THE UNIVERSITY OF TOKYO

RESEARCH INTO ARTIFACTS, CENTER FOR ENGINEERING

School of Engineering, the University of Tokyo

RACE
RESEARCH INTO ARTIFACTS, CENTER FOR ENGINEERING

The new Research into Artifacts, Center for Engineering

as a research/education hub for needs-driven next generation manufacturing

While the development and use of modern technology has filled our life with wealth and comfort, it has caused new societal/environmental issues such as global ecological destruction, disaster-vulnerable cities, emerging diseases, and increasing large-scale accidents. *Artifactology* [*1] was proposed as a discipline to tackle these problems, the so-called "modern evil."

The new RACE (Research into Artifacts, Center for Engineering) was established on the Hongo campus of the University of Tokyo as an affiliated research center of the School of Engineering. It is a center for research and education on next generation manufacturing, inheriting the tradition of the previous RACE[*2] which had been a university institution since 1992. Aiming for the sustainable development of the human society, the new RACE takes into perspective not only physical products but also services, values and social acceptance, to cover the relationship between human, society and technology. Its main challenges are as follows:

1. Social dissemination of *artifactology* through industry-academia-government collaboration

We propose the vision and framework of next generation manufacturing while solving problems at the manufacturing sites and creating new values through industry-academia-government collaboration, and promote the social dissemination of *artifactology*.

2. Education and human resource development in *artifactology*

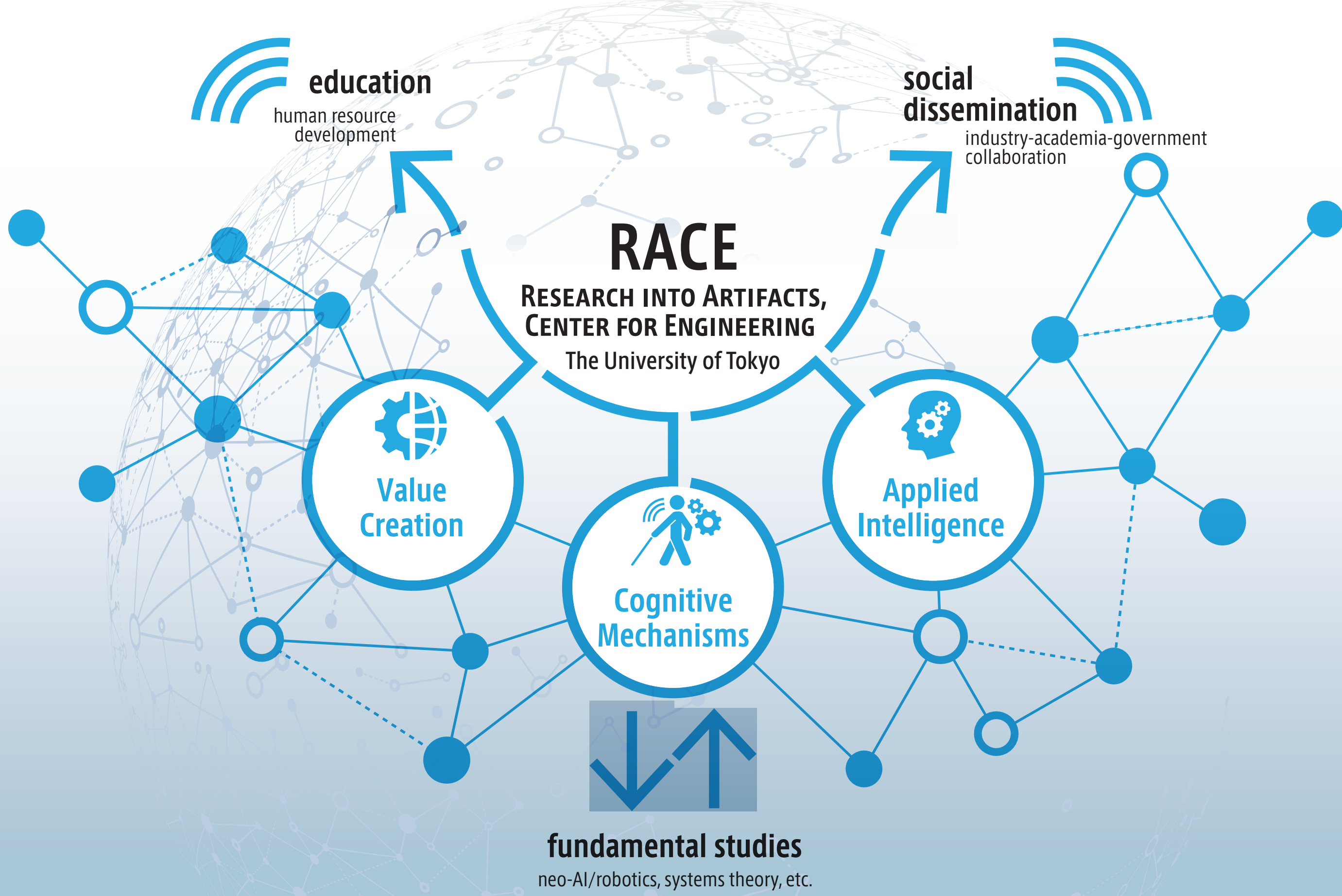
We develop human resources for next generation manufacturing, through the development and implementation of unique education programs and curriculums in *artifactology*.

3. Fundamental studies in *artifactology*

We promote next generation manufacturing through exploration in new fundamental studies on topics such as the development of neo-AI/robotics, systems theory, cutting edge manufacturing technology, and social acceptance.

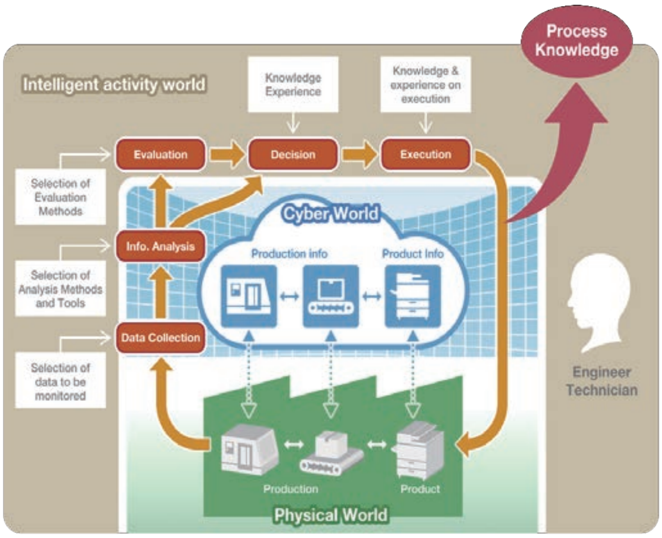
The new RACE is an open organization. We promote social dissemination of *artifactology* while searching for a means to solve problems in current manufacturing by being the hub for next generation manufacturing, connecting interdisciplinary research scientists in the university as well as external industry and research organizations, for various joint projects, donation/corporate sponsored research programs, and collaborative research. We will also collaborate with the government for making policies to support next generation manufacturing in industry.

[*1] Hiroyuki Yoshikawa "Jinko-butsu kogaku no teisho (Proposition of *artifactology*)" *Illume; A TEPCO semiannual journal for creative persons,* April 1992.
[*2] First phase 1992–2002, second phase 2002–2013, third phase 2013–2019.



Value Creation Division

To achieve next generation manufacturing it is necessary to connect and unite the physical product, the service it offers, and the social systems that support them, for the creation of values. Building on the digital twin – the system to replicate the real in the virtual world – we have added the expanded world of intellectual activity to make a "digital triplet." In this division we utilize this concept to create a social ecosystem that can grow and evolve continuously after the product/service has been implemented in real society, by enabling society to care after the system through maintenance and upgrading.



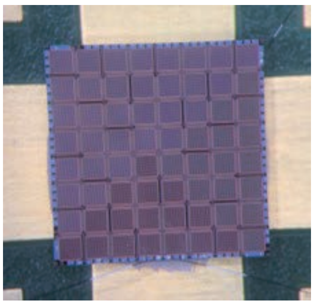
Proposal of digital triplet manufacturing systems

This research proposes "digital triplet," which realizes digitalization of manufacturing systems with making full use of strengths of Japanese manufacturing industry and ability of on-site manufacturing system engineers. Digital triplet also aims to support all engineering activities throughout product life cycles in an integrated manner. We are now trying to develop this framework, construct a learning factory based on this concept, and draw application scenarios. — Y. Umeda

Prototype system of digital ▲ triplet for an assembly process

Development of high-sensitivity photodetectors and its applications

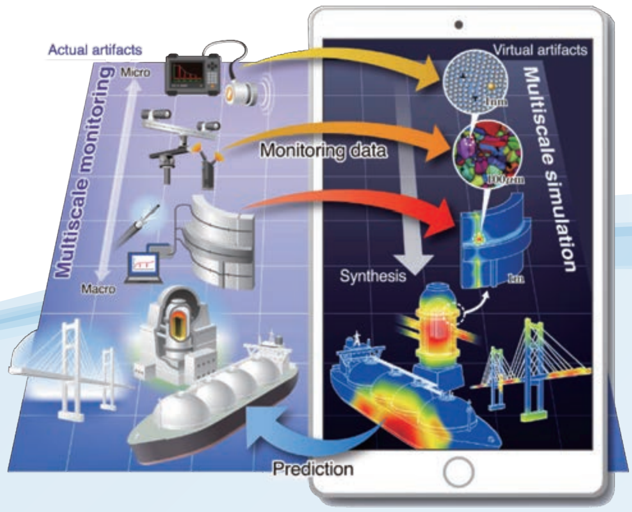
SiPM (Silicon photomultiploer) is a fast photodetector, which can detect a single photon with sub-nano second time resolution. We are developing an SiPM array to enhance the application area for value creation. — H. Takahashi



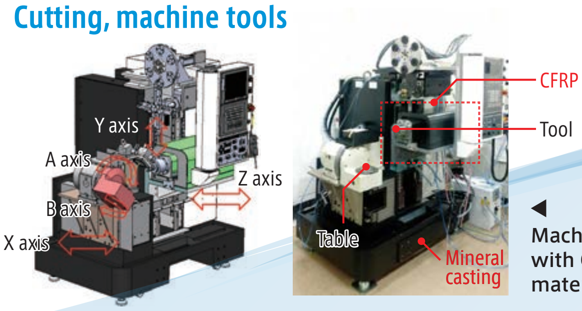
▶ High-sensitivity SiPM array implemented with CMOS technology (pixel size 500μm x 500μm, 64px)

Digital twin of artifacts

We construct an advanced digital twin of artifact systems (DTAS) in which physical and numerical models of structural materials at several length scales are constructed and integrated, while monitoring and inspection data are used as input parameters. As DTAS can reproduce the current state of structural materials and predict their degradation, it can improve the resilience and give plasticity to artifact systems. — T. Okita



Cutting, machine tools



◀ Machine tools with CFRP material

We are researching high precision and high efficiency processing for difficult-to-cut materials. Also, we are developing a machining center with carbon fiber reinforced plastic (CFRP). A simultaneous 5-axis machining center has been already developed. We begin to develop new machining centers. — N. Sugita

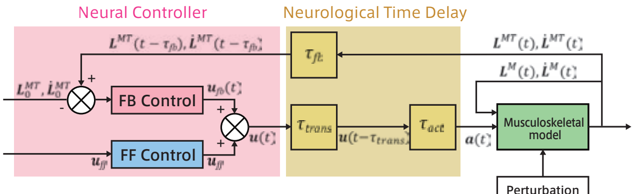
Proposing visions for future manufacturing with digitalization and sustainability.

Cognitive Mechanisms Division

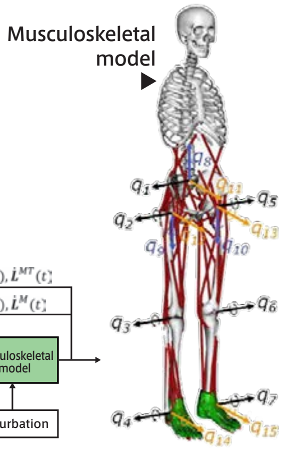
The abilities required in next generation manufacturing are the accurate understanding of the implicit needs of society and the presentation of actual values to answer those needs. If we consider society as the entirety of the users, manufacturers and other stakeholders of a product/service, and all the products/services that derive therefrom, we need to elucidate how people perceive artifacts, i.e. their cognitive mechanism. In this division we combine humanities and science in study, adapting approaches from psychology to resolve the human cognition, for the clarification of the mechanism of how people perceive and interact with artifacts, to support the manufacture of artifacts to contribute to people and society.

Human neuromusculoskeletal modeling for understanding the mechanism of stance postural control

Humans perform stance postural control with many muscles activation by integrating sensor information such as visual, vestibular, and somatosensory. Understanding the mechanism of the control is essential to provide effective rehabilitation. We aim to clarify the mechanism through the construction of a neural controller model to keep a musculoskeletal model in a stance posture. — J. Ota

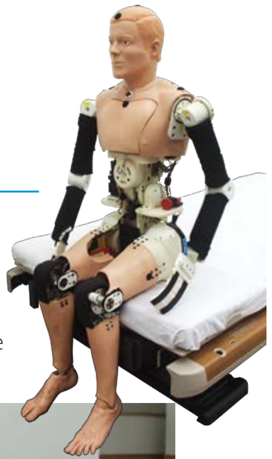


▲ Neural controller model



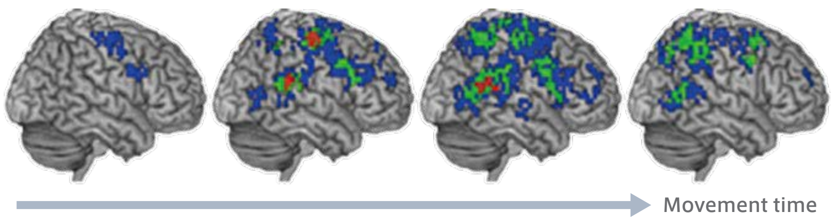
Robot patient for nursing skill training

The students are expected to learn the required skills by practicing with the robot that imitate different patients. — J. Ota



Brain mechanism for cognition of initiative

When humans voluntary move own bodies and tools, they have "sense of agency (initiative)" that they are the initiators of the movements. Our recent studies revealed neural processes that build up the sense of agency during movements. Based on this basic study, we will investigate how humans recognize their initiative and agency in service and social systems, and brain mechanisms underlying such recognition. — H. Imamizu



Design/manufacturing system based on 3D scanning technology and cognitive mechanism

We are working on the advancement of design/manufacturing system (CAD/CAM) based on 3D shape scanning as core technology. In addition, in the next-generation manufacturing, a system to take into account human cognitive mechanisms is important, and we are researching and developing the emulation technology of the cognitive mechanisms by AI and the data processing technology for its construction. — Y. Ohtake

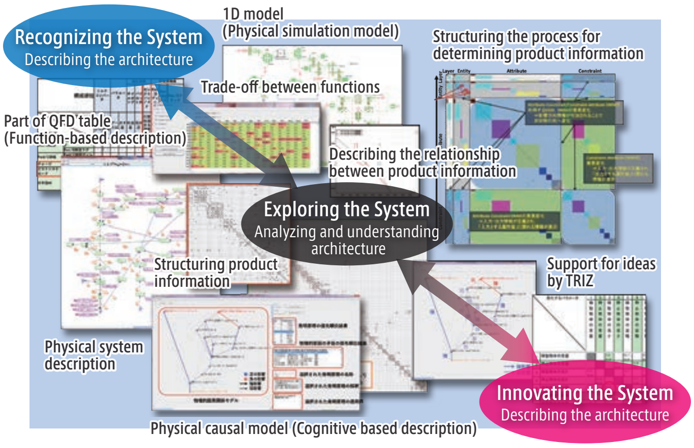
Uncovering the mechanism of human cognition, for the manufacture of artifacts that contribute to people and society.

Applied Intelligence Division

Dramatic leaps have been seen in the development of deep learning and other AI cognitive technology. Through a sophisticated integration of this field with the knowledge of hardware and infrastructure technology we have in the School of Engineering, we aim to produce product/service systems with outstanding global competitiveness. To solve a problem we start from the choice of necessary information, looking for real-life data to compose the information, the physical devices to acquire the data, the processing method of the data, service architecture and its continuous improvement, and supporting manufacturing activities – all part of the research and development centered on the construction of an information cycle system.

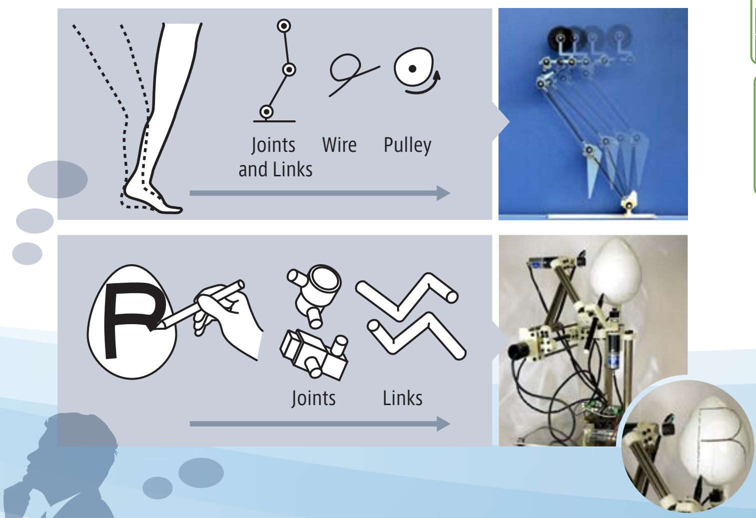
Exploring systems engineering

Due to the complexity of product systems in the modern society, it has been becoming difficult to easily see and grasp the essential points from a higher perspective. We have been researching about the Systems Engineering method that systematically handles from design and development of a product system to realizing and constructing. — K. Aoyama



Automated design of a task specific machine

We have been proposing the methods to create a machine accord ing to a given task by analysis or optimization. For example, we have introduced the way to design the constraints of the motion of joints in linkage using a wire. We also have proposed the way to design joint displacements of a robotic manipulator to follow a given trajectory with a smaller number of motors. — S. Shirafuji

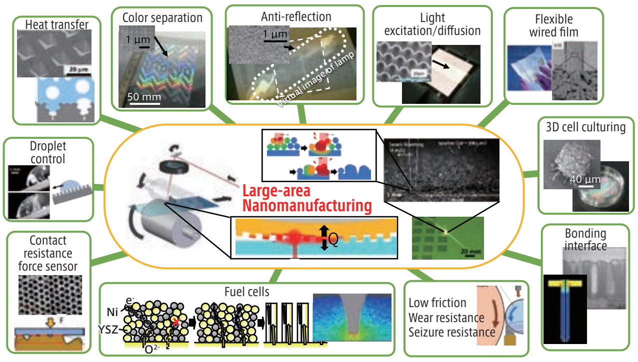


Research on deep learning and its integration to manufacturing

Deep generative models such as generative adversarial network (GAN) and variational autoencoders (VAE) are important as the core of future intelligence research. It can do various kinds of "imagination"; predict what will happen next, depict an image from sentences, and enable complex planning. We develop a joint multi-modal VAE (JMVAE), which enables modeling the multi-modal data such as image, sound, tag, and so on. — Y. Matsuo

▲ Automation of escavator using deep reinforcement learning

Micro-/nanomanufacturing of functional surface and process informatics



Micro-/nanostructured surfaces express a variety of unique physical functions. We develop high-efficiency manufacturing methods using laser or powders for these functional surfaces but also their novel applications.We also study data-driven "process informatics", to efficiently open the process windows of the laser/powder processes having complex phenomena. — K. Nagato

Utilizing AI and IT for a new social implementation process including the design and manufacture of artifacts.

Members

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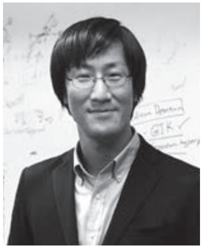

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