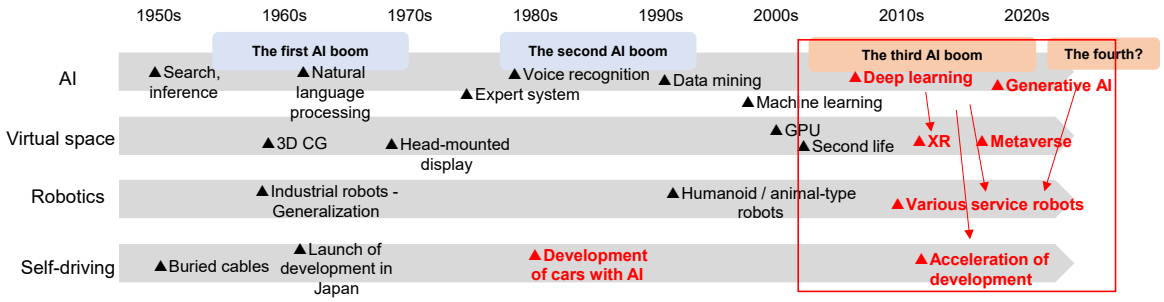
Section 2 Evolving technologies along with the progress of AI

The evolution of AI, as reviewed in the previous section, is also influencing other technologies. Particularly, the development of deep learning during the third AI boom has contributed to the development of virtual space services using XR, service robots, autonomous driving, and more. The advent of generative AI further supports the advancement of these technologies **(Figure 1-3-2-1)**.

Figure 1-3-2-1 Changes in evolving technologies along with the progress of AI



(Source) Prepared based on publicly materials

The functions that AI performs in actual services can be broadly categorized into three types: "Identification," "Prediction," and "Execution." The application of these functions spans various industrial sectors, such as manufacturing and transportation. For example, in the case of autonomous driving, it combines various functions like image recognition, voice recognition, situational judgment, and route analysis in a manner suitable for the transportation sector to achieve practical implementation[1]. Similarly, in robotics, multiple functions are combined to achieve practical implementation **(Figure 1-3-2-2)**.

Here, we will discuss the trends in virtual spaces (the metaverse and digital twin), robotics, and autonomous driving, which are further advancing in practical implementation by incorporating generative AI.

Figure 1-3-2-2 Functional area of practical implementation of AI

Identification	Accuracy of prediction	Execution
•Voice recognition •Image recognition •Video recognition •Language analysis	•Numerical prediction •Matching •Intention prediction •Need prediction	•Expression generation •Design •Optimazation of behaivor •Automation of work

(Source) MIC (2016) "Research survey on the effects on employment and work style by evolution of ICT"[1]

(1) Virtual spaces (the metaverse and digital twin)

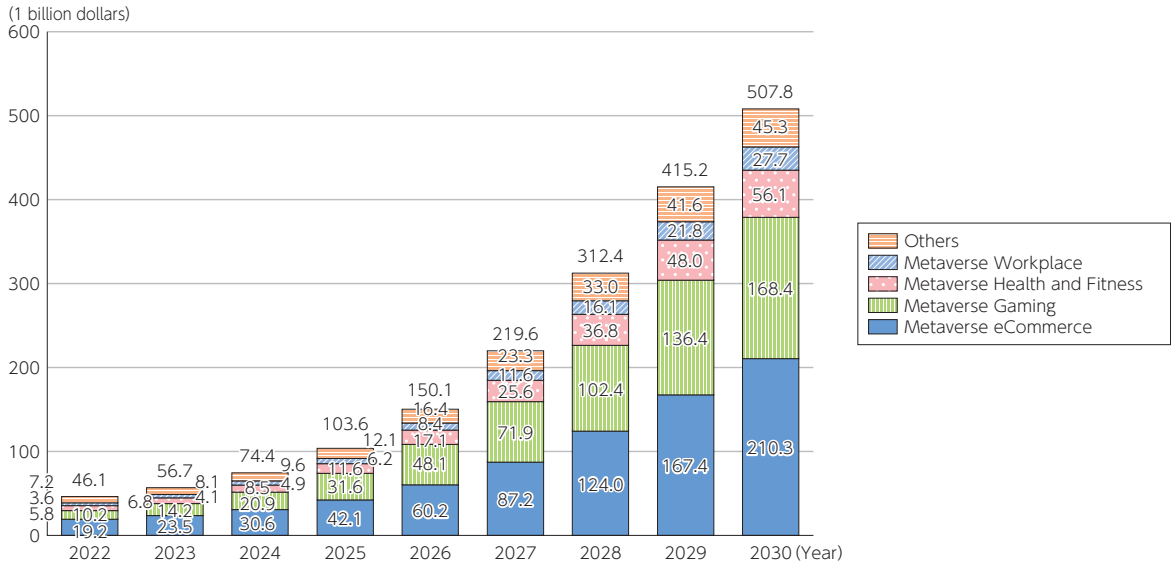
The metaverse is a virtual world created on the Internet, where users can interact with others through avatars that represent themselves. Although it is a virtual space, services that link the metaverse with the real world are being tested, such as purchasing items in the metaverse that are later delivered to the user's home. Additionally, there is growing anticipation for its use as a virtual workspace in B2B applications[2].

Another concept is the "Digital Twin," which involves recreating elements of the real world in a virtual space based on data collected from the real world. While both the metaverse and digital twin exist in virtual spaces, the key difference lies in their purpose and content. The metaverse does not necessarily replicate real-world elements and is often used for communication, gaming, and social interaction through avatars in a virtual environment. In contrast, a digital twin is a solution designed to simulate real-world scenarios, making it useful for conducting simulations that are difficult to perform in the real world[3].

The market size of the metaverse is projected to expand from 46.1 billion dollars in 2022 to 507.8 billion dollars by 2030 **(Figure 1-3-2-3)**.

[1] MIC, "Report on Research and Study on the Impact of ICT Evolution on Employment and Work Styles," March 2016, <https://www.soumu.go.jp/johotsusintokei/linkdata/h28_03_houkoku.pdf>
[2] Nikkei X Trend, "What is the Metaverse? Will it Really Spread? Eight Points to Understand the Basics," April 14, 2022, <https://xtrend.nikkei.com/atcl/contents/skillup/00008/00020/> (accessed on March 22, 2024)
[3] MIC, "The 2023 White Paper on Information and Communications in Japan" <https://www.soumu.go.jp/johotsusintokei/whitepaper/r05.html>

Figure 1-3-2-3[4] Market size of the metaverse



(Source) Statista [4]

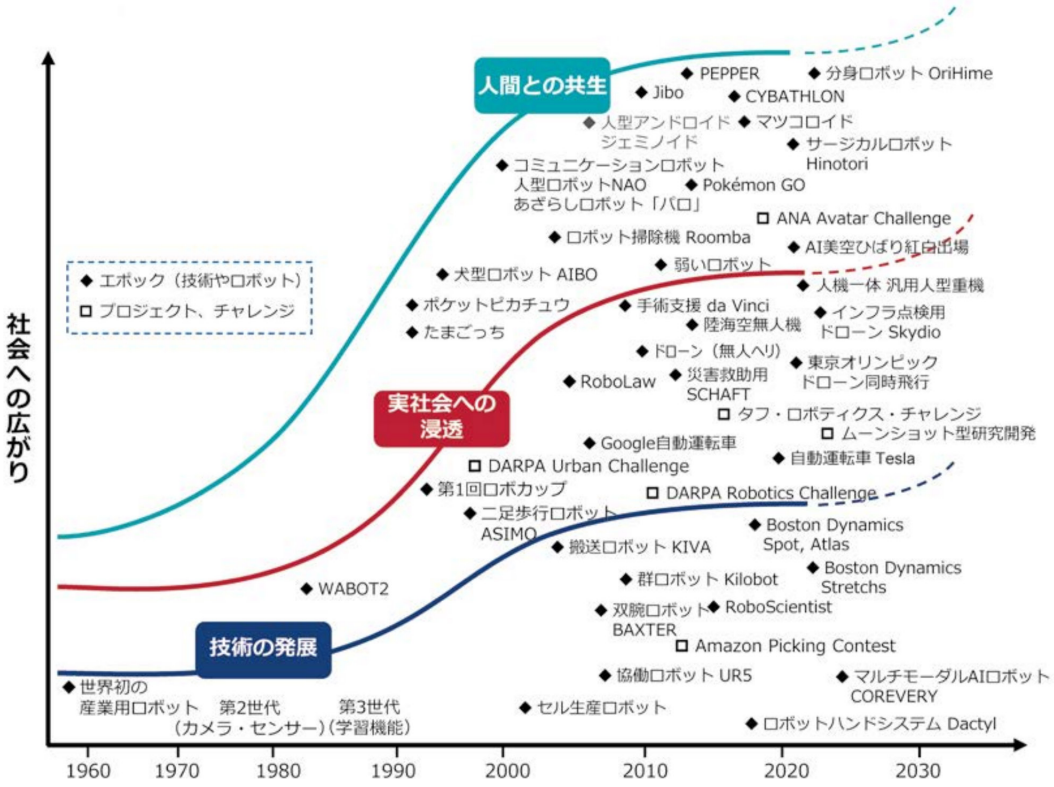
By utilizing generative AI, certain processes in the creative activities within the metaverse, such as automatic generation of 2D images and 3D models, as well as program creation support, can be simplified. This is expected to lower the technological and knowledge barriers, leading to an expansion of users. Additionally, the use of machine learning techniques such as Generative Adversarial Networks (GAN) enables individuals without design experience to create their own avatars and more, potentially giving rise to a vast economic sphere within the virtual space.

(2) Robotics

The development of robots began in the 1960s for industrial use, serving as substitutes for human assistance and dangerous tasks in industrial and military applications. Since the 1990s, robots have been developed and utilized not only for industrial purposes in factories but also for service applications in general society, such as caregiving, cleaning, and delivery. In personal and household settings, various robots like cleaning robots and companion robots have become more widespread **(Figure 1-3-2-4)**.

[4] https://www.statista.com/outlook/amo/metaverse/worldwide

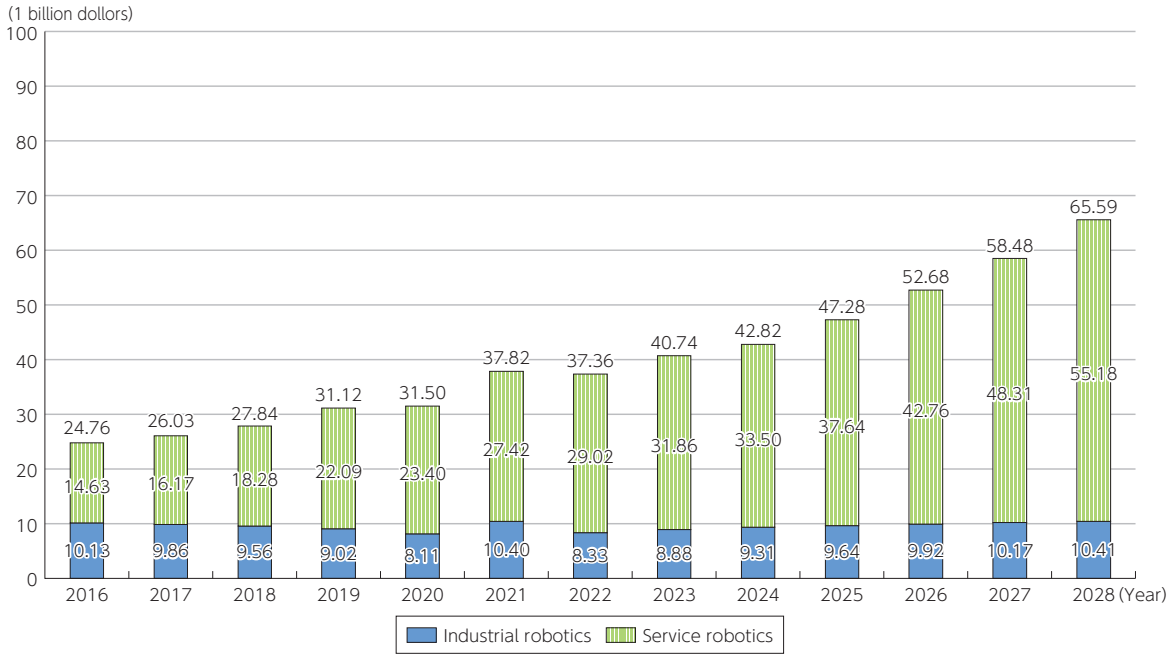
Figure 1-3-2-4 Trend of research and development of robotics



(Source) Center for Research and Development Strategy, Japan Science and Technology Agency Overview report of research and development in the field of systems and information science(2023)

The global robot market is expected to see significant revenue growth, reaching 42.82 billion dollars by 2024. Among various segments, service robotics is projected to dominate with a market size of 33.5 billion dollars in 2024. This field is expected to grow at a compound annual growth rate (CAGR) of 11.25% from 2024 to 2028, reaching an estimated market size of 65.59 billion dollars by 2028 **(Figure 1-3-2-5)**.

Figure 1-3-2-5 Market size of robotics



(Source) Statista "Statista Market Insights"[5]

[5] https://www.statista.com/outlook/tmo/robotics/worldwide

The expansion of robot development and utilization has progressed in tandem with the advancement of AI. Robots are considered intelligent mechanical systems with three key elements: sensors (perception/recognition), intelligence/control systems (decision-making), and actuators (action). By combining deep learning-based AI with reinforcement learning, the recognition capabilities of robots have significantly improved, allowing them to collect and analyze large amounts of data from cameras and sensors. AI is already being used in production sites for quality inspection and predictive maintenance of equipment. The practical application of caregiving and customer service robots is also advancing. Voice recognition and natural language generation technologies have enabled natural interactions between humans and household robots.

Furthermore, there are attempts to use generative AI as action-generating AI for decision-making and actuators. This involves interpreting multimodal information such as language and images, allowing robots to understand the surrounding environment from camera footage and perform physical actions to achieve user commands. However, challenges remain in the physical movements of robots, and research on tactile feedback, soft hardware development, and safe force control is crucial. It is expected that it will take more time for practical implementation in society[6,7].

Typically, programming is required to operate robots, but in the future, if generative AI can program itself through dialogue with humans, it is anticipated that robots will be able to understand human language and be programmed instantly, leading to a future where robots can be controlled more intuitively.

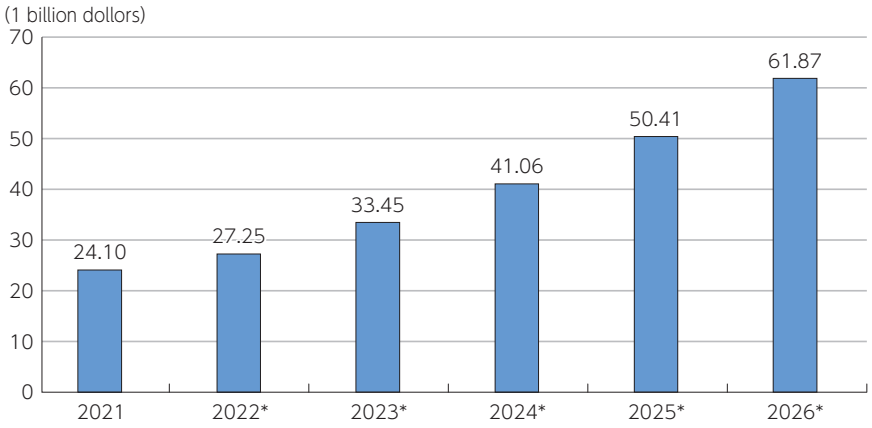
(3) Autonomous driving technology

In autonomous driving technology, AI is utilized in the three processes of perception, decision-making, and action by the system. AI processes information from cameras and sensors installed in vehicles to recognize the surrounding environment and safely navigate the vehicle, avoiding pedestrians and obstacles. Generated AI is also used for prediction and decision-making, considering the behavior of vehicles and pedestrians ahead and determining how the vehicle should be controlled based on this information. AI also plays a crucial role in supporting safe driving in vehicles.

Furthermore, the learning capabilities of generated AI enable advanced route optimization, and its speech recognition technology is also utilized, allowing drivers to give commands to the vehicle using their voice[8,9]. The realization of fully autonomous driving in the future will require not only image recognition but also the recognition of other modalities such as voice, enabling communication with passengers. As a result, there is a growing trend of integrating generated AI into vehicles.

The global market size of autonomous driving vehicles exceeded 24 billion dollars in 2021. The market is expected to continue growing, reaching a size of approximately 62 billion dollars by 2026 **(Figure 1-3-2-6)**.

Figure 1-3-2-6 Market size of autonomous driving technology



The year with * means the prediction.

(Source) Statista[10]

[6] NIKKEI Tech Foresight, "Infrastructure models will be multimodal and integrated with robots: 24-year outlook," January 24, 2024, <https://www.nikkei.com/prime/tech-foresight/article/DGXZQOUC239XV0T20C24A1000000> (accessed on March 22, 2024)
[7] SHINDO Tomonori, "Editor-in-Chief's Outlook for 2024 (No. 11) Will Robots Change with Large-Scale Language Models? - Robots and AI in 2024 -," Nikkei xTECH, January 19, 2024, <https://xtech.nikkei.com/atcl/nxt/column/18/02668/112800011/> (accessed on March 22, 2024)
[8] NEC, "Examples of AI technology used in automobiles, such as autonomous driving, and future challenges," <https://www.nec-solutioninnovators.co.jp/ss/mobility/column/07/index.html> (accessed on March 26, 2024)
[9] Jidounten LAB, "Autonomous Driving and AI (Latest 2023 Edition)," July 7, 2023, <https://jidounten-lab.com/u_35766> (accessed on March 26, 2024)
[10] https://www.statista.com/statistics/428692/projected-size-of-global-autonomous-vehicle-market-by-vehicle-type/