# Data-driven Medical and Health Support Created Using Bio-digital Twin

*Hiroshi Nakashima, Katsuyoshi Hayashi, and Hideki Gotoh*

## Abstract

Humanity is currently experiencing a pandemic unprecedented in recent history. In November 2020, NTT announced its Medical and Health Vision, "Realization of the Bio-digital Twin," to create a medical future in which people can avoid unknown risks and remain healthy and hopeful about the future through predictions of their physical and mental states. In the Feature Articles in this issue, NTT's Medical and Health Vision as well as the latest technological details concerning acquiring and analyzing biological information and enabling treatment in the body, namely, elemental technologies concerning bio-digital twins, are introduced.

*Keywords: Medical and Health Vision, bio-digital twin, well-being*

## 1. New expectations in the medical and healthcare fields

Humanity is in the midst of the Covid-19 pandemic, which has severely affected daily life, healthcare, and social systems. Covid-19 has large regional and individual differences in its symptoms, severity, case-fatality rate, and prognosis, and it has reminded us of the vast extent of the unknown areas in the living body. Even now, ensuring the safety of citizens and medical personnel and protecting the lives of citizens are urgent issues.

At NTT, we believe that for people to overcome unknown risks, live a safe and secure life, and lead a happy life in their own ways, it is important for them to be able to maintain hope for the future as well as their physical and mental health. To achieve these goals, we believe that there is a greater need than ever for (i) early detection of abnormalities in the body caused by unknown risks, (ii) prevention and treatment based on the causal relationship between the onset and worsening of diseases, and (iii) individualization and optimization of support for people who require nursing care and people with disabilities.

## 2. Our Medical and Health Vision: Realization of Bio-digital Twin

In response to the needs described above, NTT is aiming to create a precise mapping of each person's body and mind, a so-called "bio-digital twin" (BDT) (**Fig. 1**), by applying Digital Twin Computing, which is one of the components of NTT's Innovative Optical and Wireless Network (IOWN). Our vision is to contribute to the future of medical care, in which people are healthy and have hope for the future, by predicting their physical and mental conditions through BDTs (**Fig. 2**). We believe that BDTs can form not only individual mappings but also aggregate mappings of an unspecified number of individuals. In addition to the medical care provided by medical professionals, the medical care described here includes healthcare, long-term care, and support for people with disabilities.

To predict the future for the mind and body, five goals must be reached. The first is digital mapping of

Fig. 1. Schematic of bio-digital twin (BDT).

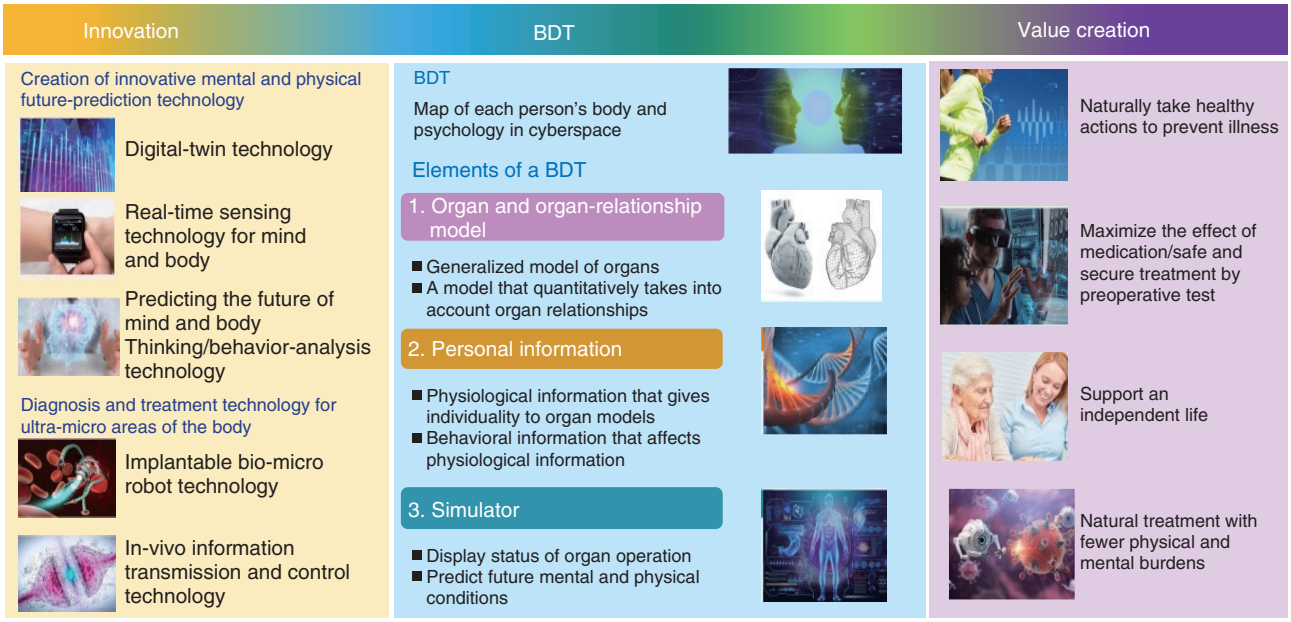


Fig. 2. NTT's Medical and Health Vision.

organ functions. Focusing on heart disease, with which the number of patients is expected to increase rapidly and which significantly decreases quality of life when it develops, we have begun studying cardiac modeling. The living body changes with each passing moment according to the environment it is in and the load on it. The second goal is therefore to measure biomarkers, such as electrocardiograms, heartbeat, and blood glucose level, constantly or in a timely manner while imposing little or no burden on the

body and mind. The third goal is predictive simulation of psychosomatic states from a multifaceted perspective, including human behavioral mechanisms, psychology, and diseases involving multiple organs. In addition, we believe that it is necessary not only to predict the future but also to link those predictions to specific treatment and support. In particular, we are also focusing on the fourth and fifth goals: diagnosis and treatment in the ultramicroscopic region of the body and control of limb movements in accordance with signals from the central nervous system. Reaching these goals will lead to nursing care and support for people with disabilities.

To reach each of these five goals, we are researching and developing technologies such as technology for creating each person's digital twin, non-invasive real-time sensing for the mind and body that captures the individuality of each person, future prediction for mental and physical conditions, thinking-and-behavior analysis, implantable-device and bio-micro-robot technology using highly biocompatible materials, and information-transmission and control implemented within the living body. In heart modeling, for example, we are simulating the function of the cardiovascular system that instantly controls the autonomic nerves and blood volume. The simulation is based on a hemodynamic model into which data, such as right-atrial pressure of the heart and pulmonary-artery pressure are input and central venous pressure and cardiac-excretion amount, are output. Using this knowledge, we are focusing on mechanisms that work in multiple layers to maintain homeostasis in the whole body by, for example, regulating load over long time scales due to lifestyle and daily stress.

A BDT is constructed from personal information with the consent of the individual on which it is based. That personal information includes sensing data collected in real time, as described above, molecular biological information of organ functions (such as genomes and proteins), and information about exercise, diet, and behavioral history that affect physiological states. While carefully considering privacy and ethical issues, we will use the assets of NTT Group companies to collect and use personal data. A BDT, which is based on a variety of information, can be used to assess a person's mental and physical state from the past to the future while taking into account the influence of the person's thoughts and surrounding environment. We believe that it is possible to use a BDT to predict and avoid unknown risks that are difficult to deal with on an individual basis. We expect a BDT to enable improvements such as (i) maximizing the effect of medication and therapeutic effects by pre-simulation of surgery and (ii) improving natural lifestyle habits unconsciously derived from individual behavioral mechanisms without forcibly suppressing diet (which might adversely affect a person's health). We also aim to use BDTs in use cases such as supporting the independent life of elderly persons.

## 3. NTT R&D in the medical and healthcare fields

In the medical and healthcare fields, as information and communication technology (ICT) and artificial intelligence (AI) analysis continue to be introduced, we are trying to make major innovations while incorporating the latest diagnostic and therapeutic technologies for remote, non-contact, daily, and home use. With the advent of the Internet of Things era, wearable healthcare devices, which allow users to easily monitor their body condition on a daily basis, are becoming increasingly competitive worldwide as various measurement functions are added to the devices. Against this background, NTT established the Biomedical Informatics Center (BMC) in July 2019 as a domestic research center in the medical and healthcare fields. Making it our mission to create data-driven medical and healthcare using ICT and AI technologies, we are promoting research and development (R&D) in cross-sectional collaboration with related NTT laboratories for making our Medical and Health Vision a reality.

NTT laboratories are engaged in a wide range of research—from basic to applied—while focusing on themes representing the building blocks of a BDT, such as future prediction technology for the body and mind, bio-sensing technology (wearable, remote, and non-invasive), cardiac-abnormality detection and prediction technology, and micro-therapy technology inside the body. Together with the Medical & Health Informatics Laboratory (MEI Labs) of NTT Research, Inc., which is an overseas research base established in July 2019, we are accelerating R&D from a global perspective and promoting co-innovation with global partners. We will also work closely with NTT Group companies to expand the area of commercial services in the medical and healthcare fields. In these rapidly evolving fields, to achieve results quickly and implement them in society in accordance with our Medical and Health Vision, it is difficult for the NTT Group alone to establish medical technologies and understand

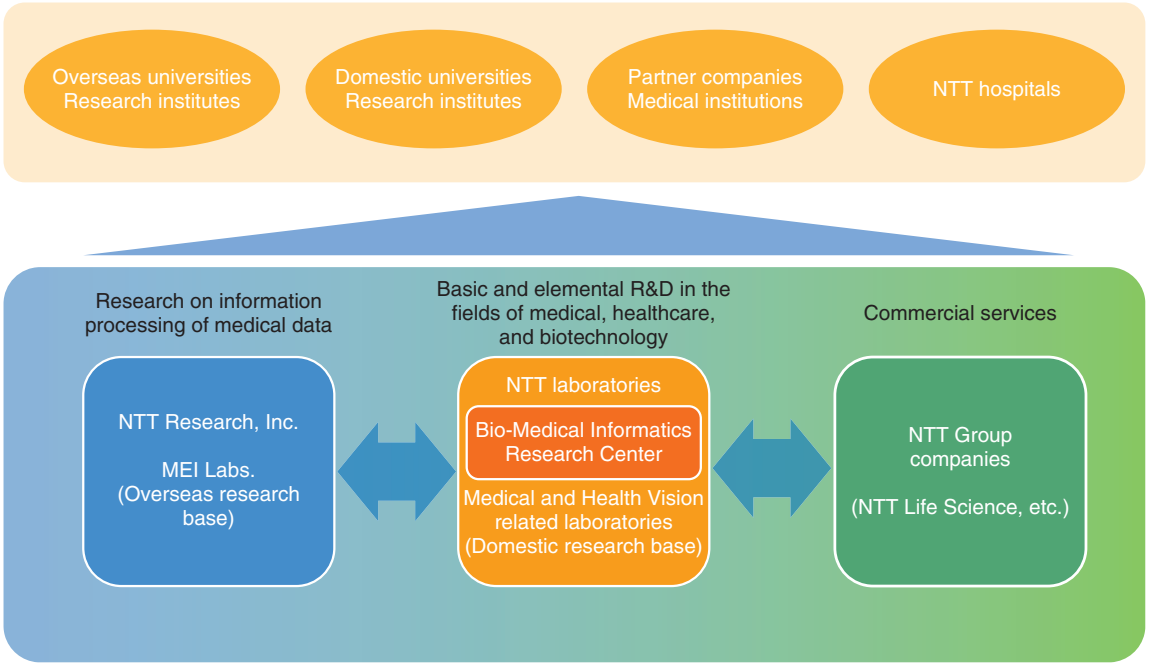


Fig. 3. Formations supporting medical science and business.

social, clinical, and advanced needs. With that difficulty in mind, we want to promote R&D through collaboration and co-creation with medical institutions, research organizations, universities, partner companies, and NTT Group hospitals in Japan and overseas. Readers should refer to the five articles in this issue (described below) for specific details about our R&D for making our Medical and Health Vision a reality (**Fig. 3**).

In the first article, titled "Efforts in Analyzing Risks and Factors Concerning Lifestyle-related Diseases and Long-term Care" [1], prediction and factor analysis of the risk of disease onset based on machine learning and AI—which aim to provide health guidance tailored to individual characteristics and lifestyles—are introduced. The main topics outlined in this article are factor analysis of disease onset considering genomic information and prediction of locomotive syndrome to prevent the need for nursing care.

The second article, titled "Behavior-change Support Technology that Brings About Positive Mental Changes" [2], focuses on the issue of health promotion, through lifestyle improvement and other measures, to address social issues such as reducing medical costs. This article introduces R&D themes for improving lifestyle habits (so-called "behavioral change") by providing advice tailored to each person's personality.

In the third article, titled "Technology for Visualizing the Circadian Rhythm: Wearable Core-body-temperature Sensor" [3], biological sensing of core body temperature, which can be used as an indicator of common colds and infectious diseases, insomnia, depression, and other body rhythms, is introduced. Continuous daily monitoring of deep body temperature—which had been difficult to easily measure—by using wearable device technology that does not place a burden on the body is also discussed.

In the fourth article, titled "New Technology for Measurement and Analysis of Biological Sounds and Electrocardiographic Signals—Toward Early Detection of Heart Disease and Rehabilitation by Using Personal Heart Modeling" [4], a method for measuring bio-acoustics by using a wearable acoustic-sensor array and new bio-signal measurement and analysis techniques (such as tensor electrocardiograms obtained by hitoe™) are introduced. Personal cardiac modeling, cardiac-abnormality detection and prediction technologies, and their applications to rehabilitation are also described as core technologies of BDTs of the future.

The fifth article, titled "Bionics Technology for the Future of Medicine and Health" [5], focuses on bionics technology, which bridges the fields of biological

systems and engineering, with a view to future micro-therapeutic technologies deployed in the body. Two technologies are introduced: (i) soft-material device technology for implementing microphysiological systems, which imitate the shape and movement of living organisms by applying the knowledge of biological systems to engineering systems, and (ii) bio-cybernetics technology, which applies engineering knowledge to biological systems, processes biological signals, and returns them to the living body to activate movements of the body. Microphysiological systems are expected to be able to reproduce and evaluate organ models and multi-organ connection models from the cell and biomaterial levels. In contrast, bio-cybernetics is highly valued in terms of providing technology for rehabilitation and handicap support. We believe that both are challenging research themes.

As described above, we have begun to work on themes of R&D in various technical fields toward making our Medical and Health Vision, "Realization of BDTs," a reality. In close collaboration with personnel of NTT Group and external partners as we pursue co-creation, we will continue to contribute to the improvement of the well-being of people and society as a whole from the aspect of R&D.

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**Hiroshi Nakashima**
Executive Research Scientist and Project Manager of Bio-Medical Informatics Research Center, NTT Basic Research Laboratories.

He received a B.E., M.E., and Ph.D. in applied chemistry from Waseda University, Tokyo, in 1995, 1997, and 2002. He joined NTT Basic Research Laboratories in 1997. Since then, he has been engaged in research on the synthesis and control of the optoelectrical properties of (semi)conductive polymers and nano-bio materials. His recent work includes research on biomonitoring using the functional material hitoe™ wearable bioelectrodes. He was a visiting researcher at University of Oxford, UK in 2002 and at University of Wollongong, Australia in 2010–2011. He is a member of the Chemical Society of Japan (and its Division of Colloid and Surface Chemistry) and the Japan Society of Applied Physics (and its Division of Molecular Electronics and Bioelectronics).

**Katsuyoshi Hayashi**
Director, Chief Producer, Research and Development Planning Department, NTT.

He received a B.E., M.E., and Ph.D. in applied chemistry from Waseda University, Tokyo, in 1996, 1998, and 2005. He joined NTT Basic Research Laboratories in 1998 and began researching electrochemical biosensing devices to detect biomolecules, including neurotransmitters and hormones in the brain and blood. From 2007 to 2008, he was a visiting scientist in the Biomedical Engineering Department, University of Wisconsin-Madison, Wisconsin, USA, where he studied cell biology with microfluidic devices. In 2017, he began working with various stakeholders to create new value using NTT R&D products. He is also working as a senior research engineer at NTT Device Technology Laboratories and Bio-medical Informatics Research Center, NTT Basic Research Laboratories.

**Hideki Gotoh**
Vice President, Head of NTT Basic Research Laboratories.

He received a B.E., M.E., and Ph.D. in engineering from Hiroshima University in 1991, 1993, and 2000. Since joining NTT Basic Research Laboratories in 1993, he has been working on optical physics and device applications of semiconductor nanostructures. He was a visiting researcher at University of Illinois at Urbana-Champaign in United States of America in 2004. He was a guest associate professor at University of Tsukuba from 2010 to 2016 and a guest professor from 2016 to 2019. He is a member of the Japan Society of Applied Physics and the Optical Society (OSA).