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Embodied AI (Robot-LLM Integration)

A Review of the Large Language Model Embodiment into Embodied Robots

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Abstract: This paper provides a comprehensive review of Embodied AI. I am writing this because it seems like the next significant trend in AI is the move away off-screen into the real world. Embodied AI implies that the brain of the robot is not a spreadsheet but the information obtained in its body is analyzed and then acted upon in reality. In this paper, 50 of the latest studies are pulled out in which individuals plug in Large Language Models (LLMs) and Multimodal Foundation Models directly into the robot hardware.

We divided the review into two sections, the technical grind (how robots plan and manage things they do not know about) and the human one (ethics, social robots, and greener optimizing automation). It happens that the majority of researchers have come to think of LLMs as the so-called high-level brain, which converts human speech into motor commands in the form of Behavior Trees and In-Context Learning. However, we are yet to nail safety, jailbreaking, and the maniacal energy prices.

Index Terms **-** Artificial Intelligence, Embodied, Large language model, Robot-LLM.

1) Introduction

What is Embodied AI?

Embodied AI (E-AI) is fundamentally the antithesis of such silent, data-driven models which are simply present within a computer. E-AI concerns more than the encumbance of a model that is merely displayed in a text box, and it is more about the robots touching and moving around robots as they learn more about their surroundings. Conventional LLMs are occupying a digital anomie, whereas E-AI creates a close circle in which sensing, thinking, and acting are all connected together. In this case, the body of the robot is not simply a tool but actually a legitimate source of the information according to which the AI perceives the reality.

How We Got Here

Robotics have long been in solid, preset reasoning. Those archaic systems were glued together with recurrent tasks, but disintegrated in the event of an unforeseen occurrence. This was altered with the coming of Foundation Models and Transformers. We suddenly now had a brain that could cross-generalize over a set of tasks. We went off-screen to off-scene - off into artificial intelligence and into people and places. That possible jump happened through multimodal learning, and allowed a robot to finally see, touch and talk and work like a natural human being.

What This Review Covers

I have divided the analysis into 2 main pillars:

Pillar A: Technical Structures - we consider memory structures (such as KARMA), task validation (VerifyLLM), and applications in the eye surgery and fish farming fields.

Pillar B: The Human Element - concentrates on Industry 5.0, the ethical minefield of healthcare robots, and the environmental cost of running such massive AI systems, in terms of carbon embodiment.

2) Procedure of the Research

Where we searched and why

I maintained its scholarly strength through having made well-organized search in IEEE Xplore, SpringerLink, and ScienceDirect (Elsevier). These are the place to go hubs in robotics, engineering and CS. The search scope was limited to the 2020-2026 period to be up to date with the booming LLM in physical robotics.

Some of the keywords that were used along with Boolean logic were;

- “Embodied AI (alternatively, Embodied Intelligence) and Large Language Models (LLM).
- “Robot Manipulation/Navigation/ Foundation Models.”
- Human-Robot Collaboration (HRC) with a subject area of “Safety or Ethics.

Organizing the data

After selecting the papers, I mapped them according to focus and robot type (four-legged quadruped, soft robot, or social robot) and technical breakthrough. That made me understand how exactly LLMs transform a high-level thinking into actual movement.

3) The Overall Results:

It is not only the move to make robots more akin to LLM but actually giving them common sense rather than speech. Having sorted through 50 major studies, I found three main categories into which I sorted the results: the technical brain structure, special physical forms and the nature of interaction with humans of these machines. One of the largest obstacles is the transformation of human expression such as clean the kitchen into its small and accurate motor skills that a robot should have. The new connective tissue to this process is becoming behavior Trees (BT) and In-Context Learning (ICL). Embodiment does not simply refer to the use of robots that resemble humans. The study includes a wild plethora of shapes and sizes which require various senses. Since the robots will not inside the factories but will enter our lives, their complete autonomy will become a thing of the past, and instead, the robot should be made human.

The Modern Factory: In industry 5.0, robots are not replacements, but an aid. This time around, the skills are acquired through demos with the use of LLMs, which assists in the difficult jobs such as aerospace wiring. Healthcare Ethics: The Prospect of AI in hospitals making things go through the screen would then beg the question. Scientists are now identifying ways of ensuring that social robots are amiable and helpful without being misleading or harmful to the patients.

4) Comparative Synthesis Table

The table below gives thematic comparison of major methodology that have been used in the literature reviewed.

Part A
Technical Foundation (Perception, Memory, Security)

SrNo	Primary Domain	Embodiment Type	Core Technology	Key Contribution
1	Robotics / AGI [1]	General Manipulators	Systematic Review	Examines the definition and fundamental problems of embodied manipulation
2	Robot Autonomy [2]	Robotic Arms	Multimodal Vision-Language Models (VLM)	Discusses perception, decision-making, and control foundations
3	Robotic Manipulation [3]	Object-centric Robots	Incarnate Perceptual & Policy Learning	Organizes the recent developments in physical environment interaction
4	Cognitive Science [4]	General Al Agents	Interaction-based Feedback	Believes that the first-person experience allows a subjective level of knowledge
5	Healthcare / Medicine [5]	Surgical/Diagnostic Robots	Perception-Action Cycle	Gives real-time perceptions to agents to diagnose and even operate on patients
6	Sociology / Al Ethics [6]	Digital Twins	Representation Models	Thought-provoking exploration of the digital twin embodiment as a feminist perspective
7	Aquaculture / a lot [7]	Fish Control Systems	RAG-LLM + Deep Q-Network (DQN)	The initial adoption of an ensemble model in autonomous aquaculture
8	Multi-agent Systems [8]	Multi-robot Explorers	Single-shot Learning Few-shot Learning	Uses the LLM to add search and exploration functionality to a cluster of robots
9	Human-Robot Interaction [9]	Social Robots (Mobi)	State-space Realization / GPT-4	Imitates human personality characteristics, such as emotion and motivation
10	General Robotics [10]	ELLMER Framework	Retrieval - Augmented Generation (RAG)	Allows one to complete long-horizon assignments in unforeseen environments
11	AGI / Mechatronics [11]	Cyber-Physical Agents	Multimodal Large Models (MLM)	A survey of bridging digital and physical name space
12	Household Tasks [12]	Embodied Agents	Dual Memory (Long/Short Term)	Enhances the performance of task of index length sequences through hierarchical 3D scene graphs

13	Vehicular Networks [13]	Autonomous Vehicles (AV)	Generative Diffusion / Contract Theory	Inter- roadside unit real-time AI twin migration efficiency
14	Cybersecurity [14]	LLM-Controlled Robots	ROBOPAIR Algorithm	Discloses that physical damage can happen in the real world as a result of gathering an LLM jailbreak
15	Robotic Manipulation [15]	General Manipulators	LLM-guided 3D Policy	Gives a point to the vision-language grounded tasks, which they can know
16	Robot Programming [16]	General Robots	In-Context Learning (ICL)	Conversion of language into motor action without fine-tuning, task-specific motor actions
17	Social Robotics [17]	Misty Social Robot	Multi-Agent LLM / Code Gen	Takes converting commands into executable robot code self-reflectively into loops of self-reflective loops
18	Task Planning [18]	General Robotics	LLM Verification Layer	Performs automated safety and altitude tests prior to the advancement of the physical process
19	Quadrupedal Robotics [19]	Quadruped Robots	Hierarchical LLM Cascade	Has both high and low level semantics, and solid low level locomotion
20	Healthcare / Biomedicine [20]	Clinical Agents	Basic Algorithms of EmAI Algorithms	The perception, planning, and memory surveys, medical surveys are pertinent
21	Human-Robot Interaction [21]	Smart Gloves (Ti-EAI)	Nanogenerators based on triboelectric principles (TENGs)	Applies gestures as a teaching interface to robot imitation learning
22	Sustainability [22]	Global Production Chains	Econometric Analysis	Examines the impact of AI development upon embodied carbon in the production updating
23	Theoretical Robotics [23]	Codes and Robots	Information Theory / Entropy	Offers the body as an information flow channel of communication to the body
24	Navigation [24]	Mobile Robots	Marking in Advice Electronic Traffic Conflict Solutions	Applies LLMs in creating efficient navigational strategies in tricky scenes it is a cool technology to use
25	Industrial Assembly [25]	Collaborative Robots	Mixed Reality (MR) + DRL	Converts instructions to collaboratively assembled reward functions

Part B
Applications and Impacts (Industry 5.0, Sustainability, Ethics).

SrNo	Primary Domain	Embodiment Type	Core Technology	Key Contribution
1	Soft Robotics [26]	Flexible Electronic Robots	Programmable Sensing/Actuating Thin-film	Commanding flexible electronics with self-education power
2	Navigation [27]	Mobile Agents	Multi-modal Learning	Investigates strategies of navigating physical environments
3	Embodied [28]	Autonomous Systems	Synthetic/Virtual	Generates training data of real-world streetscapes locomotion
4	Civil Engineering [29]	Substation Buildings	Carbon Life-cycle Analysis	Looks at the environmental impact of building material
5	Cognitive Science [30]	Human-AI Systems	4E Cognition Theory	Discusses philosophical and interactive evolution of AI
6	Robots [31]	discriminatory	Risk Analysis using LLM driven approach	Highlights the Legal and violent risks of unrestrained actions of LLM
7	AI Architecture [32]	General Robotics	critical analysis	critical analysis of transformers as a foundation of robotic logic
8	Automation [33]	Software development	Generates software used in robotics	Increase Development of software Automation Systems
9	Healthcare Ethics [34]	Social Robots	Deceptive Pattern Detection	Investigates the problem of ethical risks and deception emerging in social robotics
10	Manufacturing [35]	Human-Centered Robots	Smart Manufacturing Framework	Links AI to human operators in smart factories
11	Extended Reality (XR) [36]	Agents	LLM Integration	Enhances Productivity In Virtual/extended reality spaces
12	Industrial AI [37]	Manufacturing Systems	Adaptive Architecture	Gives new opportunities in tailored industrial production
13	Materials Handling [38]	Crafting Robots	Large Language Models	Can allow robots to manipulate and create complex on the easiest to create and manufacture elasto-plastic objects
14	General Robots [39]	Behavior Tree (BT)	Uses LLMs to generate modular and hierarchical task plans	Behavior Tree (BT) Task Planning uses LLMs to plan tasks in behavior trees

15	Multimodal HRI [40]	Human-Robot Systems	Multimodal Human Demos	Lets robots fix and replan actions on human video demos
16	Robot Programming [41]	Manipulation Robots	LLM-guided Expansion	Expands a behavior tree logic in an automated way to be manipulated
17	Multi agent framework [42]	manipulations robots	Zero-shot learning	Task completion with no prior training
18	Safety [43]	Robot Agents	Safety-constrained Planning	Makes the best use of task plans Safety-constrained Planning
19	Virtual Reality [44]	VR AI Agents	Similarity-matching	Studies the pattern of AI agents following human health behaviors in VR
20	Economics/Energy [45]	Digital-Real Systems	Using AI to Beat Progress	Analyzes digital-real integration of energy efficiency
21	Sustainability Buildings [46]	CECA	carbon footprint	carbon footprint in construction of smarter buildings An intelligent, LLCM-based Sustainability Buildings Architectural ELM
22	General Robotics [47]	Survey/Review	Holistic LLM Analysis	Discovers future vistas and obstacles to the field
23	Aerospace [48]	2 Cycle Assembly Robots	Autonomous Agent Logic	Provides Aerospace 2 Cycle Assembly Robots Autonomous Agent Logic Provides Aerospace 2 Cycle Assembly Robots
24	LLM Collaboration [49]	Collaborative Robots	Dynamic Knowledge Bases	Enhances adaptive solutions to human-robot assembly
25	Intelligent Embodied Design [50]	AR and GAI Systems	intelli-embodied Design	Explores conceptual design with AR and Generative AI

5) Conclusion:

So having plunged into 50 articles in the sphere of the most influential papers, it is made of crystal material that the gap between the Large Language Models and the physical robotics is now officially nailed. What once used to be a cool theory, now literally it is a reality and is a working reality that is assisting in addressing challenges in surgical suites as well as aerospace factories.

Nevertheless, the actual lesson is that whilst LLMs provide the robot with its brain to do intricate reasoning, the actual physical form, the hardware, the physical security, and the physical reliability, still require extensive hard engineering. In the transition to Industry 5.0, it is not going to be as simple as the level to which our robots are improved, or even the extent to which they are smart or autonomous. It is the correct balance between safety, ethical and true cooperation of a person and robot, which makes the real win in the design.

6) References

[1] Zhao, W. and Yuan, Y. 2025. Embodied intelligence is the means by which a robot manipulator is carried out. SPRINGER: 1-37.
[2] Li, J., Xu, Z., Li, N., et al. 2025. AI-embodied multi-modal flexible electronic robots with programmable sensing, actuating and self-learning. SPRINGER: 1-10.
[3] Huang, S., Wang, H., Zhou, X., et al. 2025. Advancing general robotic manipulation with multimodal foundation models: An embodied AI paradigm. SPRINGER: 1-3.
[4] Gopinathan, M. 2025. Embodied navigation. SPRINGER: 1-39.
[5] Zheng, Y., Yao, L., Su, Y., et al. 2025. Survey of Embodied Learning Surgery Object-centric Robot Manipulation. SPRINGER: 1-39.
[6] Sorkhoh, A. J., et al. 2025. Sidewalk2Synth: creating synthetic embodied locomotion in real-world streetscapes. SPRINGER: 1-36.
[7] Loftus, J. C. 2025. Survey: Will Embodied AI Become Sentient? Extended Abstract. SPRINGER: 1-5.
[8] Chen, X., Gao, X., Lu, K., and Deng, X. 2025. Embodied carbon costs of prefabricated substation buildings. SPRINGER: 1-21.
[9] Qiu, Y., Chen, X., Wu, X., et al. 2025. Embodied artificial intelligence in ophthalmology. SPRINGER: 1.
[10] Benvenuti, M. C., et al. 2025. 4E cognition and the coevolution of human-AI interaction. SPRINGER: 1-19.
[11] Abbey, S. K. 2025. My more than human digital twin: embodiment, feminist AI and the representation mine. SPRINGER: 1-15.
[12] Ribeiro, M. T., et al. 2025. LLM-Driven Robots risk executing discrimination, violence, and unlawful acts. SPRINGER: 1-49.
[13] Danvirutai, P., Charoenwattanasak, S., et al. 2025. Intelligent fish control systems using an integrating RAG-LLM and deep Q-network. SPRINGER: 1-16.
[14] Marshall, J. A. R. and Barron, A. B. 2025. Are transformers truly foundational for robotics? SPRINGER: 1-6.
[15] Zhang, H., et al. 2025. LLM enhanced metaheuristics with single shot and few shot learning in multi-robot exploration problems. SPRINGER: 1-35.
[16] Chen, K., Wang, T., Ni, M., et al. 2025. Collaborative LLM agents to develop intelligent robot control systems with flexibility with the help of software. SPRINGER: 1-37.
[17] Li, Z., et al. 2025. LLM-based simulated personality of robots and cognitive system. SPRINGER: 1-17.
[18] Jain, A. S., et al. 2025. RapidLLMed in Healthcare Forthwith Raise Ethical Concerns: an Inquiry into Misleading Tendencies in Social Robots. SPRINGER: 1-12.
[19] Mon-Williams, R., Li, G., Long, R., et al. 2025. Embodied large language models enable robots to perform complex tasks in unpredictable environments. SPRINGER: 1-10.
[20] Liu, Y., Chen, W., Lin, L., et al. 2025. Aligning Cyber Space with Physical World: A Comprehensive Survey on Embodied AI. IEEE: 1-21.
[21] Gu, X., et al. 2025. Embodied AI Meets Industry 5.0: Human-Centered Smart Manufacturing. IEEE: 1-17.
[22] Reddy, S. R. S. S. S., et al. 2025. In screens to scenes: An overview of embodied AI in healthcare. ELSEVIER: 1-12.
[23] Liang, J., et al. 2025. KARMA: augmenting Embodied AI Agents with Long-and-short TM Memory Systems. IEEE: 1-19.
[24] Gupta, S., et al. 2025. EmBARDiment: an Embodied AI Agent to enhance Productivity in XR. IEEE: 1-10.
[25] Zhang, Y., et al. 2025. Generative Diffusion-based Contract Design toungsive AI Twinns Migration in Vehicular Embodied AI Networks. IEEE: 1-16.
[26] Lim, S. and Bente, G. 2025. Artificial social relevance through the use of human-bodied AI agents during immersive virtual reality (VR). ELSEVIER: 1-45.
[27] Zhang, Z., et al. 2025. Innovative smart gloves with Phalanges-based triboelectric sensors as a dexterous teaching interface to Embodied Artificial Intelligence. ELSEVIER: 1-11.
[28] Tan, J., Shi, J., Wu, L., et al. 2025. Embodied Intelligence Empowering Customized Manufacturing: Architecture, Opportunities, and Challenges. IEEE: 1-16.

[29] Wu, L., et al. 2025. Digital-real integration effects of energy productivity on a multi-governance framework. ELSEVIER: 1-14.
[30] Shao, Y., et al. 2025. How the development of artificial intelligence will impact the embodied carbon emission. ELSEVIER: 1-9.
[31] Gu, Y., et al. 2025. CECA: An intelligent virtue of a large-language framework based on powerful machine translation: Embodied carbon in structures. ELSEVIER: 1-9.
[32] Montu Far, G., et al. 2025. Informational embodiment: Computational role of information structure in codes and robots. ELSEVIER: 1-31.
[33] Pyatkin, A., et al. 2025. Jailbreaking LLM Controlled Robot. IEEE: 1-64.
[34] Wang, C., et al. 2025. LLM-Craft Large Language Microsofts Can Robotically Craft Elasto-Plastic Objects. IEEE: 1-8.
[35] Feryal, K., et al. 2025. Large language models for robotics: Opportunities, challenges, and perspectives. ELSEVIER: 1-28.
[36] Zhang, J., et al. 2025. LLM based autonomous agent of human-robot cooperation during the aerospace wire harnessing assembly. ELSEVIER: 1-7.
[37] Hu, Y., et al. 2025. Towards Generalizable Visionunderline generation Language Robotic Manipulation: A Benchmark and LLM-directed 3D Policy. IEEE: 1-18.
[38] Li, M., et al. 2025. LLM as BTPlanner: Teaching Behavior Trees to LLMs to Plan Robot Tasks. IEEE: 1-7.
[39] Zhang, H., et al. 2025. In-Context Learning Enables Predusion of Robot Actions in LLMs. IEEE: 1-11.
[40] Liu, B., et al. 2025. Robust mobile robot path planning through the dynamic waypoint generation through LLM. ELSEVIER: 1-8.
[41] Kim, T., et al. 2025. Interactive Robot Action Replanning with Multimodal LLM Trained on Human Demonstrations Videos. IEEE: 1-7.
[42] Wang, X., Dong, L., Rangasrinivasan, S., et al. 2025. Auto Mentless: An Multi-agent llm framework of automatic code generation in the Misty Social Robot. IEEE: 1-8.
[43] Xu, W., et al. 2025. Integration of dynamic knowledge and LLM to generate adaptive human-robot collaborative assembly solutions. ELSEVIER: 1-10.
[44] Chevalier, F., Ouerghemmi, C., Ertz, M., et al. 2025. A skill synthesis of human demonstration assisted hybrid robot, with LLM, human robot collaborative assembly. ELSEVIER: 1-6.
[45] Chen, X., et al. 2025. IEDS in practice: a comparative study of an intelli embodied design space blending AR and GAI with conceptual design. ELSEVIER: 1-37.
[46] Styrud, J., Iovino, M., et al. 2025. Automatic Behavior Tree Expansion with LLMs in Robotic Manipulation. IEEE: 1-8.
[47] Chen, S., et al. 2025. VerifyLLM: LLM or Pre-Execution Task Plan Verification on Robots. IEEE: 1-8.
[48] Yan, H., et al. 2025. MALMM: Multi-agent Large Language Models to Large-scale Robotic Manipulation. IEEE: 1-48.
[49] Ling, Z., et al. 2025. Long-horizon Locomotion and Manipulation on a Quadrupedal Robot with Large Language Models. IEEE: 1-9.
[50] Sun, Y., et al. 2025. SELP: Generating safe and efficient task plans of robot agents that have learned large language models. IEEE: 1-7.