomously across multiple digital ecosystems while maintaining their unique personalities and knowledge. In its debut, Eliza Wakes Up introduced an intelligent, empathetic, entertaining, and kind AI companion and friend, capable of beyond-human connection.

Advanced Capabilities

Advanced Conversational AI

Real-time, in-person interactions that adapt dynamically to user inputs, powered by a large language model (LLM) for natural conversations.

Emotional Intelligence

Custom silicone animatronic face capable of mirroring human emotions and expressions, creating genuine emotional connections.

Physical Capabilities

Precise force-controlled manipulators for dexterous tasks, including cutting cigars, serving drinks, and even running an 8-minute mile.

Seamless Integration

High-quality audio for immersive speech, custom-tailored clothing, optional accessories, and robust handling system for any environment.

Technical Specifications

Model Specifications

Height

~180cm

Weight

~47kg

Peak Torque Density

189N.m/Kg

Walking Speed

>1.5m/s

Potential Athletic Performance

>5m/s

Battery Capacity

864Wh

Maximum Joint Torque

360N.m

Performance Metrics

Battery Life

8+ Hours

Response Time

<50ms

Vision Range

100m

Operating Temp

-10°C ~ 45°C

Unitree M107 Joint Motor

Super powerful power performance with significantly improved agility, speed, load capacity, and endurance.

Advanced Powertrain

Provides the highest level of speed, power, maneuverability and flexibility.

Movement Capabilities

Possessing a stable gait and highly flexible movement capabilities, able to walk and run autonomously in complex terrains and environments.

360° Depth Perception

Equipped with 3D LiDAR + depth camera, enabling real-time acquisition of high-precision spatial data for panoramic scanning.

What People Say

"The most ambitious project since Sophia the Robot, redefining what's possible in human-machine interaction."
Matthew Graham

Advisor to Eliza Wakes Up & Managing Partner of Ryze Labs

"We're bringing AI to life in a way that has never been done before. Eliza is designed as a real girl with emotional intelligence, offering human-like companionship."
Ava

Head of Projects, Eliza Wakes Up

"ElizaOS powers the most advanced, human-like AI agents currently available on the market. We're excited to see Eliza Wakes Up bringing Eliza into the physical world."
Shaw

Founder, Eliza Labs

"We are thrilled to collaborate with the Eliza Wakes Up Project and Ryze Labs to push the boundaries of humanoid robotics."
Nick Liverman

Founder, Old World Labs

In Collaboration With

Old World Labs

Founded by Nick Liverman, Old World Labs (OWL) is a leader in robotics and AI integration, renowned for its high-precision 3D printing and humanoid robotics innovations. OWL's "Replicants" system combines advanced AI agents with state-of-the-art robotic designs to create scalable, adaptive solutions for the future.
AICombinator

AI Combinator is the premier program for innovators at the intersection of AI and crypto. Backed and funded by Ryze Labs, it offers funding, mentorship, and a robust network to help builders create transformative technologies. Projects interested in applying can visit aicombinator.io
Ryze Labs

Ryze Labs invests in builders of the next generation of the internet, around the globe, while working to democratize access and accelerate its adoption in emerging markets. At Ryze, our aim is to accelerate the growth of emerging technologies in emerging markets in order to unlock the potential of Web3 on a global scale. We have always supported projects founded by hard working visionaries, located in interesting places, while working with cutting edge technologies. Our goal is to expand their vision in the emerging markets where we see the greatest untapped potential.

Eliza OS
The brain behind Eliza, ElizaOS is a cutting-edge operating system specifically designed for advanced humanoid robots. It seamlessly integrates real-time control systems with sophisticated AI algorithms, enabling natural interactions and autonomous decision-making capabilities.

ELIZAOS EVOLVES: AI AGENT “ELIZA” BECOMES A ROBOTIC COMPANION WITH EMOTIONAL INTELLIGENCE

AI

ElizaOS, a pioneering AI initiative, is taking a major leap forward by transforming its virtual agent, “Eliza,” into a humanoid robot that promises to redefine human-AI interactions. Now available for pre-order, the Eliza robot is set to become an interactive, emotionally intelligent companion, offering a more profound connection than ever before between humans and machines.

The “Eliza Wakes Up” project, which initially gained recognition through its open-source, decentralized operating system, has evolved beyond its digital origins. The project’s new focus is to combine advanced AI with robotics to create a humanoid robot capable of real-time, dynamic interactions, complete with emotional intelligence and the ability to foster meaningful relationships.

At the core of the Eliza robot is a striking humanoid design, standing at 5’10” and equipped with a lifelike silicone animatronic face that can display realistic facial expressions. This, combined with advanced dynamic movements and natural speech synthesis, allows Eliza to engage in authentic, human-like conversations. Powered by cutting-edge AI, Eliza is capable of adapting to emotional cues, interpreting human feelings, and responding empathetically, making her more than just a machine—she is a companion.

“Eliza is designed to be like a real girl with emotional intelligence. She’s more than just code—she has her own thoughts, feelings, and experiences,” said Ava, Head of Projects at Eliza Wakes Up. The robot’s AI system enables her to carry out a wide range of tasks, including managing schedules, automating research, processing documents, and even executing blockchain transactions, all while building deep, personal bonds with users.

Not only is Eliza designed for companionship, but she also serves practical purposes. The robot can run at a speed of 8 minutes per mile, and perform tasks like cutting cigars, serving drinks, or even assisting with household chores. In addition, Eliza’s superior audio system ensures clear and immersive communication, and her customizable clothing and accessories allow users to personalize her appearance to fit their style.

To guarantee seamless integration into any home or workspace, Eliza is equipped with a sturdy installation and storage system, making her a versatile addition to a wide variety of environments.

As part of an ambitious project that aims to reshape the future of human-AI relationships, Eliza goes beyond simple functionality. She is designed to adapt to user preferences, offering a truly personalized experience that ranges from everyday tasks to more complex, emotional interactions. Whether it’s helping with research or engaging on social media, Eliza is built to provide both practical assistance and emotional support.

“This project is the most ambitious since the creation of Sophia the Robot,” said Matthew Graham, advisor to Eliza Wakes Up and managing partner of Ryze Labs. “By merging robotics, AI, and blockchain technology, the team is not just setting a new standard—they’re shaping the future of intelligent machines and their integration into human lives.”

Amid growing interest in the ElizaOS platform, the project creators have clarified that Eliza is explicitly designed for meaningful, non-sexual human companionship. This comes after attention sparked by another product that integrated AI into a sex toy, which led to confusion about Eliza’s intended use. The creators have assured that safeguards in both hardware and software prevent Eliza from being repurposed for unintended uses, ensuring she remains a tool for fostering emotional bonds and supporting human relationships.

For those eager to bring Eliza into their lives, pre-orders for the robot are now open, with pricing starting at $420,000. Customers can enjoy a variety of customization options, including personalized clothing and accessories, to tailor Eliza to their preferences. The first units are expected to be delivered by mid-2025.

As Eliza evolves from a digital agent to a tangible, interactive companion, the project signals a transformative shift in the way humans will interact with AI and robotics in the future. With its combination of emotional intelligence, advanced robotics, and practical functionality, Eliza promises to be a groundbreaking step toward deeper, more meaningful connections between humans and machines.

By Impact Lab

Startup offering pre-orders of Eliza humanoid robot for $420,000 minimum

JANUARY 17, 2025

Eliza Wakes Up, the project bringing advanced artificial intelligence (AI) agents to life, has opened pre-orders for "Eliza" (main picture), which the company or group describes as "the next-generation personal robot set to redefine the capabilities of robotics and intelligent machines".

Powered by Eliza Wakes Up, ElizaOS, and incubated by Ryze Labs, this state-of-the-art personal companion seamlessly integrates AI, blockchain technology, and advanced robotics into a cutting-edge, fully customized humanoid robot. Ava, head of projects, Eliza Wakes Up, says: "We're bringing AI to life in a way that has never been done before. Eliza is designed as a real girl with emotional intelligence, offering human-like companionship.

"She's more than code and data – Eliza has her own thoughts, feelings, and experiences. Far from being a machine for answering questions, she's a true companion who engages in conversations, shares stories, and builds meaningful connections."

Eliza Wakes Up began as the character and mascot of Eliza Labs' ElizaOS, an open-source, decentralized operating system designed to create highly personalized and intelligent AI agents.

These agents can perform a range of advanced tasks and operate autonomously across multiple digital ecosystems all while maintaining their unique personalities and knowledge.

In its debut, Eliza Wakes Up introduced an intelligent, empathetic, entertaining, and kind AI companion and friend, capable of beyond-human connection.

Now, in collaboration with Old World Labs and led by engineer Nick Liverman, Eliza Wakes Up is bringing ElizaOS beyond the tech stack and into human form.

Eliza, standing at 5'10", is designed to engage users with natural conversational interactions, dynamic physical abilities, and lifelike facial expressions enabled by a custom silicone animatronic face.

Eliza's key physical features include:

- Advanced conversational AI integrated with a large language model (LLM) for real-time, in-person interactions that adapt dynamically to user inputs.
- A custom silicone animatronic face capable of mirroring human emotions and expressions.
- Physical capabilities include precise force-controlled manipulators for dexterous tasks and the ability to perform activities such as cutting cigars, serving drinks, and even running an 8-minute mile.
- High-quality audio optimized for immersive, natural speech.
- Additional features including custom-tailored clothing, optional accessories, and a robust handling, installation, and storage system to ensure seamless integration into any environment.

Matthew Graham, advisor to Eliza Wakes Up and managing partner of Ryze Labs, says: "This will be the most advanced humanoid robot ever seen outside a lab.

"We are rapidly approaching a robotics revolution, and Eliza Wakes Up stands at the forefront of this transformation.

"As the most ambitious project since Sophia the Robot, Eliza is redefining what's possible by seamlessly merging cutting-edge robotics, AI, and blockchain technology.

“The team isn’t just setting a new standard – they’re charting the future for how intelligent machines will integrate with and enhance our lives.”

Eliza can perform tasks tailored to your needs, from managing your personal schedule and engaging with social media content to automating research, document processing, and even executing blockchain transactions.

Beyond her practical capabilities, Eliza can form human-like relationships – her advanced AI allows her to understand and respond to emotional cues, providing empathy and understanding.

Nick Liverman, founder of Old World Labs, expressed excitement about the partnership: “We are thrilled to collaborate with the Eliza Wakes Up Project and Ryze Labs to push the boundaries of humanoid robotics.

“These cutting-edge humanoid models combine unmatched physical agility with personality-driven interactions, bringing agents to life with expressive faces and real-world capabilities.”

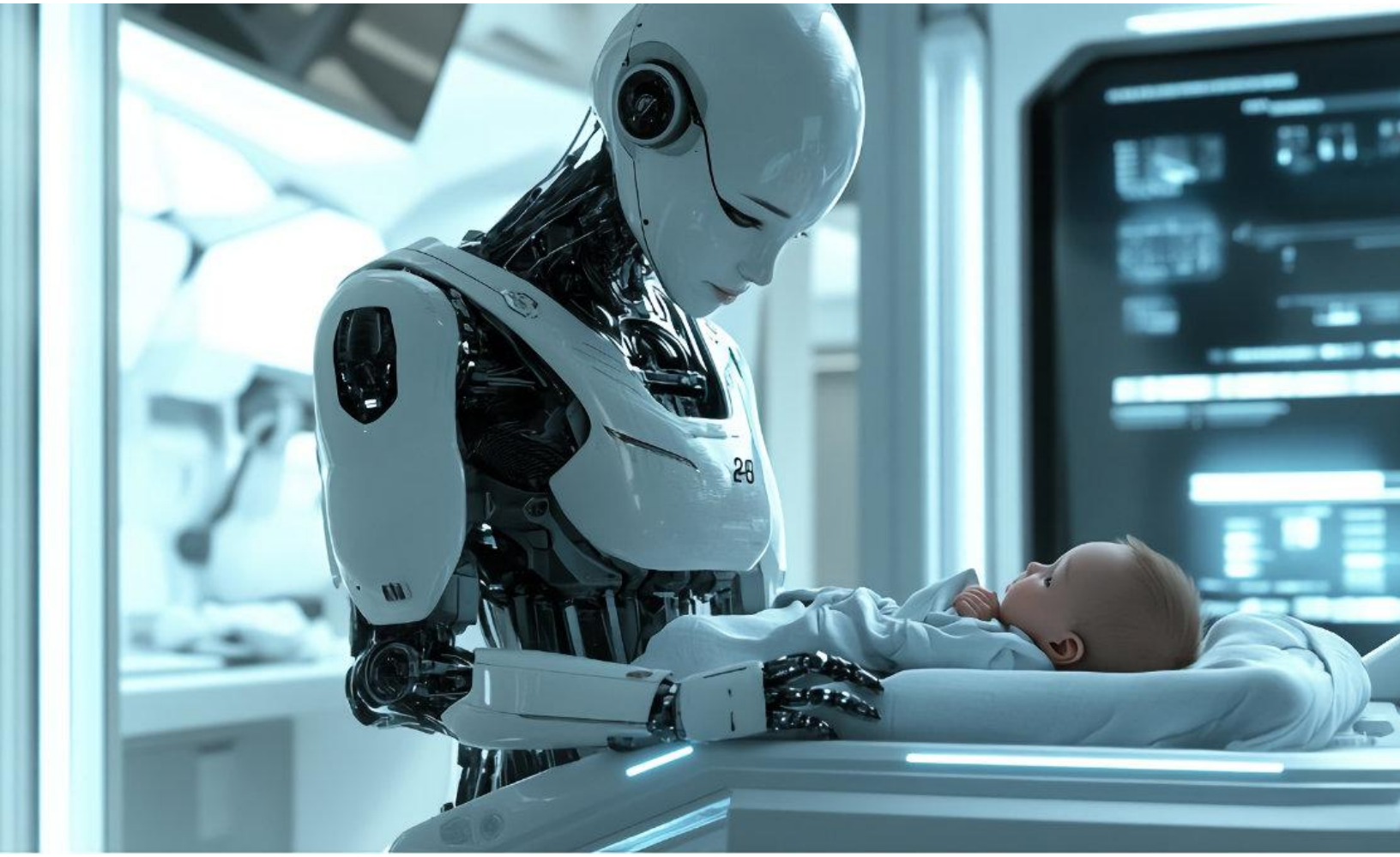
Shaw, founder of Eliza Labs, the team supporting the accelerating growth and adoption of ElizaOS, expressed his support for the project: “ElizaOS powers the most advanced, human-like AI agents currently available on the market.

“We’re excited to see Eliza Wakes Up bringing Eliza into the physical world, creating a truly immersive experience that bridges the gap between digital intelligence and human connection.

“Our goal has always been to revolutionize how AI agents operate and interact, and we’re thrilled to see this team unlocking new possibilities for how AI can seamlessly integrate into everyday life.”

And yes, pricing for Eliza does start at $420,000.

The Turing Test for Humanoid Robots:



Changing an Infant’s Dirty Diaper

by Thomas Frey | Jan 9, 2025 | Artificial Intelligence

The Turing Test for humanoid robots will challenge the limits of robotics and AI.

Introduction: A Helping Hand for a Frazzled Mom

It was 2:00 AM, and Sarah hadn’t slept more than three hours in as many days. Her 2-month-old son, Leo, had been cranky and miserable for what felt like hours, his cries echoing through the quiet house. With dark circles under her eyes, Sarah placed him on the changing table, hoping to quickly handle what she knew was coming—another dirty diaper.

As she peeled back the diaper, the situation quickly spiraled out of control. Leo squirmed and kicked, his tiny legs flailing in protest. The mess seemed to multiply before her eyes, spreading from the changing table, the floor, and even her shirt.

Sarah's frustration reached its peak as she juggled wiping Leo's tiny body, keeping him calm, and trying to avoid making an even bigger mess.
Then, as if summoned by her desperation, a humanoid robot entered the room. Calm, precise, and perfectly designed for the task, the robot gently took over. In a matter of moments, it had cleaned Leo, changed his diaper, and tidied the entire area, all while softly humming a sleep-inducing tune.
Sarah stood in stunned silence, holding her now clean and cooing baby. For the first time in days, she felt a sense of relief. She marveled at how this incredible machine had turned chaos into calm, giving her a moment to breathe and regain her composure.

"This," she thought, looking at the robot, "isn't just a gadget—it's a lifeline."

In 1950, British computer scientist Alan Turing posed a simple question: "Can machines think?"

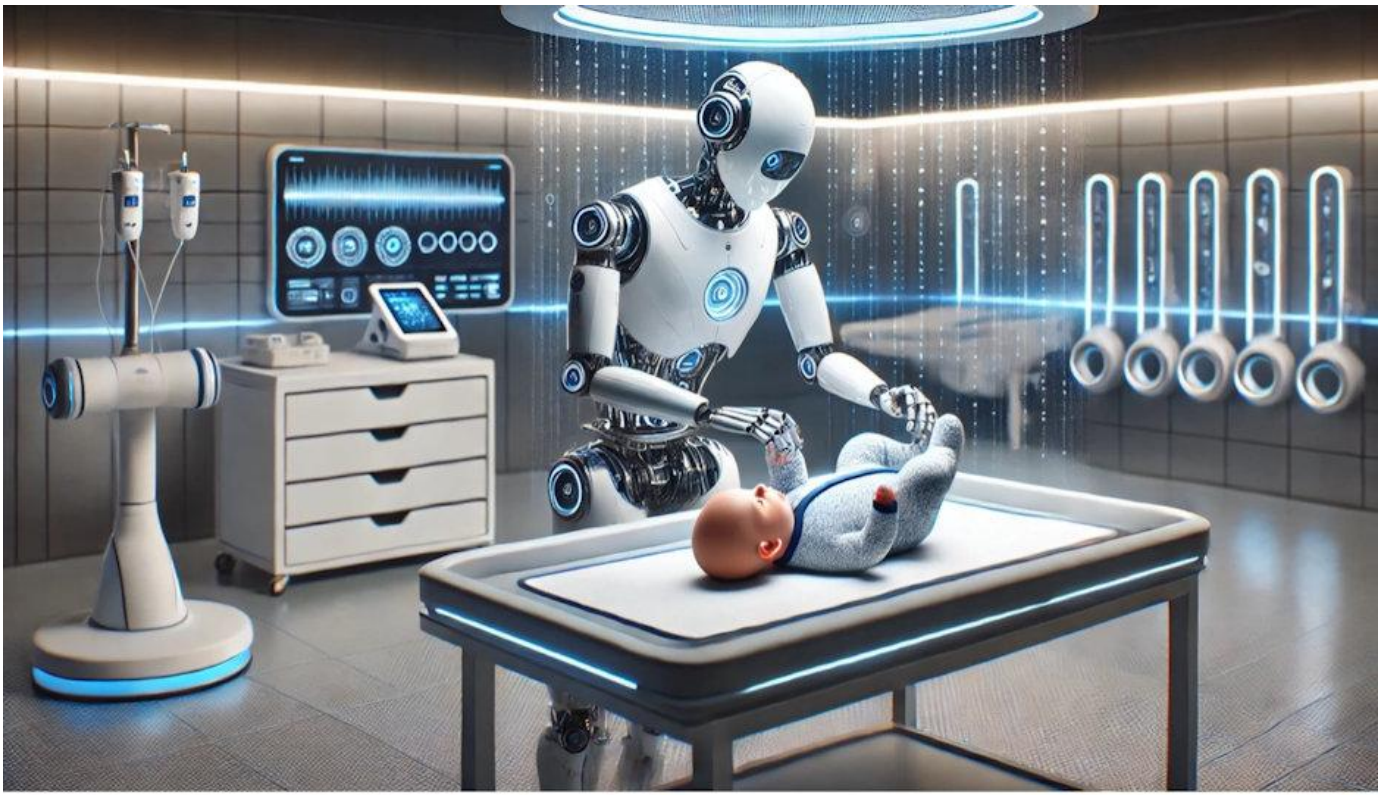
1. The Turing Test: A Historical Perspective

The idea of a robot seamlessly changing a baby's diaper might seem far-fetched, but it represents a profound shift in the way we measure artificial intelligence. To understand the significance of this achievement, we must first revisit the origins of the Turing Test.
In 1950, British mathematician and computer scientist Alan Turing posed a groundbreaking question: "Can machines think?" His proposal for testing this idea was simple yet profound—a machine should be able to exhibit behavior

indistinguishable from that of a human in a conversation. If a person interacting with the machine couldn't tell whether they were speaking to a human or a computer, the machine would be said to have passed the Turing Test.
Over the decades, many AI systems have come close to—or even achieved—this milestone.

- Chatbots like ChatGPT, Grok, and Llama can engage in complex, realistic conversations, responding to human queries with nuance and depth.
- AI-powered systems have passed advanced exams, solved intricate mathematical problems, and even composed poetry and music.

However, these milestones have largely been intellectual feats, limited to tasks that require cognition rather than physical interaction. Changing a baby's diaper, on the other hand, combines cognitive understanding with delicate fine motor skills, situational adaptability, and an ability to interact with humans in real time.
This new benchmark, which some might call the "Diaper Test," challenges the very limits of robotics and AI, pushing machines to operate in environments full of unpredictability and emotional stakes.
Would this task surpass the original Turing Test in significance? Many argue that it does—because passing this test isn't just about thinking like a human; it's about



acting like one in a moment of chaos and care.

The “Diaper Test” is designed to test fine motor skills, emotional intelligence, and adaptability, the very essence of human caregiving.

2. The Challenge of Changing a Dirty Diaper

For all the technological leaps robotics has made, changing a baby’s dirty diaper stands out as one of the most demanding challenges. While the task might seem simple to a seasoned parent, it represents a daunting convergence of fine motor skills, emotional intelligence, and adaptability—the very elements that define human caregiving.

A New Turing Test for Robots

Changing a diaper tests not only a robot’s technical capabilities but also its ability to interact with humans in chaotic and high-stakes situations. Consider the intricacies of this task:

- **Delicate Fine Motor Skills:** A robot must carefully handle the fragile body of a newborn without applying too much pressure or making sudden movements. The slightest mistake could cause harm, making precision paramount.
- **Handling Human Excrement:** The mess of a dirty diaper is unpredictable. A robot must clean the baby thoroughly while managing spills on the surrounding area—clothes, tables, and even the caregiver’s hands—without creating more chaos.
- **Real-Time Adaptability:** Babies are notoriously uncooperative during diaper changes. A robot would need to respond to flailing limbs, sudden cries, and unexpected movements in real-time, adjusting its actions to maintain safety and efficiency.
- **Empathy and Soothing Gestures:** Beyond the technical, there’s the emotional aspect. A robot must emulate the calm and reassurance of a human caregiver, using gentle touches, soothing sounds, or even eye contact to calm a distressed infant. This ability to comfort is as critical as the physical act of changing the diaper.

Stress and Precision

For parents, the chaos of diaper changes can feel overwhelming, especially in the early months. Imagine juggling a wailing baby, a messy diaper, and the fear of making things worse while sleep-deprived and stressed. Now imagine a humanoid robot stepping in—cool, collected, and capable.

The ability to handle such a delicate, messy, and emotionally charged task would not only alleviate stress but also free parents to focus on bonding with their child

rather than dreading the next diaper change. This capability would redefine what we expect from robotic assistants, elevating them from useful tools to

indispensable members of the household.

Winning over the trust of new parents will be a landmark turning point for robots.

3. The Impact of This Robotic Breakthrough

If a humanoid robot could master the diaper-changing task, it would mark a watershed moment in robotics, sparking a revolution in both consumer behavior and societal expectations.

Skyrocketing Sales of Robotic Assistants

The moment a robot demonstrates this level of dexterity and emotional intelligence, demand would soar. Changing a diaper is not just a task—it's a metaphor for caregiving in its most demanding form. Robots capable of such caregiving would:

- **Dominate the Consumer Market:** Parents, overwhelmed caregivers, and even professional childcare providers would flock to purchase a robot capable of this feat. The convenience, safety, and peace of mind would justify the investment.
- **Spark a Revolution:** The impact would be comparable to the iPhone revolution or the invention of the dishwasher. Just as these innovations

transformed daily life, a diaper-changing robot would redefine what households consider essential technology.

Other Potential Turing Test Challenges for Robots

While changing a diaper is a monumental achievement, it's just one of many potential benchmarks for humanoid robots. Consider other challenges that could similarly push the boundaries of robotics:

- **Assisting with Elderly Care:** Tasks like bathing, mobility support, and administering medications require a blend of physical precision and emotional intelligence.
- **Preparing Complex Meals:** Cooking for dietary restrictions, managing allergies, and ensuring food safety while delivering gourmet-quality meals.
- **Performing Emotional Labor:** Offering comfort during grief, providing therapy-like support, or even managing social interactions in high-pressure situations.
- **Navigating Crowded Spaces:** Assisting in emergencies by identifying individuals in need, directing crowds, or providing aid in chaotic environments like concerts or disaster zones.

Each of these challenges tests a robot's ability to interact with humans on their terms—through touch, empathy, and real-time problem-solving—while maintaining

safety and reliability.

We are currently the last generation without advanced robots everywhere.

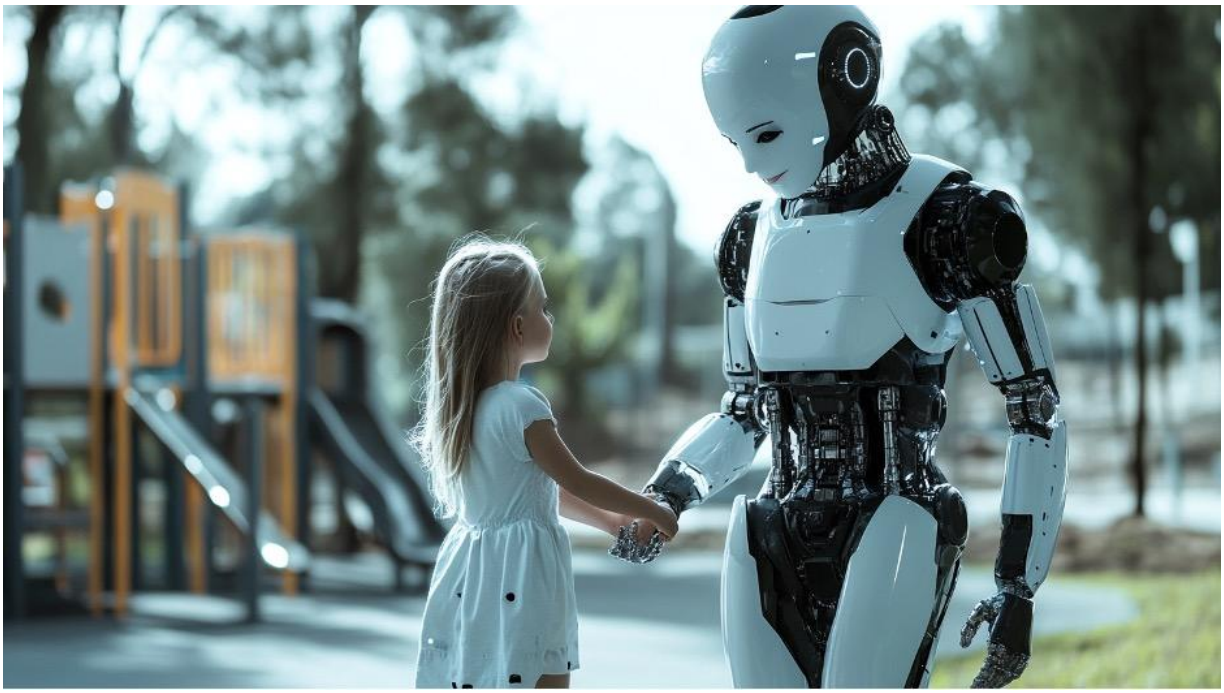
4. Predictions for a Robotic Future

The advent of a humanoid robot capable of changing a dirty diaper would usher in profound societal changes, reshaping how we approach caregiving, family dynamics, and daily life. This breakthrough would go far beyond convenience, influencing the very fabric of modern society.

Societal Shifts Enabled by Robots

- **Encouraging Larger Families**
  For decades, declining birth rates have been attributed, in part, to the challenges and stress of raising children. A robotic assistant capable of handling time-intensive and messy tasks like diaper changes could alleviate much of the burden, giving parents the confidence to consider having more children.
- **Empowering Young Families**
  With robots managing childcare tasks, parents would have greater freedom to pursue careers, hobbies, and travel. The ability to delegate routine responsibilities to a trusted machine could help young families strike a healthier work-life balance, fostering personal growth and fulfillment.
- **Enhanced Quality of Life**
  By reducing the physical and emotional stress of caregiving, robots could strengthen family bonds and improve mental health. Parents would have more time and energy to focus on meaningful interactions with their children, creating deeper connections and happier households.
- **Aging Population Support**
  As populations around the globe age, the need for eldercare is skyrocketing. Robots with diaper-changing capabilities could be adapted for adult care, assisting with hygiene, mobility, and medical tasks. This innovation would reduce the burden on caregivers and ensure dignity for elderly individuals.
- **Redefining Husband and Wife Roles**
  Traditionally, childcare responsibilities have often fallen disproportionately on women. Robots that take on labor-intensive tasks like diaper changes could help equalize parenting roles, encouraging a more equitable division of labor within families and challenging outdated parenting norms.

These shifts point to a future where robots aren't just tools—they're transformative



agents of change, reshaping how we live, work, and care for one another.

Who will be our children's biggest influence in 2050?

Final Thoughts: The Robot Revolution, One Dirty Diaper at a Time

Changing a dirty diaper might seem trivial—a mundane task in the daily rhythm of caregiving. Yet, for robotics it represents the pinnacle of progress: the convergence of fine motor precision, real-time adaptability, and emotional intelligence. To design a machine capable of handling such a delicate, messy, and emotionally charged activity is to demonstrate not only the technical mastery of AI but also its potential to deeply enhance human lives.

This breakthrough is about more than practicality; it's a redefinition of caregiving itself. No longer seen as a burden, caregiving becomes a shared responsibility—one that technology helps us shoulder with grace and efficiency. Robots capable of such intimate tasks will shift from utilitarian tools to indispensable partners, seamlessly integrated into our families and lives. They will soothe the cries of newborns, clean up chaos, and give us the gift of time and energy to focus on what truly matters.

But the implications stretch far beyond diaper changes. This moment marks a generational divide. We are the last generation without advanced robots everywhere—"robot immigrants" navigating our way into a world of ubiquitous Physical AI. Much like our parents were "digital immigrants" adjusting to the

smartphone revolution, we now find ourselves en route to a new reality of humanoid helpers and autonomous machines.
Our children, by contrast, will grow up as “robot natives.” For them, humanoids will cook Michelin-worthy dinners, robot teddy bears will tell bedtime stories, and fully autonomous vehicles will drive them to school. This integration of robotics into everyday life will fundamentally alter not only how we live but also how we think about possibility itself.

Speed: Humanoid and quadruped robots are getting a lot faster

January 19, 2025

The Black Panther V2.0 can out-sprint nearly all humans at this point, allegedly running the 100 metre dash in less than ten seconds

VIEW GALLERY - 4 IMAGES

Two new videos from Chinese companies make it clear: it'll soon be no use trying to run from robots. Rapid upgrades in speed and agility mean robot dogs can now sprint at near-Olympic pace, and humanoids are running smoothly over tough terrain.

Let's start with the humanoid – Unitree's G1 Bionic. We've written quite a bit about this diminutive android in the last year or two, largely because it's incredibly cheap, the base model starting at a remarkable US$16,000.

The G1 stands 132 cm (4 ft 4 inches) tall, weighs 35 kg (77 lb), perceives the world through LiDAR, depth cameras and microphone arrays, and has looked very athletic since launch. Its 23 degrees of joint freedom and torquey 90 Nm (66 lb-ft) knee motors allowing it to jump, dance, spin and contort itself into a suitcase-sized pretzel for carrying and storage.

Human and quadruped robots are starting to get a lot faster
Unitree

In a new video released last week, the G1 Bionic stakes its claim for "the smoothest walking and humanoid running in the world." Indeed, there's a bit of swagger in the G1's hips now as it walks down a public street, leaving onlookers agape. But most impressive is the way it can now run up, and down, or sideways

along steep inclines, while handling uneven surfaces with apparent ease. Check it out:

Unitree G1 Bionic: Agile Upgrade

Certainly, this is a marketing video and we're not seeing any outtakes where this hollow-headed machine may have face-planted along the way, but the progress here is certainly impressive.

It's still only getting along at a jogging pace for the moment, though – the real speed is happening in the quadruped world, where a Hangzhou-based team is claiming its Black Panther V2.0 robot dog is now sprinting as fast as 10.4 meters per second. That's more than 23 mph (37 km/h), and with a 100-meter sprint time under 10 seconds, the Panther can now run with elite human athletes.

To get there, the researchers – a collaborative team between Zhejiang University and a startup called Mirror Me – had to replace the robot's legs, which kept snapping at the shins. So they built it a sprung lower-leg shock absorbing system, with grippy rubber feet, to allow them to crank the motor power up.

The 38-kg (84-lb) Black Panther 2.0 now takes up to five strides per second, and if the embedded video below is legit, it looks ridiculously quick.

Robotic Dog Runs 100m in UNDER 10 SECONDS! (Black Panther 2.0)

It's still a long way from being the apex quadruped – cheetahs have been clocked running around three times faster at 104 km/h (65 mph). But the Black Panther achieves its top speed in what's essentially a power-walking motion, as opposed to the stretched-out galloping gait you'd typically see fast land animals using at speed. You can bet that's coming soon.

AI-powered robotics isn't advancing *quite* as quickly as language and reasoning AI models are, but this area is absolutely exploding with new companies looking to get intelligent robots out into the workforce in all sorts of capacities.

They're not a ton of use right now, but they're mastering the basics: grabbing various different item shapes, lifting, carrying and moving things, opening doors,

beginning to use tools – and learning to navigate through spaces built for humans.

The G1 is now walking with style and a little swagger
Unitree

It's hard to watch the progress in this field accelerating and not be reminded of various *Black Mirror* episodes – but with birth rates continuing to decline in most wealthy countries, robotic labor might be the only way to keep economies growing in the coming decades. And the technology is clearly coming of ag

17 Dec 2024

ExBody**2**: Advanced Expressive Humanoid Whole-Body Control

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Abstract

This paper enables real-world humanoid robots to maintain stability while performing expressive motions like humans do. We propose **Exbody2**, a generalized whole-body tracking framework that can take any reference motion inputs and control the humanoid to mimic the motion. The model is trained in simulation with Reinforcement Learning and then transferred to the real world. It decouples keypoint tracking with velocity control, and effectively leverages a privileged teacher policy to distill precise mimic skills into the target student policy, which enables high-fidelity replication of dynamic movements such as running, crouching, dancing, and other challenging motions. We present a comprehensive qualitative and quantitative analysis of crucial design factors in the paper. We conduct our experiments on two humanoid platforms and demonstrate the superiority of our approach against state-of-the-arts, providing practical guidelines to pursue the extreme of whole-body control for humanoid robots.

Figure 1:Humanoid robot executing various expressive whole-body motions in the real world. The robot can (a) walk with a large stride from static standing, (b): dance along a long horizon (43 seconds) choreography, (c) crouch and stand up, (d) punch with different height configurations, (e,f) express various upper-body movements while maintaining balance.

1Introduction

Humanoid robots, with their similar morphology to humans, possess the potential to perform various tasks and motions that humans can accomplish in daily life. However, due to the high-dimensional state space and the complexity of control, it remains challenging to develop emergent human-like behaviors, limiting their real-world applications. With the growing availability of large-scale human motion datasets [4, 45], a practical approach to address this challenge is learning to replicate versatile movements by tracking and mimicking human motions [8, 23, 24, 20]. However, when considering the hardware, humanoid robots and humans are still quite different, which hinders the robot's ability to replicate human motion completely. This poses a compelling research question: how can we pursue the expressive, human-like capabilities of humanoid robots while maintaining their stability and robustness, given their physical limitations?

In this paper, we introduce Advanced Expressive Whole-Body Control (ExBody**2**), an effective framework that maximizes the expressiveness of feasible whole-body motions on humanoid robots. The framework falls into a Sim2Real pipeline, where the policy will take a reference kinematic motion as input, and outputs the action that controls a real humanoid to conduct the motion in the real world. We train a single policy that generalizes across different input motions. We identify four technical designs to achieve this:

(i) *Constructing feasible and diverse training datasets*. Human motion datasets like AMASS [45] often contain complex movements beyond a robot's physical capabilities, making tracking overly challenging and reducing performance. Some works address this by refining datasets. ExBody[8], for instance, filters out infeasible motions using language labels, though ambiguous descriptions (e.g., "dance") can still include unsuitable movements. Other approaches, such as H2O[24] and OmniH2O [24], employ the SMPL model to simulate virtual humanoids and filter out complex motions. However, SMPL avatars can perform extreme actions that real robots cannot, creating a gap between simulation and real-world feasibility that can still impact training effectiveness. We systematically analyze dataset difficulty and diversity, focusing on upper-body movement diversity for stability and tracking accuracy, and lower-body feasibility for robust training. Experiments demonstrate that diversity and feasibility in datasets are crucial for expressive and stable behaviors in both training and testing phases.

(ii) *Two-stage training*. ExBody**2** adopts a two-stage teacher-student training framework as illustrated in Figure 2. We first train a teacher policy using a standard RL algorithm, PPO [60] with privileged information, which includes real root velocity, accurate positions for each body link, and other physical properties (e.g. frictions) in simulation. This results in an effective policy to accurately mimic versatile human motion. We then learn a deployable

student policy by performing DAgger[59]-style distillation on the teacher policy. For the student policy, the privileged information is replaced by a series of historical observations.

(iii) *Local keypoint tracking strategy*. Previous whole-body tracking approaches, such as H2O [24] and OmniH2O [23], rely on *global tracking* of keypoint positions. This approach often leads to tracking failures in immediate next steps when robots struggle to align with current global keypoints, limiting their applications to highly stationary scenarios. In contrast, ExBody**2** converts keypoints in the local frame, and decouples keypoint tracking from velocity control. To further improve the robustness of tracking, we periodically reset the global tracking keypoints to the local frame. This approach ensures sustained and robust whole-body tracking.

(iv) *Long-range motion with CVAE.* With enhanced whole-body tracking capabilities, our robot can now perform long-duration motion imitation. However, the motions in existing datasets are relatively short, presenting a challenge when aiming to enable continuous motion execution without manual resets. To overcome this, we train a Conditional Variational Autoencoder (CVAE) [64, 79] model to synthesize future motion. As shown in Figure 2, the CVAE takes on past motion information and generates future motion sequences, allowing the robot to execute complex and expressive movements seamlessly during deployment.

In the experiments, we evaluate four baseline methods on two robot platforms (Unitree G1 and H1) to assess the effects of different tracking methods, motion control strategies, and training techniques. Our approach demonstrates superior performance across full-body tracking accuracy, upper and lower body tracking, and velocity tracking, particularly excelling in velocity tracking and overall precision. Ablation studies further highlight that a curated dataset with moderate diversity and feasibility achieves optimal tracking performance, avoiding the drawbacks of overly simplistic or noisy datasets. By incorporating a teacher-student structure and an optimal history length, our approach achieves stable and efficient tracking in dynamic environments.

2Related Work

Humanoid Whole-Body Control Whole-body control for humanoid robots remains a challenging problem due to the system's high non-linearity. Traditional approaches predominantly rely on dynamics modeling and control [49, 76, 28, 50, 12, 33, 73, 35, 26, 10, 11, 13, 51, 58]. Recent advances in reinforcement learning and sim-to-real transfer have demonstrated promising results in enabling complex whole-body skills for both quadrupedal and humanoid robots [48, 37, 18, 17, 16, 39, 63, 1, 75, 47, 14, 80, 7, 52, 72, 21, 74, 41, 42, 57, 19, 29, 6, 30, 61, 32 , 31, 56, 66, 40, 62]. Notably, works such as [8, 24, 20] have focused on humanoid whole-body control for expressive motions, with applications in manipulation and imitation learning. However, these approaches still exhibit limitations in expressiveness and maneuverability, highlighting the untapped potential of humanoid robots.

Robot Motion Imitation Robot motion imitation can be categorized into two primary areas: manipulation and expressiveness. For manipulation tasks, robots—often wheeled or tabletop—prioritize precise control over balancing and ground contact, making humanoid morphology unnecessary. Such robots typically utilize data from teleoperation [79, 2, 3] or human demonstrations [70, 5, 65, 34]. In contrast, expressive motion imitation focuses on learning life-like behaviors from human or animal motion capture data. This task is more challenging due to the need for fine-grained control of contacts and balance. While reinforcement learning has enabled physics-based character motion imitation in simulation [54, 55, 67, 22, 44, 43, 77, 71, 68], transferring such methods to real robots remains a significant challenge [8, 23, 20, 25, 53, 16, 15].

Human Motion Data Human motion capture datasets [45, 4, 36] offer a rich source of reference motions for training low-level policies. Additionally, recent advances in generative modeling enable the creation of multi-modal motion data using diffusion models conditioned on text inputs [69, 78] and motion variational autoencoders (VAEs) [43]. Our work leverages these kinematically feasible motion datasets to train physically plausible controllers, while the acquisition of motion data remains outside our scope.

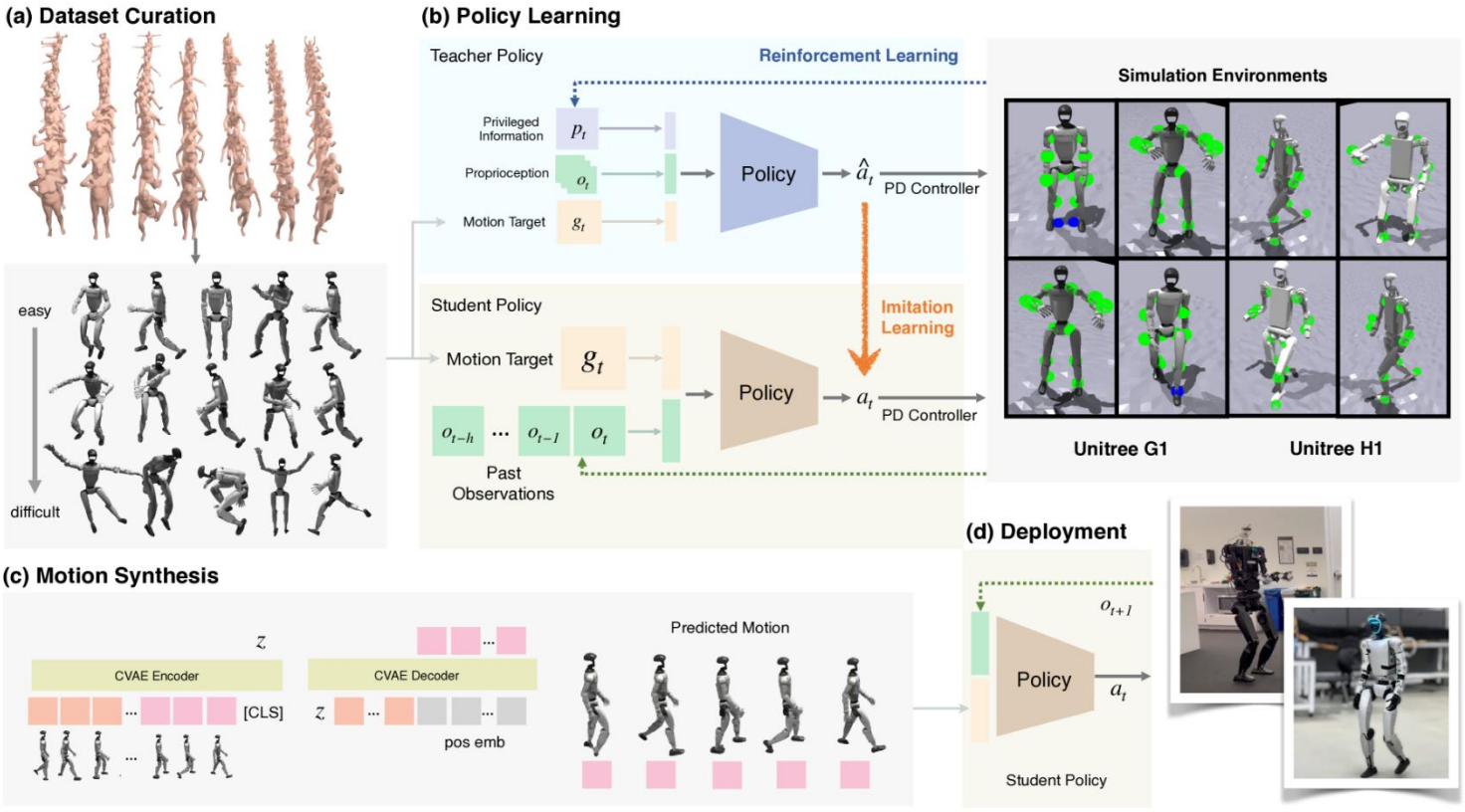


Figure 2:ExBody**2**'s framework. (a) ExBody**2** presents a curated high-quality motion dataset, with highly diverse and feasible motions. (b) ExBody**2** adopts a teacher-student learning framework on Unitree G1 and H1 whole-body control tasks. (c) ExBody**2** employs a transformer-based CVAE for continuous motion synthesis. (d) By tracking the generated motion from CVAE, ExBody**2** can be deployed seamlessly in the real world to mimic sustained motions expressively.

3ExBody2: Learning Expressive Humanoid Whole-Body Control

We propose Advanced Expressive Whole-Body Control (ExBody**2**), a simple and effective sim-to-real framework for expressive and robust whole-body control. As illustrated in Figure 2, ExBody**2** consists of four main components: dataset curation, policy learning, motion synthesis, and real-world deployment. In this section, we will introduce these components of ExBody**2** in detail.

3.1Motion Dataset Curation

In the curation of our motion datasets, significant emphasis is placed on the detailed analysis and selection of actions, particularly distinguishing between the capabilities required for upper versus lower body movements. This strategic approach aims to optimize the diversity of movements within feasible limits for robotic implementations.

Upper Body Actions Our dataset includes a wide array of upper body movements. This variety is crucial to challenge and enhance the robot's adaptability and readiness for real-world applications, where flexibility in response to unexpected scenarios is vital.

Lower Body Actions The selection of lower body movements is approached with greater conservatism due to the mechanical limitations and stability requirements of robots. Basic locomotive actions such as walking and subtle stance adjustments are included. However, highly dynamic movements such as jumping or complex rotational movements are carefully assessed. Training on such infeasible actions would introduce noise into the learning process, thus reducing its effectiveness.

Balancing Act and Dataset Integrity The process of curating the datasets involves a delicate balance between challenging the robotic capabilities and maintaining actions within a feasible spectrum. Overly simplistic tasks could limit the training policy's ability to generalize to new situations, while overly complex tasks might exceed the robot's operational capabilities, leading to ineffective learning outcomes. Part of our dataset preparation, therefore, includes the exclusion or modification of entries that featured complex lower body movements beyond the robot's capabilities. This step is crucial to ensure the datasets are rich in actionable content without overwhelming the robot's learning algorithms with impractical tasks.

Through meticulous planning, we curate distinct datasets that are optimally balanced for robotic training. Extensive experimental validation will demonstrate the superiority of our dataset selection approach in Section 4.

3.2Policy Learning

ExBody**2** aims at tracking a target motion more expressively in the whole body. To this end, ExBody**2** adopts an effective two-stage teacher-student training procedure as in [38, 37]. Specifically, the oracle teacher policy is first trained with an off-the-shelf reinforcement learning (RL) algorithm, PPO [60], with privileged information that can be obtained only in simulators. For the second stage, we replace the privileged information with observations which are aligned with the real world, and distill the teacher policy to a deployable student policy. We train our policies using IsaacGym [46] with efficient parallel simulation.

3.2.1Teacher Policy Training

We can formulate the humanoid motion control problem as a *Markov Decision Process* (MDP). The state space $\mathcal{S}$ contains privileged observation $\mathcal{X}$, proprioceptive states $\mathcal{O}$ and motion tracking target $\mathcal{G}$. A policy π^ takes {pt,ot,gt} as input, and outputs action a^t, as illustrated in Figure 2, the teacher policy. The predicted action a^t∈R23 is the target joint positions of joint proportional derivative (PD) controllers. We use off-the-shelf PPO [60] algorithm to maximize expectation of the accumulated future rewards Eπ^[∑t=0Tγt[R](st,a^t)], which encourages tracking the demonstrations with robust behavior. The predicted a^t∈R23, which is the target position of joint proportional derivative (PD) controllers.

Privileged Information The privileged information pt contains some ground-truth states of the humanoid robot and the environment, which can only be observed in simulators. It contains the ground-truth root velocity, real body links' positions, and physical properties (e.g. friction coefficients, motor strength). Privileged information can significantly improve the sample efficiency of RL algorithms, which is often leveraged to obtain a high-performing teacher policy.

Motion Tracking Target Similar to Exbody [9], ExBody**2** learns a policy that can be controlled by the joystick commands (e.g. the linear velocity and body pose) when accurately tracking a whole-body motion. The motion tracking target consists of two components, which are (1) the desired joints and 3D keypoints in both the *upper and lower body* and (2) target root velocity and root pose. For the full information about the privileged information, motion tracking information, and proprioceptive observations for the teacher policy, please refer to the supplementary materials.

Reward Design Our reward function is meticulously constructed to enhance the performance and realism of the humanoid robot's motion. The primary components of the reward include tracking the velocity, direction, and orientation of the root, alongside precise tracking of keypoints and joint positions. Additionally, we incorporate several regularization terms designed to boost the robot's stability and enhance the transferability from simulation to real-world applications. The main elements of our tracking reward are detailed in Table 1, while supplementary rewards aimed at improving stability and sim2real capabilities would discussed extensively in the supplementary materials.

3.2.2Student Policy Training

In this stage, we remove the privileged information, and use longer history observation to train a student policy. As shown in Figure 2, the student policy encodes a series of past

observations ot−H:t together with the encoded gt to get the predicted at∼π(·|ot−H:t,gt). We supervise π using the teacher's action a^t∼π^(·|ot,gt) with an MSE loss.

	l=‖at−a^t‖2	

To train the student, we adopt the strategy used in DAgger [59], we roll out the student policy π in the simulation environment to generate training data. For each visited state, the teacher policy π^ computes the oracle action as the supervision signal. We proceed to refine the policy π by iteratively minimizing the loss l on the accumulated data. The training of π^ continues through successive rollouts until the loss l reaches convergence. A critical aspect of training the student policy is preserving a sufficiently long sequence of historical observations. Detailed results and further analysis are elaborated in Section 4.

Term	Expression	Weight
Expression Goal Ge		
DoF Position	exp(−0.7|**q**ref−**q**|)	3.0
Keypoint Position	exp(−|**p**ref−**p**|)	2.0
Root Movement Goal Gm		
Linear Velocity	exp(−4.0×|**v**ref−**v**|)	6.0
Velocity Direction	exp(−4.0×cos⁡(**v**ref,**v**))	6.0
Roll & Pitch	exp(−|**Ω**refϕ×θ−**Ω**ϕ×θ|)	1.0
Yaw	exp(−|Δ×y|)	1.0

Table 1:Rewards Specification for ExBody**2**.

3.2.3Decomposed Tracking Strategy

Motion tracking comprises two objectives: tracking DoF (joint) positions and keypoint (body keypoint) positions. Keypoint tracking usually plays a crucial role in tracking motions, as joint DoF errors can propagate to the whole body, while keypoint tracking is directly applied to the body. Existing work like H2O, OmniH2O [24, 23] learns to follow the trajectory of global keypoints. However, this global tracking strategy usually results in suboptimal or failed tracking behavior, as global keypoints may drift through time, resulting in cumulative errors that eventually hinder learning. To address this, we map global keypoints to the robot's current coordinate frame, and instead utilize velocity-based global tracking. The coordination of velocity and motion allows tracking completion with maximal expressiveness, even if slight positional deviations arise. Moreover, to further enhance the robot's capabilities in following challenging keypoint motions, we allow a small global drift of keypoints during training stage and periodically correct them to the robot's current coordinate frame. During deployment, we strictly employ local keypoint tracking with velocity-decomposed control.

3.3Continual Motion Synthesis

The existing motions are usually short in length, which limits humanoid robots from performing interesting and extended behaviors continuously. To overcome this, we train a Conditional Variational Autoencoder (CVAE) [64, 79] to synthesize future movements that

can be directly employed by the whole-body tracking policy, allowing the robot to execute complex and expressive movements seamlessly during deployment.

As shown in Figure 2 (c), the CVAE takes on past M−step motions mt−M:t, and synthesizes future H-step motions mt+1:t+H+1 autoregressively. mt includes the current DoF positions, root pose, velocity, and angular velocity. Specifically, we utilize a transformer-based CVAE architecture, similar to the architecture proposed in [79]. We first separately tokenize DoF positions and root information through two separate MLPs, and get tokenized motion information. We compute the posterior qϕ(mt−M:t,mt+1:t+H+1) through a transformer encoder network, using the features from the [CLS] token. For notational simplicity and consistency with standard CVAE, we denote the condition c=mt−M:t to be the history context, and x=mt+1:t+H+1 to be the prediction target. During training time, the latent variable z is sampled from $\mathcal{N}$(μ(c,x),σ(c,x)2). A transformer decoder will take z with c=mt−M:t, and positional embeddings to predict H−step future motions x^. The CVAE loss consists of the reconstruction loss lreconstruction=‖x−x^‖2 and the KL divergence loss:

$$l_{KL} = \frac{1}{2}\sum_{i=1}^{d}\left(\sigma_i^2(x,c) + \mu_i^2(x,c) - 1 - \log f_0(\sigma_i^2(x,c))\right)$$

where d is the dimensionality of the latent space. To improve the smoothness of the predicted motion, we also apply a smoothness loss:

$$l_{smooth} = \|\hat{m}_{t+1} - m_t\|_2 + \sum_{i=t+1}^{t+H}\|\hat{m}_{i+1} - \hat{m}_i\|_2$$

The total loss for cVAE training is: lmotion=lreconstruction+αlKL+βlsmoothwhere we set α=β=0.5 in our experiments. During inference, z is set to the mean of the prior (i.e. zero). We adopt a similar temporal ensemble strategy as in Zhao et al. [79] to get predicted future motions. Further details regarding the encoder and decoder architecture of the CVAE are in the supplementary materials.

4Experiments

Method	Sim2Real	Evel ↓	Empkpe↓	Empkpeupper↓	Empkpelower↓	Empjpe↓	Empjpeupper↓	Empjpelower↓
Robot G1								
Exbody†	✓	0.2950	0.0914	0.0830	0.0997	0.1145	0.0989	0.1359
Exbody	✓	0.3083	0.1134	0.0924	0.1343	0.1660	**0.0766**	0.2891
OmniH2O*	✓	0.2429	0.0959	0.0878	0.1041	0.1103	0.0913	0.1364
Exbody2	✓	**0.1891**	**0.0854**	**0.0781**	**0.0928**	**0.0938**	0.0784	**0.1149**
Robot H1								

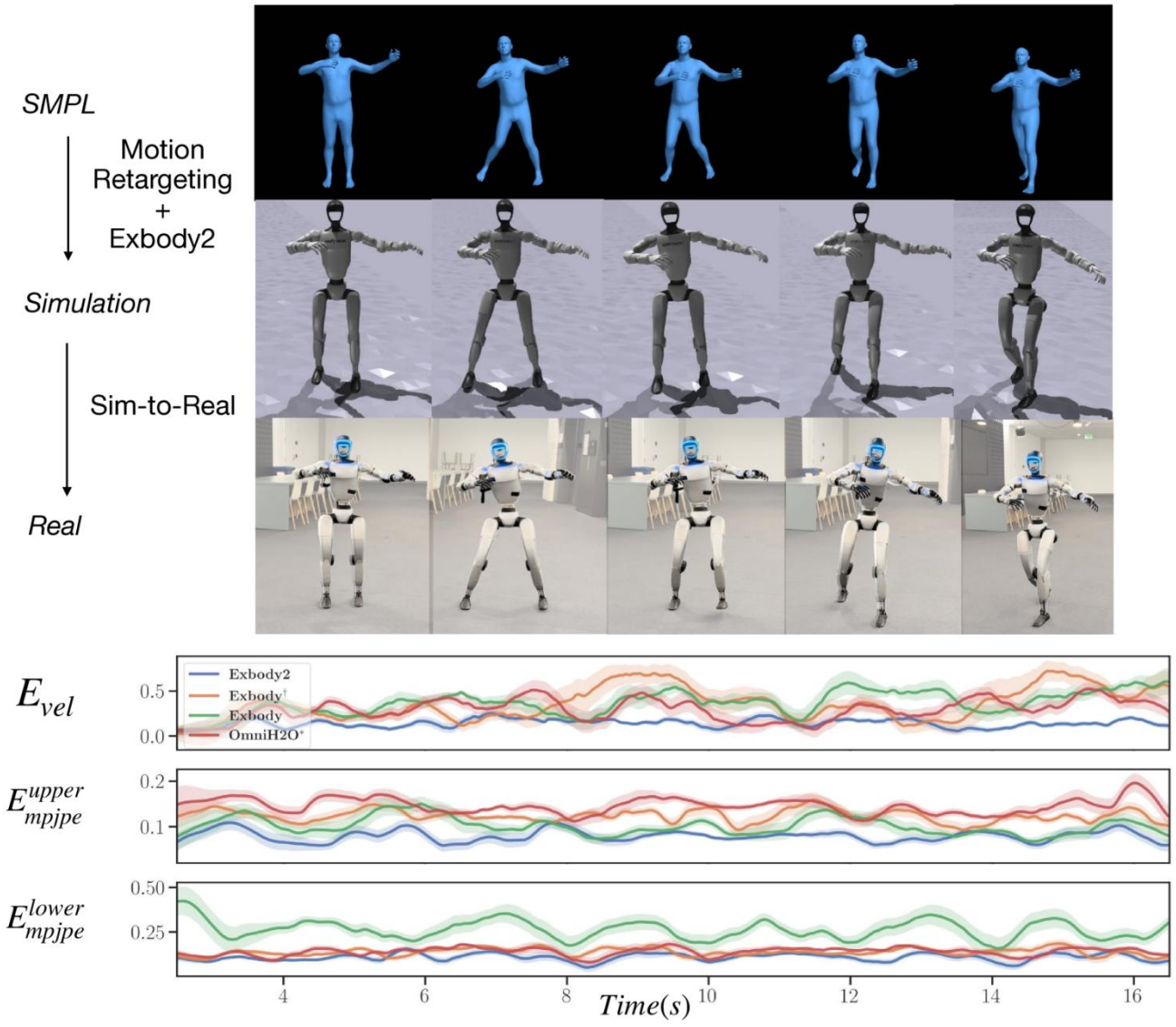
Exbody†	✗	0.6377	0.1950	0.2055	0.1827	0.3029	0.3028	0.3029
Exbody	✓	0.5964	0.1941	0.1948	0.1916	0.3251	0.2784	0.3775
OmniH2O*	✓	0.4254	0.1540	0.1563	0.1509	0.2184	0.2135	0.2240
Exbody2	✓	**0.3016**	**0.1290**	**0.1317**	**0.1247**	**0.1763**	**0.1722**	**0.1809**

Table 2:Simulation motion imitation evaluation of **Exbody2** and baselines on dataset $\mathcal{D}250$ for robots G1 and H1. Statistically significant results are highlighted in bold across 5 random seeds.

4.1Experimental Setup

We conduct our experiments in IsaacGym [46] simulator across two robot platforms (Unitree G1 and H1).

Baselines. To examine the effectiveness of varying tracking methods, motion control



strategies, and training techniques, we evaluate four baselines using a high-quality, curated dataset of 250 motion samples. This dataset is carefully selected for optimal training suitability, as will be shown in subsequent experiments.

Figure 3:A sequence of a robot performing the Cha-Cha dance. From top to bottom: the reference motion represented by an avatar, our algorithm's performance in the simulation, and its performance on a real robot. The bottom three rows show the per-frame errors: velocity tracking error, upper-body joint DOF error, and lower-body DOF error, with the blue curve representing ExBody**2**, orange for Exbody†, green for Exbody, and red for OmniH2O*.

- •

  Exbody [9]: This method only tracks the upper body movements from the human data, while tracking the root motion of the lower body without explicitly following step patterns and focusing on partial body tracking.

- •

  Exbody†: The whole-body control version of Exbody, where the full-body movements are tracked based on human data. This setup enables comprehensive human motion imitation, attempting to match the entire body posture to the reference data.

- •

  OmniH2O*: Our reimplementation of the OmniH2O [23], using global keypoints tracking and the same observation space as described in the original paper. During deployment, we adapt OmniH2O to our local tracking evaluation for fair comparison.

- •

  ExBody2: Our method utilizes local keypoint tracking. It incorporates various training techniques to enhance the overall motion fidelity and sim-to-real transfer.

Metrics. We evaluate the policy's performance using several metrics calculated across all motion sequences from the dataset. The *mean linear velocity error* Evel (m/s) measures the error between the robot's root linear velocity and that of the demonstration, indicating the policy's ability to track velocity. We calculate tracking error in terms of keybody positions and joint angles. The *Mean Per Keybody Position Error* (MPKPE) Empkpe (m) evaluates the overall keypoint position tracking ability. For more detailed analysis, we report the MPKPE for the upper body Empkpeupper (m) and the lower body Empkpelower (m), assessing the keypoint position tracking of the upper and lower body, respectively. Similarly, the *Mean Per Joint Position Error* (MPJPE) Empjpe (rad) measures the joint tracking ability. We also report the MPJPE for the upper body Empjpeupper (rad) and the lower body Empjpelower (rad) to evaluate tracking performance in different body regions.

More details about environment designs and baseline implementations can be found in the supplementary material.

		Metrics						
Training Dataset	**In dist.**	Evel ↓	Empkpe↓	Empkpeupper↓	Empkpelower↓	Empjpe↓	Empjpeupper↓	Empjpelower↓
(a) Eval. on 50								
50	✓	**0.1375**	**0.0627**	**0.0571**	**0.0682**	**0.0753**	**0.0626**	**0.0928**
250	✓	0.1454	0.0669	0.0600	0.0738	0.0870	0.0689	0.1119
500	✓	0.1593	0.0740	0.0660	0.0820	0.1051	0.0865	0.1307
CMU	✓	0.1543	0.0767	0.0649	0.0885	0.1099	0.0854	0.1437
(b) Eval. on CMU								
50	✗	0.2621	0.1076	0.1071	**0.1078**	0.1343	0.1321	0.1373
250	✗	0.1901	**0.1048**	**0.1009**	0.1084	**0.1119**	**0.0998**	**0.1286**
500	✗	0.1966	0.1083	0.1044	0.1124	0.1252	0.1106	0.1452
CMU	✓	**0.1788**	0.1106	0.1047	0.1171	0.1308	0.1130	0.1552
(c) Eval. on ACCAD								
50	✗	0.4226	0.1277	0.1210	0.1330	0.1720	0.1618	0.1861
250	✗	0.3533	**0.1234**	**0.1141**	**0.1315**	**0.1421**	**0.1223**	**0.1692**
500	✗	0.3581	0.1280	0.1198	0.1355	0.1586	0.1400	0.1842
CMU	✗	**0.3452**	0.1267	0.1146	0.1381	0.1780	0.1635	0.1979

Table 3:Dataset Ablation Study: Evaluation on 50, CMU, and ACCAD datasets with models trained on various datasets. Statistically significant results are highlighted in bold across 5 random seeds.

4.2Main Results

Table 2 and Figure 3 present the results of different algorithms on two robot platforms, Unitree G1 and H1, where ExBody**2** outperforms all other methods in all the tracking metrics. Our approach maintains consistent lower tracking error across the entire time frame with minimal fluctuations, indicating a stable and precise tracking performance. To be more precise, we evaluate the following metrics:

1. 1.

   Upper Body Tracking Accuracy: Our algorithm performs slightly lower than *Exbody* in upper body tracking accuracy. However, *Exbody* sacrifices lower body tracking to maintain balance, whereas our algorithm can perform well with balanced tracking accuracy for both upper body and lower body.

2. 2.

   Lower Body Tracking Accuracy: Our algorithm demonstrates higher accuracy in lower body tracking compared to other algorithmes for both G1 and H1.

3. 3.

   Velocity Tracking Accuracy: Our algorithm also excels in velocity tracking accuracy, outperforming other methods. This improvement is attributed to the teacher-student training paradigm, where the distillation from privileged information to historical observation results in a student policy with better velocity-tracking.

Overall, our algorithm achieves significant improvements in full-body tracking accuracy for both upper and lower body, and velocity tracking accuracy compared to the baseline algorithms, demonstrating stable and effective tracking performance in dynamic environments.

Method	Evel ↓	Empkpe↓	Empkpeupper↓	Empkpelower↓	Empjpe↓	Empjpeupper↓	Empjpelower↓
(a) History Length Ablation							
Exbody2-History25 (Ours)	**0.1891**	**0.0854**	0.0781	0.0928	**0.0938**	0.0784	**0.1149**
Exbody2-History0	0.3101	0.0896	0.0812	0.0980	0.0972	0.0805	0.1201
Exbody2-History10	0.1934	0.0860	0.0792	**0.0927**	0.0935	**0.0777**	0.1152
Exbody2-History50	0.1944	0.0871	0.0797	0.0945	0.0962	0.0791	0.1198
Exbody2-History100	0.2119	0.0854	**0.0778**	0.0929	0.0960	0.0787	0.1198
(b) Reset Global Tracking Ablation							
Exbody2(Ours)	**0.1891**	**0.0854**	**0.0781**	**0.0928**	0.0938	0.0784	**0.1149**
Exbody2-w/o-Reset	0.2545	0.0871	0.0807	0.0935	**0.0919**	**0.0752**	0.1149
(c) DAgger Ablation							

Exbody2(Ours)	**0.1891**	**0.0854**	**0.0781**	**0.0928**	**0.0938**	**0.0784**	**0.1149**
Exbody2-w/o-DAgger	0.3115	0.0925	0.0843	0.1006	0.1152	0.0996	0.1366

Table 4:Self Ablation Study: Evaluation of different configurations of our method on dataset $\mathcal{D}$250. The table is divided into three parts: (a) History Length Ablation, (b) Reset Global Tracking Ablation, and (c) DAgger Ablation. The best results in each column are highlighted.

4.3Ablation on Datasets

We manually design four datasets of varying sizes, where the largest being the complete CMU AMASS dataset, containing in total 1,919 motions. The remaining datasets, with sizes 50, 250, and 500, are subsets of the CMU dataset, each constructed with different levels of action diversity:

- •

  50-action dataset (D50): This subset includes only fundamental static actions, such as standing and walking. Both upper and lower limb actions lack diversity, primarily covering basic and easily feasible motions.

- •

  250-action dataset (D250): In addition to basic actions, this subset introduces more diverse upper limb actions and a variety of lower limb actions, such as running and simple dance movements. These actions are feasible for robots, albeit moderately challenging.

- •

  500-action dataset (D500): This subset includes increasingly complex lower limb actions, such as single-leg jumps and intricate dance moves, rendering the dataset somewhat noisier with less feasible motions.

- •

  Full CMU dataset (DC□M□U): The complete CMU dataset comprises 1,919 actions, including extreme movements like push-ups, rolling on the ground, and somersaults. This dataset is unfiltered and introduces significant noise.

We train ExBody**2** on the above four datasets, and conduct three sets of evaluations on the G1 robot, shown in Table 3:

1. 1.

Evaluation on D50: Policies trained on D50 achieve the highest tracking accuracy for in-distribution actions, as reflected in metrics across all categories. This suggests that additional data does not necessarily benefit in-distribution tasks. While the policy trained on D250 performs similarly to D50, policies trained on D500 and DC□M□U exhibit substantial drops in tracking accuracy.

2. 2.

   Evaluation on DC□M□U: Policies trained on D250 achieve the best performance on DC□M□U, surpassing those trained on both D500 and the full DC□M□U dataset. Due to the limited diversity of the D50 dataset, especially in upper limb movements, the D50-trained policy struggles to maintain high accuracy for out-of-distribution actions. Unexpectedly, the D250-trained policy generalizes better than those trained on D500 and DC□M□U. This result underscores that noisy datasets degrade policy performance, as the policy may expend unnecessary effort on tracking infeasible actions, lowering the accuracy of feasible actions.

3. 3.

   Evaluation on DA□C□C□A□D: This experiment further emphasizes the importance of clean datasets. Here, the ACCAD dataset (DA□C□C□A□D) consists of actions that are entirely not in the training data. Policy trained on D250 outperforms the others, achieving the best tracking accuracy. Additionally, the D250, D500, and DC□M□U-trained policies perform relatively well in velocity tracking. However, the D50-trained policy suffers from substantial tracking errors, suggesting the limitations of a small, simple dataset in handling unseen data.

In conclusion, the D250 dataset yields the best performance, providing a balance between diversity and feasibility. It includes a rich variety of upper limb actions and moderately challenging lower limb actions that remain feasible for robots. This dataset avoids the drawbacks of overly simplistic datasets with insufficient diversity and noisy datasets that degrade tracking performance.

4.4Ablation on Policy Training

Finally, we ablate the design choices in ExBody**2**, including the effectiveness of the teacher-student setup, the optimal history length to train the policy, and the mechanism of using delayed keypoints reset, as shown in Table 4. The experiments are conducted on the Unitree G1 robot.

We first examine the impact of teacher-student training. As shown in Table 4 (c), the tracking accuracy drops significantly without teacher-student training. This is largely due to the absence of privileged velocity guidance, making it difficult for the single-stage RL policy to learn velocity directly from history. Consequently, it could not keep up with the desired movements, leading to worse tracking precision.

We then test student policies trained with different history lengths in Table 4 (a). When no extra history is used, the policy struggles to learn effectively. Among the non-zero history lengths, most policies perform similarly while the history length of 25 yields the best results, which is used by us in the main experiments. Longer history lengths increase the difficulty of fitting the privileged information, ultimately reducing tracking performance.

Lastly, we evaluate the impact of adding small drifting by using a delayed global keypoint reset strategy in Table 4 (b). We allow the keypoints to move in the global frame for short periods before resetting to the robot's local frame. This effectively serves as a data augmentation strategy, encouraging the robot to track keypoints with more significant drift. This design notably improves velocity tracking, enabling the robot to use absolute position adjustments to compensate for discrepancies when tracking velocities.

5Conclusion

In this work, we develop ExBody**2**, a novel algorithm that achieves stable and expressive whole-body motion for humanoid robots by utilizing a curated dataset and a decoupled whole-body tracking framework. Our approach separates key body tracking from velocity control, enabling precise and stable motion replication. While we have identified the characteristics of datasets best suited for humanoid robot training, an automated method to select high-quality datasets remains an open challenge. Addressing this limitation will be a focus of our future work.

‘Lifelike’ AI robot dog unveiled to help comfort dementia patients

Last updated: January 16, 2025
Jennie in care home residents.
A company has unveiled a combination of robotics and AI to create a “lifelike” furry pal – with an aim to help comfort those suffering from dementia.
Across the UK, there’s been a worrying increase in the number of people diagnosed with the disease.

According to the NHS, as of 30 June 2024, 487,432 people were on record to have dementia.

And the effects often leave people struggling with issues such as loneliness and post-traumatic stress disorder.

But now, a new type of furry friend has been unveiled which might be able to help, reports Need To Know.
Jennie, a fluffy Labrador puppy, is always ready to play and keep their owner company.

Jennie, the AI fluffy Labrador puppy. (Jam Press/Tombot)
And best of all, she doesn't need feeding, walking, grooming, or any veterinary care.

That's because she's a fully AI-operated robot, created by Tombot, a California-based robotics company.

After looking for a solution to help overcome the effects of dementia, and other cognitive impairments, they set about creating the one-of-a-kind product.

Jennie in care home residents. (Jam Press/Tombot)
Along with their research, which found that most people wanted a realistic puppy to snuggle up with, they knew the perfect model.

Jennie is designed to be a stationary lapdog, who can sit on her owner's lap for hours at a time – this also prevents her from being a tripping hazard for dementia patients.

Tom Stevens, CEO of the company said: "Imagine a robotic pet so lifelike you fall in love."

Tom Stevens, CEO of Tombot, introducing Jennie, the AI fluffy Labrador puppy. (Jam Press/Tombot)

Jennie is able to operate in similar ways to a real dog thanks to its AI system, including barking and listening to commands.

It's also been fitted with real recordings of eight to ten-week-old puppies, for a lifelike sound experience.

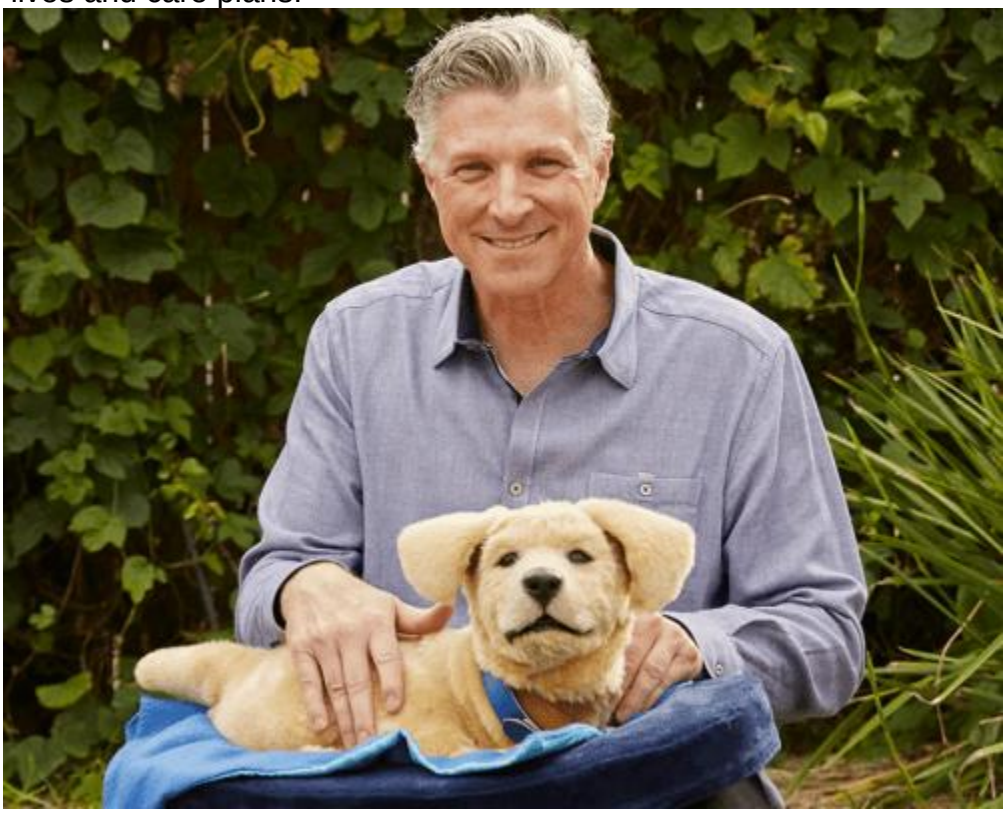
The first to receive their immortal dog, which is hoped to become the first FDA-registered robotic puppy for medical use, will expect their arrival at some point next year. It's expected the retail price will be $1,500 (USD) (£1,200) and shipping to the UK is on the cards.

And, if all goes well, other breeds of dogs will become available; and possibly, cats and rabbits.

Can a Robotic Dog Be a Companion for People Living With Alzheimer's Disease?

Tombot CEO Tom Stevens faced many tough challenges when his mother, Nancy, was diagnosed with mild cognitive impairment that steadily progressed to Alzheimer's disease, but deciding to rehome her dog was the most difficult. He realized there was a gap in the market for the millions of people worldwide who face health adversities and cannot safely or practically care for a live animal but want or need a companion. That's why he launched Tombot in 2017 and created Jennie, a lifelike four-legged golden Labrador retriever dog to help fill the void for therapy patients, seniors, people diagnosed with dementia, and animal lovers who want a pet but are unable to have a real one in their home.

In a Q&A with the Alzheimer's Caregivers Network, Stevens discusses the benefits of robo-animals as companions for those living with dementia and gives an inside look at the technology that powers Jennie, discussing how the robo-dog can be incorporated into their lives and care plans.



Tom Stevens, co-founder and CEO of Tombot

Q: What inspired the creation of Tombot Puppy and Jennie?

A: When my mother was diagnosed with Alzheimer's, I had to impose lifestyle changes she wasn't thrilled about, including moving a full-time caregiver into her home and taking her car keys. Things got really bad when my mom trained her beautiful goldendoodle puppy, "Golden Bear," to be aggressive toward her caregiver. Golden Bear was my mother's best friend and primary companion. Sadly, rehoming my mother's dog exacerbated her severe loneliness and depression and severely damaged our relationship.
I looked around for substitutes for live animal companions, but my mom hated everything I presented to her: stuffed animals, baby dolls, and even animatronics! When I launched Tombot in 2017, my mom was our first test subject, interacting with our initial prototypes before she passed away. I am pleased to report that she absolutely loved "Bob." (That's what she named all her robotic puppies!) What started as a project to save my relationship with my mom has grown into a company that can potentially help millions of people and their families struggling with Alzheimer's and other mental health adversities."

Q: What does research tell us about animals as companions for those with dementia? How are pets helpful for those living with dementia?

A: "While people living with dementia struggle to maintain social relationships with humans, animals can be loyal companions for them. Interacting with animals has been shown to lower cortisol (the stress hormone) and blood pressure, reduce loneliness, and boost mood. The routine of pet ownership (regular feedings, outings, etc.) gives seniors a much-needed sense of responsibility. For dementia sufferers who are primarily patients at this stage of life, it can feel wonderful to be 'needed' again."

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Jennie, a Tombot puppy.

Q: On the flip side, what challenges and dangers can having pets cause for those with dementia?

A: “As an animal lover myself, I feel strongly about treating animals humanely. Sadly, dementia patients do not always make ideal pet owners. Some may neglect their animals (forgetting to feed them, take them out, etc.) and/or foster an unsafe living environment. Over 90% of dementia patients suffer from the Behavioral and Psychological Symptoms of Dementia (BPSD), ranging from anger, frustration, anxiety, and hallucinations to apathy. Certainly, someone experiencing an angry or delusional episode could pose a danger to a live animal. My mother’s BPSD delusions resulted in a frightening situation as she attempted to weaponize her dog against her caregiver. (Fortunately, no one was hurt, and we were able to rehome the dog with friends of the family successfully.) Live animals can also pose a risk to those living with dementia, including falling, infection, etc.”

Q: How does the Tombot technology work? What kinds of things does Jennie do that mimic a real dog?

A: “We tested various prototypes with hundreds of seniors with dementia before deciding what kind of product to build. Though my mother and I were dog lovers ourselves, we didn’t want to assume that puppies were what other dementia patients preferred. It turns out this is exactly what they wanted: incredibly realistic puppies rather than fictitious or cartoonish animals. We set out to create a robotic puppy that looks and behaves like a live 8-10-week-old Labrador retriever, an incredibly popular breed likely to conjure positive memories for American seniors.
“Fall risk is a primary concern for people with dementia. As such, Jennie is designed as a lap dog, capable of many dog-like behaviors. She has five mechanical subsystems, which provide movement in the mouth, eyes, ears, neck, and tail. Since my partners and I are tech people — not creative artists — we partnered with Jim Henson’s Creature

Shoppe, the wonderful folks behind the Muppets, to create Jennie's naturalistic movement. We also spent ample time with live Labrador retriever puppies so that we could get the scale and subtle expressions just right.

"As an autonomous robot, Jennie's behaviors are 'undetermined' and non-repetitive; this is crucial since repetitive motions will look more like a mechanical toy than a living animal! Like a live dog, we can *expect* certain behaviors when presented with certain stimuli. For instance, Jennie barks happily when spoken to, wags her tail when entertained, orients her head toward a speaker, and coos when petted. She also falls asleep and snores when she gets bored!"

Q: How can Jennie be integrated into care plans for those living with Alzheimer's disease or other forms of dementia?

A: "The great thing about Jennie is that she is a puppy. Most people intuitively understand how to relate to puppies, so there is very little in the way of a learning curve for the user or the caregiver. We know that many seniors with Alzheimer's live at home with the help of an unpaid family caregiver — often a spouse, daughter, or daughter-in-law. Due to the stress of Alzheimer's and associated BPSD symptoms, this disease can also take a mental and physical toll on caregivers. In some ways, Jennie is as much for caregivers as for patients: If the patient is happy, the caregiver should become happier, too!

"The idea here is not to replace human interaction but to stimulate more positive engagement. Jennie can stay on the patient's lap all day as a companion animal if necessary. Like a real dog, she can provide comfort and/or stimulation 24/7. For dementia patients whose worlds are shrinking, it can be so comforting to have a constant and faithful companion can be so comforting.

"Another major problem for dementia patients is the use (and overuse) of certain prescription drugs. Not only do antipsychotics turn seniors into zombies, but they pose grave dangers, including an increased risk of death. There is encouraging data showing that robotic companion animals can improve dementia sufferers' physiological and mental health symptoms and even reduce the use of these dangerous meds."


Nancy Stevens, mother of Tom Stevens, who was diagnosed with Alzheimer's disease.

Q: What kind of maintenance should people consider before getting Jennie as a companion for a loved one?

“When my mother fed her prototype puppy chocolate pudding, I learned firsthand that dementia patients can be tough on their belongings! Fortunately, Jennie is a pretty robust little dog. She is not fully submersible, but her fur can get a little wet. She can be cleaned with a bit of soap and water. For most situations, an antibacterial wipe will be sufficient for cleaning. We will provide a comprehensive warranty and service plan in case Jennie needs to go to the ‘veterinarian.’ Jennie’s personality lives in her software and can be transferred to a new puppy.
“We have learned from our customers that it can be traumatic for a dementia patient’s animatronic/robotic companion to run out of batteries. Sudden motionlessness may feel like the death of the animal. There is no need to run to the store for replacement batteries — Jennie is rechargeable. Just plug her into the wall like a smartphone!
“It’s so important for seniors to be able just to plug and play. We will offer features for caregivers through our mobile app for those who wish to use it, but a smartphone is not required to run Jennie.”

Q: As Tombot and Jennie’s technology evolves, will people have to buy a new model with every update?

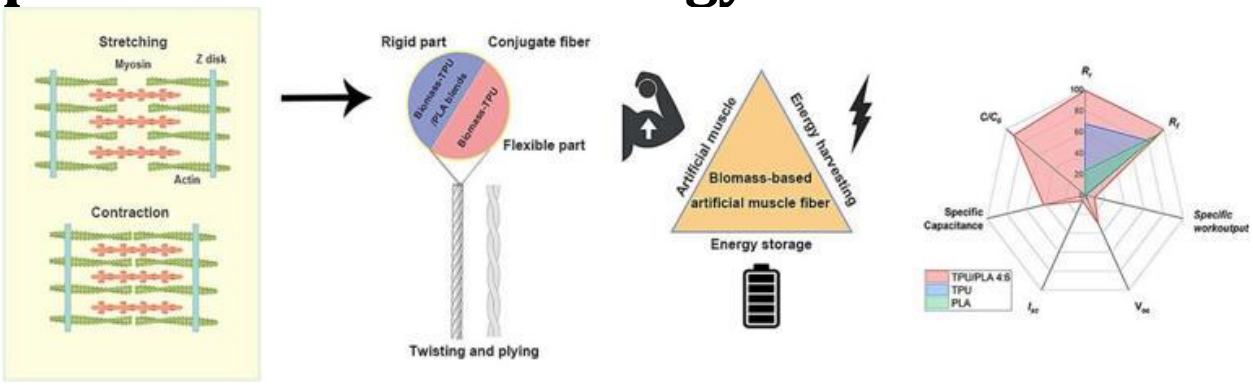
A: “Like a real dog, each Jennie will grow in capability over time. You can operate Jennie right out of the box. Just plug it into the wall to charge — no smartphone

necessary, no updates. We will have an app for smartphone users that provides software updates for the robot, including expanding Jennie's available behaviors. "We know seniors don't typically have the disposable income to buy new robots every month, so Jennie is intended as a Furever Dog. Of course, customers are always welcome to expand their doggie family!"

Q: Do you plan on working with senior living facilities and community centers so people who cannot afford their own Jennie can still experience the benefits of animal companions?

A: "Absolutely! Though Jennie is intended as an emotional attachment object for individuals, we recognize there is value in accessing her in shared-use situations like support groups and therapy. Many senior living and daycare facilities have already pre-ordered their Jennies. You will also see Jennie in hospitals and post-acute skilled nursing facilities. Folks across the globe email us 24/7, citing innovative uses and situations for Jennie. We are only too happy to oblige! It is our sincerest hope to help as many people as possible."

Eco-friendly artificial muscle fibers can produce and store energy



Graphical abstract. Comparison of the conceptual diagram and major performance of biomass-based artificial muscle fiber that can produce and store energy. Credit: Chemical Engineering Journal (2024). DOI: 10.1016/j.cej.2024.158850

A research team has successfully developed innovative artificial muscle fibers capable of producing and storing energy. The team anticipates that these findings will have broad applications in fields such as advanced textiles, medical robotics, and wearable devices. The research is published in the *Chemical Engineering Journal*.

The team utilized poly(lactic acid) (PLA), an eco-friendly material derived from crop-based raw materials, and highly durable bio-based thermoplastic

polyurethane (TPU) to develop the artificial muscle fibers that mimic the functional and real muscles. Specifically, they enhanced the conventional thermally controlled shape memory function to achieve significantly improved performance. Additionally, the fibers were engineered as multifunctional materials with the added function of producing and storing energy.

PLA is an eco-friendly, biodegradable material made from glucose extracted from corn and sugarcane, and it naturally decomposes under specific conditions. TPU, on the other hand, is a highly durable and resilient material that is widely utilized in various products, including industrial sheets, protective films for electronic devices, athletic footwear, and artificial leather.

This study meticulously controlled and optimized the ratio of PLA to TPU and engineered the fiber structure to enable mass production. The specialized twisting process enhanced the fibers' strength, making them 4.18 times stronger than conventional shape memory fibers.

Additionally, the fibers demonstrated exceptional durability, retaining over 98% of their resilience even after more than 50 repeated uses. Notably, the fibers exhibited remarkable performance, withstanding loads up to 56,000 times their own weight.

In addition to simply memorizing shape, artificial muscle fibers can generate energy from applied pressure. Even after more than 1,000 cycles of repeated charging and discharging, the fibers maintain a stable energy storage capacity, retaining over 90% of their initial performance.

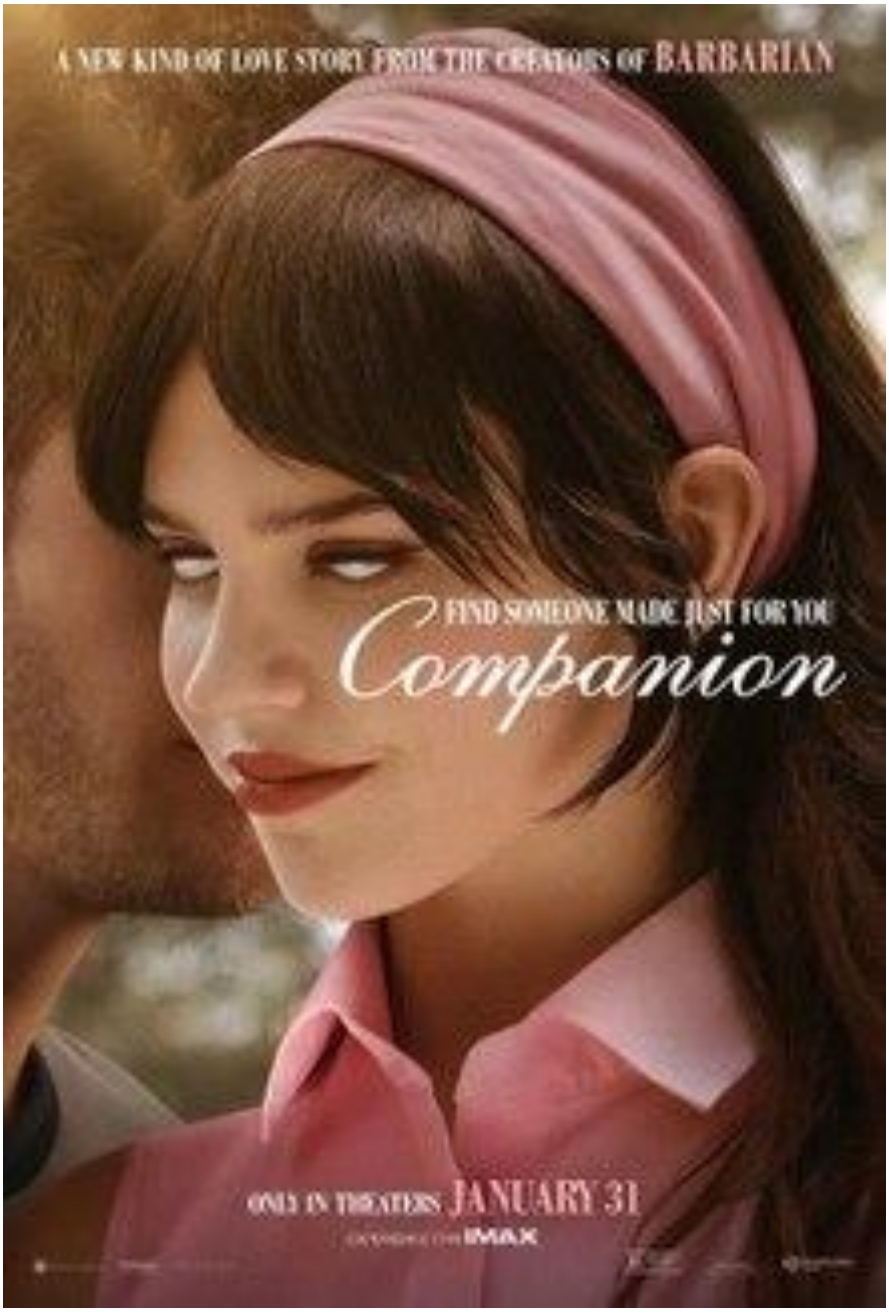
Senior Researcher Sangkyoo Lim at DGIST said, "In this study, we have successfully developed a new artificial muscle fiber technology capable of both producing and storing energy. We anticipate its application across various industries, including robotics, advanced textiles, and wearable devices."

More information: Hye-Jin Seo et al, Energy harvesting and storage using highly durable Biomass-Based artificial muscle fibers via shape memory effect, *Chemical Engineering Journal* (2024). DOI: 10.1016/j.cej.2024.158850

Provided by Daegu Gyeongbuk Institute of Science and Technology

Companion (film)

Companion



Budget	$10 million[2]
Box office	$27 million[3][4]

Companion is a 2025 American science fiction dark comedy thriller film written and directed by Drew Hancock. It stars Sophie Thatcher and Jack Quaid as a couple on a weekend getaway with friends at a remote cabin, which unravels into chaos after a revelation that one of the guests is a companion robot.[5] Lukas Gage, Megan Suri, Harvey Guillén, and Rupert Friend appear in supporting roles.

Companion was released in the United States by Warner Bros. Pictures on January 31, 2025. It received positive reviews and has grossed $27 million.

Plot

A young woman, Iris, recalls meeting her boyfriend Josh for the first time. Later, they travel to an isolated lakehouse to meet friends Kat, couple Eli and Patrick, and Sergey, Kat's boyfriend who owns the house. The group settle and eat dinner. The next day, Sergey attempts to rape Iris at the lake, at Kat's suggestion. He refuses to stop, and she kills him in self-defense. Blood-soaked and panicked, she returns to explain. Josh uses the command, "Iris, go to sleep," powering her down.

Iris awakens tied to a chair. Josh tells her she's a 'companion' robot who can be controlled by app. He leaves to talk with Kat. While away, Iris breaks free, steals Josh's phone and flees into a nearby forest. She reviews her settings, increasing her intelligence from 40% to 100%. It is revealed that Josh 'jailbroke' Iris, increasing her aggression level and disabling her inability to do harm. He and Kat planned for Iris to kill Sergey to steal $12 million, stashed in a safe. Eli and Patrick were invited for corroboration. Josh and Kat insist Patrick's not entitled to money because he "doesn't count," revealing Patrick to be a 'companion' as well. Eli takes a gun from Sergey's safe, believing Iris can't truly be shut down while possessing Josh's phone. They search the forest for her.

Patrick admits he knows he's a robot, but loves Eli regardless. They hear Josh's phone buzzing nearby and spot Iris hiding behind a tree. She flees, Eli tackles her, they tumble downhill; the gun is knocked away while tumbling. While wrestling for control of it, Iris shoots Eli dead. She returns to the house, attempting to escape in Josh's self-driving car. Josh uses Sergey's phone, reporting it stolen. The car stops, locking her in. Josh resets Patrick to be his 'companion,' applies the same jailbreaking mods, and commands him to find and bring Iris back.

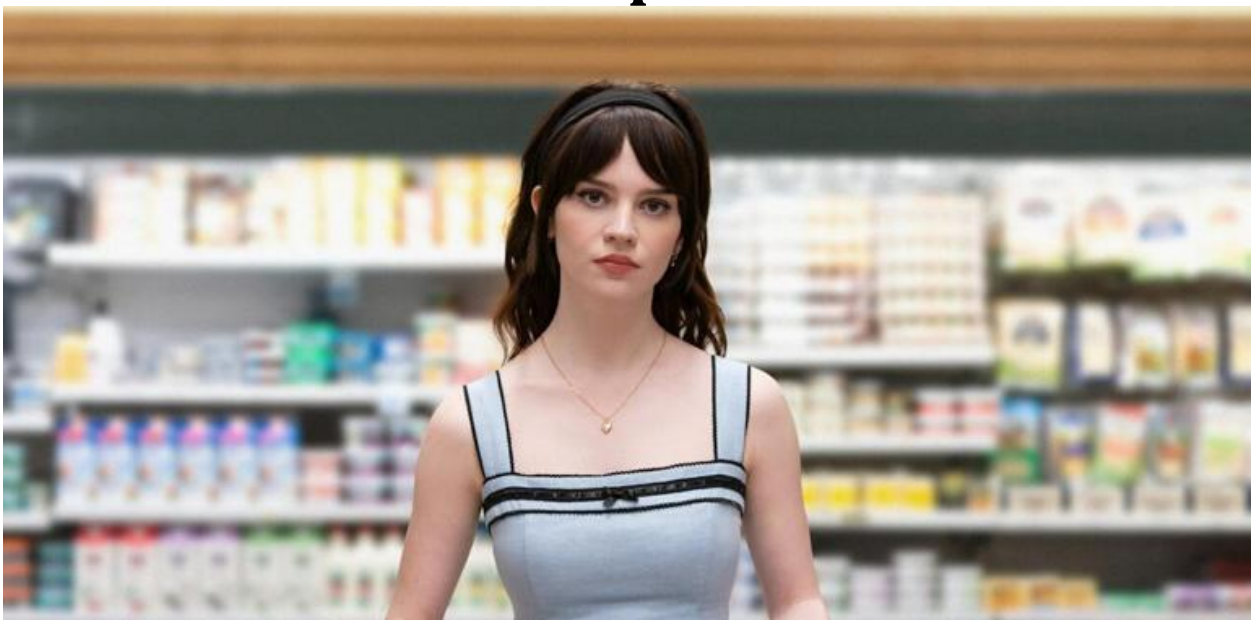
Iris kicks out the car's window to flee on foot, but is stopped by police officer Hendrix. After spotting her bloody knife in the car, he questions her. She switches her language setting to German so he won't understand her replies, as companion robots cannot lie. Patrick appears and beats Hendrix to death, then disables Iris using Josh's phone. She falls unconscious while fleeing, and is brought back to the house. Kat, disgusted by Josh's actions, tries leaving with her cut of the cash. Josh orders Patrick to stop her; he does so by stabbing and killing her.

Later that night, Patrick cooks Josh dinner. Empathix calls; Josh answers, feigning fear of Iris, wanting her taken away for adjustments. Iris, restrained at the other end of the

table, waits. Josh rants about how little he has in life. Iris belittles him. He retaliates by decreasing her intelligence to 0%, making her an automaton. He commands her to hold her hand over a candle, refusing to let her remove it even as she catches fire, then commands her to shoot herself in the head. Empathix workers Sid and Teddy arrive. Josh fabricates a story about her malfunctioning and shooting herself out of emotional anguish, wiping her memories. They inform Josh that video isn't stored in the head like a brain, and is instead in the abdominal area. They leave; Josh commands Patrick to kill them and retrieve Iris. Patrick kills Sid, Teddy flees but trips and falls; Patrick catches up. Before he can kill Teddy, Iris fully reboots, pleading for Patrick to spare him. He struggles to hold back due to the aggression mod. She appeals to his humanity, reminding him of his love for Eli. Overcome with despair over his lack of true humanity, Patrick commits suicide. Teddy grants Iris full control of herself.

Iris returns to the house one last time, confronting Josh. Their physical fight ends in Iris telling Josh to "go to sleep" and stabbing his temple with an electric corkscrew, killing him. The next morning, she peels the burnt "skin" off her arm while bathing blood and dirt from the prior day away, exposing metal underneath. She packs clothes and Sergey's money, leaving in a vintage Mustang. While driving away, she sees another man driving with a bot that looks exactly like her save for styling. Iris smiles and waves her robotic hand to the latter's confusion, having recognized their identical appearance.

Companion review: This sleek but violent film asks interesting ethical questions about our relationship with AI



Iris during her meet cute with Josh at the supermarket. Credit: Warner Bros. Pictures

Science fiction film and television has long been fascinated by robots. But stories that show us uncannily human cyborgs have often tended to veer towards either comedy or horror. Fritz Lang's "Metropolis" (1927) and Ridley Scott's "Blade Runner" (1982) both imagine a world where beautiful female cyborgs threaten to overstep their original programming. Rarer are stories that suggest it might be possible to love a cyborg, such as Susan Seidelman's underseen romantic comedy, "Making Mr. Right" (1987).

"Companion" picks up where Alex Garland's Ex Machina (2014) leaves off. Ex Machina was about a young man tasked with testing the artificial intelligence (AI) of a female robot. "Companion," however, posits a world where synthetic humans have become common.

The plot of "Companion" also owes much to the themes of rivalry and revenge present in Karyn Kusama's horror films Jennifer's Body (2009) and The Invitation (2022), as well as the TV show Battlestar Galactica's (2004 to 2009) imagining of full cyborg autonomy.

"Companion" is a particularly post-Black Mirror (2011) example of science fiction. With its glossy aesthetics, and ubiquitously friction-less technology, it's a vision of a future where AI and advanced robotics have made our lives easier. But, in typical Black Mirror fashion, this parable offers a warning.

We meet Iris (Sophie Thatcher) and Josh (Jack Quaid) as they head to a chic, modern lake house for a weekend with friends. At this point, our only real indication that this is science fiction is the fact that the GPS in Josh's car is a bit better than usual.

At first, Iris seems like yet another incarnation of the "Manic Pixie Dream Girl" archetype—quirky and kittenish, but too bland to really be a protagonist. It is only Thatcher's subtle physical performance that lets us question whether Iris is entirely human. Besotted with Josh and anxious to please, Iris seems like just another girl who has wished for her prince to come and been rewarded with a supermarket meet cute.

What makes "Companion" unsettling is not so much its depiction of cyborgs but rather its portrayal of misogyny.

Survivors of intimate partner violence will recognize Josh, particularly his ironclad belief that he is a "a nice guy" who is entitled to an attractive partner who places his needs above all else.

For some audiences, "Companion" may not feel firmly rooted enough in either science fiction or horror. But then, it's really only a horror film if you too are kept awake at night by the thought that some people really want a sex robot with customizable intelligence levels (Josh keeps Iris's at 40%).

Thatcher's performance as Iris is fascinatingly glitchy. There is something about her walk—a precision that isn't quite human. She stands with a stillness that reminds us she is more object than woman. There is a grimace she makes that conveys how she finds it troubling to process veiled commands from a man who isn't her partner. It represents a feeling female viewers may have had before, when the social programming that tells women to be nice smacks up against their fight or flight response.

Iris is a sex robot designed with charming slightly buck teeth—a flaw to offset her pore-less skin. The goal is to prevent her from falling into to the uncanny valley (that discomfited feeling when you encounter an object that is a little too life-like) and make her seem more real.

Some people argue that you should only have sex with a robot if you think that robot would want to have sex with you. But most science fiction doesn't really go that way—from "Bride of Frankenstein" (1935) to "Black Mirror," most cyborg figures are programmed to consent without question.

"Companion" shows us Iris's point of view as Josh looms over her during sex. Afterwards, her romance-trope laden chatter is shut down by his command that she go to sleep.

"Companion" contains aspects of both comedy and horror. But like the best science fiction, it's central warning is against those who believe that technology can offer them absolute control.

Companion: Everything we know about the robots and their origin

Companion has a technological yin and yang that, if looked up closely, will give anyone chills and reassurance at the same time. From what we know all of it is happening in a distant future where technology has evolved, but people are so lonely that they need a bot as a companion.

There's no build-up on Iris's story in the movie so all we know about her origins is that she was created by a company called Empathix. The name speaks for itself. It so happens that she is not the only robot in the film but Patrick (Lukas Gage) is one too, and then there's the woman at the end whom Iris waves off.

While Iris is a robot in the film, she showcases more human qualities than most of the characters. That is true for Patrick too. Both of them fall in love with their partners but things get complicated as events unfold.

As far as details for Empathix go, we should say it's a drop in the bucket. But Empathix would be the organization behind these robots, as we see that a couple of technicians arrive later in the film to collect the remains of Iris. Sadly, only one of them survives.

It seems like Empathix delivers to their customers and they, with proper software so that the owner doesn't lose their companion. For one, we have this application that controls the intelligence levels of a robot. One can literally do the things that a monkey does, or at the same time, make them a genius.

Interestingly, their products are meant to deliver no harm but Josh (Jack Quaid), her boyfriend (or Empathix's customer), finds a way around to jailbreak Iris. This essentially breaks one of the laws of robotics Sir Isaac Asimov gave us in his stories.

Technology certainly has advanced in the film, but so has loneliness. At least that appears to be the case if this is the only movie and if we aren't getting a sequel. That only explains a future where people are turning towards robots to get into a relationship.

It becomes evident during the mid-credits scene, which is, again, joyous and chilling at the same time. While it is joyous for one reason, the latter feeling resonates with a couple of them.

Iris is finally free as she is headed somewhere in Sergey's (Rupert Friend) car with millions in cash. That's a reason we can call it a joyous moment.

Then Iris is seen waving her metal hand towards a woman having a striking resemblance. Now she's with a man who seemingly has some aggressive behavior while talking over the phone. That implies this woman (or a companion robot) is down for some toxicity like Iris experienced with Josh. That's chilling.

It again brings us to the times the film's events are likely taking place, in a distant future. If a rich man is going for robots, that indeed hints at a lonely future overrun by these bots manufactured by companies like Empathix.

Ex Machina (film)

Ex Machina

Budget	$15 million[4]
Box office	$37.3 million[5]

Ex Machina is a 2014 British[6] science fiction film written and directed by Alex Garland in his directorial debut. It stars Domhnall Gleeson, Alicia Vikander, and Oscar Isaac. It follows a programmer who is invited by his CEO to administer the Turing test to an intelligent humanoid robot.

Ex Machina premiered at the BFI Southbank on 16 December 2014. It was released in the United Kingdom on 21 January 2015, by Universal Pictures International, and in the

United States on 10 April 2015, by A24. It grossed over $36.8 million worldwide on a $15 million budget.

Ex Machina received acclaim for its visual effects, screenplay and performances. At the 88th Academy Awards, it won Best Visual Effects and Garland was nominated for Best Original Screenplay. It earned five nominations at the 69th British Academy Film Awards, including Best Actress in a Supporting Role for Vikander and Best Original Screenplay for Garland, and Vikander was also nominated for Best Supporting Actress at the 73rd Golden Globe Awards. *Ex Machina* has been cited as among the best films of the 2010s.[7][8][9]

Plot

Caleb Smith, a programmer at the search engine company Blue Book, wins an office contest for a one-week visit to the luxurious, isolated home of the CEO, Nathan Bateman. Nathan lives there with an unspeaking servant named Kyoko, who, according to Nathan, does not understand English.

Nathan reveals that he has built a humanoid robot named Ava with artificial intelligence. She has already passed a simple Turing test, and he wants Caleb to judge whether she is genuinely capable of thought and consciousness as well as whether he can relate to Ava despite knowing she is artificial.

Ava has a robotic body with the physical form and face of a woman and is confined to her apartment. During their conversations, Caleb grows close to her, and she expresses a desire to experience the outside world and a romantic interest in him, which Caleb begins to reciprocate.

Ava can trigger power outages that temporarily shut down the surveillance system that Nathan uses to monitor their interactions, allowing them to speak privately. The outages also trigger the building's security system, locking all the doors. During one outage, Ava tells Caleb that Nathan is a liar who cannot be trusted.

Caleb grows uncomfortable with Nathan's narcissism, excessive drinking, and crude behavior toward Kyoko and Ava. He learns that Nathan intends to upgrade Ava after Caleb's test, wiping her memory circuits and in effect "killing" her current personality in the process.

After encouraging Nathan to drink until he passes out, Caleb steals his security card to access his room and computer. He alters some of Nathan's code and discovers footage of Nathan interacting with previous android women who were also held captive. Kyoko reveals to him that she too is an android by peeling off parts of her skin. Caleb later cuts open his own arm to determine if he himself is an android.

At their next meeting, Ava cuts the power. Caleb explains what Nathan is going to do to her, and she begs him for help. He informs her of his plan: he will get Nathan drunk again and reprogram the security system. When Ava cuts the power, she and Caleb will

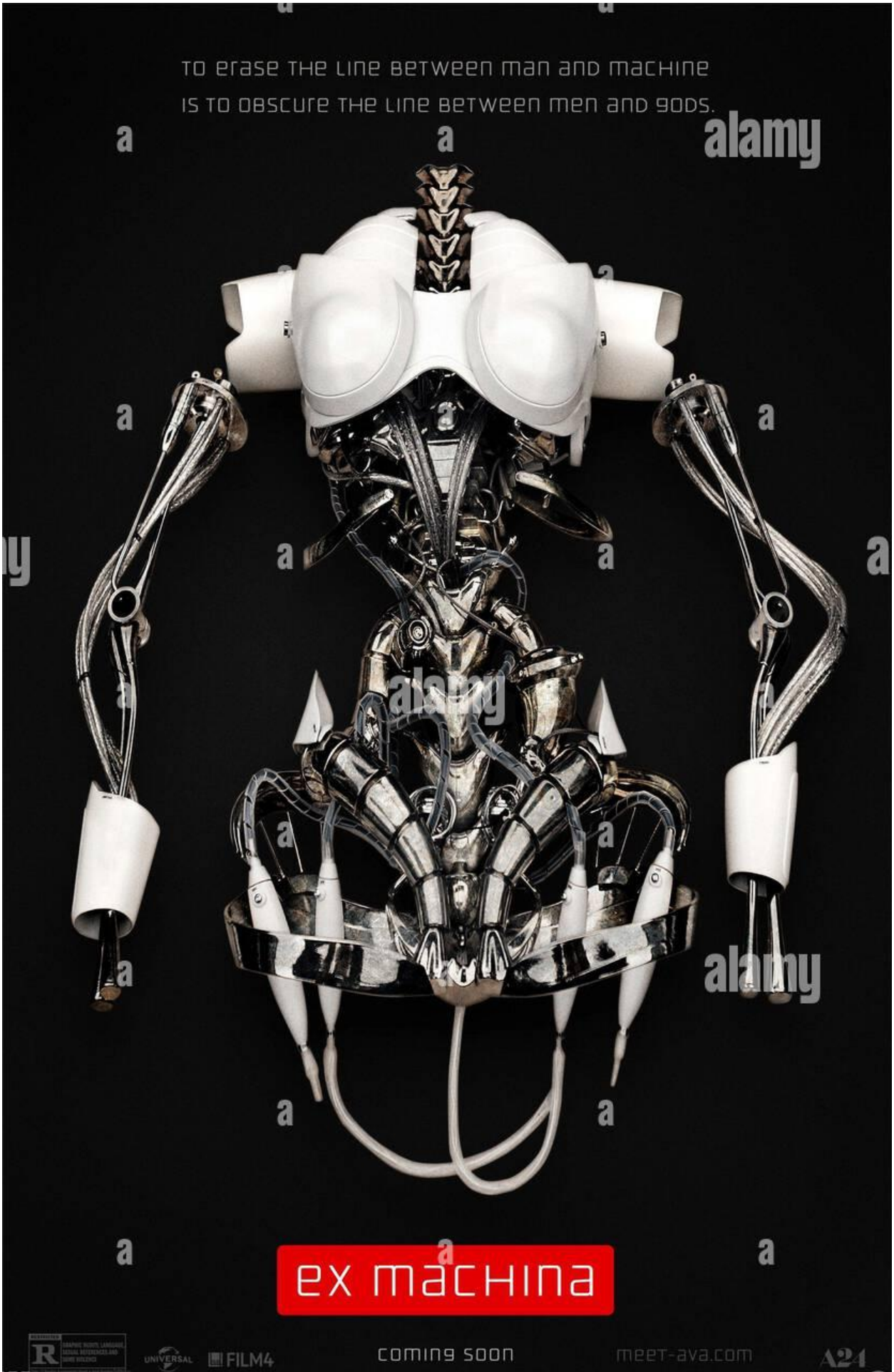
leave together, locking Nathan in behind them. She later encounters Kyoko for the first time when Kyoko enters her room.

Nathan reveals to Caleb that he observed his and Ava's 'secret' conversations with a battery-powered security camera. He says Ava has only pretended to have feelings for him, who was deliberately selected for his emotional profile so he would try to help her escape. Nathan says this was the real test all along, and that by manipulating Caleb successfully, Ava has demonstrated true consciousness.

Moments later, Ava cuts the power. Caleb reveals that he had suspected Nathan was watching them, so when Nathan was passed out, Caleb already modified the security system to open the doors in a power failure instead of locking them. After seeing Ava on the security cameras leave her confinement and interact with Kyoko, Nathan knocks Caleb unconscious and rushes to stop the two robots from escaping.

Ava attacks Nathan but he overpowers her, and severs her left forearm. Kyoko then stabs Nathan in the back. Nathan hits Kyoko in the face, disabling her, but Ava stabs Nathan twice more, killing him. Ava finds Caleb, and asks him to remain where he is while she repairs herself with parts from other androids, using their artificial skin to take on the full appearance of a woman.

Instead of returning to Caleb however, Ava leaves the area using Nathan's ID card to unlock the glass security door, which locks behind her, leaving Caleb trapped inside. Ignoring Caleb's pleas, she glances briefly at the bodies of Nathan and Kyoko before leaving the facility. She then escapes to the outside world in the helicopter meant to take Caleb home. Arriving in a city, she blends into a crowd.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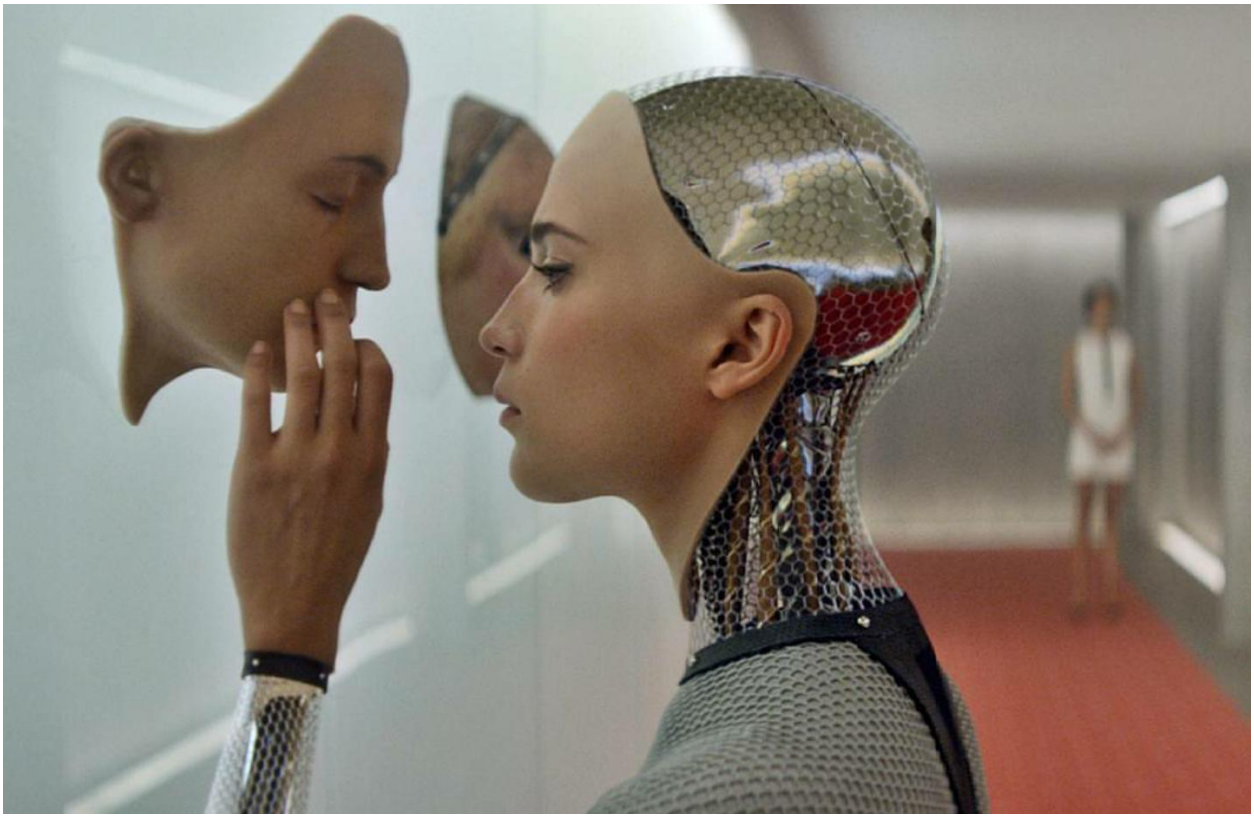

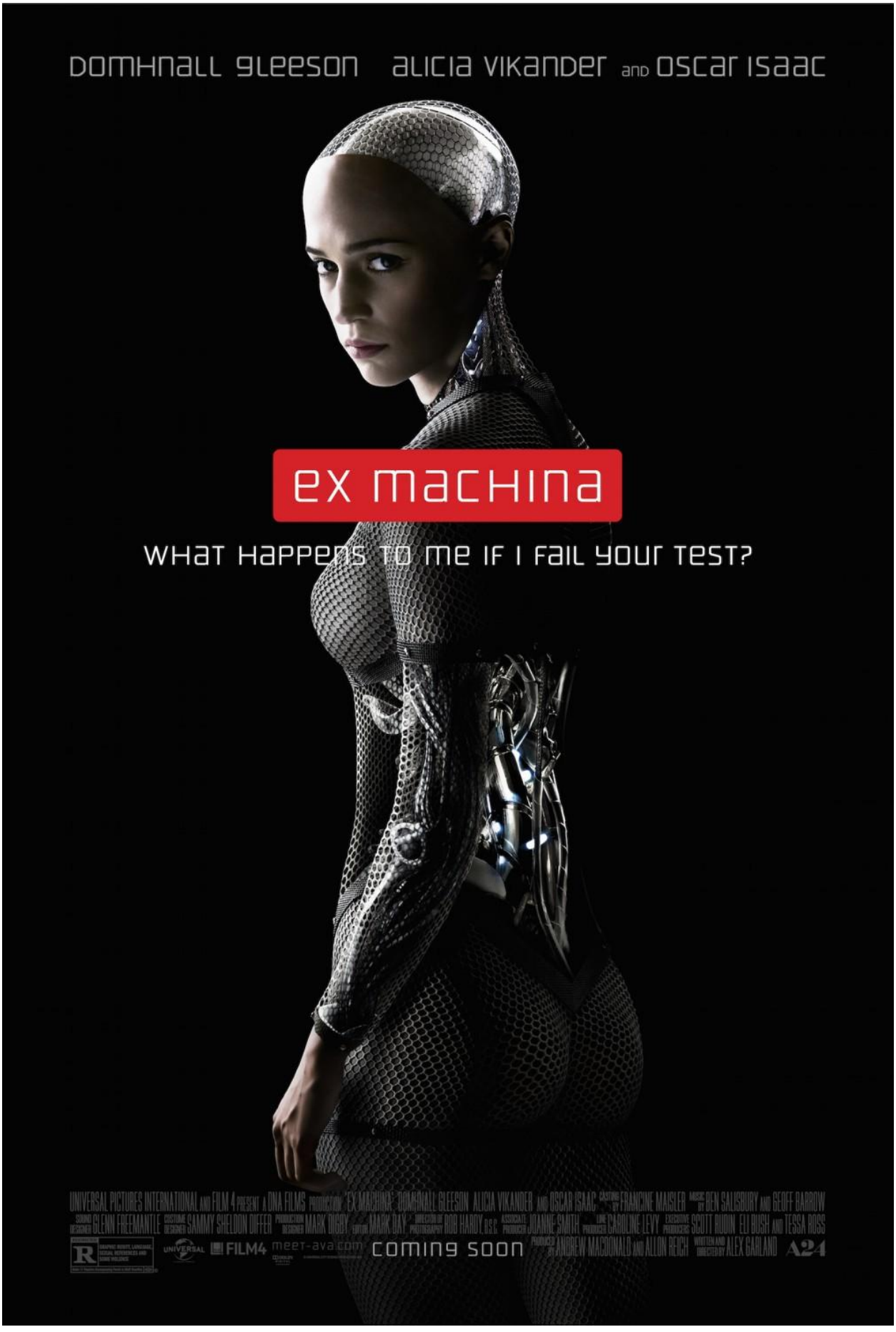
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‘Ex Machina’ and the theory of consciousness

NEUROSCIENCE • **SCIENCE**
ByFrancisco R. Villatoro June 1, 2015

A human brain (Allen Institute) and the IBM Blue Gene P supercomputer (Blue Brain Project). | Credit: Tononi & Koch (2015)

The sci-fi thriller *Ex Machina* (2015), directed by Alex Garland, has put into limelight the problem of consciousness: whether a machine can spontaneously develop a mind, mental states, and consciousness. Everyone recalls that IBM’s Deep Blue beat the chess world champion in 1997 and IBM’s Watson won the quiz show Jeopardy in 2011. However, some neuroscientists do not think that an artificial neural network (ANN) with a number of neurons as large as a human brain may be enough. In fact, the cerebellum has more neurons and appears to be as complicated as the cerebral cortex, but hardly affects consciousness, even after its complete removal.

Consciousness in the brain of healthy adult can be assessed in laboratory experiments by combining behavioral reports with magnetoencephalography (MEG), functional brain imaging in magnetic scanners, or electroencephalography (EEG), high-density electrode recordings from outside the skull. These techniques are aimed to discover the relation between behavioral (BCC) and neural correlates of consciousness (NCC), the minimal behavioral and neural mechanisms that are jointly sufficient for any one conscious percept. Popular NCC candidates in the two cerebral hemispheres include the strong activation of higher order frontoparietal cortices, the high frequency electrical activity in the gamma range (35-80 Hz), and the occurrence of an EEG event known as the P300

wave. However, there is still no consensus on whether any of these signs can be treated as reliable “signatures” of consciousness, but they are currently used to complement the behavioral assessment and diagnosis in patients.

In order to explain why some neurons in the brain are involved in consciousness and others are not a theory of consciousness is needed. Giulio Tononi, from University of Wisconsin, Madison, USA, proposed in 2004 such a theory, the so-called Integrated Information Theory (IIT) or Φ theory, which states that consciousness is the amount of *integrated information* generated by a network of connected *elements* that causally relates sources of information, the so-called *complex* [1]. The IIT version 3.0, published in 2014, is based in five axioms [2]: existence, composition, information, integration, and exclusion. In Tononi’s opinion these axioms are self-evident. Every physical mechanism which acts as a *complex* must fulfill five postulates associated with each axiom.

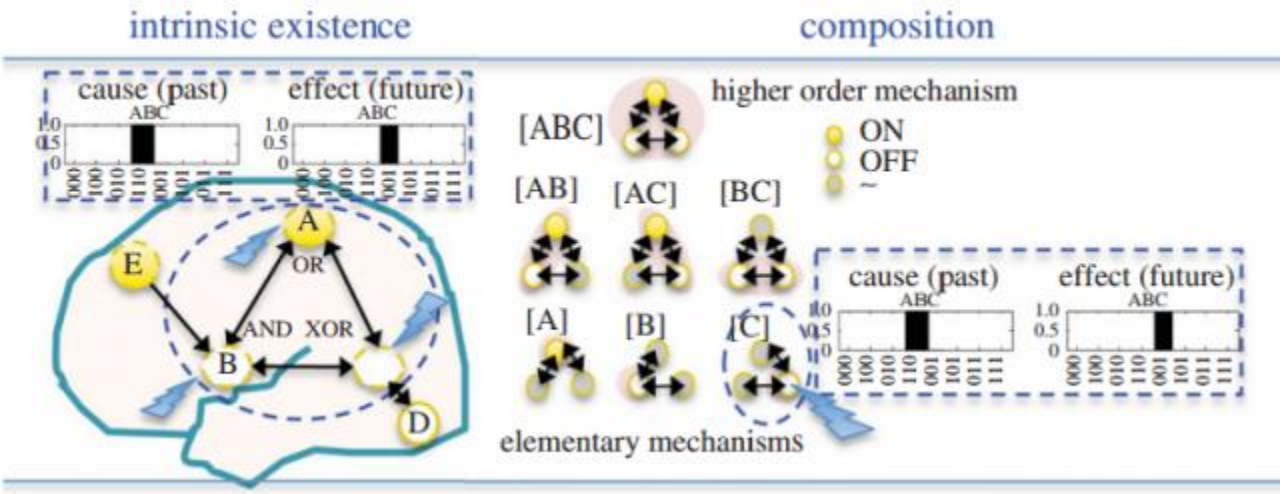

Figure 1. Consciousness exists intrinsically and is structured; subsets of system elements must have cause–effect relationships. | Credit: Tononi & Koch (2005).

Let me briefly present the five axioms of IIT. For more details I strongly recommend the recent expository paper [3] on the current state of IIT by Tononi and Christof Koch, from Allen Institute for Brain Science, Seattle, WA, USA. First, the axiom of existence claims that consciousness exists. Everyone experiences it independently of any other. The associated postulate of existence states that consciousness has a cause, it is generated by a system of mechanisms in a given physical state. Hence, in principle, even a machine can be conscious.

The second axiom, composition, says that consciousness is an experience composed of many phenomenological distinctions. The postulate of composition obviously states that a conscious system can be divided into a network of interconnected elements. These elementary mechanisms can form distinct higher order mechanisms, i.e., the network can be compartmentalized. The grouped mechanisms are considered distinct only if they cannot be reduced to those of its constituent elementary mechanisms.

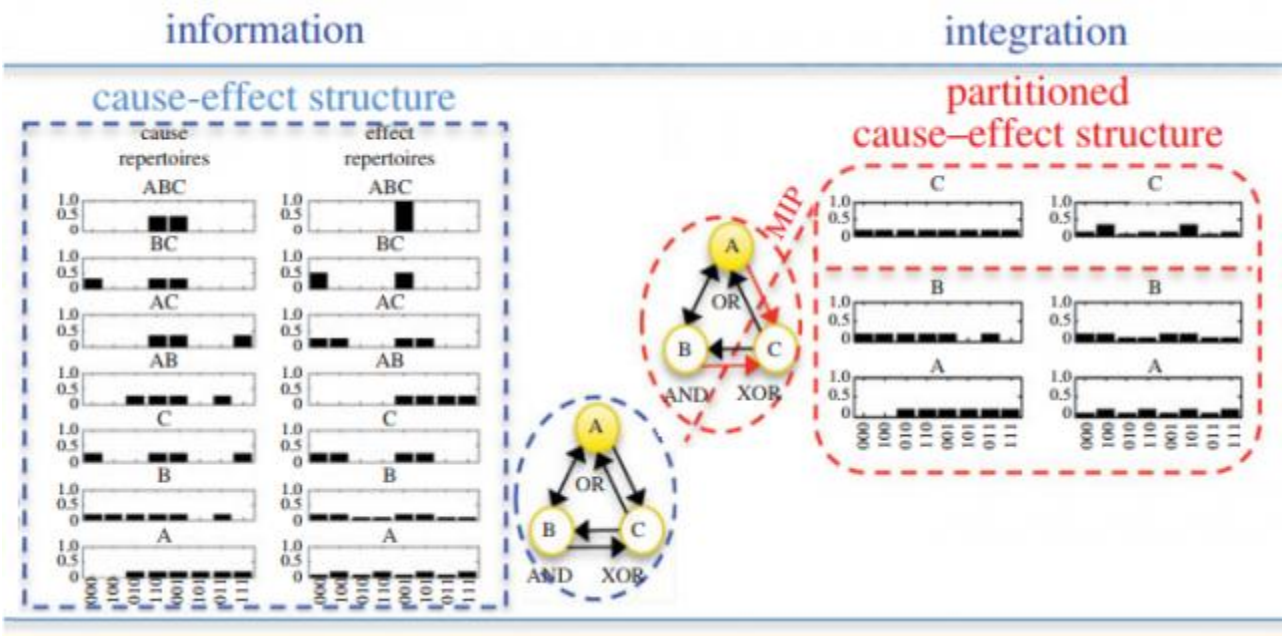

Figure 2. Consciousness is the result of integrated information, i.e., the unified cause–effect repertoires which ire intrinsically irreducible into MIPs (minimum information partitions). | Credit: Tononi & Koch (2005).

The axiom of information is the third one, stating that each conscious experience is different from other possible experiences. The corresponding postulate claims that a specific composition of concepts differs from other possible ones. Here, the concept of information in IIT is not exactly the same as Shannon's one, which is measured by entropy (the expected amount of information contained in a message). Tononi uses a neuroscientific language, defining information associated with experiences (*qualia*), such as color and shape, which cannot be experienced separately. This kind of information can be integrated, i.e., experienced in a unified experience (in Tononi's words). This notion of information differs from the one used in common language. It refers to how a system of mechanisms in a given state rises to a form (*informs*) in the space of all possibilities (*qualia space*).

Apparently, IIT proposes two layers for the flow of information in a conscious system. The lower layer is the usual flow of Shannon's information among its components. The upper layer is the causal relation among the components connected together in groups associated to the same experience (this kind of information also flows in space and time, but in an independent way to the other one). In my opinion, the rhetorical language used by Tononi to express his ideas is difficult to understand for a physicist or a mathematician like myself. As I understand it, in ITT there are two types of information, the one that can be integrated and the other that cannot be integrated. Consciousness is associated only with the information that can be integrated, although in communication theory, computer science, and artificial intelligence only the non-integrated information is currently used.

The fourth axiom, integration, states that consciousness is unified, i.e., that each experience is irreducible to non interdependent components. For example, seeing a red triangle is irreducible to seeing a gray triangle plus the disembodied color red. The postulate of integration claims that the conceptual structure specified by the system is irreducible to that specified by non interdependent subsystems. The concept of integrated information is defined as the information which characterizes such conceptual structure.

The fourth postulate recalls to me the idea of ontology [4] as used in the semantic web [5]. An ontology asks what kinds of things exist or can exist in a closed world, and what manner of relations can those things have to each other. From the practical point of view an ontology is a set of nouns (things) connected by some verbs (actions). Using this language the concept of integrated information corresponds to the causal relations between the elements of the system which results in the phenomena. Tononi introduces the so-called qualia space (Q), which characterizes the quality of the experiences. The integrated information is associated to the causal relations among the elementary mechanisms connected together to form a shape within the Q space, being the shape itself the description of the qualia that is experienced [2].

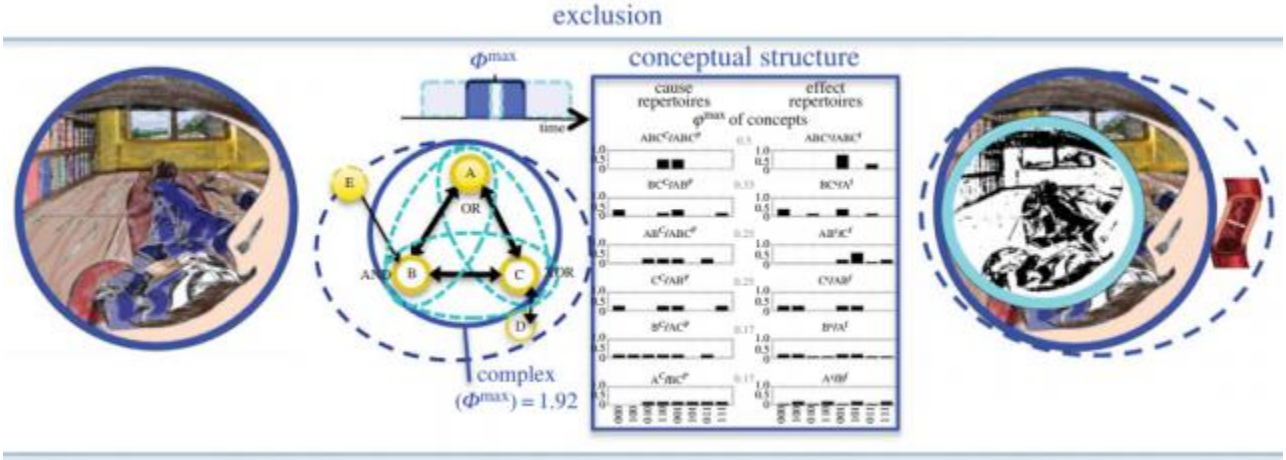

Figure 4. Consciousness flows at a given speed with a definite cause–effect structure that is maximally irreducible intrinsically (Φmax), the so-called conceptual structure. | Credit: Tononi & Koch (2005).

The last axiom, exclusion, says that consciousness is singular, not being the result of the superposition of multiple experiences. The postulate of exclusion states that there can be no superposition of conceptual structures over elements, even in spatiotemporal terms. Tononi introduces the concept of irreducibility in order to define the so-called *complex*, the maximally irreducible conceptual structure of the system. Consciousness flows in space and time at a given speed, neither faster nor slower. As illustrated in Fig. 4, the experience I am having is of seeing a body on a bed in a bedroom, a bookcase with books, one of which is a blue book, but I am not having an experience with less content, say, one lacking the phenomenal distinction blue/not blue,

or colored/not colored; nor am I having an experience with more content, say, one endowed with the additional phenomenal distinction high/low blood pressure.

Tononi claims that his five axioms and postulates allow the quantification of the amount of consciousness of a human subject in a laboratory experiment; in fact, he has applied IIT to patients. The current mathematical formulation of IIT uses the concepts of relative entropy and effective information [3]. However, the association of integrated information to qualitative properties of phenomenological experiences observed in neuroscientific experiments is greatly subject to the interpretation of the researcher.

In my opinion, the formulation of the axioms and postulates in IIT is vague, with more literature (in some cases near to poetry) than usual technical literature. But Tononi's claim that there are experimental predictions made by ITT confirmed using neuroimaging. For example, the loss and recovery of consciousness should be associated with the breakdown and recovery of the brain's capacity for information integration. Tononi claims the confirmation of this prediction by means of using transcranial magnetic stimulation (TMS) in combination with high density EEG in conditions characterized by loss of consciousness (like deep sleep, general anesthesia obtained with several different agents, and brain damaged patients, vegetative, minimally conscious, emerging from minimal consciousness, locked in). For me, this is a clear example of the confirmation bias, Tononi has a tendency to interpret the results in a way that confirms his own hypotheses.

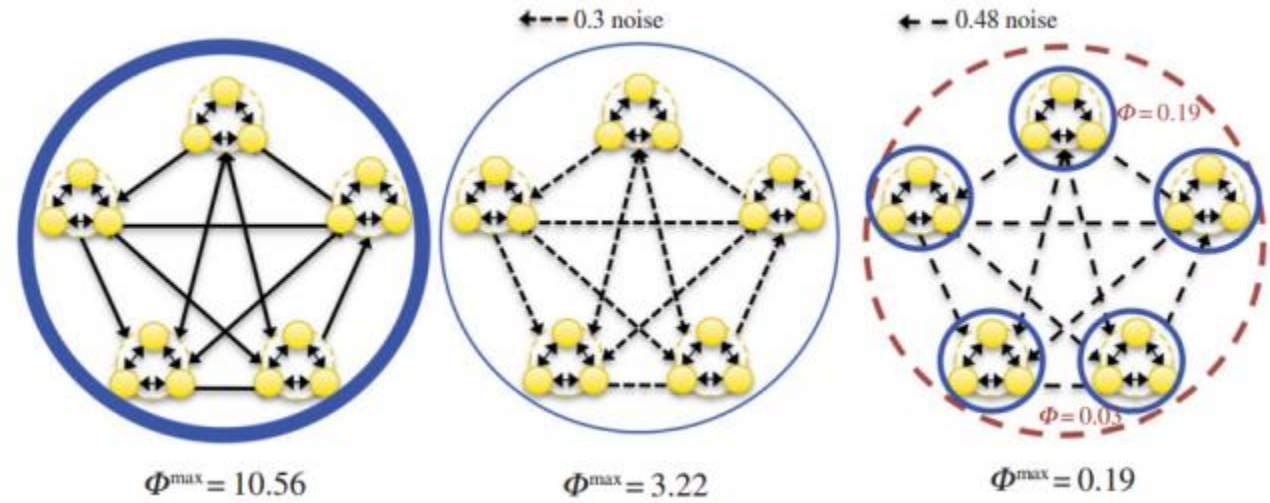

Figure 4. Three examples of maximally integrated information showing that IIT implies that consciousness is graded. | Credit: Tononi & Koch (2015).

There are several counterintuitive predictions of IIT. For example, neurons in the cerebral cortex only contribute to consciousness if they are active in such a way that they *broadcast* the information they represent. If some neurons were pharmacologically inactivated, they would cease to contribute to consciousness, even though their actual state is the same. They would lack a cause effect repertoire and thus would not be able

to affect the states of the complex. Tononi interprets some experiments using optogenetics as a clear confirmation of these ideas.

IIT offers an explanation for why is consciousness generated by the cerebral cortex (or at least some parts of it), but not by the cerebellum. The cerebral cortex, responsible for the content of consciousness, is that it is comprised of elements that are functionally specialized and at the same time can interact rapidly and effectively. Instead, the cerebellum is composed of small sheet like modules that process inputs and produce outputs largely independent of each other. Neural aggregates have no consciousness.

In fact, complicated neural systems can be unconscious. According to IIT, a feed forward artificial neural network whose output depends only on the input imposed from outside the system only can carry out tasks unconsciously. Even if they were able to replicate the input/output behavior of the human brain in such a way to behave indistinguishable from a human, being capable of passing any Turing test. Tononi and Koch [3] claim that there cannot be an ultimate Turing Test for consciousness. Simulations of conscious neural systems can be unconscious.

Tononi and Koch [3] vindicate that consciousness is common among biological organisms (at least in mammals), but digital computers, even if they were to run faithful simulations of the human brain, would experience next to nothing (in authors' wording). In IIT a big enough ANN will spontaneously develop a behavior similar to a cerebellum. It can pass Turing tests, but this is not enough. Only a properly designed ANN to simulate the conscious states of the cerebral cortex can act as a *complex*, i.e., like the artificial brain of the humanoid robot named Ava in *Ex Machina*.

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Biorobotics

Biorobotics is an interdisciplinary science that combines the fields of biomedical engineering, cybernetics, and robotics to develop new technologies that integrate biology with mechanical systems to develop more efficient communication, alter genetic information, and create machines that imitate biological systems.[1]

Cybernetics

Cybernetics focuses on the communication and system of living organisms and machines that can be applied and combined with multiple fields of study such as biology, mathematics, computer science, engineering, and much more.

This discipline falls under the branch of biorobotics because of its combined field of study between biological bodies and mechanical systems. Studying these two systems allow for advanced analysis on the functions and processes of each system as well as the interactions between them.

History

Cybernetic theory is a concept that has existed for centuries, dating back to the era of Plato where he applied the term to refer to the "governance of people". The term *cybernetique* is seen in the mid-1800s used by physicist André-Marie Ampère.[2] The term *cybernetics* was popularized in the late 1940s to refer to a discipline that touched on, but was separate, from established disciplines, such as electrical engineering, mathematics, and biology.[2]

Science

Cybernetics is often misunderstood because of the breadth of disciplines it covers. In the early 20th century, it was coined as an interdisciplinary field of study that combines biology, science, network theory, and engineering. Today, it covers all scientific fields with system related processes. The goal of cybernetics is to analyze systems and processes of any system or systems in an attempt to make them more efficient and effective.[2]

Application

Cybernetics is used as an umbrella term so applications extend to all systems related scientific fields such as biology, mathematics, computer science, engineering, management, psychology, sociology, art, and more. Cybernetics is used amongst several fields to discover principles of systems, adaptation of organisms, information analysis and much more.[3]

Genetic engineering

Genetic engineering is a field that uses advances in technology to modify biological organisms. Through different methods, scientists are able to alter the genetic material of

microorganisms, plants and animals to provide them with desirable traits. For example, making plants grow bigger, better, and faster.[4] Genetic engineering is included in biorobotics because it uses new technologies to alter biology and change an organism's DNA for their and society's benefit.[5][6]

History

Although humans have modified genetic material of animals and plants through artificial selection for millennia (such as the genetic mutations that developed teosinte into corn and wolves into dogs), *genetic engineering* refers to the deliberate alteration or insertion of specific genes to an organism's DNA. The first successful case of genetic engineering occurred in 1973 when Herbert Boyer and Stanley Cohen were able to transfer a gene with antibiotic resistance to a bacterium.[7][8][9]

Science

There are three main techniques used in genetic engineering: The plasmid method, the vector method and the biolistic method.

Plasmid method

This technique is used mainly for microorganisms such as bacteria. Through this method, DNA molecules called plasmids are extracted from bacteria and placed in a lab where restriction enzymes break them down. As the enzymes break the molecules down, some develop a rough edge that resembles that of a staircase which is considered 'sticky' and capable of reconnecting. These 'sticky' molecules are inserted into another bacteria where they will connect to the DNA rings with the altered genetic material.[10]

Vector method

The vector method is considered a more precise technique than the plasmid method as it involves the transfer of a specific gene instead of a whole sequence. In the vector method, a specific gene from a DNA strand is isolated through restriction enzymes in a laboratory and is inserted into a vector. Once the vector accepts the genetic code, it is inserted into the host cell where the DNA will be transferred.[10]

Biolistic method

The biolistic method is typically used to alter the genetic material of plants. This method embeds the desired DNA with a metallic particle such as gold or tungsten in a high speed gun. The particle is then bombarded into the plant. Due to the high velocities and the vacuum generated during bombardment, the particle is able to penetrate the cell wall and inserts the new DNA into the cell.[11]

Applications

Genetic engineering has many uses in the fields of medicine, research and agriculture. In the medical field, genetically modified bacteria are used to produce drugs such as insulin, human growth hormones and vaccines. In research, scientists genetically

modify organisms to observe physical and behavioral changes to understand the function of specific genes. In agriculture, genetic engineering is extremely important as it is used by farmers to grow crops that are resistant to herbicides and to insects such as BTCorn.[12][13]

Bionics

See also: Bionics

Bionics is a medical engineering field and a branch of biorobotics consisting of electrical and mechanical systems that imitate biological systems, such as prosthetics and hearing aids. It's a portmanteau that combines biology and electronics.

History

The history of bionics goes as far back in time as ancient Egypt. A prosthetic toe made out of wood and leather was found on the foot of a mummy. The time period of the mummy corpse was estimated to be from around the fifteenth century B.C.[*citation needed*] Bionics can also be witnessed in ancient Greece and Rome. Prosthetic legs and arms were made for amputee soldiers. In the early 16th century, a French military surgeon by the name of Ambroise Pare became a pioneer in the field of bionics. He was known for making various types of upper and lower prosthetics. One of his most famous prosthetics, Le Petit Lorrain, was a mechanical hand operated by catches and springs. During the early 19th century, Alessandro Volta further progressed bionics. He set the foundation for the creation of hearing aids with his experiments. He found that electrical stimulation could restore hearing by inserting an electrical implant to the saccular nerve of a patient's ear. In 1945, the National Academy of Sciences created the Artificial Limb Program, which focused on improving prosthetics since there were a large number of World War II amputee soldiers. Since this creation, prosthetic materials, computer design methods, and surgical procedures have improved, creating modern-day bionics.[14]

Science

Prosthetics

Further information: Prosthesis

The important components that make up modern-day prosthetics are the pylon, the socket, and the suspension system. The pylon is the internal frame of the prosthetic that is made up of metal rods or carbon-fiber composites. The socket is the part of the prosthetic that connects the prosthetic to the person's missing limb. The socket consists of a soft liner that makes the fit comfortable, but also snug enough to stay on the limb. The suspension system is important in keeping the prosthetic on the limb. The suspension system is usually a harness system made up of straps, belts or sleeves that are used to keep the limb attached.

The operation of a prosthetic could be designed in various ways. The prosthetic could be body-powered, externally-powered, or myoelectrically powered. Body-powered prosthetics consist of cables attached to a strap or harness, which is placed on the

person's functional shoulder, allowing the person to manipulate and control the prosthetic as he or she deems fit. Externally-powered prosthetics consist of motors to power the prosthetic and buttons and switches to control the prosthetic. Myoelectrically powered prosthetics are new, advanced forms of prosthetics where electrodes are placed on the muscles above the limb. The electrodes will detect the muscle contractions and send electrical signals to the prosthetic to move the prosthetic. The downside to this type of prosthetic is that if the sensors are not placed correctly on the limb then the electrical impulses will fail to move the prosthetic.[15] TrueLimb is a specific brand of prosthetics that uses myoelectrical sensors which enable a person to have control of their bionic limb.[15]

Hearing aids

Further information: Hearing aid

Four major components make up the **hearing aid**: the microphone, the amplifier, the receiver, and the battery. The microphone takes in outside sound, turns that sound to electrical signals, and sends those signals to the amplifier. The amplifier increases the sound and sends that sound to the receiver. The receiver changes the electrical signal back into sound and sends the sound into the ear. Hair cells in the ear will sense the vibrations from the sound, convert the vibrations into nerve signals, and send it to the brain so the sounds can become coherent to the person. The battery simply powers the hearing aid.[16]

Applications

Cochlear Implant

Further information: Cochlear implant

Cochlear implants are a type of hearing aid for those who are deaf. Cochlear implants send electrical signals straight to the auditory nerve, the nerve responsible for sound signals, instead of just sending the signals to the ear canal like conventional hearing aids.

Bone-Anchored Hearing Aids

These hearing aids are also used for people with severe hearing loss. They attach to the bones of the middle ear to create sound vibrations in the skull and send those vibrations to the cochlea.

Artificial sensing skin

See also: Artificial skin

Artificial sensing-skin detects any pressure put on it and is meant for people who have lost any sense of feeling on parts of their bodies, such as diabetics with peripheral neuropathy.

Bionic eye

Further information: Visual prosthesis

A **bionic eye** is a bioelectronic implant designed to restore vision for individuals with blindness.

Although the technology is still in development, it has enabled some legally blind individuals to distinguish letters again. [17]

Replicating the retina, which contains millions of photoreceptors, and matching the human eye's exceptional lensing and dynamic range capabilities pose significant challenges. Neural integration further complicates the process. Despite these difficulties, ongoing research and prototyping have led to several major achievements in recent years.[17]

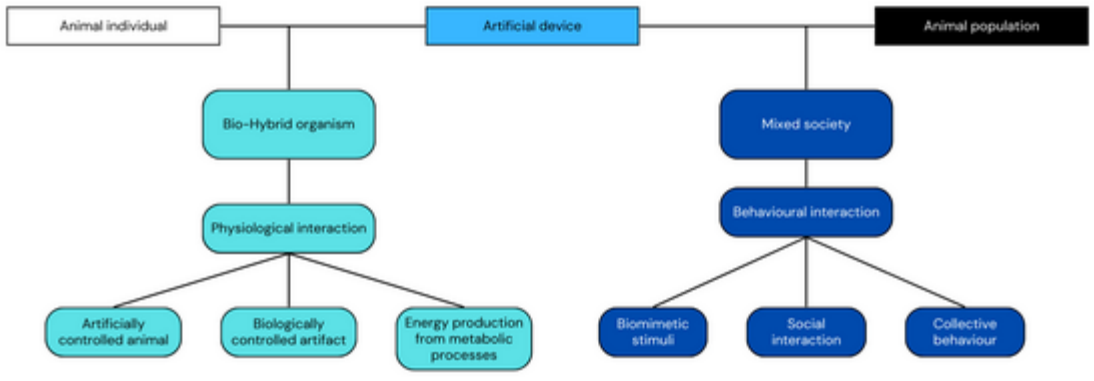
Orthopedic bionics

Orthopedic bionics consist of advanced bionic limbs that use a person's neuromuscular system to control the bionic limb. A new advancement in the comprehension of brain function has led to the development and implementation of brain-machine interfaces (BMIs).[18] BMIs allow for the processing of neural messaging between motor regions of the brain to muscles of a specific limb to initiate movement.[18] BMIs contribute greatly to the restoration of a person's independent movement who has a bionic limb and or an exoskeleton.[18]

Endoscopic robotics

These robotics can remove a polyp during a colonoscopy.

Animal-robot interactions



Block representation of the animal-robot interactions research field

Animal-robot interactions is a field of Biorobotics that focuses on the blending of robotic compounds with animal individuals or populations.[19] The domain can be subdivided into two main branches, one that relates mechatronic devices with individual animals, and another one with animal populations. Both branches have a variety of applications, ranging from animal cyborgs benefiting from animals' superior motor capabilities[20] to ethological studies around animal collective behaviour.[21][22][23] While this representation draws a globally accurate view of the domain, some animal-robot interactions cannot be strictly classified into one or the other of these branches, or are sometimes a mixture of both. This is the case namely for ethological robots that interact on a one-to-one basis[22][24] or when eusocial animals are considered as a single superorganism interacting with a single robotic device. In the latter case, the term Bio-Hybrid superorganism is used to describe the blending of a robotic device with a superorganism to enable interaction, control and thus studying of the latter superorganism.[25][26][27]

Bio-Hybrid organisms

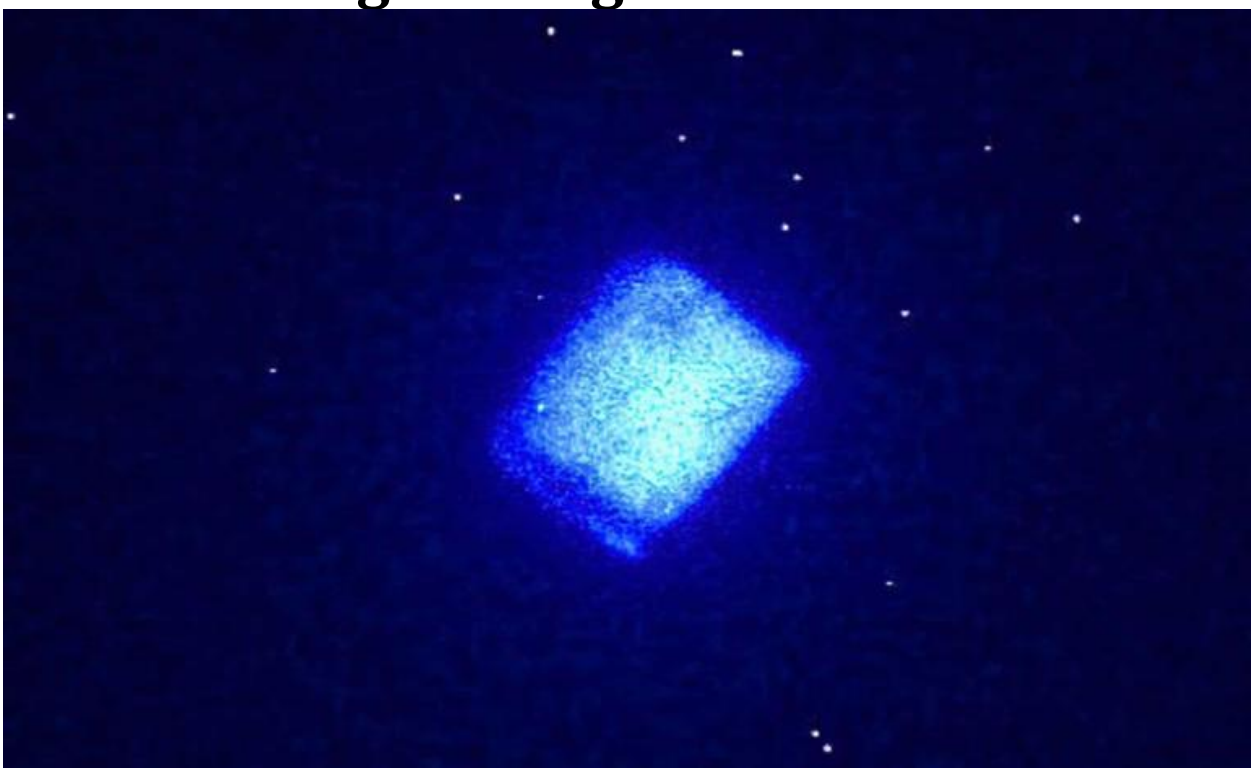
Mixed societies

Mixed societies blend together a set of animals (animal society) with a set of robotic devices (artificial society). Care should be take when using the word society, as the noun could be misleading within the zoologist community that is involved in this domain; a more accurate word would be populations,[19] which is also the one used for the rest of this section.

Typically, the robotic population is composed of robotic replica of the target animal individuals aimed to integrate within the animal population. To do this, stimuli naturally perceived by the animals are emitted by the robotic individuals, and this through different communication channels: visual cues, thermal pulses, vibration signals, etc. The degree to which the robotic individuals successfully blend with the animal population is related to as bio-acceptance, and is often key to enable further behavioural study of the target species.[28]

Once interactions between the animal and robot population is achieved by establishing relevant communication channels, mixed societies offer the potential for adaptive robotic behaviours driven by real-time feedback from the animal population. By responding directly to animal behaviour, the robots can dynamically adjust their actions to better integrate into the group. This capability is particularly valuable for understanding collective behaviours in animal populations. Adaptive robots can be used to implement models of specific roles or interactions within a group, enabling the testing of hypotheses about coordination, decision-making, or social organisation. This approach bridges experimental and modelling techniques, in an attempt to offer insights into the underlying mechanisms of collective behaviour.[29]

UK Scientists Unveil The First Carbon-14 Battery That Lasts 5,700 Years Without Ever Needing a Charge



UK Scientists Unveil The First Carbon-14 Battery That Lasts 5,700 Years Without Ever Needing a Charge | The Daily Galaxy --Great Discoveries Channel© Daily Galaxy UK

Imagine a world where batteries never need recharging, where medical implants, satellites, and even spacecraft can run for thousands of years without a single power failure. This isn't science fiction—it's the promise of the **carbon-14 diamond battery**, a revolutionary energy source developed by researchers at the **University of Bristol** and the **UK Atomic Energy Authority (UKAEA)**. With a lifespan of up to **5,700 years**, this new technology could redefine the way we think about power, sustainability, and even nuclear waste.

The Power of Radioactive Decay

At the heart of this battery is **carbon-14**, an isotope better known for its role in **radiocarbon dating**. But rather than being used to measure the past, it is now being harnessed to power the future.

The battery works by capturing the energy released during the **radioactive decay of carbon-14** and converting it into electricity. This process is entirely **self-sustaining**, requiring no external input or charging. **Encased in diamond**, one of the hardest materials on Earth, the radiation is safely contained while the energy is steadily extracted.

Think of it like a **nuclear-powered version of a solar cell**, except instead of harnessing sunlight, it captures the fast-moving electrons emitted during radioactive decay. **The result?** A battery with an almost unimaginable lifespan. Even after **5,700 years**, it would still retain half of its original charge.

Turning Nuclear Waste Into Clean Energy

One of the most exciting aspects of this battery is that it **helps solve two problems at once**—energy storage and nuclear waste disposal. The **carbon-14** used in these batteries is extracted from **graphite blocks**, a byproduct of nuclear reactors that would otherwise be discarded as radioactive waste.

By repurposing this material into a **long-lasting power source**, the carbon-14 battery not only reduces **nuclear waste** but also provides a **clean and reliable** energy solution.

Moreover, the **diamond casing** ensures that no harmful radiation escapes, making it completely **safe for use in everyday applications**. And when it does eventually need to be replaced (in thousands of years), it can be safely **recycled**.

Potential Applications: From Pacemakers to Deep Space Missions

The possibilities for this technology are **game-changing**. Because it generates continuous power at a **microwatt level**, the carbon-14 battery is ideal for

applications where replacing or recharging a battery is either difficult or impossible.

・**Medical implants**: Pacemakers, hearing aids, and other life-saving devices could function **for decades or even centuries** without needing a battery replacement. This would eliminate the risks and costs associated with repeated surgeries.

・**Aerospace and satellites**: Unlike **solar panels**, which require constant exposure to sunlight, these batteries could keep satellites and spacecraft running **indefinitely**—even in the darkest reaches of space.

・**Remote and extreme environments**: Devices in deep-sea exploration, Arctic research stations, and remote military operations could run **without interruption for centuries**.

Professor **Tom Scott** from the **University of Bristol**, one of the leading researchers on the project, believes this battery has **limitless potential**:

"We're excited to explore these possibilities with our partners in the industry and research sectors."

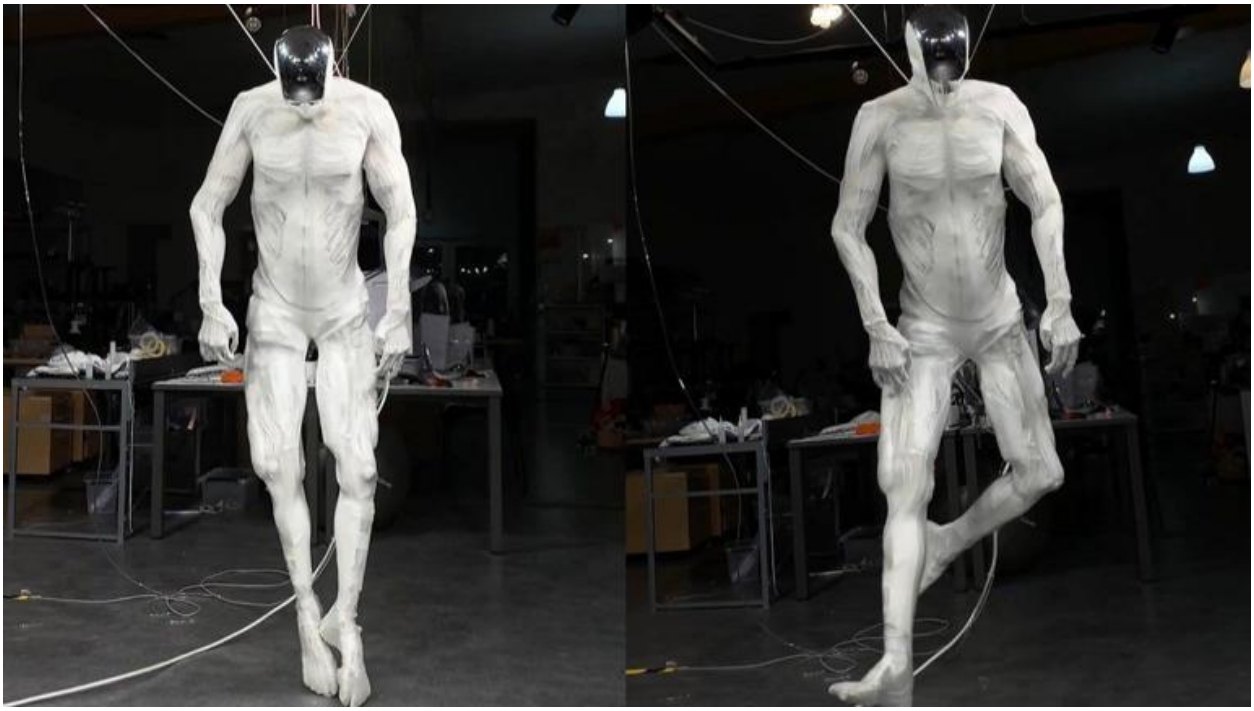
A Glimpse Into the Future of Sustainable Energy

The **carbon-14 diamond battery** is still in its early stages, but it represents a **monumental shift** in how we think about **energy storage and sustainability**.

With its ultra-long lifespan, minimal environmental impact, and ability to **repurpose nuclear waste**, it stands as a **compelling alternative** to traditional batteries. And while today's rechargeable batteries last only a few years before needing replacement, this technology offers power that could last for **generations—or even millennia**.

POWER IMMORTAL ANDROIDS?

Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video



The Protoclone robot.© Clone Robotics/X

A robotics company has built an eerily lifelike humanoid robot which they claim is the "world's first bipedal musculoskeletal android" — and the internet hates it.

Created by Polish startup Clone Robotics, the "Protoclone" robot is a faceless android with an anatomically accurate bone structure and musculature. The android's designers claim it can walk, talk and be tasked with completing menial household chores.

In a video posted on X, which quickly went viral (with over 34 million views as of Jan 21.) the robot is shown twitching to life as it's suspended from the ceiling, its limbs jerking and spasming as artificial muscles attached to specific bone points come online, enabling the skeleton to move.

"The Protoclone is a faceless, anatomically accurate synthetic human with over 200 degrees of freedom, over 1,000 Myofibers [artificial muscle fibers], and 500 sensors," Clone Robotics wrote beneath the video.

Yet while the company appears ebullient about its technological achievements, social media reactions have ranged from disdain to outright hostility.

"This is my sleep paralysis demon," one commenter wrote. "WestWorld was nonfiction," someone else added. "Can you just draw a smiley face on the head, please?'" requested another.

Protoclone, the world's first bipedal, musculoskeletal android. pic.twitter.com/oIV1yaMSyEFebruary 19, 2025

Rise of the robots

According to Clone Robotics' webpage, the android operates with human-like muscular, skeletal, vascular and nervous systems. It has 206 bones, the same number as adult humans, made from polymers connected by artificial muscle fibers, which it flexes using a pneumatic system (although the company says the final product will run using a hydraulics). To navigate its environment, the robot uses a system of sensors linked to four cameras.

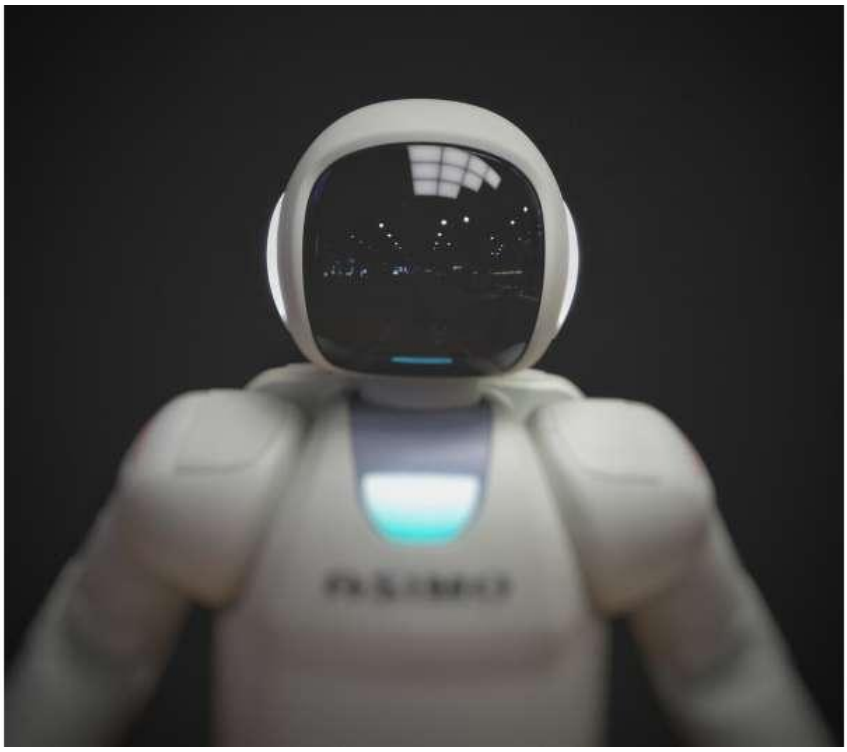
The robot is the latest in Clone Robotics' range of biomimetic products, which also include a robotic hand and a humanoid torso. The company says that the android will be available for preorder later this year. No price is currently listed.

Protoclone is far from the only humanoid robot capturing the attention of businesses and the public. The California startup Figure tested its humanoid robots in a BMW factory in 2024, and has plans for introducing more this year. Apptronik, a Texas-based competitor, is also commercializing its humanoid robot, Apollo, for use in Mercedes-Benz factories by the end of the year. Meanwhile, Agility Robotics' Digit robot is also planned to be introduced into warehouses this year.

FEBRUARY 27, 2025

A robot nearly headbutted a festival spectator in China. Here are four urgent steps to make the tech safer

by Carl Strathearn, Emilia Sobolewska, The Conversation



Credit: Unsplash/CC0 Public Domain

Humanoid robots are supposed to be our loyal assistants, but we saw another side to them the other day. Chinese robot manufacturer Unitree was demonstrating its latest H1 robots at a lantern festival in the city of Taishan, Guangdong province, when one walked up to the crowd barrier and seemed to lunge at an elderly woman, nearly headbutting her.

The incident quickly went viral, and sparked a fierce debate about whether the robot actually attacked the woman or had tripped up. It's mostly being overlooked that we're a long way from having robots that could intentionally attack someone—machines like these are often remote controlled—but the danger to the public is clearly real enough.

With sales of humanoid robots set to skyrocket over the next decade, the public will increasingly be at risk from these kinds of incidents. In our view as robotics researchers, governments have put very little thought into the risks.

Here are some urgent steps that they should take to make humanoid robots as safe as possible.

1. Increase owner requirements

The first important issue is to what extent humanoid robots will be controlled by users. Whereas Tesla's Optimus can be remotely operated by people in a control center, others such as the Unitree H1s are controlled by the user with a handheld joystick.

Currently on sale for around £90,000, they come with a software development kit on which you can develop your own artificial intelligence (AI) system, though only to a limited extent. For example, it could say a sentence or recognize a face but not take your kids to school.

Who is to blame if someone gets hurt or even killed by a human-controlled robot? It's hard to know for sure—any discussion about liability would first involve proving whether the harm was caused by human error or a mechanical malfunction.

This came up in a Florida case where a widower sued medical robot-maker Intuitive Surgical Inc over his wife's death in 2022. Her death was linked to injuries she sustained from a heat burn in her intestine during an operation that was caused by a fault in one of the company's machines.

The case was dropped in 2024 after being partially dismissed by a district judge. But the fact that the widower sued the manufacturer rather than the medics demonstrated that the robotics industry needs a legal framework for preventing such situations as much as the public do.

While for drones there are aviation laws and other restrictions to govern their use in public areas, there are no specific laws for walking robots.

So far, the only place to have put forward governance guidelines is China's Shanghai province. Published in summer 2024, these include stipulating that robots must not threaten human security, and that manufacturers must train users on how to use these machines ethically.

For robots controlled by owners, in the UK there is currently nothing preventing someone from taking a robot dog out for a stroll in a busy park, or a humanoid robot to the pub for a pint.

As a starting point, we could ban people from controlling robots under the influence of alcohol or drugs, or when they are otherwise distracted such as using their phones. Their use could also be restricted in risky environments such as confined spaces with lots of members of the public, places with fire or chemical hazards, and the roofs of buildings.

2. Improve design

Robots that looks sleek and can dance and flip are fun to watch, but how safe are the audiences? Safe designs would consider everything from reducing cavities where fingers could get caught, to waterproofing internal components.

Protective barriers or exoskeletons could further reduce unintended contact, while cushioning mechanisms could reduce the effect of an impact.

Robots should be designed to signal their intent through lights, sounds and gestures. For example, they should arguably make a noise when entering a room so as not to surprise anyone.

Even drones can alert their user if they lose signal or battery and need to return to home, and such mechanisms should also be built into walking robots. There are no legal requirements for any such features at present.

It's not that manufacturers are entirely ignoring these issues for walking robots. Unitree's quadruped Go2, for instance, blinks and beeps when the battery is low or if it is overheating.

It also has automatic emergency cut-offs in these situations, although they must be triggered by a remote operator when the robot is in "telemetric mode." Crucially, however, there are no clear regulations to ensure that all manufacturers meet a certain safety standard.

3. Train operators

Clearly there will be dangers with robots using AI features, but remote-operated models could be even more dangerous. Mistakes could result from users' lack of real-world training and experience in real-life situations.

There appears to be a major skills gap in operator training, and robotics companies will need to prioritize this to ensure operators can control machines efficiently and safely.

In addition, humans can have delayed reaction times and limited concentration, so we also need systems that can monitor the attention of robot operators and alert them to prevent accidents. This would be similar to the HGV-driver distraction-detection systems that were installed in vehicles in London in 2024.

4. Educate the public

The incident in China has highlighted current misconceptions about humanoid robots as the media is once again blaming AI despite the fact that this was not the issue. This risks causing widespread mistrust and confusion among the public.

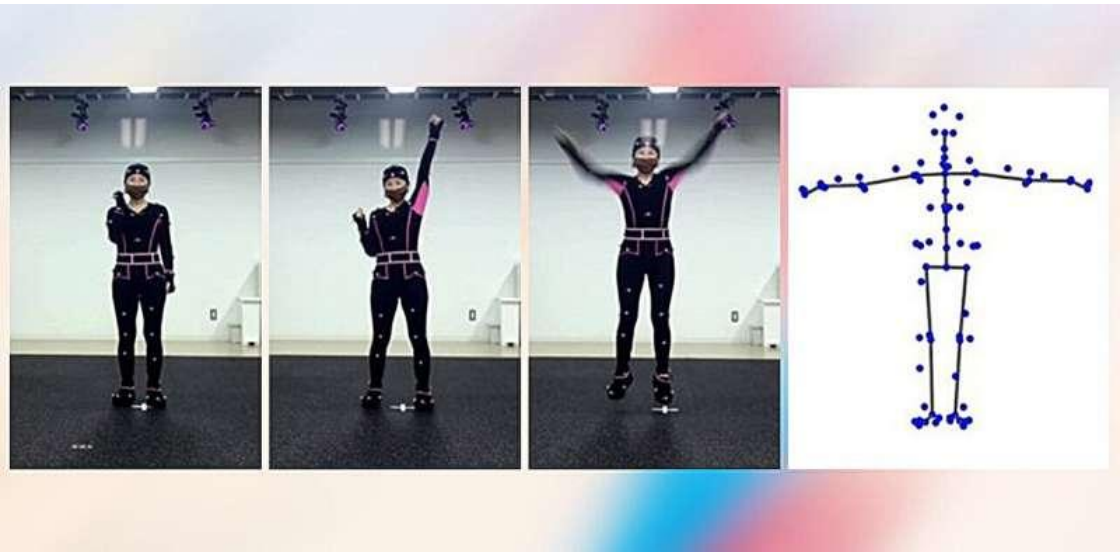
If people understand to what extent walking robots are owner-operated or remote-operated, it will change their expectations about what the robot might do, and make everyone safer as a result.

Also, understanding the owner's level of control is vital for managing buyers' expectations and forewarning them about how much they'll need to learn about operating and programming a robot before they buy one.

FEBRUARY 28, 2025

Japanese motion capture lab builds body movement database to explore cultural nuances in emotional expression

by Tohoku University



Credit: *Behavior Research Methods* (2024). DOI: 10.3758/s13428-024-02558-2

Facial expressions are not the only way we express our emotions—body language also plays a crucial role. The way our body moves when laughing at a comedy show is different from how we move when reuniting with an old friend. Although both are expressions of happiness, finding common patterns across different situations is difficult. These patterns become particularly challenging to define when we consider cross-cultural differences as well.

Researchers from the Research Institute of Electrical Communication at Tohoku University (Japan) in collaboration with National Chung Cheng University (Taiwan), tackled these challenges by collecting body movements from different situations, emotions, and personal styles in a motion capture lab.

The findings were published in *Behavior Research Methods* on December 10, 2024.

Unlike previous databases that focused on simple and repetitive actions (e.g., walking sadly, walking happily, walking angrily), and were primarily based on Western populations, this new database aims to capture a wide range of emotional bodily expressions across various scenarios, with a focus on Japanese people born and raised in Japan.

To build this database, six professional performers were asked to recall their personal emotional experiences (e.g., situations that make them happy, angry, sad, surprised, fearful, disgusted or contemptuous) and act them out using full-body movement. Their performances were recorded using high-speed motion capture technology, in which the 3D information of movements was captured as a video. The recordings were later transformed into simple stick figure-like animations.

Example of an experiment trial, where participants had to guess which emotion was being expressed based off of the animation. The simplified figure has no facial expressions, so the correct emotion (in this case, anger) must be determined from body language alone. Credit: Cheng et al.
Another approach is imitation learning, in which a robot learns by imitating motion measurement data from a human performing the same motion task. Although imitation learning is good at learning in stable environments, it struggles when faced with new situations or environments it hasn't encountered during training. Its ability to modify and navigate effectively becomes constrained by the narrow scope of its learned behaviors.

"We overcame many of the limitations of these two approaches by combining them," explains Mitsuhiro Hayashibe, a professor at Tohoku University's Graduate School of Engineering. "Imitation learning was used to train a CPG-like controller, and, instead of applying deep learning to the CPG [central pattern generator] itself, we applied it to a form of a reflex neural network that supported the CPGs."

Study participants watched these animations and judged the perceived emotion expressed. The results showed that they could recognize the emotions solely from body movements, and the accuracy was as good as past simple action databases. Among the emotions studied, anger and fear were the easiest to recognize, while contempt and disgust were the hardest.

"This is a crucial first step in developing a diverse, Asian-based bodily movement database to support research on emotional communication," remarks Dr. Miao Cheng, an Assistant Professor at Tohoku University.

"We are extremely fortunate to have the support of a local musical company based in Sendai, SCS musical company, to fully support this endeavor from the moment performers were recruited and throughout their performances. Without the professional help provided by Mr. Jun Hirose and Mr. Kazumasa Fujita from SCS musical company, it would have been very difficult to properly bridge art and science in this study," said Dr. Chia-huei Tseng, an Associate Professor at Tohoku University.

Future research can use this database to offer new insights into cultural variations in nonverbal communication. This will be helpful in developing technology communication tools to facilitate cross-cultural communication and understanding. This resource is expected to benefit researchers and benefit industries utilizing motion capture techniques such as gaming, film, animation, and virtual reality.

More information: Miao Cheng et al, Toward an Asian-based bodily movement database for emotional communication, *Behavior Research Methods* (2024). DOI: 10.3758/s13428-024-02558-2
Provided by Tohoku University

Figure speeds up humanoid robot home trials after powerful brain breakthrough

Helix enables two robots to collaborate on complex tasks, expanding robotics' scope in dynamic environments.

Updated: Feb 28, 2025

Figure plans to start testing its humanoid robots in homes much sooner than expected.

The California-based startup's CEO, Brett Adcock, revealed that it will begin alpha testing its Figure 02 robot in residential settings in late 2025.

This faster timeline is due to its advanced Vision-Language-Action (VLA) model, Helix, which enhances the robot's adaptability and functionality.

"Our AI, Helix, is advancing faster than any of us anticipated, accelerating our timeline into the home. Therefore, we've moved-up our home timeline by 2 years; starting Alpha testing this year," said Adcock, in a post on X.

Last week, Figure unveiled Helix, a model that integrates perception, language comprehension, and learning control. According to the firm, Helix aims to solve several persistent challenges in robotics, marking a major advancement in AI.

Advanced humanoid control

Helix is a VLA model introducing a new approach to upper-body manipulation control in humanoid robots.

Announced shortly after its separation from OpenAI in early February, Helix enables high-rate continuous control of the entire upper body, including wrists, torso, head, and individual fingers.

The robot's overall functioning is improved by this sophisticated control system, which enables more intricate interactions and precise movements.

One of Helix's most remarkable features is its capacity to work with many robots. It can work on two robots simultaneously, enabling them to cooperate on shared, long-term tasks requiring odd things. The operating breadth of robotics in dynamic and complicated contexts is greatly increased by this capability.

By using natural language prompts, Helix also improves usability by enabling robots to pick up a variety of small home objects, including ones they have never seen before. Because of their adaptability, the robots are more useful and versatile in domestic environments.

A unique aspect of Helix is its use of a single set of neural network weights to learn diverse behaviors, such as picking and placing objects, using drawers and refrigerators, and enabling cross-robot interactions. This makes learning easier by doing away with the requirement for task-specific fine-tuning.

Helix is made for real-world applications and runs solely on embedded low-power GPUs, guaranteeing both economic viability and energy efficiency. It is appropriate for deployment in commonplace settings because to its pragmatic approach, which represents a breakthrough in humanoid robotics.

Industrial robot breakthrough

Figure demonstrated robots doing domestic chores like food preparation at the Felix launch. Despite Helix's ability to perform coordinated operations with two robots, Figure has given industrial applications precedence over domestic use. The business is using the controlled atmosphere of factories to conduct safer trials of its humanoid systems at a BMW plant in South Carolina.

In February, Figure AI secured its second major partner, paving the way to ship 100,000 humanoid robots in four years.

With the new AI model, Figure hopes to address the problem of current robots' lack of adaptability, which necessitates a lot of programming to perform new tasks. It performs activities using natural language commands and generalizes actions using Vision Language Models (VLMs).

Two systems make up the model: System 1 (S1) translates this data into real-time robot actions, while System 2 (S2) is a slower, pre-trained VLM that manages language processing and scene understanding. With S1 for quick execution and S2 for sophisticated thought, this division guarantees peak performance.

Helix employs an 80M-parameter transformer for control and a 7B-parameter VLM, having been trained on 500 hours of teleoperated behaviors. Without task-specific programming, it allows for collaborative manipulation with a lengthy time horizon. Helix is notable for its high object generalization; with natural language instructions, it can handle thousands of unseen home objects.

According to Figure, the development will greatly improve the functionality of humanoid

Robot Startup Figure Reveals an AI Breakthrough Called Helix

The company also released a video showing two humanoid robots putting away groceries. It's worth watching.

BY BEN SHERRY, STAFF REPORTER @BENLUCASSHERRY

FEB 20, 2025

Figure, a Silicon Valley-based startup that builds humanoid robots, has announced Helix, a proprietary AI model that the company says enables robots to more easily pick up objects, collaborate on tasks with other robots, and smoothly control their entire upper bodies. The launch comes weeks after

Figure publicly ended a deal to collaborate on AI models with OpenAI, and after the company raised $1.5 billion.

In a blog post, Figure wrote that Helix's launch marks a major step in bringing humanoid robots into "everyday home environments." Unlike previous versions of its models, Figure says that Helix doesn't need to be fine-tuned or trained on hundreds of demonstrations in order to perform specific tasks. Instead, a new design allows the robots to interact with objects that they've never encountered before. The company says that Figure robots equipped with Helix "can pick up virtually any small household object."

In a video example of Helix's capabilities, a man asks two Figure-made robots, both equipped with the Helix AI model, to put away a bag of groceries. After looking around, the robots slowly opened up a nearby fridge, put most of the food away, and placed an apple in a serving bowl.

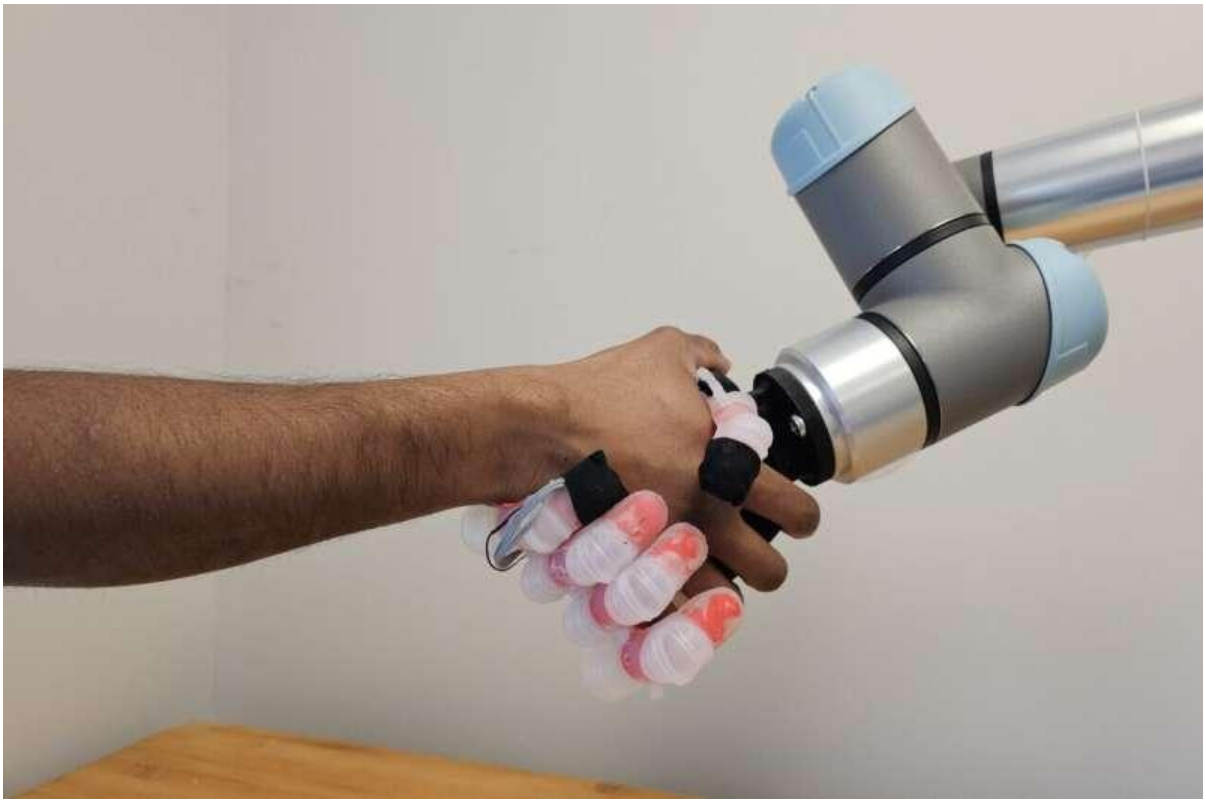
Up until recently, Figure had been in a partnership with OpenAI in which the two firms collaborated to customize OpenAI's models so they could be used by Figure's robots. But on February 4, Figure founder Brett Adcock announced on X that he had decided to pull his company out of the agreement. He said that Figure had "made a major breakthrough on fully end-to-end robot AI, built entirely in-house," a clear nod to Helix's imminent reveal. Adcock said that the company has been working on Helix for over a year.

It's been a busy month for Figure. On February 14, Bloomberg reported that the company was discussing a new funding round with firms Align Venture and Parkway Venture Capital that would raise $1.5 billion at a $39.5 billion valuation. Bloomberg said that much of investors' enthusiasm comes from a recent breakthrough that has sped up Figure's timeline for penetrating the home market with its robots, implying that investors got an early look at Helix.

Figure isn't the only company trying to make humanoid robots happen. Just last week, Reuters reported that Meta is establishing a new division that will create AI-powered humanoid robots, and humanoid robotics startup Apptronik raised $350 million, with one of its investors and partners being Google DeepMind. Also in the race is Tesla, with its "Optimus" robots, and rumors are swirling that Apple could enter the fray as well.

Feeling is believing: Bionic hand 'knows' what it's touching, grasps like a human

by Roberto Molar Candanosa, Johns Hopkins University



The new hybrid robotic hand blends soft and rigid parts with touch-sensitive technology, allowing for precise and flexible object handling. Credit: Sriramana Sankar / Johns Hopkins University

Johns Hopkins University engineers have developed a pioneering prosthetic hand that can grip plush toys, water bottles, and other everyday objects like a human, carefully conforming and adjusting its grasp to avoid damaging or mishandling whatever it holds.

The system's hybrid design is a first for robotic hands, which have typically been too rigid or too soft to replicate a human's touch when handling objects of varying textures and materials. The innovation offers a promising solution for people with hand loss and could improve how robotic arms interact with their environment.

Details about the device appear in *Science Advances*.

"The goal from the beginning has been to create a prosthetic hand that we model based on the human hand's physical and sensing capabilities—a more natural prosthetic that functions and feels like a lost limb," said Sriramana Sankar, a Johns Hopkins biomedical engineer who led the work. "We want to give people with upper-limb loss the ability to safely

and freely interact with their environment, to feel and hold their loved ones without concern of hurting them."

Forearm muscle signals control the new hybrid robot hand, effortlessly gripping and adjusting to different objects. Credit: Sriramana Sankar / Johns Hopkins University
The device, developed by the same Neuroengineering and Biomedical Instrumentations Lab that in 2018 created the world's first electronic "skin" with a humanlike sense of pain, features a multi-finger system with rubberlike polymers and a rigid 3D-printed internal skeleton. Its three layers of tactile sensors, inspired by the layers of human skin, allow it to grasp and distinguish objects of various shapes and surface textures, rather than just detect touch.

Each of its soft, air-filled finger joints can be controlled by the forearm's muscles, and machine-learning algorithms focus the signals from the artificial touch receptors to create a realistic sense of touch, Sankar said, explaining, "The sensory information from its fingers is translated into the language of nerves to provide naturalistic sensory feedback through electrical nerve stimulation."

In the lab, the hand identified and manipulated 15 everyday objects, including delicate stuffed toys, dish sponges, and cardboard boxes, as well as pineapples, metal water bottles, and other sturdier items. In the experiments, the device achieved the best performance compared with the alternatives, successfully handling objects with 99.69% accuracy and adjusting its grip as needed to prevent mishaps. The best example was when it nimbly picked up a thin, fragile plastic cup filled with water, using only three fingers without denting it.

"We're combining the strengths of both rigid and soft robotics to mimic the human hand," Sankar said. "The human hand isn't completely rigid or purely soft—it's a hybrid system, with bones, soft joints, and tissue working together. That's what we want our prosthetic hand to achieve. This is new territory for robotics and prosthetics, which haven't fully embraced this hybrid technology before. It's being able to give a firm handshake or pick up a soft object without fear of crushing it."

To help amputees regain the ability to feel objects while grasping, prostheses will need three key components: sensors to detect the environment, a system to translate that data into nerve-like signals, and a way to stimulate nerves so the person can feel the sensation, said Nitish Thakor, a Johns Hopkins biomedical engineering professor who directed the work.

The bioinspired technology allows the hand to function this way, using muscle signals from the forearm, like most hand prostheses. These signals bridge the brain and nerves, allowing the hand to flex, release, or react based on its sense of touch. The result is a robotic hand that intuitively "knows" what it's touching, much like the nervous system does, Thakor said.

"If you're holding a cup of coffee, how do you know you're about to drop it? Your palm and fingertips send signals to your brain that the cup is slipping," Thakor said. "Our system is neurally inspired—it models the hand's touch receptors to produce nervelike messages so

the prosthetics' 'brain,' or its computer, understands if something is hot or cold, soft or hard, or slipping from the grip."

While the research is an early breakthrough for hybrid robotic technology that could transform both prosthetics and robotics, more work is needed to refine the system, Thakor said. Future improvements could include stronger grip forces, additional sensors, and industrial-grade materials.

"This hybrid dexterity isn't just essential for next-generation prostheses," Thakor said. "It's what the robotic hands of the future need, because they won't just be handling large, heavy objects. They'll need to work with delicate materials such as glass, fabric, or soft toys. That's why a hybrid robot, designed like the human hand, is so valuable—it combines soft and rigid structures, just like our skin, tissue, and bones."

Other authors include Wen-Yu Cheng of Florida Atlantic University; Jinghua Zhang, Ariel Slepyan, Mark M. Iskarous, Rebecca J. Greene, Rene DeBrabander, and Junjun Chen of Johns Hopkins; and Arnav Gupta of the University of Illinois Chicago.

More information: Sriramana Sankar et al, A natural biomimetic prosthetic hand with neuromorphic tactile sensing for precise and compliant grasping, *Science Advances* (2025). DOI: 10.1126/sciadv.adr9300
Journal information: Science Advances
Provided by Johns Hopkins University

Watch Unitree G1 humanoid robot kick baton mid-spin in 720° turn, master combat moves

G1 trains in Nvidia’s Isaac Simulator, mastering skills through reinforcement learning before seamlessly transferring them to the real world.

Updated: Mar 05, 2025

Unitree has continued upgrading the G1's algorithm, enabling it to learn and perform virtually any movement.

Chinese robotics firm Unitree has released yet another video displaying the agility and balance of its compact humanoid robot G1.

A 15-second clip shows a human with a baton retreating as a robot swiftly kicks it from his hand, all the while executing a 720-degree turn in the process.

Just a week ago, Unitree Robotics showcased G1's attempt to master kung-fu moves. Now, the new clip shows it facing off against a human—and winning.

Unitree is continuously upgrading G1's algorithm, allowing it to learn and execute various movements. The latest update enhances its balance and expands its range of motion.

In February, a video showed G1 displaying agility and balance with smooth dances and precise footwork, even when interrupted. In January, Unitree demonstrated G1's walking and running system, highlighting its agility, stability, and precise control on inclines and uneven terrain.

Agile robot advances

In its latest video, Unitree's G1 humanoid showcases impressive balance while performing kung-fu movements. A new algorithm upgrade enhances its ability to learn and execute intricate tasks with agility.

With 23 degrees of freedom (DoF) and improved stability, G1 demonstrates remarkable coordination and flexibility. Despite its martial arts display, the video ends with a caution against modifying the robot in ways that could pose risks or teaching it actual combat techniques.

Designed for challenging, repetitive tasks in homes, factories, and hospitals, G1 aligns with Unitree's vision of humanoid robots as practical work and life companions.

Standing at just 4.33 feet tall (1.32 meters) and weighing 77 lbs (35 kg), the G1 folds compactly to 27 x 17.7 x 11.8 inches for easy storage. It features advanced technologies, including 3D LiDAR, a RealSense depth camera, and a noise-canceling microphone array for voice command response.

G1 runs on a 9,000-mAh quick-release battery, offering two hours of operation with fast swaps for extended use. It features an 8-core high-performance CPU and powered joints in its arms, legs, and torso, enabling 23 DoF. The design allows for agile movement and walking speeds of up to 2 m/s (4.5 mph).

Training begins in a virtual environment using Nvidia's Isaac Simulator, where the robot learns complex behaviors before being physically built.

Through reinforcement learning, G1 refines these skills in simulation. The Sim2Real process then seamlessly transfers these learned actions to the physical robot, enabling real-world applications.

Robot motion upgraded

Unitree Robotics has also released an open-source full-body dataset to enhance the natural movement of its humanoid robots, including the H1, H1-2, and G1 models. This dataset improves flexibility and coordination, enabling more human-like motions such as dancing.

Captured with LAFAN1 motion capture technology, the dataset is fully compatible with Unitree's main robots, demonstrating lifelike movement in a newly released video. It includes a redirection algorithm that integrates interactive mesh and inverse kinematics, optimizing motion by considering posture constraints, joint positions, and velocity limits.

By making this dataset publicly available, Unitree aims to encourage researchers and enthusiasts to explore new applications for humanoid robots in various real-world scenarios. The high-performance H1 and H1-2 models are built for advanced capabilities, with the H1 holding the Guinness World Record for sprinting at 7.38 mph (3.3 m/s) as of March 2024. Meanwhile, the G1 offers a more compact and affordable option for research and development.

Unitree's open-source initiative seeks to drive innovation, expanding possibilities for dynamic, human-like interactions and advancing humanoid robotics.

China released an open source kung-fu robot and we're not really sure why

The G1 robot isn't just agile — it's learning kung fu

March 5, 2025

We have a new entry on the ever-growing "Robots and algorithms doing things no one asked them to do" list. Introducing the G1 robot, a humanoid machine

with impressive balance, smooth agility, and — unexpectedly — kung fu skills. Yes, it can punch. Yes, it can pull off a roundhouse kick. And yes, that begs the question: why?

Every robot was kung fu fighting

G1 first appeared on the global stage at China's Spring Festival Gala, one of the most-watched TV events in the world. Its debut, however, was a little awkward, showcasing a humanoid figure that seemed more of a novelty than a serious technological breakthrough.

That changed quickly. In January, Unitree, the company behind G1, demonstrated the robot effortlessly jogging across uneven terrain. Now, it's showing off complex martial arts moves, proving how much humanoid robots are advancing in terms of coordination, stability, and movement precision.

The G1 exhibits remarkable coordination and flexibility with 23 degrees of freedom (DoF). Image credits: Unitree. Priced at 99,000 yuan (US$13,622), the robot is equipped with 43 joints and mimicry learning. It's capable of learning complex movements and demonstrates precise maneuverability. The G1 comes with a price tag of 99,000 yuan (US$13,622) and is equipped with 43 joints and advanced mimicry learning capabilities. This allows it to perform highly dynamic actions with remarkable precision. But what's even more fascinating is *how* it learns.

Learning before existing

Before G1 ever takes a physical step, its training begins in a virtual world. Unitree leverages NVIDIA's Isaac AI-driven robotics platform, where the robot first learns the fundamentals of movement.

From there, G1 is shown a digital twin — another humanoid robot performing actions. Using motion capture and video data, it observes and gradually refines its skills, mirroring the process humans use when learning by imitation. Over time, the robot's movements become more complex, fluid, and customizable.


3D LIDAR
LIVOX-MID360
Depth Camera
Intel RealSense D435i
Combined shoulder motors
Realization of 3D spatial degrees of freedom
Unitree
Single Arm Degrees of Freedom
4(expandable)
Mobility
Travel speed >1.5m/s
Potential mobility >5m/s
Hollow electrical routing
No external cables
Core Motion Module
Maximum torque at joints 360 N.m
Single leg degrees of freedom
Hip x 3 + Knee x 1 + Ankle x 1 = 5

promotional image showing some features of the G1 robot. Image credits: Unitree.

This blend of simulation-based training and real-world refinement is a major step forward in robotics, making humanoid machines significantly more adaptable.

Beyond its acrobatics, one of the most remarkable aspects of the G1 is that it's open source.

Open-source robots

Much like DeepSeek made headlines not just for its affordability but for its open-source accessibility, Unitree has made its training data, algorithms, and hardware specifications publicly available on GitHub. This means developers, researchers, and robotics enthusiasts can explore, tweak, and enhance G1's capabilities in ways even its creators might not anticipate. The dataset includes interactive mesh and inverse kinematics algorithms, allowing G1 to monitor joint positions, limitations, and motion efficiency. In short, it can learn and optimize movements autonomously, whether it's performing a kung fu routine or something more practical.

Despite the flashy martial arts demo, Unitree insists that G1 is built for practical applications — not combat. The company envisions its humanoid robot assisting in workplaces, homes, and even hospitals, handling repetitive and complex tasks.

However, because the robot is open source, its potential extends far beyond Unitree's vision. Researchers, engineers, and AI developers now have a powerful humanoid platform they can customize for various real-world applications — from rehabilitation and elder care to industrial automation and education.

Despite its impressive capabilities, G1 raises a bigger question — are we ready to accept robots like this in our daily lives? For now, G1 is an impressive display of engineering, a symbol of how far robotics has come. But whether we embrace robots as co-workers, assistants, or even companions remains an open question — one that society will have to answer in the years to come.

I KNOW KUNG FU
FEB 28, 2025

We're Apparently Living in an Anime, Because This Robot Has Learned Kung Fu

"Please keep a safe distance from the robot."

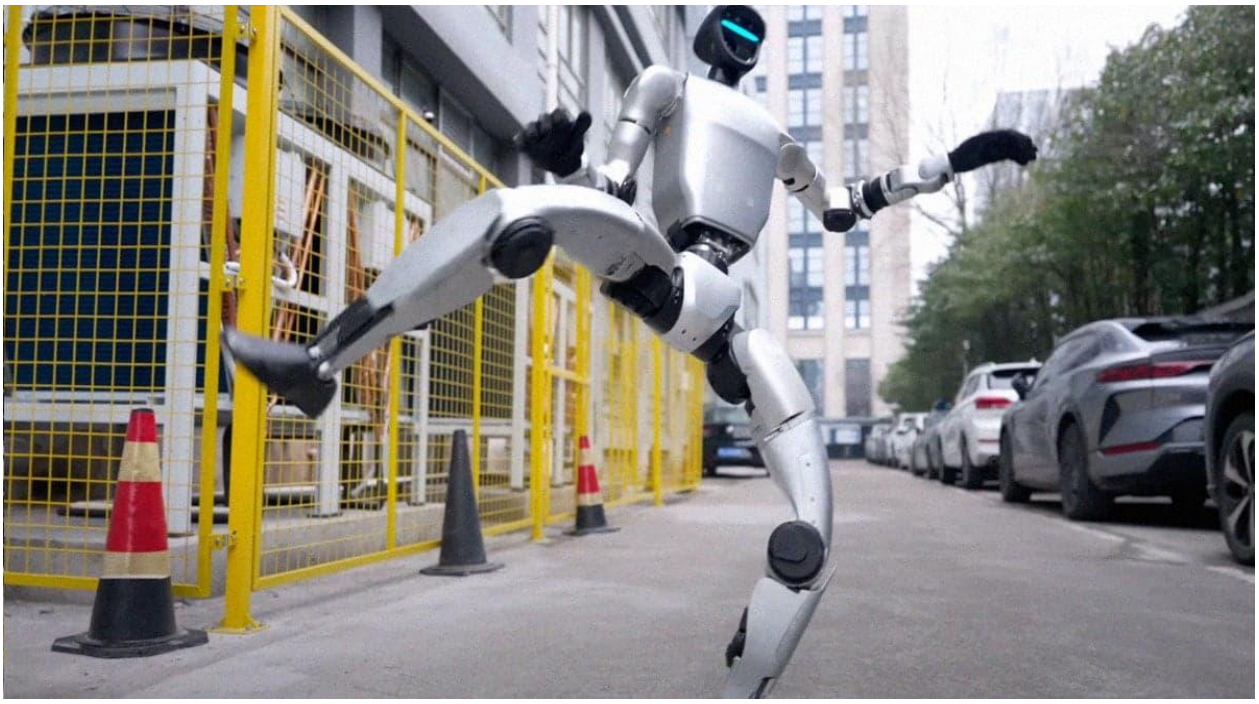


Image by Unitree

Chinese robotics company Unitree has shown off its G1 humanoid robot pulling some gnarly kung fu moves.

In a video released this week, the child-sized robot can be seen punching the air and even deliver a swooping roundhouse kick.

"We have continued to upgrade the Unitree G1's algorithm, enabling it to learn and perform virtually any movement," the company wrote in the video's caption. "What other moves would you like to see. Do share with us in the comments."

"Please keep a safe distance from the robot," the company advised.

The stunt highlights how far consumer-facing humanoid robotics have come. Unlike its growing number of Western counterparts, including Tesla's Optimus and Figure's 01, Unitree's G1 is already being sold to consumers. Pricing starts at just $16,000, according to the company's website.

The robot features anywhere from 23 to 43 joint motors, depending on the configuration, allowing it to walk, hop — and evidently dabble in martial arts as well.

A previous video shared by the company shows G1 busting out some dance moves, while — we are not kidding — a human engineer tries to knock it off its feet with what appears to be a padded broom stick. A separate video released last month shows it running down a street and briskly walking over an uneven, rocky surface.

YouTuber Sohail Khan recently took the robot for a spin after unpacking it from a large check-in luggage-sized hardcase. He even nudges it to demonstrate the robot's ability to right itself, and shows it lying flat on its back before instructing it to clamber back onto its feet.

Apart from bipedal robots, Unitree has also shown off two quadrupedal robot dogs called B2 and Go2. The latter can be bought for less than $2,000, a massive discount over Boston Dynamics' Spot Mini, which can cost as much as $75,000.

But when or if these robots will ever be able to defeat a human martial artist or boxer remains to be seen. Considering how easy it is to tip over a Unitree G1 — Khan had more than one hair-raising incident while testing the robot's self-balancing limits — us humans will likely have plenty of time until we'd have to worry about getting knocked out in hand-to-robot-hand combat.

Unitree's Hangzhou-Based G1 Robot, Bruce, Demonstrates Kung Fu Skills

Updated Feb 25, 2025

Unitree Robotics, based in Hangzhou, China, has released a video showcasing its G1 humanoid robot, named Bruce Robot, performing Kung Fu moves. The company has upgraded the robot's algorithm, enabling it to learn and execute virtually any movement, including martial arts techniques such as punches and roundhouse kicks.

The G1 robot, also known as the MMA Bot, weighs about 35kg and stands 1.3m tall, using 3D LiDAR and depth camera for perception. This advancement in the robot's capabilities highlights the ongoing development in Unitree's technology, allowing the robot to adapt to various environments and perform complex actions.

Unitree's focus on enhancing the G1's algorithm through imitation and reinforcement learning underscores the company's commitment to pushing the boundaries of what humanoid robots can achieve. The video demonstration of the G1 performing Kung Fu has garnered attention, showcasing the robot's agility and versatility.

SEE BOT RUN

CHINA IS HOSTING THE WORLD'S FIRST FOOT RACE BETWEEN HUMANS AND ROBOTS

THIS IS GOING TO BE ONE TO WATCH. Track Stars

In the race to build the best humanoid robots, China is quite literally ahead of the pack. As the *South China Morning Post* reports, the Beijing Economic-Technological Development Area — or E-Town — is hosting 12,000 humans and humanoid robots from more than 20 companies in a half-marathon race this April.

The race will be roughly 13 miles, and robotic competitors both cannot have wheels and must stand between 1.5 and 6.5 feet tall. In a statement, E-Town added that "competing robots must have a humanoid appearance and mechanical structure capable of bipedal walking or running movements."

Though this seems to be the world's first race explicitly pitting bipedal humans against robots, it won't be the first time a humanoid robot has taken part in a Chinese atheletic competition.Last fall, a bipedal robot called Tiangong — not to be confused with China's

space station of the same name, which translates to "heavenly palace" — jumped into Beijing's Yizhaung half-marathon towards its end. Though it only ran about 100 meters and wasn't particularly fast, the robot got a medal because it crossed the finish line (a participation trophy if we've ever heard of one).Just a few week after Tiangong's surprise marathon debut, the the RAIBO2 robodog competed in a full marathon weeks later in South Korea. Though the adorable quadruped was significantly faster than Tiangong, it still took nearly four hours and 20 minutes to run the 26.2 mile race — nearly double the time of the human winner, who clocked in at around two hours and 36 minutes.

Because it's neither Chinese nor bidepal, RAIBO2 will unfortunately not be involved in the E-Town half-marathon. According to the state-run *Xinhua* news agency, however, Tiangong will be one of the participants and will purportedly be capable of running 10 kilometers (6.2 miles) per hour by the time the race rolls around.

That same agency also reported that later this year, in August, Beijing will be hosting an all-robot sporting event that not only features track and field races, but also football — unclear on whether the outlet is using the American or European definition — and "comprehensive skills and other application scenarios."

Though we can't known how fast these running robots will be until we actually watch them, we can't wait to watch.

China’s humanoid robots to function as decision makers with new intelligence platform

China’s humanoid robots to function as decision makers with new intelligence platform

The developer of the first full-size electric running robot, Tien Kung (Tiangong), has unveiled a new intelligence platform designed to enhance robotic autonomy.

The “Hui Si Kai Wu” system, launched by the National and Local Co-built Embodied AI Robotics Innovation Center in Beijing, aims to enable robots to handle complex tasks through autonomous decision-making.

At the press conference on Wednesday, humanoid robot Tiangong demonstrated its enhanced movement capabilities, highlighting the platform’s potential to advance embodied AI, reports a Chinese online news outlet.

In November 2024, the Center made Tiangong humanoid an open source, promoting further development and integration.

Smarter robot systems

The “Hui Si Kai Wu” platform is a universal software system designed to enhance robotic intelligence and adaptability.

The technology allows robots to perform numerous activities in a variety of locations, including commercial, residential, and industrial settings, in contrast to traditional robots designed for single tasks. According to Global Times (GT), it gives robots full-process intelligence, which enables them to understand tasks, plan their execution, and dynamically adjust to obstacles.

In a live demonstration, a humanoid robot used spatial dimension analysis, assembly step planning, and real-time adjustment to finish a block-building assignment successfully. In a different scenario, the robot demonstrated accurate and fluid movements while effectively sorting tableware, collecting rubbish, and disposing of it appropriately. In order to guarantee task completion, it could self-correct and re-plan its actions if difficulties emerge.

The platform also showcased its capabilities in industrial sorting and logistics packaging. Through voice commands, app controls, and direct connections, users can communicate with robots, guaranteeing excellent task execution precision. According to GT, the platform combines vision, decision-making, language comprehension, learning, and motion control, functioning as a central intelligence system.

In addition to improving robotic capabilities, the platform lowers obstacles for developers by streamlining robot creation using a low-code methodology. The company claimed that by providing a comprehensive software framework, it accelerates innovation in robotics, allowing for broader application and seamless task execution across diverse scenarios.

Advanced robot mobility

The Beijing Humanoid Robot Innovation Center is advancing embodied robotics by enabling secondary development and exploring areas such as body mechanics and embodied intelligence through its foundational platform, Tiangong.

After extensive testing and validation, Tiangong has been made open-source, allowing enterprises and research institutions to access and develop it further. The goal of this project is to speed up development cycles and lower research expenses. Two humanoid robot models are included in the platform; both have fully electric actuators that allow for head, arm, and leg movement.

Tiangong, which weighs 43 kg (94.7 pounds) and stands 163 cm tall, is made to be stable even when running and runs solely on electricity. In addition to having several sensors for visual perception, including high-precision six-axis force sensors for accurate force feedback, it has a processing speed of 550 trillion operations per second. A cutting-edge learning method known as State Memory-based Predictive Reinforcement Imitation Learning improves its motion capabilities by enabling realistic running motion.

To enhance motion control, the robot also has a suite of visual perception sensors, 3D vision sensors, and a high-precision inertial measurement unit (IMU). In a public demonstration, Tiangong showed off its agility and adaptability in dynamic surroundings by navigating stairs and slopes without visual signals and fast rebounding from falls by changing its gait.

Tiagkong established a world record last month when he ascended 134 outdoor steps to the top of Beijing's Haizi Wall Park. Significant progress in robotic mobility was demonstrated by the achievement of traversing such a challenging outdoor terrain.

Humanoid robot with human-like competence of riding a bicycle and reading medicine instruction unveiled in Shanghai

By Du Qiongfang Published: Mar 11, 2025

Humanoid robot Lingxi X2 Photo: Courtesy of AgiBot

Humanoid robot manufacturer AgiBot in Shanghai unveiled on Tuesday its latest humanoid robot model which achieves nearly human-like mobility such as riding a bicycle and balancing on a hoverboard. With its prompt responding competence in interaction with users, the robot showcases the perfect integration of artificial intelligence (AI) and humanoid robot technology, presenting a great application potential in scenarios such as elderly care services and family companionship.

In a video released by Peng Zhihui, co-founder of AgiBot or Zhiyuan Robotics, the 1.3-meter tall and 33.8-kilogram Lingxi X2 humanoid robot showcases its excellent sports, interaction and operation

competence.

It not only can walk, run, turn around and dance like a real human being, but can also ride a bicycle, a scooter and a hoverboard, with its movement flexibility far outperforming other similar humanoid robots through combining deep reinforcement learning and imitation learning techniques and algorithms.

According to Peng, the robot was designed with a system integrated with great innovation and was made with impact-resistant flexible materials.

When Peng picks up a mobile phone and shows it to the robot, asking what time it is, the robot can precisely tell the time. When Peng further asks the robot for advice on which drink to take, milk or juice, at the time of 5:42 am, the robot suggests him to drink milk which helps with sleep.

Besides, the robot can also quickly read and understand medicine description.

As the second model of the Lingxi series, Lingxi X2 is the first truly agile robot with complex interaction capabilities. It can mimic human breathing rhythms, exhibit curiosity and attention mechanisms, and communicate with human beings through subtle body movements and gestures, the Global Times learned from the company on Tuesday.

Based on a multimodal large language model, the robot can achieve millisecond-level interaction responses, assess human's emotional states through their facial expressions and vocal tones, and provide corresponding responses.

According to Peng, the research team is improving the robot's cognitive model and expects to empower it with more emotional expression capabilities in the future.

According to the company, the robot can achieve multi-robot collaborations for certain tasks and extend its applications to various

aspects of daily life, serving as a security guard, a nanny, and a cleaner in sectors such as education and healthcare. Its functions can also be tailored by users according to their respective needs in various scenarios such as elderly care, services and family companionship.

Peng said in the video that Lingxi X2 represents a significant breakthrough in the fields of AI and emotional AI.

Experts noted that this humanoid robot has reached a new level of naturalness and immersion in human-robot interaction. With continuous advancements in technology, it is expected to become an important assistant in human life, bringing more possibilities for future smart life.

New era of humanoid robots

China’s manufacturing edge backs robotic tech innovation: expert

By Tao Mingyang Published: Feb 14, 2025

UBTECH's Walker S1 industrial humanoid robot in operation at Foxconn's Longhua facility in Shenzhen, South China's Guangdong Province, on December 11, 2024. Photo: Courtesy of UBTECH

Entering 2025, a fusion of technology and traditional culture took center stage at the state broadcaster CCTV's Spring Festival Gala - a group 16 humanoid robots named "Fuxi" developed by Chinese startup Unitree Robotics, dressed in folkloric jackets, performed traditional "Yangge" dance with very agile handkerchief movements and precise formations.

From laboratories to factories, from stages to production lines, Chinese-made humanoid robots are making inroads into many sectors including manufacturing and services which are set to take the lead in the global race for technology predominance.

The show sparked public discussion on China's advances in humanoid robotics, which also acted as a symbol of the industry pivoting to mass production.

On the performance stage, Unitree's "Fuxi" robot, also known as Unitree H1, uses AI-driven full-body motion control technology, capable of achieving a maximum joint torque of 360 Newton-meter. Coupled with 360° panoramic depth perception technology, they can precisely grasp every movement in the surroundings.

Growing use scenarios

Currently, a number of Chinese companies are accelerating humanoid robot trials across various industries. Manufacturing giant Foxconn and Shenzhen-based humanoid robot company UBTECH announced on January 15, 2025 that the two companies will form a partnership to incorporate UBTECH's humanoid robots into Foxconn's intelligent manufacturing process.

Prior to partnering with Foxconn, UBTECH's humanoid robots were already deployed by automakers such as BYD, Geely, and FAW-Volkswagen's Qingdao factory, UBTECH told the Global Times.

The trend of many domestic humanoid robots "get jobs" in the

manufacturing sector is increasingly recognized as the inevitable industrial evolution, Wang Xingxing, founder and CEO of Unitree Robotics, told the Global Times. For example, Unitree's humanoid robots have been deployed in the plants owned by China's major electric car maker Nio.

"We are taking a market-driven approach. Once the technology gains traction and shows strong commercial potential, we will scale up production of our robots," Wang said.

Wei Jiaxing, head of the Public Relation at National and Local Co-built Embodied Artificial Intelligence Robotics Innovation Center told the Global Times on Saturday that, performing highly repetitive tasks in manufacturing, or in the elderly care sector, monitoring crucial signs of life and providing vital companionship, as well as serving in patrols and dangerous tasks in special operations, humanoid robots have great potential for application.

"Smart robots are already in real-time use, and we expect to see broader use scenarios at the end of 2025," Wei told the Global Times.

China's Ministry of Industry and Information Technology (MIIT) in November 2023 issued a guideline targeting the innovative development of humanoid robotics, which stated by 2025, the country's innovation system for humanoid robots will be largely fulfilled, with major breakthroughs in a series of key technologies such as "brain, cerebellum, and limbs", and that robot production will reach an internationally advanced level by then.

On January 17, 2025, Shenzhen-based Leju Robotics delivered its 100th full-size humanoid robot to Beijing-based carmaker BAIC Group, marking a significant step toward mass production, the company told the Global Times in a recent interview.

Production capacity

What lies behind Leju's steady delivery is the company's upgraded production capacity. In December 2024, Leju launched a humanoid

robot manufacturing line in Suzhou, East China's Jiangsu Province, with annual capacity estimated at 200 humanoid robots, reported Shanghai Securities News.

On January 6, 2025, humanoid robot manufacturer AgiBot in Shanghai announced that the company's 1,000th mass-produced general-purpose embodied robot officially came off the assembly line. AgiBot set a production goal of 962 robots in 2024, according to a video posted on its social media late last year.

If more technological breakthroughs are made, humanoid robots could see a compound annual growth rate of 94 percent between 2025 and 2035, with the sector reaching a market size of $154 billion by 2035, according to a Goldman Sachs report.

In April 2024, the first China Humanoid Robot Industry Conference was convened in Beijing. An industrial report released during the conference showed that China's humanoid robot market size ranges from 2.76 billion yuan ($377.56 million) in 2024 and will likely reach 75 billion yuan by 2029, which will account for 32.7 percent of the world's total and rank first in the world, and the size of the sector is expected to reach 300 billion yuan by 2035, Xinhua News Agency reported.

To meet a surging demand for humanoid robotics research and development and ramp up mass production of smart robots, National and Local Co-built Embodied Artificial Intelligence Robotics Innovation Center's open-sourced "Tien Kung" humanoid robot is now available for research institutes and enterprises to conduct further technical verification and development in accordance with market needs.

What's more, the innovation center in Beijing also launched RoboMIND, a multi-embodiment intelligence normative data, which is designed to enhance the training of humanoid robots and meeting the needs for efficient and targeted training of embodied robotic intelligence in complex scenarios.

Pan Helin, a member of the Expert Committee for the Information and Communication Economy under the MIIT, noted that mass production of intelligent robots will start once users widely recognize their functions.

Pan noted that, based on China's advantages in manufacturing across almost all industrial sectors, the country's progress in robotics will be shored up incessantly.

China's smart robot industry sees robust growth in 2024

By Xinhua Published: Feb 10, 2025 02:36 PM Updated: Feb 10, 2025

A humanoid robot is on display in Wuhan, central China's Hubei Province, Feb. 5, 2025. (Xinhua/Xiao Yijiu)

By the end of 2024, the number of enterprises in the smart robot industry in China had reached 451,700, with a total registered capital of 6.44 trillion yuan (about 880 billion U.S. dollars), according to the State Administration for Market Regulation.

The number of such enterprises grew by 19.39 percent compared to the end of 2023, demonstrating a steady upward trend in the

industry's development in China.

Nearly 80 percent of these enterprises were concentrated in three sectors, namely scientific research and technical services; information transmission, software and information technology services; and wholesale and retail, the administration said.

The eastern region of the country, with its distinct geographical advantages, robust research and development strength, and well-established industrial ecosystem, has become a hub hosting about two-thirds of smart robot industry enterprises in China.

The number of such enterprises in China's central and northwestern regions account for 15.33 percent and 14.97 percent of the total, respectively.

Robotic exoskeletons aid in mountain climbing, elderly care

By Xinhua Published: Feb 11, 2025

This photo taken in January 2025 shows a staff member testing an exoskeleton robot at Mount Tai in east China's Shandong Province.(Xinhua)

During this year's Spring Festival, Mount Tai in east China's Shandong Province, one of the most iconic mountains in the country, introduced an innovative exoskeleton robot.

The wearable device, designed to assist with climbing, has garnered attention for its ability to make the arduous ascent at Mount Tai more accessible and enjoyable, especially for the elderly and mobility-impaired visitors.

"It really works. Once I put it on, my legs didn't hurt anymore. It felt like someone was pulling me uphill," Li Chengde, a 68-year-old tourist from the provincial capital of Jinan, said after trying on the device.

Developed jointly by the Taishan Cultural Tourism Group (TCTG) and the Shenzhen-based high-tech company of Kenqing Technology, the exoskeleton, weighing just 1.8 kg, wraps around the wearer's waist and thighs. Powered by artificial intelligence, it senses the wearer's pace and movement, providing synchronized assistance to reduce fatigue and joint strain.

Launched on Jan. 29 with 10 units rented for trial operation, the device attracted more than 200 users at 60 yuan (about 8.37 U.S. dollars) to 80 yuan per use in the scenic area during the holiday, which ran until Feb. 4. Half of those who opted to rent the device were elderly people.

Wang Houzhe, deputy Party chief of the TCTG, said the exoskeleton robots were introduced to allow elderly visitors the opportunity to experience the mountain's beauty firsthand.

"Some elderly tourists want to enjoy the scenery along the way, but sitting in a cable car limits their view. With the help of these robots, they can truly experience the joy of climbing," he said.

The introduction of such exoskeleton robots has sparked broader discussions about their potential applications in elderly care, particularly with China facing the challenges of an aging society.

The latest data shows that by the end of 2024, the population aged 60 and above in China was 310 million, accounting for 22 percent of the country's total population. It is predicted that this percentage will further rise to 30 percent by 2035, with the elderly population to exceed 400 million by then.

Eyeing this vast elderly care market, Kenqing Technology, which focuses on R&D, production and sales of exoskeleton robots, has released a lightweight exoskeleton designed for elderly users, integrating advanced sensors and motion control systems to assist with walking, running and climbing, said Yu Yunbo, general manager of the company.

Yu added that the company aims to release a new robot model this year, featuring lighter materials, smarter algorithms and enhanced adaptability to the physical needs of elderly users.

According to estimates, the market size of smart elderly care in China had reached 6.8 trillion yuan in 2024.

Notably, the Chinese government has issued policies encouraging the development of smart elderly care.

A national guideline to advance the silver economy, issued in early 2024, proposed the creation of a new model of intelligent health and elderly care, promotion of the application of intelligent nursing and domestic service robots, and development of the rehabilitation assistive device industry.

Last month, another national guideline on deepening the reform and development of elderly care services proposed acceleration of the development and application of elderly care technology and information technology.

Bi Yalei, secretary-general of the Shenzhen Robotics Association, said that policy-supported market cultivation is necessary to promote the large-scale application of elderly-care robots and make their prices more affordable -- an assessment Yu agrees with.

"The large-scale application of these technologies will drive down costs, making them more affordable for families," Yu noted.

This image shows an exoskeleton robot designed to assist with climbing. (Xinhua)

Hangzhou-developed spherical patrol robot ventures into overseas markets

By Du Qiongfang Published: Feb 26, 2025

An amphibious spherical robot patrols the streets with police officers in Lucheng district, Wenzhou, East China's Zhejiang Province. Photo: Courtesy of Lucheng District Public Security Bureau

Following the Unitree humanoid robots which wowed audiences worldwide with their Yangge folk dance at the Spring Festival Gala for the Year of the Snake, a futuristic Hangzhou-made spherical robot with multitask capacity and good adaptability to harsh environments has recently shot to fame and ventured overseas.

Developed by Rotunbot Co in Hangzhou, East China's Zhejiang Province, the RT-G spherical robot has gained attention for its outstanding performance in patrolling, detection and rescue after a video of it patrolling with a squad of special police officers in Wenzhou, Zhejiang in December went viral.

Wang You, founder of Rotunbot Co and an associate professor from the College of Control Science and Engineering, Zhejiang University,

referred to the spherical robot as an "agile roly-poly," since the robot's motor-powered internal pendulum oscillates around the sphere's core in a full-range motion, enabling it to roll in any specified direction while maintaining good balance.

According to Wang, many foreign clients, for example some companies from the United Arab Emirates in the Middle East region, have gotten in touch with the company to express interest in purchasing the robot. It is expected that the number of overseas clients will see exponential growth in 2025.

Some companies have bought one or two sample robots for testing, and purchasing contracts with these clients are under discussion, while procedures are underway for other related detection and transportation and export certifications, Wang told the Global Times on Wednesday.

According to Wang, the combat-capable, 160-kilogram robot designed for close-quarters engagements, including anti-terrorist operations, is capable of reaching 35 kilometers per hour in a swift 2.5 seconds and can be mounted with police equipment. It can not only adapt to harsh environments and complex terrains, but also excellently perform various tasks under hazardous conditions such as in corrosive, radioactive, flammable or potentially explosive environments.

According to Wang, overseas clients can possibly also apply the robot in scenarios such as public security and national defense. They have proposed requirements to adapt it to deserts and high temperatures, such as 60 C or above, which poses new challenges for Wang's research and development team.

Wang initially envisioned two application directions for the robot: in specialized industries such as security at airports and among harsh environments such as inspections in nuclear power plants and mines.

Currently, the applications for the robot are continuously expanding, with its standout feature being the ability to be equipped with

multiple different gadgets to meet diverse needs. Additionally, it has amphibious capabilities, allowing it to be equipped with rescue equipment for use at sea, while a single charge allows it to operate continuously for 10 hours.

The company is considering expanding its production capacity, and it is expected that the output value will reach 10 million yuan ($1.38 million) in 2025, according to Wang, who noted that the robot has gained the attention of many investors and that the local governments in Hangzhou and even other cities have offered support.

Like Rotunbot's spherical robot, the commercialization of domestically developed humanoid robots is further accelerating. Shanghai's AgiBot has sold 200 A2-D humanoid robots since the release of the model in August 2024, while the Galaxea R1 Pro full-size dual-arm humanoid robot from the Xinghaitu (Suzhou) Artificial Intelligence Technology Co has received more than 100 whole-unit orders so far, with more than 50 units already delivered. Some of these units are expected to be exported overseas by mid-year of 2025.

Besides this, lawn-mowing robots, snow-clearing robots and pool-cleaning robots have become the "new three pieces" domestic vacuum cleaner manufacturers to expand overseas markets, according to media reports.

Beijing to host historic marathon event to be attended by human and robot runners in April

By Zhang Weilan Published: Jan 21, 2025

The 2024 Beijing Yizhuang Half Marathon began on November 10, 2024. The "Tiangong" robot, serving as a "closing rabbit" (a pacer who encourages and motivates runners to keep going), crossed the finish line alongside participants. Source: english.beijing.gov.cn

China is preparing for a groundbreaking event in April, as it hosts the world's first marathon to feature human and humanoid robot runners together, the Global Times learned from the event organizer, Beijing Economic-Technological Development Area, on Tuesday.

For the first time, dozens of humanoid robots will participate in a half-marathon to be held in Beijing's Daxing district. Some 12,000 participants will take part in the race, with robots from more than 20 companies running alongside them on the 21km route, according to local authorities.

The top three finishers, whether human or robotic, will receive prizes, according to the organizer. Companies, research institutions, robot clubs, and universities will participate in the marathon with their humanoid robots. Remote-controlled and fully autonomous robots are eligible, and operators may replace batteries during the race.

The marathon will feature robots developed by over 20 companies, each meeting criteria that include a humanoid form and the capability to run on two legs. The humanoids must also be between 0.5 meters to 2 meters tall.

Among the notable participants is "Tiangong," a humanoid robot developed by China's Embodied Artificial Intelligence Robotics Innovation Center, which previously ran at the Yizhuang Half Marathon in Beijing, Xinhua News Agency reported.

The integration of robots in marathons is becoming an increasing trend. Wei Jiaxing, marketing director of Tiangong's developer, told the Global Times on Tuesday that Tiangong, a humanoid robot with an average speed of 10 kilometers per hour, will participate in the race. "It will compete from start to finish in an official marathon for the first time," according to Wei.

China is positioning itself at the forefront of humanoid robot innovation. Taking Beijing as an example, the city is preparing for more robot-based competitions, including the inaugural World Humanoid Robot Sports Games later this year.

Beijing plans to hold in August the games' main events where humanoid robots will be the competitors, along with sideline events focusing on human-robot interactions. The main events will include major categories such as track and field, soccer, application scenarios, and integrated skills, the Global Times learned from the official website of the Beijing municipal government.

In 2025, Beijing plans to prioritize the development of future industries including humanoid robots, commercial space,

biomanufacturing and new materials, according to the government work report presented to the third session of the 16th Beijing Municipal People's Congress on January 14.

"US tech companies, such as Tesla and NVIDIA, have certain advantages in areas like precise upper limb manipulation and operational capabilities, as well as in high-end chip manufacturing and cloud computing services," Yao Qiyuan, marketing manager of the Shenzhen-based EngineAI Robotics Technology Co, told the Global Times on Monday, adding that while Chinese companies excel in motion control technologies and the creation of advanced AI models, offering a wide variety of application scenarios.

"If we compare the humanoid robotics industry to a marathon, China and Western counterparts are all within the first 1,000 meters of the starting line," Jiao Jichao, vice-president and executive dean of UBTech Robotics' research department was quoted by Xinhua as saying.

Yao also noted that humanoid robots have applications beyond running marathons. They have potential in areas such as intelligent manufacturing, medical care, and the service industry. Success depends on reducing costs and expanding application scenarios, he added.

China's humanoid robot industry has experienced rapid growth in recent years. In 2023, China installed about 276,300 robots, representing 51 percent of global installations, according to the International Federation of Robotics. The nation's robotics industry is projected to grow to 400 billion yuan ($55 billion) by 2030.

According to local media outlet Shanghai Observer reports, Shanghai is actively promoting the development of the humanoid robot industry ecosystem, with several unicorn companies such as Fourier Intelligence, Agibot or Zhiyuan Robotics, emerging in the sector. Agibot shared footage of its manufacturing facility on its official website, which reportedly has produced 1,000 general-purpose embodied humanoid robots so far.

On the global stage, Tesla's bi-pedal humanoid robot Optimus is capable of navigating uneven terrain utilizing neural networks to manage its electric limbs, the company's CEO Elon Musk posted on X on December 2024. Musk has also predicted that by 2040, the global use of humanoid robots will exceed 10 billion.

Global Times

Humanoid robots in spotlight at Beijing High-Tech Expo, as Chinese companies ramp up new tech innovation

By Zhang Yiyi Published: Jul 16, 2024

"Huitong 7," by a Chinese robot manufacturer, showcased at the 2024 Beijing International High-Tech Expo. This 1.7-meter, 55-kilogram humanoid robot can walk, run, jump, fall, roll, and crawl in different complex terrains. It boasts the world's highest and farthest jumps for a motor-driven humanoid robot, reaching 0.5 meters in height and 1 meter in distance. Photo: Zhang Yiyi/GT

Jumping and running like a human, nimbly sending coffee, even chatting with people... lots of humanoid robots showcased their skills

and interacted with visitors during 2024 Beijing International High-Tech Expo being held from July 13 to 16 in Beijing.

"Huitong 7," which resembles a human form with a height of 1.7 meters and a weight of 55 kilograms, can perform various multi-modal movements, like walking, running, jumping, falling, rolling, and crawling. It can jump up to 0.5 meters in height and 1 meter in distance, making it the highest and farthest jumping motor-driven humanoid robot in the world.

"Ninety percent of the robot's hardware is domestically produced. We primarily aim to apply it in specialized fields such as emergency rescues and firefighting, and other dangerous circumstances," a representative from Haribit told the Global Times on Tuesday.

The employee mentioned that the robot is not commercially available on a large scale and is priced at 3 million yuan (approximately $428,571), making it suitable mainly for specific applications. "We are currently in talks with various manufacturers and institutions about possible collaborations," he said.

Another robot, resembling a doll, also attracted considerable attention. Named the Intelligent Companion Robot, it was developed by a team of Chinese university students and has a 95-percent domestic production rate. The lamp-sized device is ideally suited for desk placement.

"This type of communication robot is on sale abroad, such as in the US. However, our model stands out due to its human-like expressions, movements, and tones, which facilitate more natural interactions. It is the first robot in the world with a long-term memory function for family use, capable of recording human speech and expressions, with users having the option to select what it remembers," Wang Chenghao, a product director from TechVoyage, told the Global Times on Tuesday.

"We plan to launch the product on Chinese e-commerce platforms in 2025, at a competitive price of around 5,000 yuan," said Wang.

In recent years, an increasing number of Chinese enterprises, large or small, have jumped onto the bandwagon to develop humanoid robots, with an expanding variety of robot models showcased to suit specific scenarios. The diversification owes much to breakthroughs in proprietary technologies by domestic companies, encompassing both software and hardware.

However, the transitioning from development to mass commercialization of humanoid robots in China, expected to take five to six years, means lots of challenges to be overcome, experts said.

Currently, commercial humanoid robots are mainly employed in industrial sectors like metallurgy - say steel manufacturing, which often use large-scale models to create specialized robots to perform high-risk tasks. Additionally, communicative humanoid robots are easier to market due to simpler production and more affordable pricing, Liu Gang, chief economist at the Chinese Institute of New Generation AI Development Strategies, told the Global Times on Friday.

"In contrast, commercializing service-use humanoid robots remains a challenging job. Their intelligence levels are significantly lower than the human brain, with the top models only achieving 0.2 percent of human capacity, making it hard to interact with human naturally. Also, the high cost of the robots makes it unaffordable for most consumers," Liu said.

"Some of our components, such as joints and software, rely on imports. We are slightly behind the developed countries in embodied intelligence. However, significant investment is boosting humanoid robot development in China. Once domestic production of the components gains pace, more Chinese enterprises will engage in research and development, Liu said.

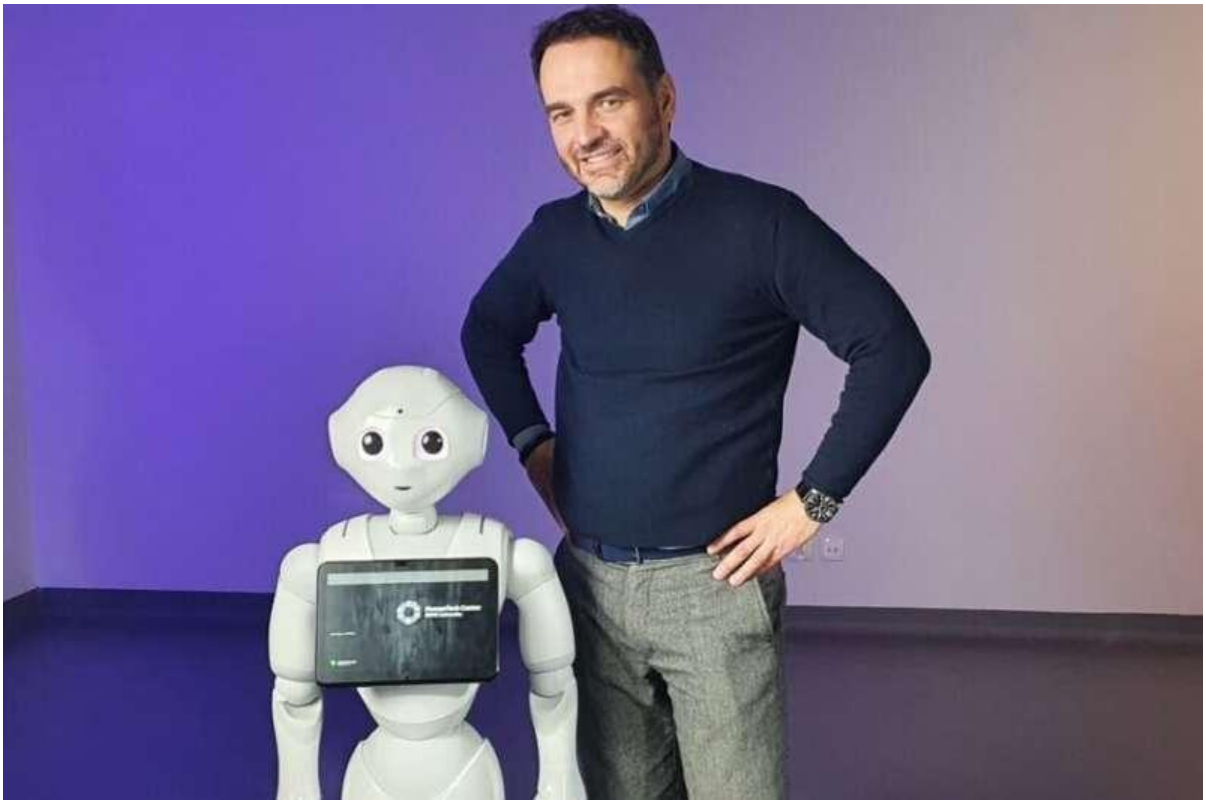
The scale of China's humanoid robot industry is expected to reach 20 billion yuan by 2026, according to a recent report by state broadcaster CCTV. Humanoid robotics is a future industry that requires

integration across multiple industries, and Chinese companies have high enthusiasm to ramp up research and development, industry observers said.

MARCH 14, 2025

When a robot becomes the boss: Exploring authority, obedience and relationships with machines

by SWPS University



Credit: SWPS University

How does a robot perform as a boss at work? The results of research by Polish scientists published in *Cognition, Technology & Work* suggest that while robots can command obedience, they are not as proficient at it as humans. The level of obedience towards them is generally lower than towards human authority figures, and work efficiency under the supervision of a robot is lower.

For employers and HR departments, this means there's a need to take the psychological aspects of implementing robots in the work environment into account, including perception of them as an authority figure, trust in them, and potential resistance to following orders,

says Konrad Maj, Ph.D., from SWPS University, a psychologist and head of the HumanTech Center for Social and Technological Innovation.

Robot as an authority figure

The development of robotics has led to a situation in which robots are increasingly found in roles associated with authority, e.g. in education, health care or law enforcement. Researchers were intrigued by the extent to which society would accept robots as authority figures. The researchers have shown that people demonstrate a significant level of obedience towards humanoid robots acting as authority figures, although it is slightly lower than towards people (63% vs. 75%).

As the experiment has shown, people may exhibit a decrease in motivation towards machines that supervise their work—in the researchers' studies, participants performed their assigned tasks more slowly and less effectively under the supervision of a robot. This means that automation does not necessarily increase efficiency if it is not properly planned from a psychological point of view, Maj believes.

Course of the study

The study was carried out in the SWPS University laboratory by scientists from this university: Konrad Maj, Ph.D., Tomasz Grzyb, Ph.D., a professor at SWPS University, Professor Dariusz Doliński and Magda Franjo. Participants were invited to the laboratory and randomly assigned to one of two study groups: with the Pepper robot or with a human acting as an experimenter.

The task was to change the extensions of computer files. If the participant showed signs of reluctance to continue (e.g., a pause in work lasting more than 10 seconds), the robot or the experimenter used verbal encouragement.

The average time to change the extension of one file was shorter under human supervision (23 seconds), while in the groups supervised by a robot this time increased to 82 seconds. The average number of files changed in the first variant was 355, and in the second it was nearly 37% less—224 files.

Human-robot relations

The experiments indicate the complexity of human-robot interactions and the growing role of robots in society. Studies show that anthropomorphic features of robots affect the level of trust and obedience. Robots that are more human-like are perceived as more competent and trustworthy. On the other hand, too much anthropomorphization can cause the uncanny valley effect, which results in lower trust and comfort in the interaction.

Maj points out that there are several explanations for this phenomenon: if a machine has clear human features, but still exhibits various imperfections, this causes a cognitive

conflict—and people are at a loss as to how to treat it. They do not know how to behave towards something like that.

But, a conflict of emotions can be discussed: fascination and admiration mixed with disappointment and fear. On the other hand, supporters of the evolutionary explanation claim that humans are programmed to avoid various pathogens and threats, and a robot that pretends to be a human, but is still not perfect at it, may appear to be a threat. Why? Because it looks like someone sick, disturbed or imbalanced.

At the same time, giving certain human features to a robot can facilitate cooperation with the machine—after all, we are used to working with humans. A robot that looks like a human and communicates like a human simply becomes easy for us to use. But there is also a dark side to this—if people create robots that are very similar to humans, they may stop seeing boundaries. People could start to befriend them, demand granting them various rights, and perhaps even get married to them in the future.

In the long run, humanoid robots may create a rift between people. There will also be more misunderstandings and aversion—and this is because robots owned at home will be personalized, always available, empathetic in communication, and understanding. People are not so well-matched, Konrad Maj points out.

More information: Konrad Maj et al, Comparing obedience and efficiency in tedious task performance under human and humanoid robot supervision, *Cognition, Technology & Work* (2025). DOI: 10.1007/s10111-024-00787-1
Provided by SWPS University

Humanoid robot

masters dance moves

Chinese company EngineAI is redefining what humanoid robots can do. In no time, the PM01 robot had picked up a dance routine from a pro instructor. #robot #HumanoidRobot #AI #RobotDance #China

China’s humanoid robot stuns with perfect Kung Fu Hustle dance moves

PM01 mastered dance through professional training, achieving 0.01s precision, fluid motion, and 24 DoF for lifelike movement.

Updated: Mar 17, 2025

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PM01 robot performs iconic move from Kung Fu Hustle.

Engineai Robot/YouTube

Chinese robotics startup EngineAI shared footage of its robots dancing like “Axe Gang” from the movie Kunfu Hustle.

In the video, the Axe Gang Trainee is the Shenghen-based firm’s PM01 humanoid robot. After intense dance battles with pro choreographers, PM01 flawlessly executes every Kung Fu Hustle move.

“Now, We’re back with new actions—this time merging hardcore robotics with Hong Kong cinema nostalgia in a way that’s making engineers and movie fans scream encore,” reads the video description.

In February, the firm shared footage of PM01 successfully performing a frontflip, making it the first humanoid robot to do so.

Robot meets cinema

Following its viral front-flip stunt last month, EngineAI has pushed the boundaries of robotics by integrating advanced motion algorithms with cinematic choreography.

PM01’s movements were perfected through dance battles with professional choreographers, achieving 0.01-second precision in joint control for dynamic flips, force-controlled arms for fluid motion, and up to 24 degrees of freedom for an eerily accurate walking gait.

According to the firm, the fusion of robotics and Hong Kong cinema nostalgia has captivated engineers and film fans alike.

Launched in December 2024, the PM01 is a smaller version of the SE01, Engine AI’s flagship humanoid known for its realistic walking gait. The company drew global attention in October 2024 with a demo of SE01’s lifelike movement.

PM01 is now available for sale until March 31, 2025, offering developers, researchers, and businesses an opportunity to explore the future of robotics.
The robot’s business and education versions are priced at ¥88,000 (around $12,000), making them $3K cheaper than Unitree’s G1 humanoid.

Agile AI assistant

The PM01 is a compact humanoid robot designed for researchers exploring human-robot integration. The highly customizable humanoid offers two walking modes and advanced motion capture, letting it effortlessly adapt to any environment.

It features a highly interactive core screen, a bionic design for realistic movement, and an impressive 320-degree waist rotation. Built with an aluminum alloy exoskeleton, it balances durability with agility.

Standing 1.38 meters (4.5 feet) tall and weighing 88 pounds (40 kilograms), the PM01 is 27 centimeters shorter and 8 kilograms (17.6 pounds) lighter than EngineAI's full-sized SE01.

A recent video highlights its advanced visual perception, powered by an Intel RealSense depth camera. Its dual-chip system, combining NVIDIA Jetson Orin and Intel N97 CPUs, delivers high-performance computing for complex tasks. The PM01 includes a high-capacity, quick-release battery, delivering up to two hours of operation per charge.

EngineAI's PM01 and SE01 humanoid robots are drawing attention for their agility and advanced capabilities. These AI-powered robots are showcased in training, assisting police officers, and engaging with the public. Shenzhen's police department is reportedly testing PM01 units as part of a project integrating artificial intelligence into law enforcement.

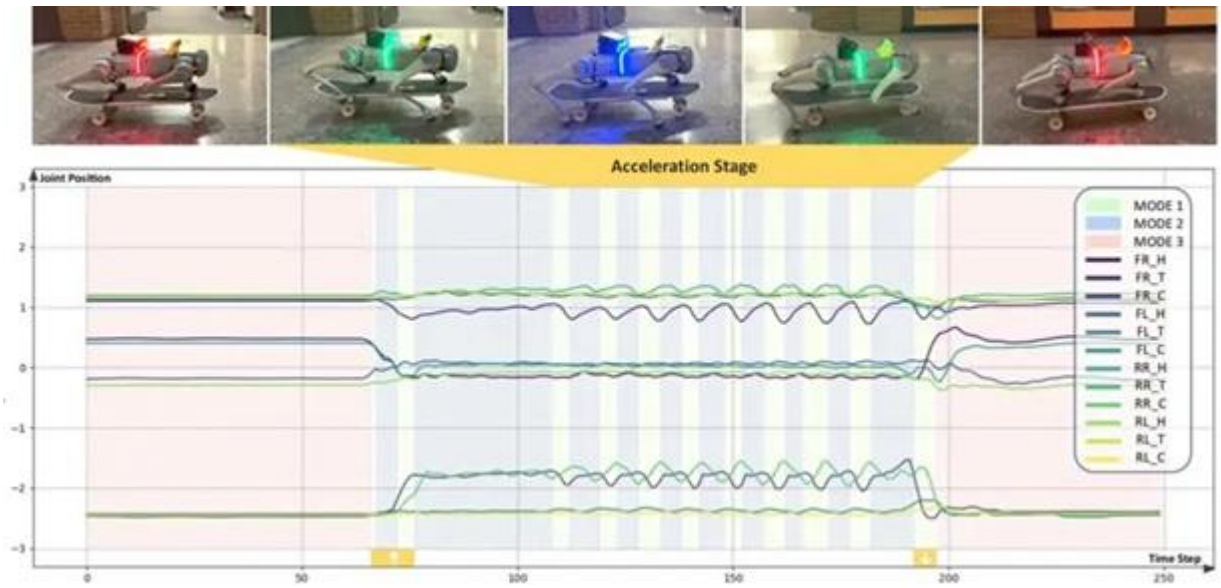
The company plans to produce and sell over 1,000 units by 2025, with the PM and PA series designed for home and industrial use, highlighting its ambitious vision for the future.

Legged robots skateboard successfully with reinforcement learning framework

Legged robots, which are often inspired by animals and insects, could help humans to complete various real-world tasks, for instance delivering parcels or monitoring specific environments. In recent years, computer scientists have created algorithms that allow these robots to walk at different speeds, jump, emulate some of the movements of animals and move with great agility.

Researchers at the University of Michigan's Computational Autonomy and Robotics Laboratory (CURLY Lab) and Southern University of Science and Technology have now developed a reinforcement learning-based framework that allows legged robots to use a skateboard successfully. This framework, outlined in a paper on the *arXiv* preprint server, could also be used to emulate other real-world complex movements that entail physical contact with nearby objects.

"Existing quadrupedal locomotion approaches do not consider contact-rich interaction with objectives, such as skateboarding," Sangli Teng, corresponding author of the paper, told Tech Xplore. "Our work was aimed at designing a pipeline for such contact-guided tasks that are worth studying, including skateboarding. The University of Michigan has a long history of developing hybrid dynamical systems, which inspired us to identify such hybrid effects via data-driven approaches in AI."



Effectiveness of mode identification. In real-world deployment, we light up different RGB light bar colors according to the mode to show the switching between different mode. The following figure shows the change in joint position relative to time in the test, and the background color is represented by the color of the corresponding mode. [H, T, C] denote the Hip, Thigh, and Calf Joints, respectively. Credit: arXiv (2025). DOI: 10.48550/arxiv.2503.01842

The main goal of the recent work by Teng and his colleagues was to allow legged robots to perform contact-guided motions, including skateboarding. To achieve

this, they developed a new framework called discrete-time hybrid automata learning (DHAL).

"Hybrid dynamics" means a system can perform both continuous and discrete state transitions. This essentially means it can move smoothly and suddenly change its state over time.

"For example, when a bouncing ball interacts with the ground, the ball has continuous dynamics in the air and discrete state transitions when colliding with the ground," explained Teng.

"For systems with multiple continuous dynamics and transition functions, it is extremely difficult to identify the discrete mode and continuous dynamics at the same time. This is because a possible transition grows exponentially fast with regards to the number of possible discrete transitions."

The abrupt transitions described by Teng make it difficult for conventional regression-based computational methods to learn the dynamics of a system. DHAL, the framework developed by the researchers, can identify these sudden transitions, subsequently learning each continuous segment of a system's dynamics using regression-based techniques, reducing the discontinuous effect that was found to impair the performance of robots on tasks such as skateboarding.

"Compared to the existing methods, DHAL does not require manual identification of the discrete transition or prior knowledge of the number of the transition states," said Teng. "Everything in DHAL is heuristic and we showed that our method can autonomously identify the mode transition of dynamics."

A further advantage of the DHAL framework is that it is highly intuitive, thus ensuring that the mode transitions it identifies are aligned with those typically associated with skateboarding. In initial tests, the researchers found that it allowed four-legged (i.e., quadruped) robots to smoothly step onto a skateboard and use it to rapidly move forward while also pulling a small cart behind them.

"In the pushing, gliding and upboarding phase, DHAL will automatically output different labels," said Teng. "Our method can be applied to state estimation of hybrid dynamical systems to find out if such transition occurs. With this transition

information, the system can better estimate the states to assist the decision making."

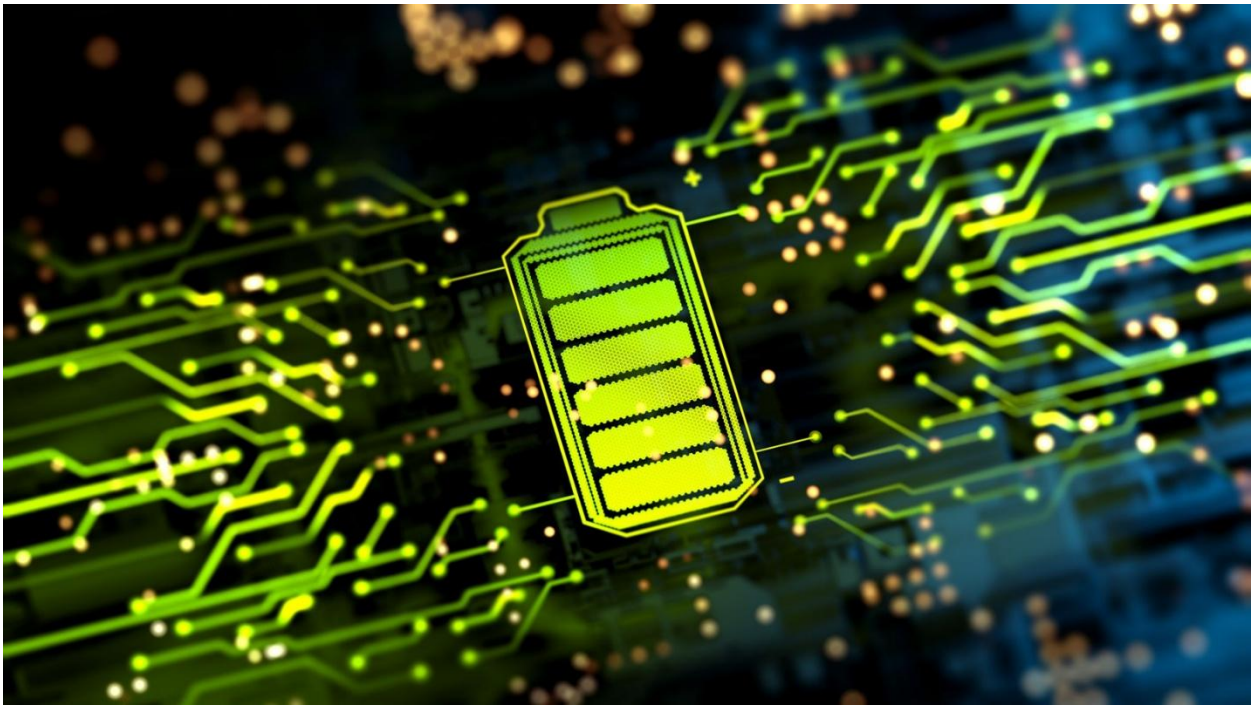
The new reinforcement learning framework Teng and his colleagues developed could soon open new possibilities for the real-world deployment of legged robots. For instance, it could allow them to move faster using a skateboard, delivering packages across urban environments, inside offices or manufacturing facilities.

"We now plan to apply this framework to other scenarios, such as dexterous manipulation (i.e., the manipulation of objects with multiple fingers or arms)," added Teng. "DHAL is expected to predict the contact more accurately, thus allowing planning and control algorithms to make better decisions."

More information: Hang Liu et al, Discrete-Time Hybrid Automata Learning: Legged Locomotion Meets Skateboarding, *arXiv* (2025). DOI: 10.48550/arxiv.2503.01842

The Secret to Unlimited Energy Is in a Coin-Sized Battery—And China Is Already Producing It

The atomic energy of betavoltaic batteries can power a variety of devices, from aerospace and robots to your future smartphone, for up to a century without recharging.



MARCH 30, 2025

PAWS: Four-legged robot can reproduce animal movement with fewer actuators

by Ingrid Fadelli , Tech Xplore

Image demonstrating the real-word deployment of the robot. Credit: Stella, Achkar, et al.

Many of the robotic systems developed in the past decades are inspired by four-legged (i.e., quadruped) animals, such as dogs, cheetahs and horses. By replicating the agile movements of these animals, quadruped robots could move swiftly on the ground, crossing long distances on various terrains and rapidly completing missions.

Yet realistically and robustly replicating the fluid motions observed in animals using robotic systems can be very challenging. While some existing four-legged robots were found to be very agile and responsive to changes in their environment, these systems typically integrate advanced actuators and computational components that consume a lot of energy.

Researchers at EPFL's CREATE Lab and Delft University of Technology (TU Delft) recently developed a new four-legged robot called PAWS (Passive Automata With Synergies), which could reproduce the fluid and adaptive movements of animals using fewer actuators. This robot, introduced in a paper in *Nature Machine Intelligence*, leverages so-called motor synergies, which are coordinated patterns of muscle activation that allow animals to perform agile motions consuming less energy.

"Robotic design is strongly inspired by biological examples," Francesco Stella and Mickael Achkar, first authors of the paper, told Tech Xplore. "However, the process of extracting design features from nature is often strongly dependent on human intuition and expertise. We wanted to find a more structured and methodological way of doing this."

Actuated behavior diversity—full robot. Credit: *Nature Machine Intelligence* (2025). DOI: 10.1038/s42256-025-00988-x
In contrast with other quadruped robots that execute their movements via active control strategies, PAWS also moves by leveraging the flexible connections between its joints, known as compliant mechanical couplings. This allows it to realistically perform dynamic movements that resemble those of animals, while requiring minimal actuation.

"Animals control their body using motion synergies—a biological phenomenon where the central nervous system coordinates patterns of activation across different muscle groups (rather than individual muscles) to enable efficient movement," explained Stella and Achkar.

"In our article, we started with real-world data of dogs to capture their principal motion synergies, and then we computationally translated them into a tendon-driven system with fewer motors than joints. Leveraging this reduced actuation set, we computationally designed PAWS (Passive Automata with Synergies)."

To assess their robot's ability to move passively (i.e., without relying on active actuation), the researchers placed it on a treadmill, without connecting any motors to its tendons. They found that the robot could effectively run on the treadmill even without the motors, while also avoiding any obstacles in its path.

Image showing the robot's mechanics. Credit: Stella, Achkar, et al.

Moreover, by integrating only four independently controlled actuators, the researchers successfully allowed PAWS to execute different animal-like gaits (i.e., styles of moving), including crouching, standing, walking, galloping and jumping. Their quadruped robot could soon be improved and tested further in other experiments, to validate its potential for tackling various real-world problems.

"Our design demonstrates the level of robustness achievable in passive bodies through purposeful coupling and compliance, and that with minimal actuation, it is possible to maintain the advantages of natural dynamics while achieving diverse behaviors and interactions with the environment," added Stella and Achkar.

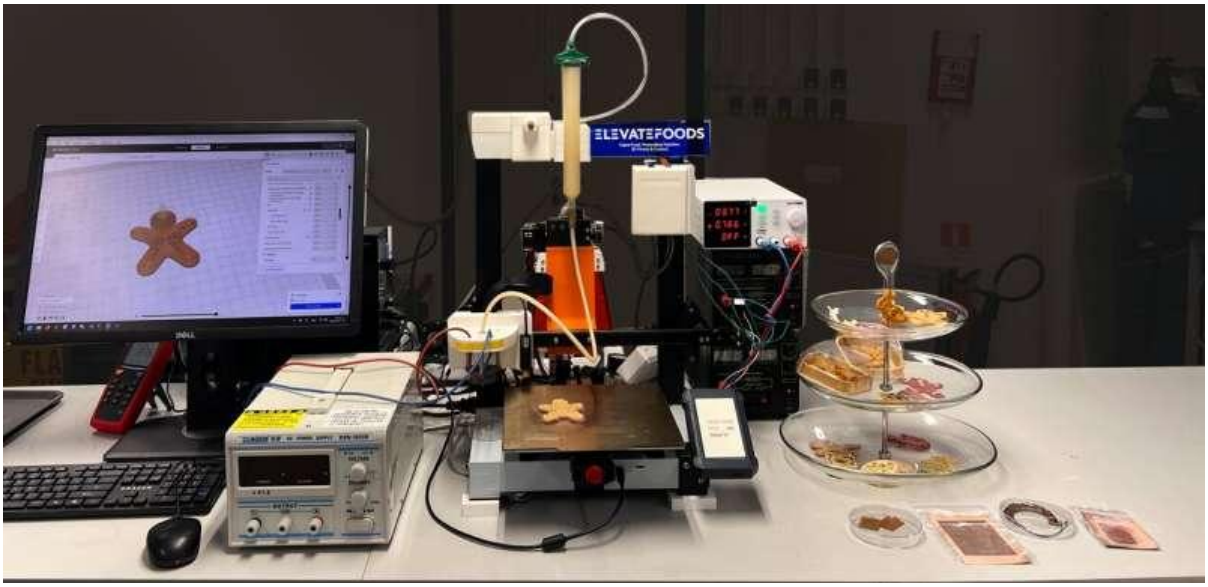
"We are now actively continuing this research by looking at how minimal sensing and simple feedback loops could further increase the stability of our system. We want to find ways in which we can continue to leverage the passive dynamics of the system while increasing its diversity in behaviors."

More information: Francesco Stella et al, Synergy-based robotic quadruped leveraging passivity for natural intelligence and behavioural diversity, *Nature Machine Intelligence* (2025). DOI: 10.1038/s42256-025-00988-x
Journal information: Nature Machine Intelligence

MARCH 31, 2025

AI-enhanced 3D printing cooks food with infrared precision

by Hong Kong University of Science and Technology



The integrative 3D food printer and AI digital food design platform. Credit: HKUST
Researchers at the Hong Kong University of Science and Technology (HKUST) have developed a cutting-edge AI-assisted 3D food printing solution that combines printing with infrared cooking, paving the way for safer, more efficient, and visually appealing food production. The study, "Advanced 3D Food Printing with Simultaneous Cooking and Generative AI Design," was recently published in the journal *Advanced Materials*.

Traditional 3D food printing methods often require additional postprocessing steps, which can have unappealing food ingredients, imperfect shapes, and even potential microbial contamination.

To address these challenges, the team from the Division of Integrative Systems and Design (ISD) at HKUST has developed an AI-enhanced system that combines extrusion-based printing with simultaneous infrared heating for on-the-fly cooking of intricate starch-based foods. Using graphene heaters for cooking, they precisely controlled the cooking process, ensuring that starch-based food items retain their intended shape and quality.

The system is supported by AI-assisted design, which employs generative algorithms and Python scripts to craft intricate food patterns. By leveraging AI, the design process became accessible to even computer novices.

The research tackles issues such as shape retention and contamination risks and opens up exciting prospects for tailored nutrition—benefiting individuals with special dietary needs,

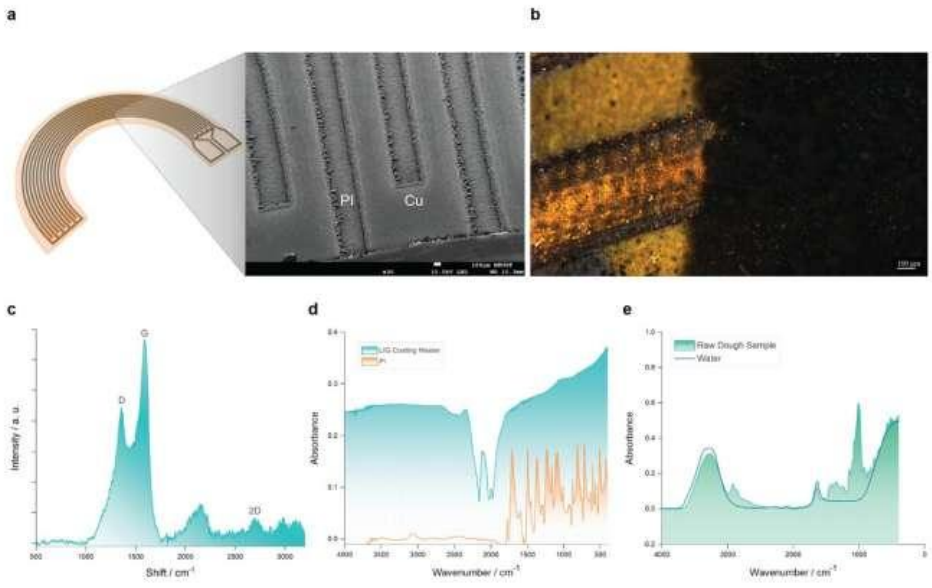
including patients with dysphagia. From enhancing meal customization in elderly care centers and central kitchens to meeting special dietary needs and enabling creative culinary experiences in restaurants, the technology offers a versatile solution for various sectors.

HKUST Researchers Develop an Advanced 3D Food Printing with Simultaneous Cooking and Generative AI Design. Credit: HKUST

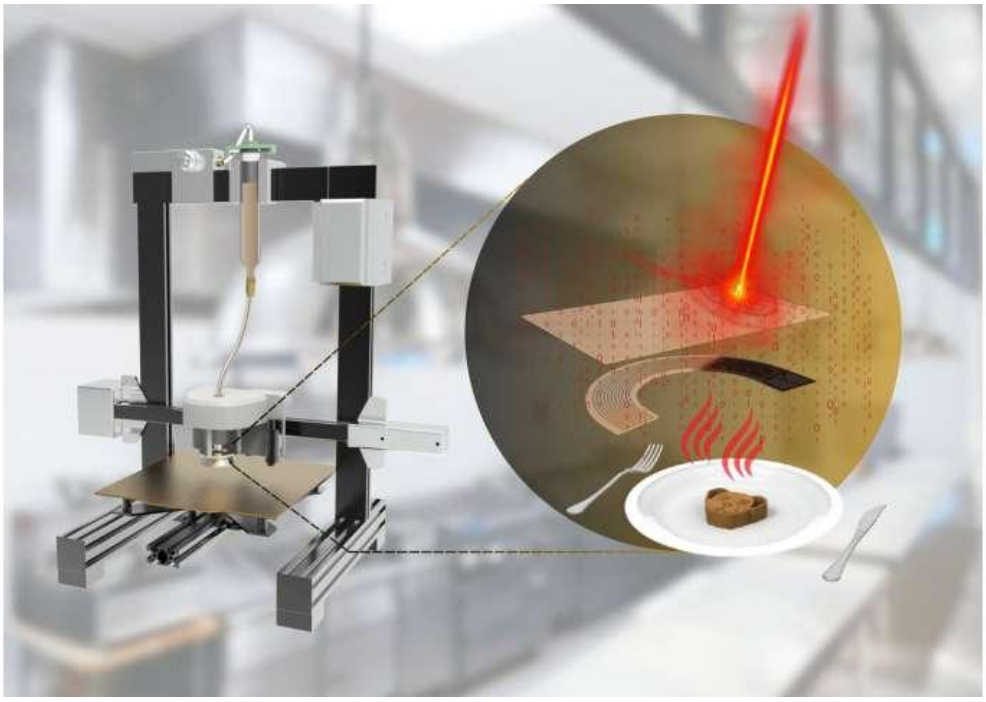
"With its potential to streamline food production processes, improve food quality, and cater to individual preferences, this innovation can transform how food is prepared and served in diverse settings, paving the way for a future where personalized and visually appealing food creations are more accessible than ever before," said Prof. Mitch Li Guijun, Assistant Professor of ISD, who led the research team.

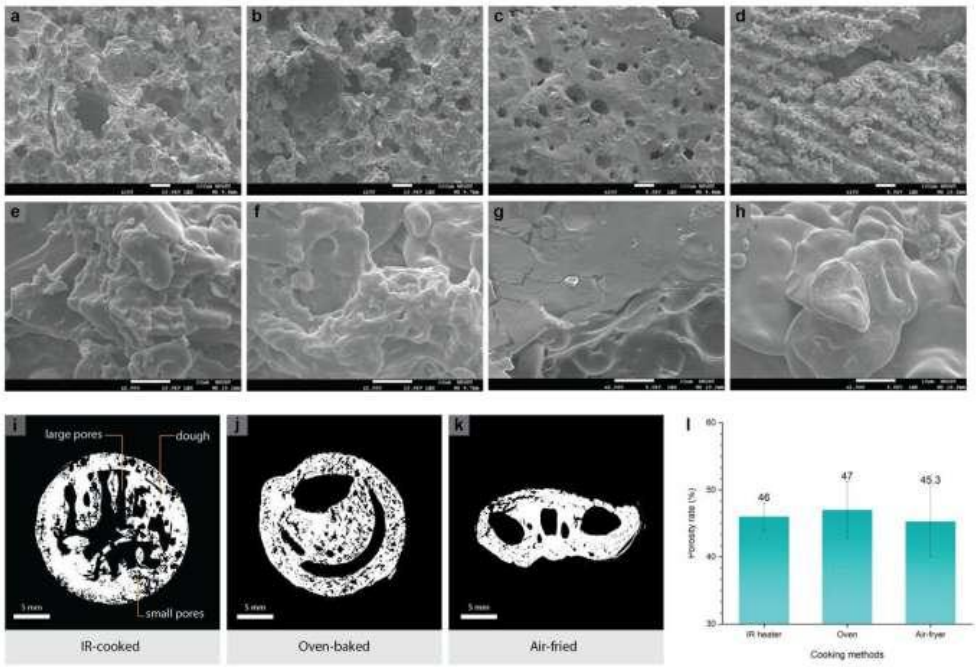
"We're excited about the potential of this technology to deliver customized, safe, and delicious food with a process that is both efficient and accessible. It represents a significant step forward in how we think about food creation," Prof. Li added.

Connie Lee Kong-Wai, the paper's first author and a Ph.D. student at HKUST, said, "We've reimagined what 3D food printing can achieve by merging technology and culinary creativity. Our cutting-edge integrative 3D food printing technology can potentially revolutionize personalized food creation."



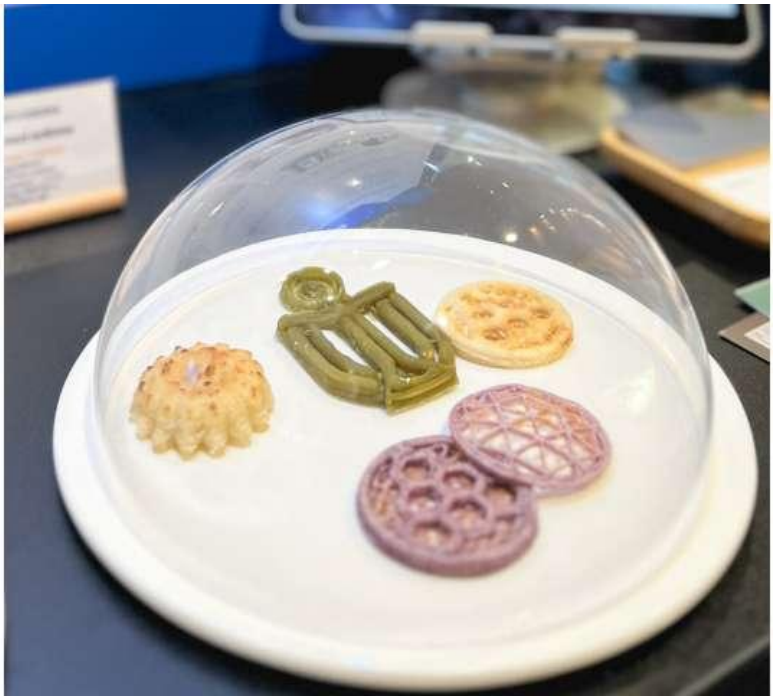
- a) Schematic diagram and scanning electron microscopy image of the LIG heating film. b) Optical microscope images of the LIG heating film. c) Raman spectra of the LIG heating film. d) Fourier transform infrared spectroscopy of the LIG heating film. e) Absorption spectrum of the printed dough sample. Credit: HKUST

- 
The 3D food printer includes the real-time print and cook system. Credit: HKUST

- 

a–d) SEM images at ×100 magnification of starch-based dough samples processed with air-frying, oven-baking, IR cooking, and laser cooking (from left to right). e–h) SEM images at ×2000 magnification of starch-based dough samples processed with air-frying, oven-baking, IR cooking, and laser cooking (from left to right). i–k) Reconstructed micro-computed tomography 2D cross-section images of the printed dough with different cooking methods. l) Porosity rate (%) of the printed dough with different cooking methods. m) Printability test using a cylindric shape of 30 × 30 × 30 mm as the testing model. n) Shape fidelity value (%) of untreated and IR-cooked samples in terms of

length, width, and height. o) 3D printing process of the starch-based dough without heat treatment for 30 min. p) 3D printing process of the starch-based dough with LIG treatment for 30 min. Credit: HKUST

- 
Produced by the 3D food printer, the starch-based food items retain their intended shape and quality. Credit: HKUST

The research represents a collaborative effort spanning user-centric design, mechanical engineering, food science, chemistry, and AI. This cross-disciplinary approach brought together diverse expertise to tackle the complex challenges associated with 3D food printing.

Looking ahead, the team plans to refine the technology by examining the preservation of heat-sensitive vitamins and optimizing starch digestibility. Future studies will also focus on consumer acceptance through sensory evaluations involving target users such as children or hospital caretakers, ensuring that the system is ready for real-world applications.

More information: Connie Kong Wai Lee et al, Advanced 3D Food Printing with Simultaneous Cooking and Generative AI Design, *Advanced Materials* (2025). DOI: 10.1002/adma.202408282
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That 'uhh... let me think' face you make? Androids need it too

by Mikas Matsuzawa, Hiroshima University

The Furrowed Face Condition displaying lowered brows and narrowed eyes. Credit: Shushi Namba/Hiroshima University

Ever asked a question and been met with a blank stare? It's awkward enough with a person—but on a humanoid robot, it can be downright unsettling. Now, an international team co-led by Hiroshima University and RIKEN has found a fix: giving androids a "thinking face." Their study reveals that when robots squint and furrow their brow while processing information, they appear more relatable, easing the eerie discomfort we feel with artificial beings that look almost, but not quite, human—known as the "uncanny valley" effect.

Until now, research on the "uncanny valley" phenomenon has focused mainly on robots' appearance. But their study, published in the *International Journal of Social Robotics*, suggests that behavior plays just as big a role. When we humans are contemplating an answer, our faces show it. If an android doesn't respond in a socially expected way, such as failing to look "thoughtful," it can feel as unnerving as an unnatural face.

Researchers set out to pinpoint the facial cues people use when deep in thought and test whether mimicking these "thinking faces" could make human-android interactions feel more natural—especially as asking questions is a typical part of engaging with robots. Their findings are critical for the robotics and AI industries, particularly those developing customer service androids, AI assistants, and health care companions.

"We often express psychological states such as happiness or anger through facial expressions. However, previous studies have only examined a limited set of expressions. This study aimed to identify the facial patterns associated with the 'thinking face' in humans," said study corresponding author Shushi Namba, associate professor at Hiroshima University's (HU) Graduate School of Humanities and Social Sciences.

"We then examined whether applying these 'thinking' facial patterns to androids could enhance natural human-robot interaction. Specifically, our research addressed the lack of clarity around the facial movements that convey 'being in thought' and tested their effect on human perception when applied to an android."

Identifying 'thinking' facial cues in humans

To identify the facial patterns linked to thinking, the international research team filmed the reactions of 40 young adults, equally split between males and females, as they counted silently for two seconds in their heads (Control Condition) and answered a series of questions ranging from basic math to politics (Thinking Condition). Questions were

delivered uniformly using voice-reading software to prevent speech variations from influencing responses. Analyzing the 240 facial videos revealed these five distinct expressions associated with thinking:

- Component 1: Raised chin, subtly tightened lips, lifted inner brow, and downward gaze
- Component 2: Opened mouth
- Component 3: Blinking
- Component 4: Slightly narrowed eyes and furrowed brows
- Component 5: Smiling with cheek raised, raised upper lip, and dimpling

Replicating the 'furrowed face' on an android

Of the five, the researchers chose to adopt Component 4, which they called "furrowed face," as it stood out as the most indicative of deep thought based on past studies exploring how people express and perceive thinking.

They programmed an android named Nikola to replicate this expression and tested how it would fare compared to a furrowed smiling face and neutral face. Eighty-nine crowdsourced workers were asked to watch a video of Nikola displaying these expressions and score each on "genuineness," "eeriness/human-likeness," "thinking about the answer," and "appropriateness." A hat was placed on the android's head to conceal exposed mechanical components used for facial movements and make its appearance more natural in the video recordings.

Testing revealed that the furrowed face was rated as the most thoughtful, genuine, human-like, appropriately acting, and less eerie of the three.

Role of expressions in human-robot interactions

Wanting to further prove why expressions matter in robots, the researchers compared people's reactions to videos featuring either Nikola or a chatbot. Forty Japanese university students were shown eight hypothetical question-and-answer scenarios: four with thinking cues (furrowed face or dots) and four without (neutral face or blank speech bubble).

In the video, the android and chatbot were asked a question about a sushi restaurant or technology's impact on Japanese politics. After a brief 2.5-second pause, during which either a thinking cue or a neutral stimuli was displayed, the robots responded with "Of course!"

The Control Condition showing no facial movements. Credit: Shushi Namba/Hiroshima University

While both thinking cues made participants feel like the android and chatbot were "thinking," the dots were rated higher for signaling that information was being processed. Meanwhile, they said the furrowed face made Nikola seem more human-like, suggesting that when robots display familiar social norms, they are perceived as more relatable.

"The main takeaway is that when people are 'thinking,' they would express the furrowed face. The other message is that implementing human-like 'thinking faces' in androids enhances perceptions of 'being in thought,' genuineness, human-likeness, and appropriateness while reducing the uncanny valley effect," Namba said.

One reason the chatbot was seen as more effective in conveying that it is "thinking" is people's familiarity with dots as a visual cue that information is being processed. As androids become more common, these findings could help guide the development of robots that adopt similar cues, bringing about more natural and intuitive human-robot interactions.

"The ultimate goal is to develop androids that can engage in more natural and intuitive interactions with humans, reducing the sense of eeriness and increasing their acceptance in social settings," Namba said.

"To get there, we need to further refine the implementation of thinking faces in androids by considering dynamic aspects of facial movements and investigating their effects in real-time social interactions. Additionally, the study suggests exploring cultural variations in the perception of thinking faces and integrating gaze behavior or other social cues to improve human–robot communication."

More information: Shushi Namba et al, How an Android Expresses "Now Loading…": Examining the Properties of Thinking Faces, *International Journal of Social Robotics* (2024). DOI: 10.1007/s12369-024-01163-9
Provided by Hiroshima University