FUJITSU

The Rise of Physical AI

From Humanoid Robotics to Industrial Reality

Contents

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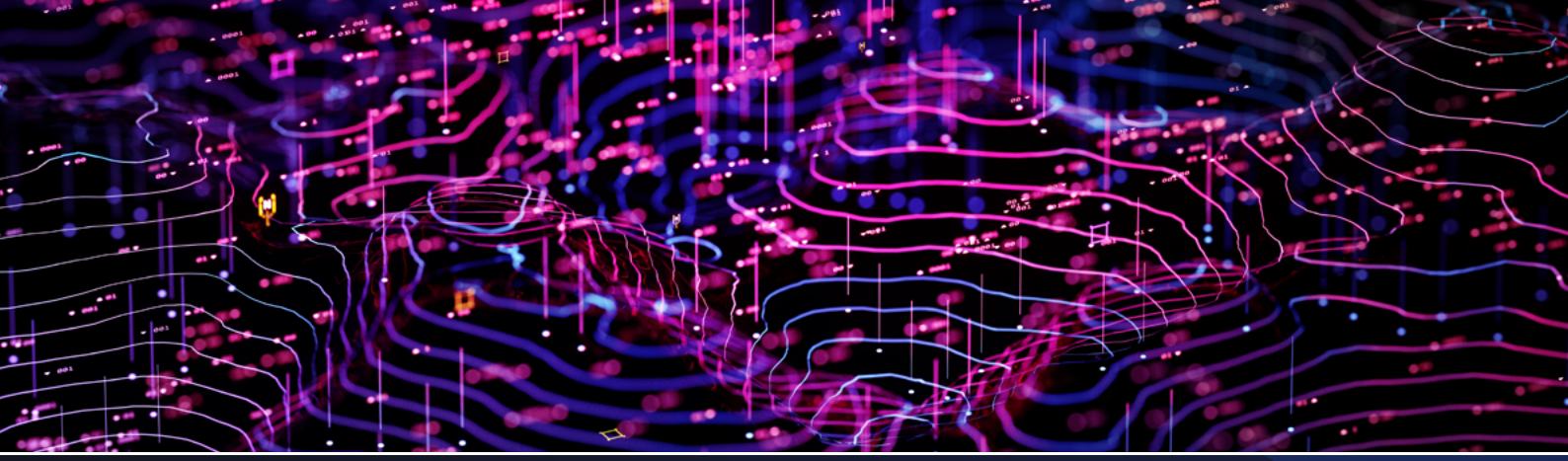


1. Introduction: Why Humanoid Robotics Now?

In recent years, robotics has advanced at an unprecedented pace. Breakthroughs in sensors, AI chips, and battery systems–combined with the rapid evolution of AI models and control software–are transforming robots from single-purpose machines into autonomous systems capable of sensing, reasoning, and executing tasks in dynamic environments. The emergence of "learning, continuously improving robots" is no longer a theoretical vision but a practical reality.

Underlying this shift are structural challenges: plateauing productivity gains, persistent labor shortages, and growing demand for new digital-enabled industrial foundations.
Against this backdrop, humanoid robots*1 –systems that integrate mobility, dexterity, and a human-like form factor–are drawing increasing attention. Positioned as embodiments of physical AI, these next-generation platforms are expected to perform a wide range of general-purpose tasks, extending far beyond the scope of traditional industrial robots. As such, they are emerging as a foundational technology for the future industrial infrastructure.

From a technical perspective, Physical AI refers to a paradigm in which AI models the physical world and plans and executes actions while learning causal relationships through interaction. Humanoid robots represent the most advanced application of Physical AI, integrating world models and action generation at the highest level.

The competitive landscape is rapidly intensifying. The United States, leveraging its leadership in AI models and AI-optimized hardware, and China, supported by strong industrial policy and formidable manufacturing capacity, have become the primary drivers of global development. Japan and Europe–longtime leaders in conventional robotics–are also accelerating their participation, contributing to both technological innovation and the exploration of new use cases. At present, the U.S. and China hold a relative lead in product development and scaled deployment: the former through technological superiority, the latter through policy-backed commercialization and mass-production readiness.

This paper examines the evolving global dynamics by focusing on leading emerging players in the U.S. and China. Through case studies of their integrated hardware–software strategies, we analyze the current state of embodied intelligence and identify the next competitive frontiers. Finally, we outline key implications and strategic considerations for industry leaders as physical AI enters its formative stage as a new industrial platform.

*1: **Physical AI**: AI that perceives and judges real-world situations through sensors and autonomously executes tasks through the operation of actuators i.e., in robots.
Embodied AI: AI embedded in a physical body that learns intelligence through interaction with its environment.
Humanoid Robot: A robot with a human-like body that performs tasks autonomously using integrated AI.

2. The Rise of Physical AI: A New Engine of Industrial Transformation

The global robotics market has evolved from traditional industrial robots toward an increasingly diversified and advanced landscape, encompassing collaborative robots (cobots), autonomous mobile robots (AMRs), drones, wheeled humanoids, and fully articulated humanoid platforms (see Table 1).

This evolution has been driven by the convergence of multiple foundations: advances in hardware such as precision components and materials; rapid progress in AI models and robot control software; and the maturation of surrounding ecosystems including talent development, regulatory frameworks, and policy support. Together, these forces are repositioning robots from conventional automation tools into Physical AI – autonomous, intelligent systems that act directly within the real economy and serve as a new engine of industrial transformation.

Table 1 The Evolution of Robots Toward Intelligence and Generalization

Period	Focus	Key Technologies	Representative Products
Before 2010	Fixed-function, task automation	Task-specific automation, no sensors	SCARA robots, industrial robots, AGVs
2010–2025	Intelligent enhancement	SLAM* navigation, motion control	6-axis collaborative robots, AMRs**
2025–2030	Advanced intelligence	Large-scale multimodal models, VLA***, reinforcement learning	Mobile manipulators, wheeled humanoid robots, ToB (for Industrial), humanoid robots
After 2030	General-purpose intelligence	AGI, generalization, high autonomy	ToB/ToC (for consumer) humanoid robots

* **SLAM** : Simultaneous Localization and Mapping. Simultaneous self-localization and environmental mapping.
** **AMR** : Autonomous Mobile Robot.
*** **VLA** : Vision-Language-Action. An AI model that integrates images (vision), text (language), and behavior (action) to enable robots to understand natural instructions and perform tasks autonomously.
Source : Created by the author based on Morgan Stanley (June 16, 2025) "China's Emerging Frontiers: Robotics Unleashed, A New Era"

Morgan Stanley highlights a structural shift at the intersection of AI and the physical economy, noting that the boundary between mobile devices–such as vehicles and drones–and robots is rapidly dissolving. As AI acquires physical capabilities, it is evolving into what can be described as Physical AI. Markets driven by Embodied AI, including humanoid robots, are projected to reach USD 430 billion annually, approaching the scale of the Agentic AI market (USD 490 billion).*2

While Agentic AI is expected to influence a broad range of professions by accelerating the shift toward higher-value work, Embodied AI is likely to have a more direct impact on automation and human labor substitution, even if its effects on overall job structures are relatively narrower.

*2 Morgan Stanley (Jun 2, 2025) "The Robots Are Coming"

From a market perspective, 2025 is set to mark the beginning of mass production of humanoid robots, with global revenues projected to reach USD 3 billion. Market size is forecast to expand to USD 24 billion in 2030, USD 211 billion in 2035, and approximately USD 4.7 trillion by 2050. In China alone, shipments are estimated at 7,000 units in 2025, 114,000 units in 2030, and approximately 2.11 million units in 2035. Across advanced economies, the installed base of humanoid robots is expected to reach 1.2 billion units by 2050.*3

Technologically, advances in AI-driven coordination and autonomy are rapidly expanding application domains. In the near term, the convergence of AI, sensors, and mobility technologies will drive adoption across factories, logistics warehouses, commercial services, and residential environments. Over the longer term, humanoid robots are expected to emerge as the largest category within the robotics market.

Reflecting this market potential, a wide range of players–including major technology firms, startups, established robotics companies, and large manufacturing enterprises–have entered the field, particularly in the United States and China. According to the International Federation of Robotics (IFR), 65 humanoid-focused companies across 15 countries are currently active (covering both legged and wheeled robots, excluding upper-body-only platforms), indicating that the global ecosystem is now rapidly taking shape.*4

Nevertheless, McKinsey reports that most companies remain at the R&D stage. Of the current landscape, 41 firms are engaged in pilot deployments, while only seven companies have reached the early commercialization phase.*5 These seven are split between four U.S. companies and three Chinese companies, underscoring that the emerging humanoid sector is already being led by U.S. and Chinese players, and that competition among this frontrunner group is intensifying.

*3 Humanoid Robot Summit (June 16, 2025) "Morgan Stanley: China's Emerging Frontiers: Robotics Unleashed, the Arrival of a New Era"
*4 IFR (July 2025) "Humanoid Robots: Vision and Reality"
*5 McKinsey (October 15, 2025) "Humanoid robots: Crossing the chasm from concept to commercial reality"

3. Global Leading Players in Action: Case Studies of Integrated Hardware–Software Strategies (U.S. Top 4)

This section examines the development strategies of the seven leading humanoid robotics companies in the U.S. and China, with a focus on the integration of hardware and software. We begin with the U.S. landscape.

In the United States, core robotics capabilities were initially built through government-funded programs led by DARPA and the Department of Defense. Commercialization for civilian markets, however, has progressed mainly through private-sector initiatives.*6 The Association for Advancing Automation has issued the National Robotics Strategy Vision and submitted policy recommendations to Congress,*7 while major technology firms such as NVIDIA, Tesla, Amazon, along with venture capital investors, have driven the rapid expansion of startup activity in the humanoid sector.

According to McKinsey, U.S. companies typically pursue vertically integrated architectures, designing in-house actuators, control systems, and AI stacks.*8 This approach aims to optimize performance and safety while protecting intellectual property, enabling differentiated systems through step-by-step commercialization rather than rapid mass deployment.

Boston Dynamics

Boston Dynamics has long led global robotics R&D with its advanced mobility platforms, including Atlas and Spot. Recently, it has combined classical control with learning-based AI,*9 highlighted by its collaboration with the Toyota Research Institute on Large Behavior Models and reinforcement-learning-based mobile manipulation.*10 Under Hyundai Motor Group ownership, the company is shifting from research leadership toward scalable industrial implementation. While its motion performance and durability remain best-in-class, large-scale commercial deployment is still developing. Meanwhile, at CES 2026, Boston Dynamics unveiled the production-ready version of its humanoid "Atlas," signaling a clear transition from a research-driven phase to large-scale production and commercialization.*11

*6 See IFR (July 2025); Nathaniel Stone (September 5, 2025) "Why Chinese Robotics Firms Like UBtech Are Outpacing Western Competitors in the Humanoid Robotics Race"

*7 A3 (March 26, 2025) "A3 Releases Vision for a U.S.National Robotics Strategy"

*8 See McKinsey (October 15, 2025)

*9 Brian Heater (February 5, 2025) "Boston Dynamics joins forces with its former CEO to speed the learning of its Atlas humanoid robot"

*10 Boston Dynamics Press Release (October 16, 2024) "https://bostondynamics.com/news/boston-dynamics-toyota-research-institute-announce-partnership-to-advance-robotics-research/?utm_source=chatgpt.com"

*11 Boston Dynamics (January 5, 2026) "Boston Dynamics Unveils New Atlas Robot to Revolutionize Industry"

Tesla

Tesla applies its vertically integrated model–refined in electric vehicles–to humanoid robotics through its Optimus program. Powered by large-scale training on its Dojo AI infrastructure and custom actuators, Tesla reuses autonomous driving perception and control software to accelerate robot development.*12 Its end-to-end strategy links data collection, training, manufacturing, and deployment within a single corporate system, targeting mass production and cost scalability. Challenges remain in validation, safety assurance, and real-world operational readiness.*13

Figure AI

Figure AI is rapidly expanding by developing learning-based general-purpose humanoid control built around VLA models*14 while simultaneously establishing high-volume manufacturing capacity.*15 Its pilot deployments at BMW facilities represent one of the first large-scale real-world uses of humanoid robots in industrial production.*16 Strategic integration with major AI partners, including OpenAI, strengthens its high-level cognitive capabilities. Speed of development and scaling is a core advantage, though long-term reliability and operational robustness remain to be fully proven.

Agility Robotics

Agility Robotics specializes in logistics and warehouse automation with its bipedal robot Digit. Focused on practical deployment, it has achieved stable operations with partners such as Amazon using its internally developed control and orchestration platforms.*17 The company emphasizes simplified system design optimized for load handling, floor layouts, safety standards, and warehouse workflows.*18 While highly effective for targeted applications, expanding toward broader general-purpose humanoid functionality remains a future challenge.

Summary of the U.S. Top Four

All leading U.S. players share a strategy centered on vertically integrated development of AI, control systems, and hardware, prioritizing safety, reliability, and intellectual-property protection while advancing commercialization in gradual stages.

- **Boston Dynamics** – Industry benchmark for mobility, control, and durability, while increasingly moving toward mass production and commercialization
- **Tesla** – Mass-production strategy leveraging automotive-scale AI and manufacturing
- **Figure AI** – Fastest path to commercialization via VLA-driven general-purpose platforms
- **Agility Robotics** – Application-specific deployment leader in logistics automation

This "cautious vertical integration and reliability-first approach" stands in clear contrast to the rapid deployment and ecosystem-driven expansion strategies pursued by leading Chinese players, discussed in the following section.

*12 See McKinsey (October 15, 2025)
*13 See Nathaniel Stone (September 5, 2025)
*14 Figure (February 20, 2025) "Helix: A Vision-Language-Action Model for Generalist Humanoid Control"
*15 Figure (March 15, 2025) "BotQ: A High-Volume Manufacturing Facility for Humanoid Robots"
*16 BMW (November 9, 2024) "Humanoid Robots for BMW Group Plant Spartanburg"
*17 Marcus Law (April 03, 2025) "Advances in AI: Enhancements to Agility's Digit";
The Robot Report (September 14, 2025) "Agility Robotics explains how to train a whole-body control foundation model"
*18 See McKinsey (October 15, 2025)

4. Comparing U.S. and Chinese Leaders: Competitive Structures and Strategic Implications

Chinese Emerging Leaders – Case Studies (Top 3)

Following the U.S. case studies in Chapter 3, this section examines three leading Chinese humanoid developers already advancing into large-scale manufacturing and early commercial deployment: **UBTECH, Unitree, and AGIBOT**. Their strategies emphasize rapid integration of technology and production to accelerate market entry.

UBTECH

UBTECH[*19] operates as a full-stack humanoid developer integrating proprietary AI software, control systems, and in-house hardware design. Its robotics framework ROSA (Robot Operating System Application) enables end-to-end integration of multimodal perception, SLAM-based navigation, and LLM-linked task planning through its own platform BrainNet + Co-Agent.

On the hardware side, UBTECH internalizes actuator development, lightweight high-rigidity structures, and high-DOF joint design (over 50 degrees of freedom), targeting both scalability and durability. A vertically integrated supply chain and a patent portfolio exceeding 2,400 filings support its production ambitions.

Commercially, UBTECH has begun industrial deployments, including multiple Walker S1 units operating at Zeekr EV factories, and secured large manufacturing orders slated for delivery with the battery-swapping Walker S2 model. While its industrial positioning is the most advanced among Chinese players, challenges remain around system complexity, cost control, and long-term operational reliability that must be validated at scale.

UNITREE

Founded in 2016, Unitree[*20] expanded from quadruped robots into humanoids and manipulators, building a broad product portfolio including the industrial H1, educational G1, and low-cost R1 series, as well as the wheeled G1-D variant. In 2024 humanoid shipments reached approximately 1,500 units, supported by government-backed manufacturing expansion in Hangzhou.

Unitree's core competitive edge lies in its extraordinarily high internalization of components–more than 90% of motors, reducers, drivers, sensors, and control boards are developed in-house–giving the company unmatched cost competitiveness and production speed. Its AI platform UnifoLM leverages reinforcement learning, complemented by UniTracker full-body motion training for fluid locomotion.[*21]

However, compared with higher-end rivals, payload capacity, safety certification, and durability remain limited. Current deployments concentrate on research, education, and entertainment rather than industrial missions. The depth of its cognitive AI stack, including LLM[*22] capability, is also still evolving.

*19 UBTECH https://www.ubtrobot.com/en/about/company-profile
Arendse Huld (April 7, 2025) "Investing in the Future: Opportunities in China's Humanoid Robotics and Embodied AI Industry"
*20 Unitree Robotics https://www.unitree.com/about
*21 百态老人 (May 28, 2025) "UnifoLM (Unitree Robot Unified Large Model) 技术架构解析" (Chinese)
*22 Reuters (July 25, 2025) "China's Unitree prices new humanoid robot at deep discount to 2024 model"

AGIBOT

Established in 2023, AGIBOT[*23] differentiates itself through a software-centric approach focused on human–robot interaction and autonomous decision-making. Its self-developed Embodied Intelligent Brain architecture–combining cloud and on-robot processing layers–is integrated with the multimodal LLM WorkGPT, enabling intent recognition, task adaptation, and dynamic environmental awareness.

AGIBOT's product lineup includes the service-oriented A2, targeting customer engagement and reception tasks, and the general-purpose RAISE A1, used in education and applied research. In 2025, the firm announced the wheeled humanoid G2 for manufacturing applications in partnership with industrial integrator Junpu Intelligent. Current production capacity has reportedly reached roughly 3,000 units annually, with more than 1,000 units already manufactured, marking one of the fastest commercialization ramps in the sector.

Summary – Chinese Strategic Pattern

The strategies of the Chinese leading trio share common themes:

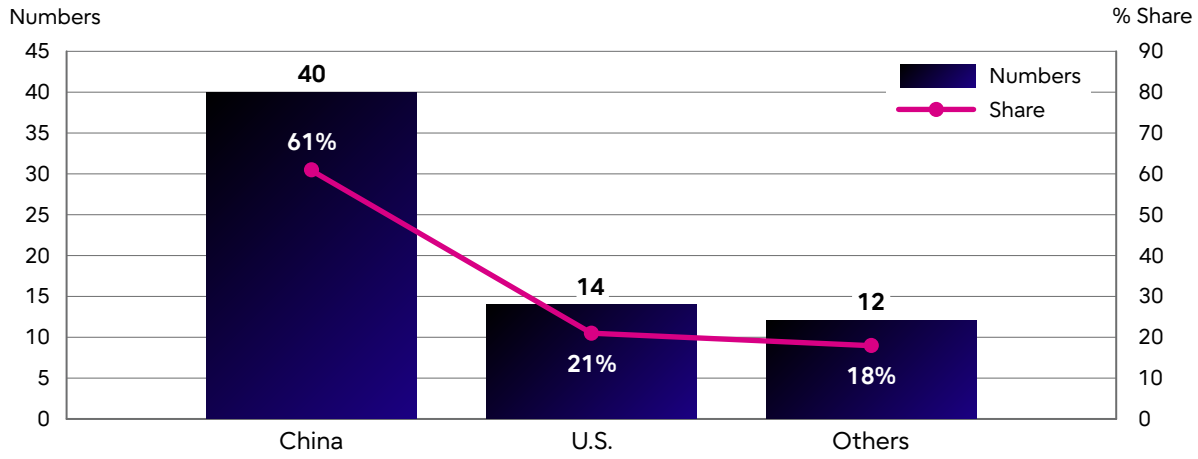
- UBTECH focuses on vertically integrated full-stack development to push early industrial deployment.
- Unitree prioritizes extreme cost efficiency and scale, flooding the market with accessible humanoids for education and service domains.
- AGIBOT leads with AI-first architectures centered on human interaction and cognitive autonomy.

Summary of Leading U.S. and Chinese Humanoid Strategies

Chinese players have established an early commercial presence by rapidly deploying multiple models. UBTECH, UNITREE, and AGIBOT closely collaborate with domestic supply chains and leverage open innovation across both hardware and software, prioritizing speed of deployment and market penetration. However, challenges remain in safety validation, long-term durability, stable autonomy, and ROI verification at operational scale. Their approach can be characterized as an "implementation-first model," where commercialization precedes full technical maturation.

*23 See Arendse Huld (April 7, 2025)

Figure 1 Humanoid Robots Unveiled by Country (2022–2024)



Source: Created by the author based on data from Morgan Stanley (February 6, 2025) "The Humanoid 100: Mapping the Humanoid Robot Value Chain"

In contrast, U.S. leaders pursue a vertically integrated model, building proprietary stacks across actuators, control systems, and AI. By minimizing supplier dependence and retaining full system ownership, they aim to optimize performance, enhance safety, and establish defensible intellectual property positions. Against the backdrop of rapidly increasing Chinese patent activity,[*24] U.S. firms emphasize differentiation through closed, integrated architectures and IP protection. Their commercialization follows a "validation-first path," advancing cautiously through phased deployment and rigorous testing.

This contrast between China's speed-driven market expansion strategy and the United States' vertically integrated, reliability-focused approach defines the core competitive structure of the emerging humanoid robotics industry (see Table 2).

*24 Rieko Tsuji (March 27, 2025) "Humanoid Robots –Technological Advancements Driven by Generative AI and the Launch of Pilot Programs–"; Morgan Stanley (February 6, 2025) "The Humanoid 100: Mapping the Humanoid Robot Value Chain"

Table 2 Leading U.S. vs. Chinese Humanoid Robotics Companies: Strategic Comparison

Company	Key Features & Strengths	Strategy & Commercial Approach
Boston Dynamics	• High mobility, reliability, and durability • Reinforcement learning & large behavior models for "intelligent body + general behavior"	• Vertical integration of control, AI, and hardware for optimized performance • Gradual commercialization, focused on practical industrial applications • Research-driven, with a transition toward mass production and commercialization
Tesla (Optimus)	• Production-oriented with AI integration, leveraging vehicle AI assets • Vertically integrated actuators and control, aiming for general-purpose tasks	• Scale-driven strategy using large data sets for learning optimization • Stepwise demonstration targeting factories and daily task applications
Figure AI	• Agile tech innovation and mass production with BotQ facility • Promotes practical deployment of general-purpose robots, flexible across applications	• Mass-production focus and early market entry via commercial contracts • Integrates learning-based control for broad applicability
Agility Robotics	• Proven operational performance in industrial applications • Legged format and stable operation platform for real-world use	• Optimized for specific use cases with internal software integration plus outsourced manufacturing • Gradual deployment in warehouses/ logistics; limited general-purpose capability
UBTECH	• Full-stack integration: AI/control & hardware, 50+ DOF joints, long operation time • Strong IP portfolio, R&D capability, and industrial deployment track record	• Vertically integrated from development to production, adaptable to industrial facilities • Leverages government/local support for early adoption and scaling
UNITREE	• Over 90% core components developed in-house, cost-efficient mass production • Flexible motion control via UnifoLM AI platform, multi-purpose model offerings	• Accelerates market penetration via low-cost mass production and multiple model releases • Focused on research, education, and service markets for early deployment
AGIBOT	• Multimodal LLM-based "Embodied Intelligent Brain" enabling autonomous task execution • Designed for interactive services, rapid scaling of production capacity	• Utilizes external manufacturing capacity for rapid scale-up • Expands commercial services and international exports

Source: Author's compilation and creation

Key Insights from the Global Humanoid Market: Strategic Implications from the U.S. – China Comparison

(1) Divergent Development Philosophies Shape Competitive Advantage

Chinese firms leverage broad supplier networks and rapid development cycles to pursue "Multi-model launches × rapid commercialization × low-cost scaling." Companies such as UBTECH and Unitree expand share through open ecosystems and ecosystem-driven scale advantages. However, questions remain around long-term reliability, safety validation, and operational stability.

U.S. players emphasize vertical integration and proprietary AI–control–hardware stacks, prioritizing performance, safety assurance, and IP protection. Tesla and Boston Dynamics pursue phased commercialization, enabling disciplined risk management but often delaying scale-driven cost advantages.

(2) AI Integration Is the Core Competitive Frontier

Across both regions, the decisive battleground is the integration of learning-based control with multimodal AI.

- China: AGIBOT's multimodal LLMs and reinforcement-learning platforms at UBTECH and Unitree accelerate gains in autonomy and task generality.
- U.S.: Figure AI's learning-based control, next-generation VLA models such as Helix, and reinforcement learning programs at Boston Dynamics–often supported by external research partnerships–advance large-scale behavioral modeling.

Globally, competitive differentiation increasingly hinges on AI integration capability and control-stack maturity.

(3) Speed-to-Market vs. Reliability: A Structural Trade-off

- China: A "rapid launch × frequent iteration" lean strategy, using market deployment as the primary learning loop.
- U.S.: A "phased deployment × vertically integrated development" model, prioritizing safety, validation, and durability.

This defines a fundamental industry trade-off between "fast implementation and volume scaling" versus "reliability, safety, and long-term system value."

Going forward, the winning formula is likely a hybrid strategy–combining rapid iteration with selective vertical integration of critical subsystems–balancing market speed and operational trustworthiness.

Global Expansion of Humanoid Robot Development and Deployment

Since 2022, the number of publicly announced humanoid robots has increased not only in the U.S. and China but also across Europe, Japan, Canada, and South Korea, reaching levels comparable to those in the United States. Notable players such as 1X Technologies (Norway), Neura Robotics (Germany), and Toyota Research Institute (TRI) (Japan) have emerged as globally recognized contributors to humanoid development.

On the adoption side, leading automotive manufacturers including BMW and Mercedes-Benz are actively conducting proof-of-concept (PoC) deployments of humanoid robots. In Japan, the government is investing in generative-AI foundations and data platforms for robotics, with AIST and NEDO leading the development of foundational models and datasets. On the corporate side, Fujitsu is advancing the development of embodied AI–related World Models,[*25] for spatial understanding and multi-robot coordination, while expanding its strategic collaboration with NVIDIA.[*26] In addition, the three companies have initiated discussions on joint collaboration toward the societal deployment of Physical AI by integrating AI robotics technologies from industrial robotics leader Yaskawa Electric. Together, these developments signal a steady expansion of large-enterprise–led initiatives in this domain.

*25 Fujitsu (December 2, 2025) "Fujitsu develops new technology to support human–robot collaboration Spatial world model helps robots assess spatial dynamics and react appropriately"

*26 Fujitsu (October 3, 2025) "Fujitsu expands strategic collaboration with NVIDIA to deliver full-stack AI infrastructure"
As a result, Fujitsu have developed and launched "Fujitsu Kozuchi Physical AI 1.0"

5. State of Embodied Intelligence and the Next Competitive Frontier: VLA, Hierarchical Policies, and Control Architectures

The competitive frontier of embodied AI is rapidly converging on high-level control–namely, the depth of AI integration that combines world models and causal reasoning to robustly plan and execute actions under changing environments–and mid-level control. LLMs are becoming commoditized, while low-level control draws on industrial-robot technologies, offering limited differentiation. True generality–and thus true competitiveness–will be defined by intelligence built around VLA models, and ultimately by world models capable of prediction, adaptation, and continuous self-updating (See Table 3). The degree to which companies can integrate complex environment understanding, generalized manipulation skills, and situational adaptability will determine not only competitive advantage but also the early practical deployment of humanoid robots. This, in turn, positions humanoids as a foundational driver of industrial and societal transformation, shaping future investment priorities and strategic decisions.

Table3 Embodied AI Intelligence Stack: A Three-Tier Conceptual Map

Layer (Perspective)	Humanoid Intelligence & Control	Leading Company Examples	Human Intelligence & Control (Intuitive Analogy)
High-Level Control (Intent, Goal Setting, Task Planning)	When a VLA model incorporates LLM-level capabilities: task understanding, plan generation, and context-aware reasoning	• Figure (OpenAI aligned) • Tesla Optimus (future roadmap) etc.	Cerebrum: Meaning understanding, planning, decision-making
Mid-Level Control (Motion Planning, Spatial Reasoning, Skills)	VLA Latent / Action Policies: Spatial perception, object manipulation planning, multi-step skill execution, trajectory generation	• Agility Robotics (Digit skill policy) • Tesla (motion planning stack) etc.	Motor-related cortical regions: spatial perception, motion plan generation, and coordinated actions.
Low-Level Control (Real-Time Motor Execution, Stability)	Servo torque control, balance maintenance, real-time control loops: Gait stabilization, force modulation, reflex-like responses.	• Boston Dynamics (high-performance dynamic control) etc.	Cerebellum & spinal system: Fine adjustments, posture control, reflexive actions

Source: Author's compilation and creation

Software Control Stacks of Leading Humanoid Players (U.S. and China)

Table 4 provides an overview of the humanoid control software stacks adopted by seven leading U.S. and Chinese companies. Their respective software strategies can be summarized as follows.

Boston Dynamics

A leading pioneer in embodied intelligence, Boston Dynamics combines high-precision MPC and torque control with learning-based approaches. The company pursues generality through diffusion models and advances high-performance VLA development via joint research on Large Behavior Models (LBMs) with Toyota Research Institute (TRI). Strategically partnered with Google DeepMind, integrating the Gemini Robotics foundation model into the new Atlas.

Tesla

Tesla is developing mass-producible general-purpose intelligence by training proprietary multimodal LLMs and VLAs on large-scale datasets, integrating imitation learning and reinforcement learning to achieve vision-driven autonomy.

Figure AI

Figure AI leverages state-of-the-art LLMs from OpenAI for high-level cognition and connects language directly to action through its proprietary Helix VLA. The company prioritizes rapid implementation with a strong focus on embodied intelligence.

Agility Robotics

Agility Robotics concentrates on whole-body control foundation models and MPC, emphasizing walking stability and task reliability. Its strategy reflects a pragmatic, operations-oriented approach aimed at real-world deployment.

UBTECH

Centered on its ROSA platform, UBTECH integrates multimodal perception, LLM collaboration, and VLA-based control. The company aims to standardize humanoid intelligence stacks and scale industrial applications as a comprehensive system provider.

Unitree

Unitree emphasizes scalable whole-body motion intelligence through UnifoLM (VLA-equivalent), reinforcement learning, and UniTracker-based imitation learning. Its strength lies in combining physical performance with mass-production capabilities to rapidly deploy "action-ready intelligence."

AGIBOT

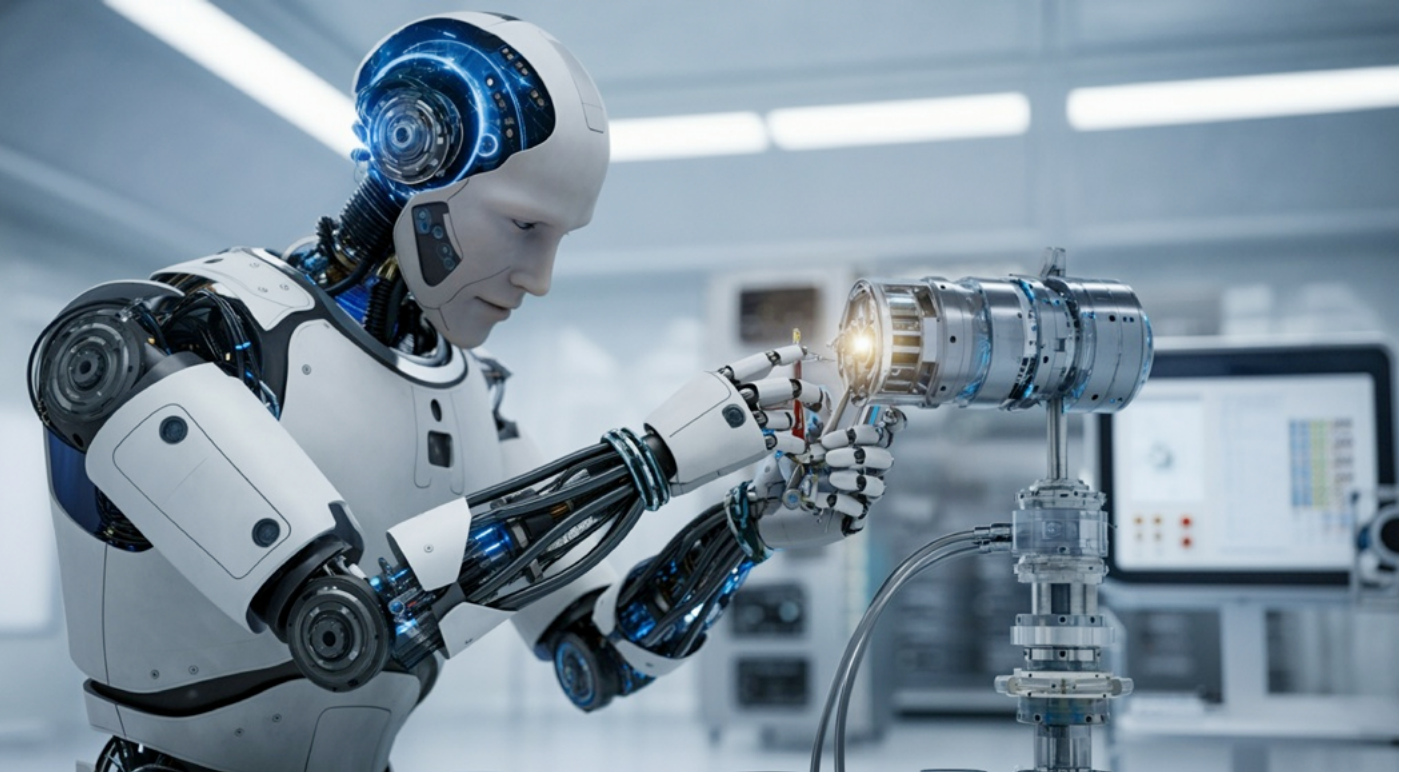
AGIBOT is advancing one of the most AGI-oriented architectures, building an integrated "Embodied Brain" composed of WorkGPT, world models, and multi-layer VLAs, targeting tightly unified cognition and action.

Table 4 Humanoid Control Software Stacks: An Overview of the Leading U.S. and China Players

Company	High-Level (Cognition & Planning)	Mid-Level (Policy / VLA)	Low-Level (Motor Control)
Boston Dynamics[*27]	• Rule-based & limited VLM • A new way of thinking based on Diffusion Models, not LLM • Strategic partnership with Google DeepMind; Gemini Robotics integrated into the new Atlas	• Learned behavior primitives • Joint development of LBM with TRI, etc.	MPC (Model Predictive Control), etc.
Tesla[*28]	In-house multimodal LLM	Horizontal expansion of the car model Dojo, Vision-driven VLA + imitation learning & RL	Whole-body Control/ real-time control
Figure AI[*29]	OpenAI-powered LLM cognition & task planning	Helix VLA: end-to-end language-vision-action policy	In-house whole-body & grasp stabilization
Agility Robotics[*30]	Rule-based planners & basic VLM + LLM	Whole-body foundation model + MPC	Dynamic walking & balance control
UBTECH[*31]	ROSA + BrainNet platform with LLM integration	Multimodal VLA policy execution	Coordinated whole-body motion control
Unitree[*32]	Partial multimodal LLM integration	UnifoLM (VLA-equivalent) + RL & UniTracker imitation learning	Ultra-fast torque control & gait optimization
AGIBOT[*33]	WorkGPT multimodal LLM + world model	"Embodied Intelligent Brain" layered VLA	Whole-body stability & force-feedback control

Source: Created by the author based on various sources

*27 Boston Dynamics "Large Behavior Models and Atlas Find New Footing";
Vlad Larichev "Boston Dynamics just revealed how their new humanoids think – not with LLMs, but with Diffusion Models"
*28 Tesla "AI & Robotics"; Humanoid Robotics Technology "Tesla Unveils Ambitious Optimus Humanoid Roadmap";
Lauren Edmonds and Lakshmi Varanasi (September 8, 2025)
"The story of Optimus, the humanoid robot at the heart of Elon Musk's growth plans for Tesla"
*29 See note 13
*30 Agility "Meet DIGIT", "Training a Whole-Body Control Foundation Model",
Marcus Law (April 03, 2025) "Advances in AI: Enhancements to Agility's Digit"
*31 UBTECH "Core Technology"; Aaron Saunders "2026 Humanoid Robot Market Report: UBTECH' Walker S2"
*32 See notes 19, 20, and 21
*33 See Arendse Huld (April 7, 2025)



Strategic Implications: U.S. vs. China

Overall, U.S. players are enhancing humanoid generality by tightly integrating next-generation AI models–such as LLMs and diffusion models–while accelerating the development and industrialization of high-performance VLAs. In addition, strategic collaboration with major technology firms, including NVIDIA (advanced chips and VLA frameworks), OpenAI (frontier LLMs), and Google DeepMind*34 (Gemini Robotics and Gemini Robotics-ER), provides strong support for both embodied reasoning (ER) models and execution-focused VLA development.

In contrast, Chinese players emphasize the "OS-ification" of humanoid platforms and the scalable deployment of embodied intelligence. While collaboration with large domestic tech firms is less prominent, strong partnerships with leading universities, public research institutions, and specialized embodied AI startups–such as those seen with UBTECH, AGIBOT,*35 and Unitree*36–are actively pursued. This reflects a software strategy that also strongly favors open innovation.

*34 Humanoids Daily (September 26, 2025) "Google DeepMind Gives Robots a 'Thinking' Brain with Agentic Gemini 1.5 Models"
*35 AGIBOT "Agibot×Physical Intelligence: Co-Advancing the Frontier of Embodied Intelligence"
*36 A-Bots.com "A-Bots.com is Your Unitree R1 Software Partner - Unitree R1 Programming"

6. Implications for Industry and Vision: How Humanoids Will Reshape Future Business Models

While this paper has focused primarily on leading humanoid players in the United States and China, recent years have also seen significant advances across Europe, Japan, Canada, and other regions. Japan and Europe, in particular, possess world-class industrial foundations in factory automation, motors, actuators, and control systems, as well as deep expertise in safety-critical design and system integration. Pilot deployments by leading European automakers and Japan's public investment in AI and robotics infrastructure highlight this latent potential.

At present, however, initiatives in Japan and Europe remain largely government- and incumbent-led, with comparatively limited momentum in startup-driven experimentation, rapid iteration, and large-scale commercialization. The comparison of the U.S. and Chinese top seven firms makes clear that progress in humanoid robotics is being driven by a powerful combination of learning-based control, startup-led development, and speed to market. The central challenge for Japan and Europe is therefore to fuse their strengths in precision engineering, reliability, and safety with the agility and execution speed required in the AI era.

Humanoid robots should not be viewed merely as tools for labor substitution. They represent a strategic platform capable of redesigning industrial structures themselves. As humanoids are deployed across manufacturing, logistics, maintenance, healthcare, education and social infrastructure, countries that achieve early and scalable adoption will build the foundations of next-generation industrial competitiveness. This future will not arrive by default. It will be shaped by today's policy choices, investment priorities, and industrial strategies. In this sense, humanoids are not only a technological frontier, but a decisive test of how societies choose to compete, collaborate, and lead in the coming industrial transformation.

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Dr. Jianmin Jin, who integrates expertise in both engineering and social sciences, leads thought leadership initiatives from a global and business-oriented perspective. Focusing on digital economy, digital innovation, and corporate transformation in the age of AI, Dr. Jin provides business leaders with fresh perspectives and actionable insights through research-based publications, media contributions, speaking engagements, and consulting activities.

- The Maritime Industry's Next Frontier: AI Agents Driving Autonomy (November 2025)
- Generative AI to Agentic AI: The Next Leap in Business Transformation (October 2025)
- Transforming the Digital Core in the Age of Generative AI —From Modernization to Value Creation— (October 2025)
- Reimagining Fashion Retail with Generative AI: Toward an AI-Native Integrated Platform Strategy (September 2025)
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- AI Agents and the Pathway to Evolving Intelligent Manufacturing (June 2025)
- Creating a Virtuous Cycle of Transformation and Trust: A Future Strategy Powered by AI and Net Positive Thinking (June 2025)

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