Latest Developments Concerning Grand Challenges to Implement the Digital Twin Computing Concept

Takao Nakamura, Koya Mori, and Ryo Kitahara

Abstract

One of the major pillars of the Innovative Optical and Wireless Network (IOWN) being promoted by NTT is the concept known as Digital Twin Computing (DTC), which aims to enable future predictions and optimization by combining the real and digital worlds, and NTT has set *grand challenges* as ambitious research and development goals to implement DTC. In this article, our efforts toward the common use of digital twins and our recent activities to achieve these grand challenges are introduced.

Keywords: Digital Twin Computing, IOWN, grand challenge

1. Efforts concerning Digital Twin Computing concept and the grand challenges

The concept known as Digital Twin Computing (DTC) is a key component of NTT's Innovative Optical and Wireless Network (IOWN). By combining highly accurate digital information about objects, people, and society in the real world, DTC aims to enable (i) large-scale and highly accurate future predictions and simulations that transcend the limits of conventional information and communication technologies and (ii) advanced communication with new value. It will accelerate the creation of a smart society by solving various social issues around the world and creating innovative services (**Fig. 1**).

DTC is a technology that covers a wide range of application fields—ranging from the microscopic world of individual humans to the macroscopic world on the global scale. We aim to actualize the DTC concept by setting the following four *grand challenges* as major research and development (R&D) goals (**Fig. 2**).

(1) *Mind-to-mind communication* transcends not only differences in language and culture but also differences in personal characteristics, such as experience and sensibility, in a manner that creates a new form of communication that enables people to directly understand one another's thoughts and feelings.

(2) *Another Me* expands opportunities for people to play an active role and grow by having another person (digital reproduction of a real person) act autonomously as that person beyond the constraints of reality and share the results as the real person's own experience.

(3) *Exploring Engine for the Future Society* aims to create a mechanism that digitally represents society and people with high precision, interacts with them to search for a future society, and allows individuals to choose their desired behavior.

(4) *Global Inclusive Sustainability* presents multiple options for transformation of social systems leading to an inclusive equilibrium that harmonizes the autonomy of the global environment and the autonomy of the social and economic systems that are part of it.

2. Efforts toward common use of digital twins

To achieve the above grand challenges targeting the implementation of the DTC concept, building applications by combining various digital twins, such as humans, vehicles, buildings, and weather environments,

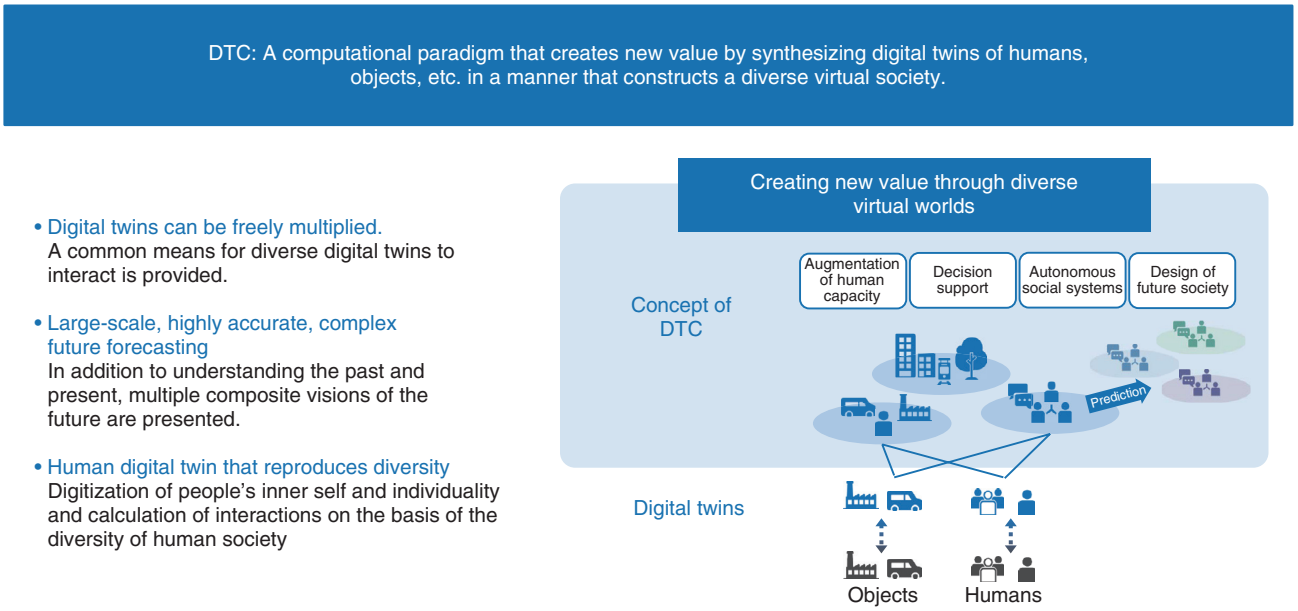

Fig. 1. What is DTC?

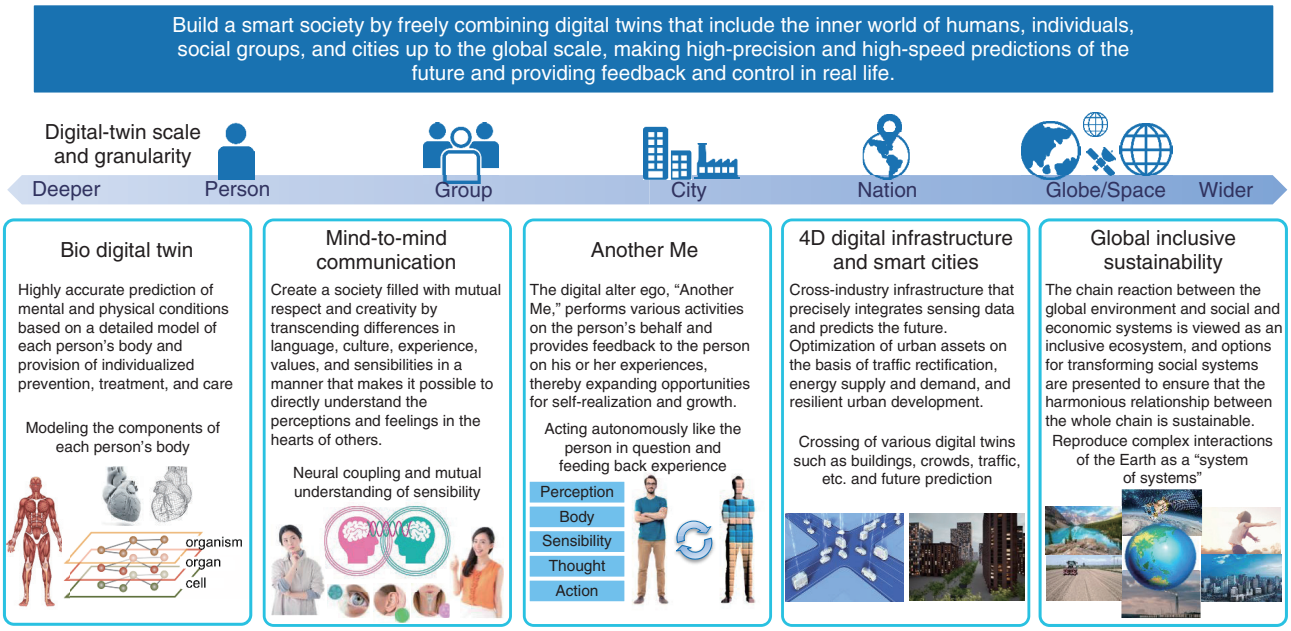

Fig. 2. Expansion of DTC.

will require the ability to freely combine such various digital twins and compute their interactions. It is essential to ensure the interconnectivity of digital twins. Accordingly, we are making efforts toward common use of necessary digital twins while focusing on collaboration with various stakeholders in related industries at the IOWN Global Forum (IOWN GF).

The DTC concept is not something that we at NTT can make a reality on our own; that is, we need to

work together with related companies, universities, and research institutes to determine its technical specifications and framework. IOWN GF is considered an ideal forum for discussions with such organizations because it covers everything from network infrastructure to the application layer and includes a wide range of specialists from technology providers to users. By combining the requirements and findings acquired from these broad perspectives, we can discuss effective schemes to ensure interoperability of digital twins.

In February 2022, IOWN GF launched a task force called the "Digital Twin Framework" to begin discussions on interoperability of digital twins. As of November 2022, about 30 specialists from more than 10 companies, universities, and research institutes from Japan, the U.S., and Europe regularly participate in discussions and create documentation through bi-weekly online meetings and the remote team workspace Confluence.

We have started with use-case analysis and gap analysis and begun discussions by clarifying the technical scope that should be defined by IOWN GF in the future. Many of the use cases defined by IOWN GF use digital twins effectively in terms of energy efficiency, reduction of greenhouse-gas emissions, and safety monitoring in smart cities, and by analyzing these use cases, issues to achieving the interoperability of digital twins can be clarified. As a result, a common recognition is emerging: data-model interoperability and access control are important issues in regard to the process by which many stakeholders exchange, process, and modify digital-twin data, and we plan to discuss addressing these issues in the task force.

3. Latest developments concerning the grand challenges

The Feature Articles in this issue describe our research on the above-mentioned grand challenges, the status of development of technologies necessary for achieving them, and our recent activities as summarized in the following order.

3.1 Applied neuroscience technology for enabling mind-to-mind communication

Regarding mind-to-mind communication, we aim to construct a new communication modal that allows people to directly understand one another's sensibilities, such as how they perceive and feel. In this issue, the following applied neuroscience technologies that use human-brain information (including mind-to-mind information) are introduced: technology for decoding the sense of discomfort or satisfaction from electroencephalogram data, technology for perceiving the state of the brain containing sensory information as a representation in the brain, and neural-coupling technology for enhancing mutual understanding [1].

3.2 Creating "Shido Twin" by using Another Me technology

Regarding Another Me as a social implementation of creating a human digital twin that reproduces the appearance and inner self of a real person and acts autonomously, a digital twin of kabuki actor Shido Nakamura was built and performed in a kabuki performance. In this issue, automatic body-motion-generation technology that can reproduce an individual's subtle habits from a small amount of data as well as deep neural network-based text-to-speech synthesis technology that reproduces a variety of speakers and tone at low cost are introduced [2].

3.3 Digital twins for streamlining road-traffic flow

Regarding Exploring Engine for the Future Society, our aim is to construct a mechanism to digitally represent a society in which people are active with high accuracy and to explore the future with iterative changes in people's behavior. In this issue, reproducing and predicting traffic flow with a digital twin and traffic-demand-estimation technology to generate realistic traffic-demand data by interpolating known fragmentary cross-sectional traffic-volume data are introduced [3].

3.4 Research and development of co-simulation technology for attaining inclusive sustainability

Regarding Global Inclusive Sustainability, our aim is to evaluate the effects of policies with an understanding of the complex interactions among the environment, economy, and society to attain inclusive sustainability. Accordingly, we are building a system for evaluating those interactions by reproducing them on a computer. In this issue, a co-simulation technology for coordinating multiple simulation models, policy-evaluation prototyping, and their future prospects are introduced [4].

4. Concluding remarks

Our grand challenges are bold visions for the future that may seem unattainable at first glance. Achieving these challenges is difficult simply by improving technologies or adding new ideas. It is therefore important to use an approach to research called backcasting, i.e., goals are reached by identifying problems to be solved so that challenging goals can be reached in the shortest time. To enable this approach, it is necessary to establish promising use cases, identify areas to focus on, identify technical issues, and evaluate the impact of social implementation.

For mind-to-mind communication and Another Me, we used the sci-fi prototyping method to express concretely—in novel form—a future society that may occur when these technologies are implemented (i.e., highlighting possible social changes and the perceptions and issues of the people living there) and feeding this information back to R&D. These efforts are introduced in a special report in this issue [5].

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Takao Nakamura
Senior Research Engineer, Supervisor, NTT Digital Twin Computing Research Center.
He received a B.S. in mathematics from Waseda University, Tokyo, in 1994, and Ph.D. in informatics from the Graduate University for Advanced Studies, Kanagawa, in 2008. He joined NTT Human Interface Laboratories in 1994 and studied media processing technologies, content distribution systems, artificial intelligence, and their applications. He is currently the director of NTT Digital Twin Computing Research Center and engaged in R&D of the concepts and technologies for DTC.

Koya Mori
Senior Research Engineer, NTT Digital Twin Computing Research Center.
Since joining NTT in 2004, he has been involved in the R&D of an Internet-of-Things application based on software technologies, such as OSGi, OpenStack, and edge computing. Since 2020, he has been researching DTC at NTT Digital Twin Computing Research Center.

Ryo Kitahara
Senior Research Engineer, NTT Digital Twin Computing Research Center.
He joined NTT in 2003. His research interests include image-processing technologies. Since 2020, he has been researching DTC at NTT Digital Twin Computing Research Center.