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EMERGING SPACE BRIEF

Humanoid Robotics

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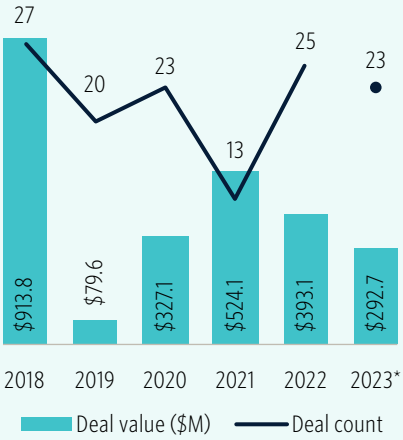
Trending companies

Boston Dynamics · APPTRONIK · HANSON ROBOTICS · Embodied · SANCTUARY AI · AGILITY ROBOTICS

Humanoid robotics VC deal activity



Source: PitchBook • Geography: Global
*As of December 18, 2023

Overview

Companies specializing in humanoid robotics design and develop robots that mimic human appearance and behavior. They focus on features such as bipedal movement, object handling, facial recognition, and social interaction. Their interdisciplinary work blends mechanical engineering, computer science, AI, and materials science to build advanced robotic systems.

Background

Humanoid robots have captivated human imagination for millennia. Ancient civilizations such as the Egyptians and Greeks envisioned "automata": self-operating objects made of metal or stone. Historical figures such as the Muslim inventor Ismail al-Jazari created early prototypes;[1] his robotic beverage server is said to have influenced Leonardo da Vinci's robotic experiments. Since then, robots have woven their way into science fiction and popular culture, emerging as iconic figures that are either adored or feared, transforming into mass-produced toys, and remaining a constant source of intrigue.

In a landmark event in 2017, Saudi Arabia awarded citizenship to Sophia, a humanoid robot with realistic skin and a neural-network-based interface. Despite such groundbreaking developments and over $4.6 billion invested, the widespread integration of humanoid robots into everyday life still appears to be a distant reality. Functional prototypes generate much buzz on social media, but humanoid robots have only just been introduced in industries such as hospitality, warehousing, and healthcare. Future adoption will depend on savvy business models and cost-effective decision-making by technology strategists.

1: "Ancient Discoveries Islamic Science Part1," YouTube, uploaded by shazpk, July 24, 2008.

Technologies and processes

Robotics in general involves a complex network of systems that interact with one another to produce a fully autonomous machine.

- **Mechanics and kinematics**
  - **Structure:** The structure of humanoid robots resembles a human skeleton, complete with a head, a torso, arms, and legs. This structure is essential for replicating the human form and facilitating complex movements.
  - **Actuators, motors, and dexterity:** These components are vital for emulating human muscle functions, enabling humanoid robots to perform intricate tasks such as gripping, lifting, and manipulating objects with precision.
  - **Bipedal locomotion:** Advanced systems enable humanoid robots to walk, run, and maintain balance, mirroring human mobility and agility, which is crucial for navigating diverse environments.

- **Control systems**
  - **Microcontrollers and processors:** Serving as the robot's brain, these elements are responsible for autonomous, real-time input processing and decision-making, which is crucial for the robot's self-governance and intelligent behavior.
  - **Software algorithms and feedback loops:** These are integral for dynamic response to external stimuli, facilitating planning, balance control, and adaptive decision-making to ensure that the robot can interact smoothly and safely with its surroundings.

- **Sensors and perception**
  - **Computer vision systems:** Cameras and image-processing technologies enable humanoid robots to recognize objects and navigate spaces, mimicking human visual perception.
  - **Environmental sensors:** Technologies such as ultrasonic, infrared, and lidar provide essential spatial awareness, allowing the robot to understand and adapt to its environment.
  - **Tactile sensors:** These sensors detect touch and pressure, which is crucial for delicate and precise object handling and enhances the robot's interaction with physical objects.

- **Artificial intelligence & machine learning (AI & ML)**
  - **Cognitive computing and learning algorithms:** These systems allow humanoid robots to imitate human thought processes, problem-solving, and decision-making and continually improve through feedback and learning.
  - **Natural language processing:** This technology enables robots to understand and generate human language, facilitating seamless communication between humans and robots.

- **Human-robot interaction**
  - **Speech recognition and synthesis:** These features enable effective verbal communication, allowing humanoid robots to understand spoken commands and respond in kind.
  - **Gesture and facial-expression recognition:** This enhances nonverbal communication capabilities, making interactions with humans more intuitive and natural.
  - **Emotion detection and response:** By recognizing and responding to human emotions, humanoid robots offer more empathetic and context-aware interactions, improving their effectiveness in social environments.

Power and energy management: In humanoid robotics, efficient power and energy management is crucial for ensuring longevity and optimal performance. Advanced battery technologies and energy-efficient designs are pivotal in enabling these sophisticated machines to operate effectively over extended periods, making them more practical and viable for a range of applications.

Materials and fabrication: The choice of materials and fabrication methods plays a critical role in the development of humanoid robots, directly impacting their durability, safety, and functionality. Utilizing lightweight yet durable materials, alongside cutting-edge techniques such as 3D printing, allows for the creation of robots that are not only robust and adaptable to various environments but also safe for close human interaction.

Applications

Healthcare: In the healthcare sector, humanoid robots such as Fourier Intelligence's GR-1 bot are making their debut, specifically targeting rehabilitative therapy and assistance for the elderly.[2] With their ability to emulate human interactions and actions, these robots are progressively being integrated into patient care and rehabilitation processes, serving as a supplementary aide to medical professionals.

Education: In educational settings, humanoid robots may serve as interactive tools, aiding in teaching various subjects, language learning, and special education. Their interactive capabilities can offer a novel approach to student engagement.

Customer service: In customer service, humanoid robots are being used for tasks such as greeting customers, providing information, and assisting in navigation in environments like retail stores, hotels, and airports. Their ability to interact with humans in a relatable way can enhance customer experiences.

Entertainment: The entertainment industry sees humanoid robots as potential performers or interactive elements in theme parks, exhibitions, and stage shows. Their unique presence can add a novel aspect to entertainment experiences.

2: "GR-1 General-Purpose Humanoid Robot Will Carry Nearly Its Own Weight," New Atlas, Loz Blain, July 13, 2023.

Search and rescue operations: Humanoid robots are also being considered for search and rescue missions, especially in environments that are unsafe for or inaccessible to humans. Their ability to navigate difficult terrain can be valuable in emergency situations.

Domestic assistance: For domestic use, humanoid robots are being developed to assist with chores, home security, and companionship, particularly for individuals who require additional assistance at home.

Manufacturing and heavy industry: In the manufacturing sector, humanoid robots are being introduced as collaborators, as seen with Amazon's use of Digit robots in its warehouses.[3] These robots are capable of working in tandem with human employees, particularly in tasks demanding a degree of dexterity and decision-making, where traditional robots typically fall short. Their application in environments like Amazon's warehouses exemplifies the potential of humanoid robots to enhance efficiency in complex industrial settings.

Limitations

Despite their technological advancements, humanoid robots face several limitations that impact their widespread adoption. One of the primary challenges is cost; developing and manufacturing humanoid robots can be prohibitively expensive due to the complexity of their design and the advanced technology required. Advanced humanoid robots can cost anywhere from $20,000 to over $1 million, depending on their capabilities and applications. This high cost limits their accessibility, especially for small businesses or personal use. Additionally, humanoid robots often struggle with energy efficiency, as maintaining bipedal locomotion and complex sensory processing systems requires significant power, leading to limited operational time and the need for frequent recharging. The sophistication of AI & ML algorithms also presents a challenge; despite considerable progress, humanoid robots still lag human capabilities in terms of decision-making, adaptability, and understanding nuanced human interactions. These limitations, combined with ongoing ethical and social concerns, such as job displacement and privacy issues, make the practical deployment of humanoid robots a complex and evolving issue.

Recent deal activity and market outlook

The market outlook for humanoid robots is marked by a mix of high expectations and practical limitations. A notable development in this space is Tesla's Optimus project, with CEO Elon Musk stating that these robots could eventually be priced around $20,000. This pricing strategy, if achieved, could significantly broaden the market for humanoid robots, making them more accessible to a wider range of consumers and businesses.

Venture capital interest in this sector is robust, as evidenced by recent funding rounds. 1X, known for developing EVE, a labor-saving android, successfully raised $87.5 million in October 2023. Collaborative Robotics, led by Brad Porter, a former

3: "Getting to Know 'Digit,' the Humanoid Robot That Amazon Just Started Testing for Warehouse Work," GeekWire, Todd Bishop, October 26, 2023.

vice president of Amazon Robotics, secured $30.0 million in a Series A funding round led by Sequoia Capital. Additionally, Figure, which is focusing on creating robots to address labor shortages, raised a substantial $70.0 million in its Series A. These investments reflect strong confidence in the potential of humanoid robots to revolutionize various industries, particularly by addressing labor shortages and enhancing productivity.

Despite these advancements and investments, widespread market adoption of humanoid robots faces several challenges. First, the high cost of development and potential retail prices, even at the lower end speculated by Musk, may limit initial ownership to wealthier households and businesses. If humanoid robots—as opposed to application-specific, nonhumanoid robots—do provide consistent value more than the cost of labor, then businesses may adopt them at a faster rate. Gartner estimates that by 2035, only about 10% of wealthy households in developed countries will have humanoid robots, suggesting a gradual penetration into mainstream markets.[4]

The possibility of a "robotics-as-a-service" business model could emerge as a solution to these accessibility issues. Under this model, businesses and consumers could lease or rent humanoid robots, thereby reducing the upfront costs and making advanced robotic technology more accessible to a broader audience.

While the future of humanoid robotics will be interesting, fueled by technological advancements and new venture capital investments, its path to becoming a ubiquitous presence in homes and businesses is paved with challenges. These include high costs, the need for continued technological refinement, and the development of innovative business models to enhance accessibility and practicality.

Quantitative perspective

For a deeper dive into the data and to explore additional insights, visit the PitchBook Platform or request a free trial.

84 companies	**258** deals	**389** investors	**$4.6B** capital invested
32 deals (TTM) *23.1% YoY*	**$3.3M** median deal size (TTM) *25.9% YoY*	**$109.0M** median post-money valuation (TTM) *82.6% YoY*	**$370.6M** capital invested (TTM) *-9.3% YoY*

*As of December 18, 2023

4: "Emerging Technologies: AI Roadmap for Smart Robots — Journey to a Super Intelligent Humanoid Robot," Gartner, Annette Jump and Bill Ray, October 4, 2023.

Top humanoid robotics companies by total raised*

Company	Total raised ($M)	Latest deal value ($M)	Latest deal date	Deal type	HQ location	Year founded
UBTECH	$1,861.0	N/A	January 31, 2023	IPO	Shenzhen, China	2012
Agility Robotics	$178.0	N/A	N/A	PE growth/expansion	Pittsburgh, US	2015
Figure	$170.0	$70.0	May 31, 2023	Early-stage VC	Sunnyvale, US	2019
Plus One Robotics	$95.1	$50.0	January 17, 2023	Late-stage VC	San Antonio, US	2015
Sanctuary AI	$93.8	$30.0	December 1, 2022	Early-stage VC	Vancouver, Canada	2018
Moxie	$75.1	$19.3	November 30, 2022	Late-stage VC	Pasadena, US	2016
Rainbow Robotics	$70.8	$46.8	January 19, 2023	PIPE	Daejeon, South Korea	2002
Elementary	$47.6	$30.0	December 16, 2021	Early-stage VC	South Pasadena, US	2017
LEJU Robotics	$46.1	N/A	February 25, 2023	Late-stage VC	Shenzhen, China	2016
1X	$40.4	$87.5	October 19, 2023	Late-stage VC	Moss, Norway	2014

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Top humanoid robotics companies by Exit Predictor opportunity score*

Company	Opportunity score	Success probability	M&A probability	IPO probability	Total raised ($M)	HQ location	Year founded
Sanctuary AI	99	89%	30%	59%	$93.8	Vancouver, Canada	2018
1X	98	94%	91%	3%	$40.4	Moss, Norway	2014
Apptronik	98	89%	78%	11%	$28.6	Austin, US	2016
Cobot	97	91%	90%	1%	$40.0	Santa Clara, US	2022
Duality Robotics	97	92%	91%	1%	$14.9	San Mateo, US	2018
Beyond Imagination	88	80%	79%	1%	$4.2	Burbank, US	2018
Elementary	86	98%	97%	1%	$47.6	South Pasadena, US	2017
GenRobotic	86	78%	77%	1%	$3.1	Thiruvananthapuram, India	2015
Plus One Robotics	81	98%	74%	24%	$95.1	San Antonio, US	2015
Oversonic	66	62%	61%	1%	$10.8	Besana in Brianza, Italy	2020

Source: PitchBook • Geography: Global • *As of December 18, 2023
Note: Probability data based on PitchBook VC Exit Predictor Methodology.

Top humanoid robotics companies by number of active patents*

Company	Active patent documents	Total raised ($M)	HQ location	Year founded
UBTECH	609	$1,861.0	Shenzhen, China	2012
Boston Dynamics	455	$37.0	Waltham, MA	1992
SoftBank Robotics	63	$13.0	Tokyo, Japan	2014
Rollomatic	39	N/A	Le Landeron, Switzerland	1964
Rainbow Robotics	38	$70.8	Daejeon, South Korea	2002
Shadow Robot	27	N/A	London, UK	1987
Sanctuary AI	26	$93.8	Vancouver, Canada	2018
Meltin MMI	21	$31.3	Tokyo, Japan	2013
Beyond Imagination	18	$4.2	Burbank, US	2018
Furhat Robotics	18	$4.6	Stockholm, Sweden	2014

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Top humanoid robotics investors by deal count*

Investor	Investments	HQ location
Intel Capital	5	Santa Clara, US
National Science Foundation	5	Alexandria, US
Osage University Partners	5	Bala Cynwyd, US
Plug and Play Tech Center	5	Sunnyvale, US
Calibrate Ventures	4	Pasadena, US
Capital Factory	4	Austin, US
Pritzker Group Venture Capital	4	Chicago, US
SoftBank Group	4	Tokyo, Japan
Toyota Ventures	4	Los Altos, US
United States Department of Defense	4	Washington, DC, US
Whale Capital	4	Shanghai, China
Zhengxuan Investment	4	Shenzhen, China

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Recommended reading

- "Humanoid Robots Are Here, But They're a Little Awkward. Do We Really Need Them?" The Associated Press, Matt O'Brien, November 29, 2023.
- "The First Humanoid Robot Factory Is About to Open," Axios, Jennifer A. Kingson, Axios, December 5, 2023.
- "Humanoid Robots - Applications and Future Scope," Universal Robots, May 24, 2019.
- "Understanding Humanoid Robots and Smart Materials," YouTube, uploaded by Mechanical Engineering at UT Dallas, September 1, 2023.

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