The World Beyond the Metaverse

~ Artificial Perception Enables the Fusion of Human and Machine ~

Introduction

Metaverse is a concept proposed as “a three-dimensional virtual space and its services built on computers and computer networks”. It continues to heat up as a buzzword, with global companies changing their company names to something related to the concept.

In this paper, we will decipher the background and future of Metaverse through a bird’s-eye view of the technology evolution, and we will introduce Kudan’s strategic initiatives.

Outline

The outline of this paper is as follows

- **The “mechanization of humans” and the “humanization of machines” are two major trends in technology.**
- **The Metaverse has so far been an AR/VR metaverse for the “mechanization of humans,” but it can be extended to a robotic metaverse for the “humanization of machines.”**
- **The two metaverses will be integrated in the future, focusing on the core technology of “coupling human space and machine space.”**
- **Toward this end, spatial coupling is required for everything from AR/VR to robotics, and the highly independent and versatile technology provided by Kudan will be necessary.**

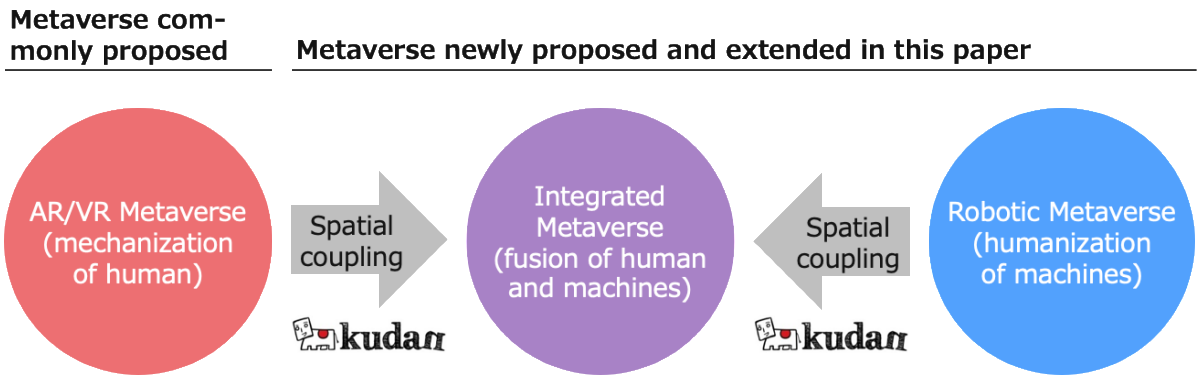

Figure: the proposed integration and extension of Metaverse

Trends in technology development

One perspective from which to view technology is the axis between humans and machines. When we look back at history from the perspective of humans and machines acquiring each other's characteristics and approaching each other, **the technology industry has always developed in a way that fits either the "mechanization of humans" or the "humanization of machines."**

(The term "machine" here includes not only powered mechanical devices, but also intelligent computers and robots.)

For example, the development of the Internet and social networking services from the telephone and telegraph in the past can be called the "mechanization of humans" in the sense that human communication and relationships are being shifted to the digital world. On the other hand, the development from the industrial revolution to artificial intelligence can be said to be the "humanization of machines" in the sense that machines have acquired the power, intelligence and other abilities that humans possess.

The Metaverse, as commonly proposed, fits into the "mechanization of humans" and accelerates it by transferring human consciousness and experience to the digital world. Therefore, **the Metaverse as a buzzword is the latest concept of "human mechanization."**

On the other hand, **the latest concept of "humanization of machines" can be seen as robotics and autonomous driving**. These trends are in complete contrast to the Metaverse, as machines are acquiring a higher level of ability to make human decisions and actions.

Space coupling

When viewed from the perspective of humans and machines approaching each other, **an essential technological element for both "human mechanization" and "machine humanization" emerges. It is the "coupling of human space and machine space."**

In the following, we will look at how the coupling of space occurs in both "human mechanization" and "machine humanization."

Spatial coupling in "mechanization of human"

Until now, the "real space where humans exist" and the "digital space where machines process" have been established separately. For example, the image seen from the monitor of a computer game and the real space of the room where the game is being played have been unrelated.

The Metaverse, on the other hand, combines spaces that have been separate for humans and machines in order to accelerate the "mechanization of humans" through the digitization of entertainment experiences. For example, in a computer game based on the Metaverse, through a headset device, the CG world in the game pops out of the monitor and provides an experience that swallows up the real space of the room where the game is being played.

This allows the user to immerse themselves in the CG and see and move around in the virtual world, as the virtual world appears to the user in conjunction with the user moving around in the room, giving the user the feeling that the real space and the digital space are connected.

In this case, it is important that the real space (the real space in which humans move around) and the digital space (the CG space in which machines process information) are synchronized smoothly in real time, and a highly realistic user experience is based on advanced spatial coupling technology.

There are two types of Metaverse: one is called virtual reality (VR), in which the virtual space completely overrides the real space, and the other is called augmented reality (AR), in which the virtual space overrides the real space while partially retaining the real space. **Since AR and VR work on the same spatial coupling principle, the Metaverse currently commonly proposed can be called an "AR/VR-based metaverse."**

Spatial coupling in the "humanization of machines"

The same kind of "coupling of human space and machine space" is essential in "humanization of machines" such as robotics and autonomous driving.

For example, in computer games with car racing, it is easy to simulate driving by the computer. This is because information processing in the digital space is all that is needed to complete the simulation.

On the other hand, it becomes overwhelmingly difficult to drive a car automatically in a real urban environment. In automated driving, there are two spaces, the digital space where the computer is processing and the real space where the car is driving, and it is necessary to connect the two.

Specifically, as long as the digital space processed by the computer and the real space information in which the car is actually running are not synchronized (i.e., as long as the spatial information showing the ever-changing position and posture of the car and the surrounding environment is not updated in real time), no matter how sophisticated the computer's driving simulation is, it will not be able to detect the actual driving conditions. (i.e., unless the spatial information that indicates the ever-changing position and orientation of the car's surroundings is updated in real

time), no matter how sophisticated the simulation, the car cannot be driven in a real city.

Spatial coupling is necessary not only for cars, but for any type of robot that moves around. If a robot drives on a roadway, it is an automated car; if it moves around in a factory or warehouse, it is an automated transport robot; if it moves around a commercial facility, it is a service robot; if it flies in the sky, it is a drone. In this paper, we will refer to all of them collectively as robots.

Two sides of a coin

Focusing on spatial coupling, we can see that the Metaverse and robotics are opposite concepts. The Metaverse is where humans living in the real world enter the digital space, while robots that process the digital space move around in the real space.

Metaverse and robotics are two sides of the same coin, or mirrored twins, just as “human mechanization” and “machine humanization” are. Spatial cohesion as a core technology is the interface between the real and the digital for both sides, and the positions of humans and machines are directly opposite in Metaverse and robotics.

This paper focuses on this point and expands the concept of Metaverse by proposing a “robotic metaverse” that corresponds to robotics in addition to the “AR/VR metaverse” that has been generally proposed.

The “robotic metaverse” is not as common a concept as the “AR/VR metaverse” at this point. However, robotic Metaverse will be important to develop the Metaverse and integrate “mechanization of humans” and “humanization of machines” by integrating with AR/VR metaverse in the future.

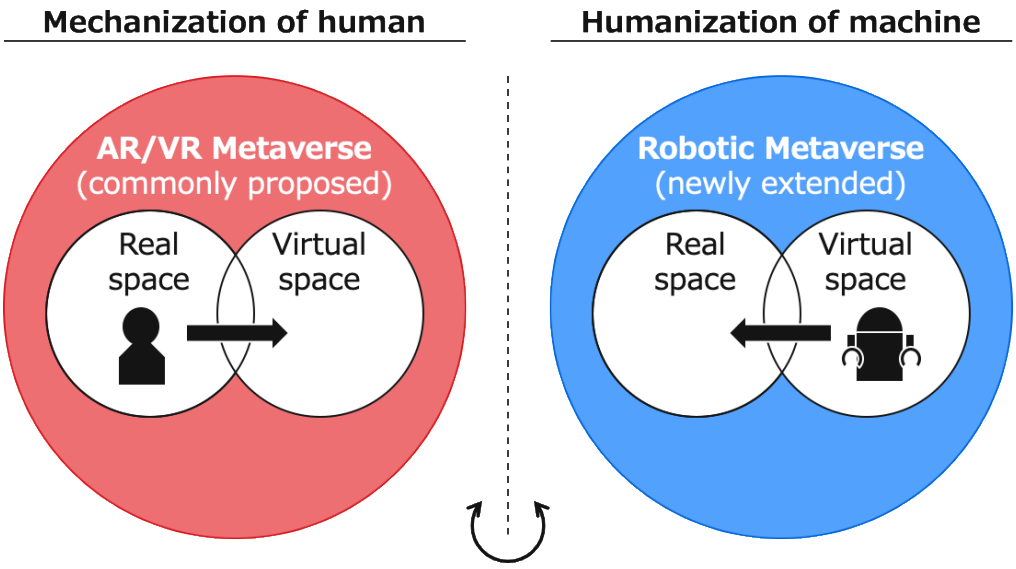

Figure: structure of AR/VR Metaverse and Robotic Metaverse

Artificial perception as a core technology

In both an AR/VR and robotics metaverse, I explained that the core technology is the spatial coupling of the real and the digital, which is technically called artificial perception or SLAM.

Artificial perception is a technology that is the counterpart of artificial intelligence, and while artificial intelligence is responsible for pattern recognition, artificial perception is responsible for spatial position recognition.

SLAM (Simultaneous Localization and Mapping), on the other hand, is more technical and narrowly defined. This is a technology that creates a virtual space (a digital 3D map, to be precise) that is synchronized with the real space situation and the machine's movements when the machine moves around in the real space.

These are very similar to the human ability to perceive space. For example, when a person with a good sense of direction walks around in an unknown environment, they can imagine a map in their brain that copies the three-dimensional structure of the real space, rotate and move the map in their brain according to their movements, and understand exactly where they are in the map in their brain.

When machines as well as humans are able to do this, it will be possible to perfectly synchronize the real space in which humans exist with the digital space in which machines process.

Step-by-step development of the Metaverse

So far, we have extended the concept of the Metaverse from AR/VR systems to robot systems, focusing on the coupling of space. These two types of Metaverse, which share core technologies, are closely related and can be integrated on a common technology platform.

Such integration is very likely in the future, based on increasing demand and economic rationality, and **is expected to proceed in three stages: Metaverse 1.0, Metaverse 2.0, and Metaverse 3.0**.

Metaverse 1.0

In the first Metaverse 1.0, multiple incompatible individual Metaverses will emerge for AR/VR and robotics, respectively.

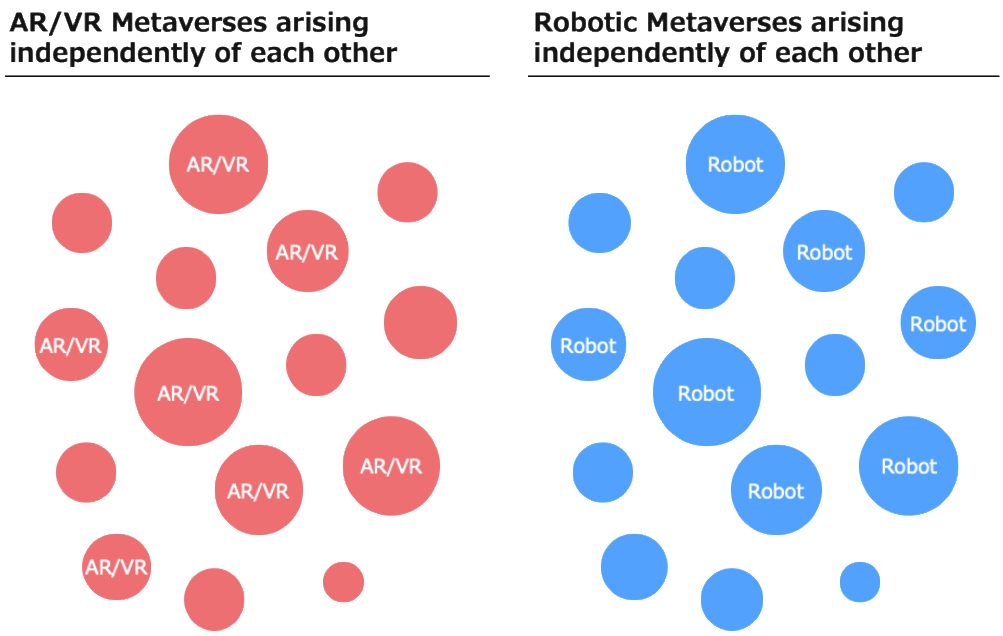

Figure: structure of Metaverse 1.0

This stage applies to almost all Metaverses in general, including robotics. Currently, the Metaverse is in its infancy, and companies are focusing on retaining users. For the metaverse providers, the fact that it will eventually become technically easy to switch to another company is an inconvenience that they do not want their own users to notice, so their priority is to keep the system closed.

As a result, metaverse providers will optimize their services and implement space-coupling technologies that are not compatible with other companies, so all Metaverse will exist in pieces for users.

Metaverse 2.0

In the next Metaverse 2.0, operators that do not depend on individual Metaverses will enter the Metaverse and provide solutions that integrate multiple Metaverses. As a result, the individual Metaverses will begin to become compatible with each other, but the barrier between AR/VR systems and robot systems will remain. In other words, the integration of Metaverses will proceed within the respective domains of AR/VR and robotics. Such an integrated metaverse is also called an inter-metaverse.

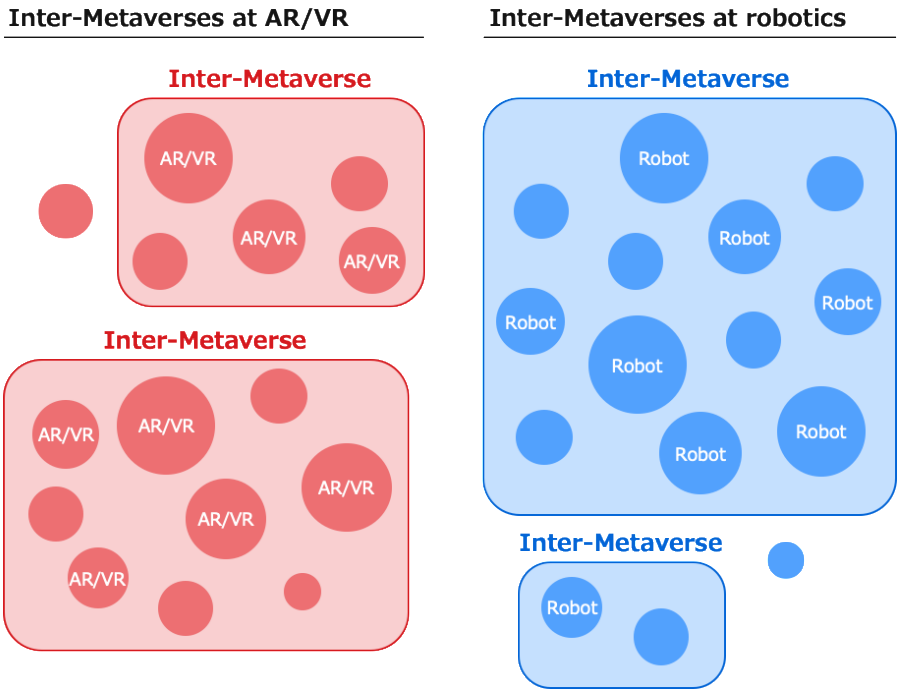

Figure: structure of Metaverse 2.0

At this stage, the spatial coupling in the same space is shared by multiple Metaverses, and efficiency is greatly improved in each Metaverse. Specifically, the specifications of each device (AR/VR device or robot) can be drastically downgraded to reduce costs.

More importantly, the ability for users and robots to move back and forth between multiple parallel Metaverses will provide a great deal of convenience. **In AR/VR, a user's experience can be realized on multiple metaverse simultaneously, and in robotics, many types of robots will be able to function together on the same platform**.

This stage is emerging mainly in AR/VR systems, and Kudan is launching advanced initiatives with partner companies (telecommunications, communication devices, semiconductors, etc.). For example, we are working on demonstrating the integration of various platforms to realize an AR cloud that aims to enable multiple users in the same real space to have the same AR experience. At the stage of Metaverse 1.0, the AR experience shared by all Google (Android) users is completely invisible to Apple (iOS) users in the same space, but with a unified platform, all Android and iOS users will have the same AR experience, and the true value that AR originally aimed for can be realized.

A similar experiment has started to be tested in the robotic Metaverse, which Kudan is demonstrating through partnerships with telecom partners. As mentioned earlier, robots are not generally recognized as a metaverse, but it is likely to develop into a versatile robotics platform for some time to come.

Metaverse 3.0

Finally, in Metaverse 3.0, the compatibility between Metaverse will be further expanded, and the integration will go beyond the boundaries between AR/VR systems and robot systems, resulting in the emergence of the ultimate inter-metaverse.

At this stage, spatial coupling will be more widely shared than in Metaverse 2.0, so efficiency and cost cutting in individual Metaverse will be accelerated.

More importantly, many advanced solutions will emerge as even robotic systems that were not previously thought to be related to the Metaverse are integrated.

This has important implications for the development of technology. The integration of AR/VR and robotics, which have been two sides of the same coin, as a metaverse means that the two major trends in technology, “mechanization of humans” and “humanization of machines,” will finally merge.

Therefore, from the standpoint of the relationship between humans and machines, Metaverse 3.0 is a stage that will inevitably occur, and solutions that increasingly integrate human and machine activities will become a reality. At this stage, all sorts of possibilities are envisioned, and in this paper we will introduce two directions: the fusion of AR and robots, and the fusion of VR and robots.

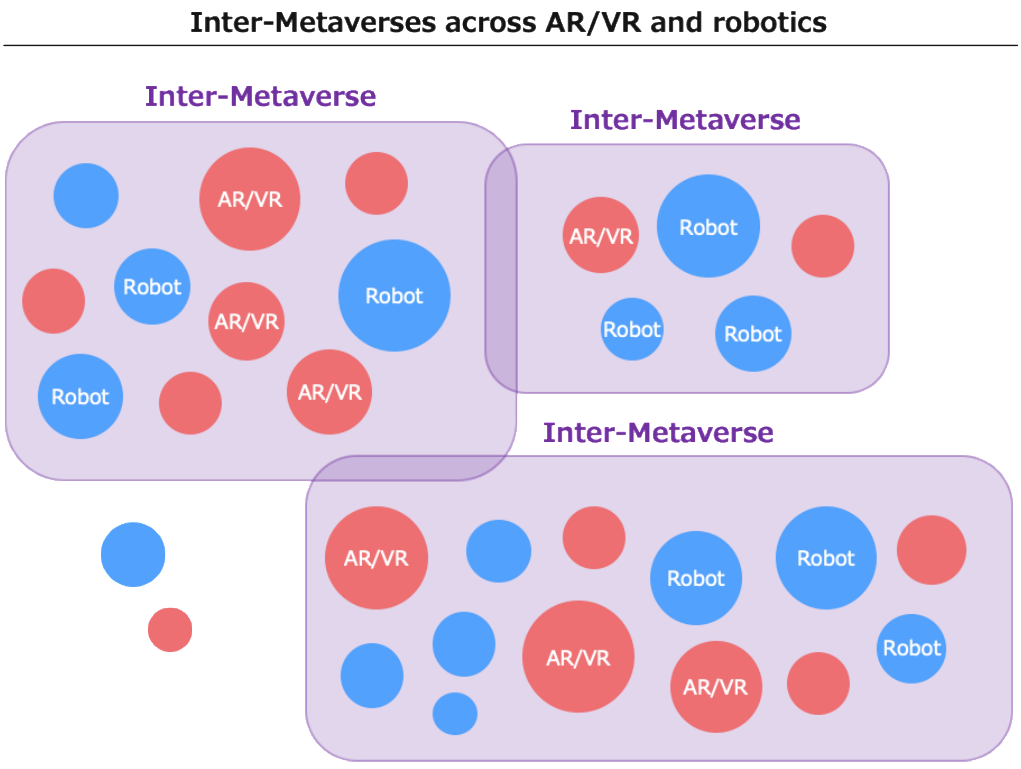

Figure: structure of Metaverse 3.0

Fusion of AR (Augmented Reality) and Robot

In AR and robotics fusion, virtual augmentation (AR) and physical augmentation (robotics) in space are fused together. Specifically, any digital display (AR) that appears to float in the real space and the robot that moves around in the real space are mutually linked, and information and control are updated to achieve the user's intended goal from both information and physical perspectives.

For example, imagine Mr. A working at a plant construction site, wearing an AR headset and relying on AR navigation to understand the complex site conditions and move from one process to another. AR navigation can be linked to standing mobilities such as Segways to efficiently navigate vast job sites, and can be automated when needed. Furthermore, AR navigation works not only with AR mobility, but also with automated transport robots to help Mr. A transport materials efficiently. During the work, the system can not only plan the work by displaying 3D drawings and 3D models in full-scale AR on the site, but also manage the work progress by flying a survey drone on autopilot and displaying the survey results in AR if necessary. All of these functions are linked to the field information that Mr. A sees through the headset, and can be displayed and operated in real time.

In this way, **the visualization of various information in the real environment (AR) and the control of the robot in that environment can be highly coordinated by Metaverse 3.0, and can be used in any situation where humans and robots coexist.** Industrial and construction sites are examples that are easy to visualize, as robots have already been introduced, but in the future, robots will become indispensable in people's lives as their introduction accelerates in all residential, work, and public environments.

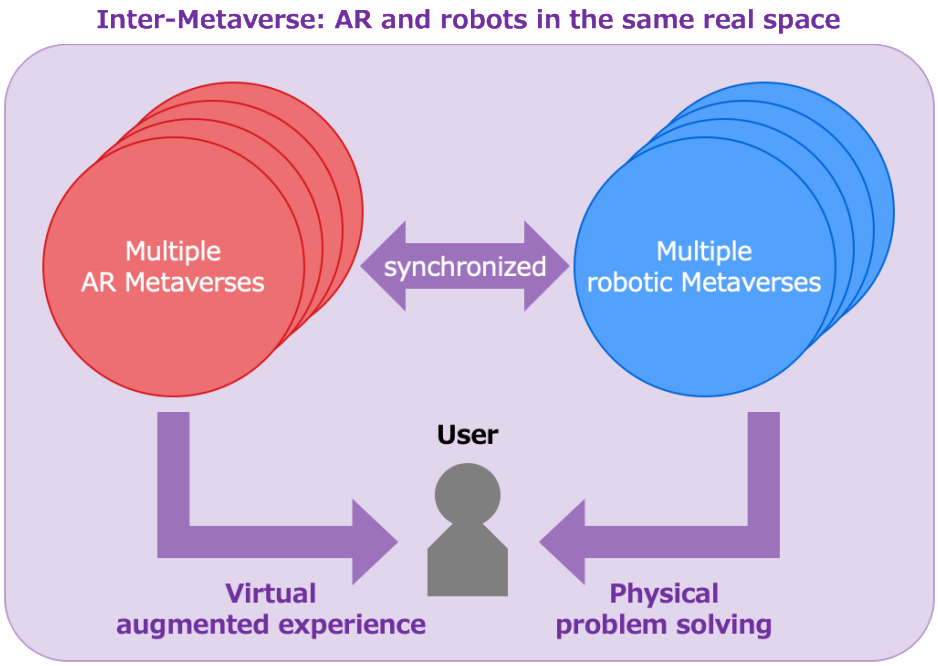

Figure: fusion of AR and robot

Although the fusion of AR and robotics sounds like a sci-fi vision of the future, the initial development has already begun. For example, Kudan is working with major auto parts partners (HERE, NNG) to develop a platform for spatial location awareness that will enable both automated driving and AR navigation (See here for more details). The platform allows cars to recognize highly accurate location information at the driving lane level, and aims to work with highly accurate maps in the future to make high-level automated driving practical. In addition, the same information can be used to link AR experiences with automated driving/driving assistance by displaying various useful information on the vehicle's navigation and roadside on the vehicle's window.

For example, a user can leave the control of the car to the automatic driving function, and when they see a restaurant on the roadside, they will be able to see information on parking availability and congestion in the restaurant as an AR display in the window. It will also be possible to reserve a seat at the restaurant by touching the AR display, or set it as a destination for the automatic driving route.

Furthermore, it is also possible to switch from automatic driving to manual driving and steer the car according to the navigation on the AR display in the windshield.

Until now, AR has been primarily a digital experience where the user has to move around, but when the user is in a self-driving mobility vehicle, the AR digital experience can be integrated with the automatic operation of the mobility vehicle, providing a more advanced and advanced user experience.

Fusion of VR (Virtual Reality) and Robotics

The fusion of VR and robotics will greatly expand the scope of the user's activities, both virtual and real, beyond the physical limitations of the individual. Specifically, users will not only be able to operate in the virtual space on the Internet, but will also be able to operate in any real space through robots. **By connecting to a virtual avatar (VR), you can operate in any virtual space; by connecting to a physical avatar (robot), you can operate in any real space; and by freely switching between the connected spaces, you can move back and forth between them**.

For example, let's assume a day in the life of Ms. B, who works in the retail industry. Ms. B, who is in charge of inventory management, connects to the virtual workspace from her home in Tokyo and has a meeting with her colleagues. There, she discovers that the inventory information for a store in Kyoto may be wrong, so she connects himself from the virtual workspace to a robot in the store, which she hijacks and moves around the store to investigate. As a result, she confirms the status of the problem, reconnects her consciousness to the virtual workspace again, and discusses with her colleagues to further clarify the cause of the problem. As a result of the discussion, she comes up with a hypothesis that the problem is caused by mismanaged inventory at the warehouse in Osaka. So, Ms. B connects herself to a robot in the warehouse in Osaka and hijacks the robot to investigate the warehouse. Finally, she identifies the problem in the warehouse and returns to

her virtual workspace to report the problem and countermeasures to her boss. After completing her work, Ms. B then returns to her real space in Tokyo.

Here, the avatar for Ms. B is not only a digital object in the virtual workspace, but also a real robot in a store or warehouse away from home. This allows Ms. B to freely move herself back and forth between the virtual avatar and the physical avatar.

The image is that of the popular science fiction movie Ready Player One (released in 2018, directed by Steven Spielberg), which depicts a virtual avatar, and Avatar (released in 2009, directed by James Cameron), which depicts a physical avatar.

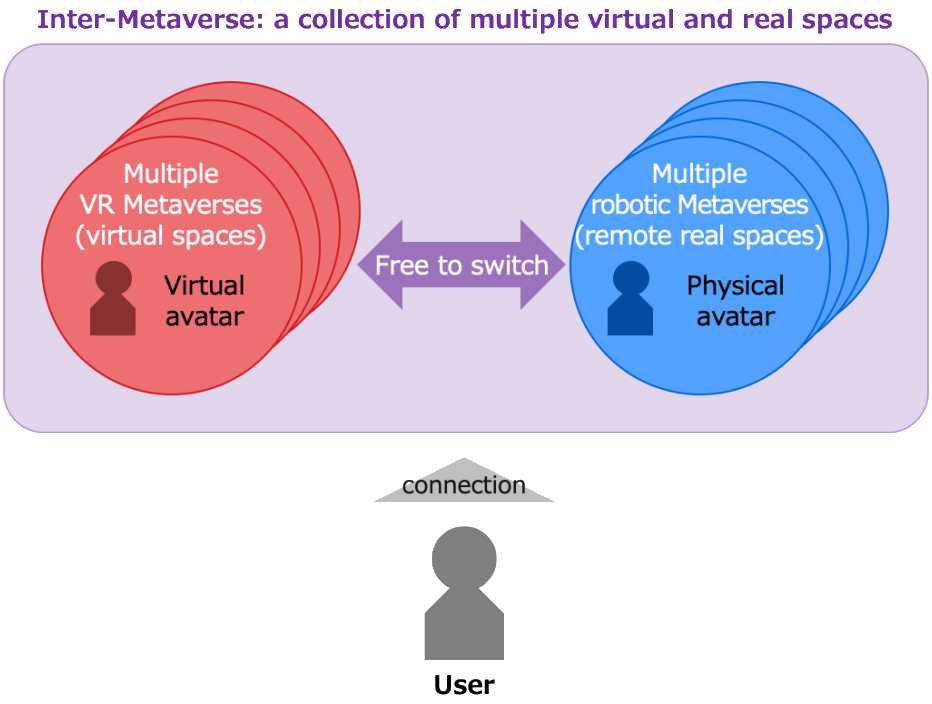

Figure: fusion of VR and robot

Although the concept sounds like a sci-fi, far-future vision, attempts to connect consciousness to remote robots have already begun as an early development leading to the fusion of VR and robotics.

For example, due in part to the effects of the Coronavirus disaster, the development and demonstration of delivery robots is gaining momentum around

the world, and Kudan is participating in several projects. Although delivery robots are equipped with unmanned automatic operation functions, there are still many cases where safety problems occur or if the robot gets stuck. In such cases, it is necessary to solve the problem by switching control to a remote standby operator. In this case, instead of the operator checking the robot's camera image through a monitor, a VR headset is being used to immerse the operator in the robot and control it. In other words, the goal is to connect your perception to a distant robot and control it, switching between the target robots as needed.

In the same way that video games that used to be played on a flat screen can now be played through a VR headset, creating a completely different user experience, we aim to enable more advanced operations than the remote control through a monitor. Specifically, not only can the operator have a sense of immersion and unity as if they are riding inside an unmanned delivery robot (AR/VR-based Metaverse), but it is also possible to efficiently reflecting the sensor and image recognition information acquired by the robot through its automatic operation function to the operator (robot-based Metaverse), thus enabling more efficient and accurate control of the delivery robot.

These efforts will continue to expand into a variety of areas, including transportation, construction, disaster relief, security, and entertainment.

Kudan's Strategic Position

Kudan has been researching and developing spatial association (artificial perception/SLAM) even before the Metaverse became a focus of attention. For the Metaverse 1.0, which is currently in its infancy, we are working on providing technology for both AR/VR systems and robotics.

On the other hand, considering the future development of the Metaverse, we assume that the demand for technology will increase explosively as the Metaverse evolves to Metaverse 2.0 and Metaverse 3.0. **Anticipating such trends, Kudan**

has been strategically developing its technology and business to meet the needs of not only Metaverse 1.0, but also Metaverse 2.0 and Metaverse 3.0.

Technology Independence

For Metaverse 2.0, which will realize compatibility among Metaverses, technologies that are not dependent on individual metaverse businesses are required.

For example, in the AR Cloud initiative introduced as an example of Metaverse 2.0, individual metaverse businesses (vertical operators) have adopted a technology strategy that is closed to their own services. Therefore, companies such as telecommunication and semiconductor companies (horizontal operators) that want to enter the metaverse 2.0 through the provision of integrated solutions cannot directly use the proprietary technologies of the vertical operators.

Therefore, horizontal operators must secure independent technologies against vertical operators that are already far ahead in core technologies through corporate acquisitions, etc. Independent spatial connectivity technologies (artificial perception/SLAM) are already extremely rare.

As a result, although the development of the metaverse 2.0 is about to begin in earnest, the choices of technology partners that major companies are looking for are already very limited. Kudan has been focusing on a dedicated independent position to meet this growing demand, and has continued to be chosen as the technology partner of choice by horizontal operators so its presence will become even more important in the future.

Technology versatility

As we move toward Metaverse 3.0, which will transcend the boundaries between AR/VR and robotics, we need a general-purpose technology that supports both AR/VR and robotics.

Until now, Metaverse has generally been limited to AR/VR systems only, and no technology has been developed to extend to robotic Metaverse or for future integration with that robotic Metaverse.

Although Kudan originates from AR/VR technology, we have greatly expanded our technology development towards robotics with an eye on the trend of not only “mechanization of humans” but also “humanization of machines”. As a result, we have been able to build basic technologies that can function universally for both AR/VR and robot systems. These achievements have led to advanced initiatives with various partners for the current Metaverse 3.0.

In Metaverse 3.0, this versatility needs to be combined with the technology independence required in Metaverse 2.0, which is becoming extremely rare, and the importance of Kudan’s technology is expected to increase further in the future.

Conclusion

The expansion and development of the Metaverse proposed in this paper is our interpretation of a recent trend that has become a buzzword. We do not know if the existing Metaverse will continue its boom or if new buzzwords will replace it in an evolving way.

As Kudan focuses on deep technologies, it is important for us to focus on core technologies that are more in line with universal trends, rather than being locked into the framework of existing Metaverse. As a result, we believe that we will be able to accelerate the inevitable development of “human mechanization” and “machine humanization” and evolve the nature of humans and machines.