

## Software Engineering Technologies for Cyber-Physical Systems (CPS)

**Toward Transformation from Software Factory to Service Factory – Strategic Change to CPS Service Provider**

YAMAMOTO Hiroshi

**Toshiba Group's Approach to Software Systems Engineering for Cyber-Physical Systems**

FUKAYA Tetsuji / IMAMURA Daisuke

Cyber-physical systems (CPS), which form the core of the fourth industrial revolution, have made it possible to efficiently offer high-value-added products and services through the interaction of information systems and various physical components. CPS systems are controlled by software that must not only respond to frequent updates but also operate in conjunction with various types of systems via application programming interfaces (APIs). As a result, software systems engineering techniques different from those used for conventional information systems are essential for the development of CPS software.

The Toshiba Group has systematized a method for software systems engineering encompassing the development processes, development environment, and architecture of such software, and applied this method to the development of CPS services.

**Use of Modern Application Architecture for Development of CPS Software**

FUNAKI Ryoichi / HANAI Katsuyuki

In order to develop software for cyber-physical systems (CPS) services, particularly for social infrastructure systems requiring high reliability, there is a need for effective utilization of modern application architecture incorporating highly independent microservices as well as a container platform for the efficient deployment of software.

The Toshiba Group is responding to this need by standardizing the framework of software development and the related guidelines and establishing a software development environment utilizing a modern application architecture. We are also making effective use of accumulated development assets of infrastructure systems as modern applications.

**Process Standardization for Realization of CPS Services Based on System of Systems**

SHIRAI Yasutaka / KITAGAWA Takayuki / KATO Hideki / YAMADA Atsushi

The Toshiba Group has set the goal of becoming a cyber-physical systems (CPS) technology company. To provide customers with more attractive services and agility, it is necessary to integrate multiple products and related technologies that have so far been implemented and managed independently. It has therefore become essential not only to obtain an in-depth understanding of the concept of system of systems, but also to implement process standardization in order to achieve cross-business collaboration for the efficient and effective development and operation of such services.

As part of these activities, we have been engaged in efforts to promote process standardization compliant with the International Organization for Standardization/International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (ISO/IEC/IEEE) 15288:2015 standards by means of several methodologies including DevOps and the microservices architecture (MSA).

**Standardization of Agile and DevOps Software Development Processes for Swift and Effective Improvement of CPS Systems and Application to VPP Project**

MIYATA Makiko / OMORI Mari

The primary objective of cyber-physical systems (CPS) services is to enhance business value. Each service comprising a CPS system should therefore be able to swiftly respond to changes in business configuration and technological innovations as required. This can be accomplished through the introduction of methodologies including agile software development and DevOps combining software development and operation.

Toshiba Digital Solutions Corporation is making efforts to achieve the swift and effective improvement of CPS systems through the standardization of software development processes using agile and DevOps methodologies. As part of these activities, we have applied such standardized processes to a virtual power plant (VPP) system development project and are rapidly developing and releasing various VPP systems and services.

**Software Development Environment Allowing Continuous Delivery of Software Based on DevOps Methodology**

MAEDA Naoto / TAHARA Ayumu / NAGAOKA Takeshi / AMAMOTO Kazuko

For the successful development of software supporting cyber-physical systems (CPS) services, it is essential to frequently release software updates providing enhanced functions in line with the changes taking place in the business environment and customers' needs as well as the progress of technologies.

The Toshiba Group has constructed a proprietary software development environment for sharing software components between different development bases, managing and controlling the quality of development assets, and automating development processes, through the use of DevOps methodology. This software development environment makes it possible to ensure the traceability of development processes from requirements to source codes and reduce the time and cost required to find and correct defects.

**Co-Creation Platform to Efficiently Enhance Software Development**

NINJOUJI Takashi / KOBAYASHI Yoshitake / KOGA Kunihide

With the ongoing digitalization of social infrastructure systems, high-quality products combining continuously evolving services have begun to be developed with the aim of creating new value. In the area of software development, there is a need for co-creation utilizing technologies in a variety of different fields as well as for higher development efficiency than has been attained up to now.

In this context, Toshiba Corporation is promoting the development of software applying the InnerSource collaboration method. In order to support software development by means of this method, we have established a co-creation platform for software development consisting of a software development management system to support data sharing and collaborative work in multiple sections, and a software asset management system to grasp overall information on developed software components and support the reuse of available software.

**Microservice Development Technologies to Realize Efficient Development of Various Services**

KOJIMA Yoshiharu / SAITO Minoru

The Toshiba Group has set the goal of becoming a cyber-physical systems (CPS) technology company that can offer solutions to various social problems based on digital technologies. In order to efficiently provide a broad range of CPS services, we have adopted a software architecture style known as microservices architecture, in which a service is constructed through the collection of small-scale services called microservices. A feature of this method is that it allows a service to be easily constructed as an aggregate of microservices. However, it is necessary to design microservices of the appropriate size and to develop them in an agile manner, for flexible transformation of the microservices themselves.

As part of this approach, Toshiba Digital Solutions Corporation is promoting the establishment of a development environment for the swift and agile development of microservices through the preparation of development guides, architecture patterns, and execution platforms. We are also responding to the sophistication of microservices by continuously improving related technologies and promoting the rapid expansion of their application based on a feedback cycle from development sites.

**HABANEROTS Toshiba Industrial IoT Platform Service Enabling Rapid Start of CPS Services Utilizing Service Mesh Technology**

UCHIDA Masayuki / HIGUCHI Yasukazu

To promote the development of cyber-physical systems (CPS) services and expansion of CPS businesses, establishment of the appropriate development platform and processes is becoming essential in order to rapidly start services and continuously improve quality. As part of these activities, the microservices architecture (MSA) is playing an important role in the rapid development cycles of CPS services. However, higher development and operation costs are serious issues accompanying the increase in the number of microservices.

Toshiba Corporation is developing HABANEROTS, previously known as Habanero, an industrial Internet of Things (IoT) platform service utilizing a service mesh technology to overcome issues related to MSA. HABANEROTS makes it possible to enhance the efficiency of development by shortening the time required for investigating bottlenecks in performance tests, as well as to realize continuous improvements in service quality based on the aggregated results including the frequency of error occurrence in Web application programming interfaces (APIs).

**Standardization of System Development Guidelines and Checklists for Each Phase of Development of Managed Services**

SAIKA Tsubasa / MURATA Naohiko

Cyber-physical systems (CPS) for social infrastructure must provide a high level of business continuity management. The need has consequently arisen for managed services to secure the stable operation of systems while ensuring customers' business continuity through rapid recovery, identification of the main cause, and implementation of measures to prevent a recurrence in the event of a problem occurring in their systems.

As a managed service provider (MSP), Toshiba Digital Solutions Corporation has developed system development guidelines and checklists for use in each phase of development of managed services. These guidelines and checklists provide standardized methods including methods for incorporating countermeasures against problems into a system and methods for preparing the various documents necessary for operation and maintenance services, making it possible to offer CPS services capable of being continuously updated.

## Feature Articles

**GridDB Scale-Out Database Facilitating Handling of Petabytes of Data at High Speed**

HATTORI Masakazu / FUKUSHIMA Nobuyuki / SUHERMAN Angga

In line with recent world trends in application of the Internet of Things (IoT), attention is being increasingly focused on cyber-physical systems (CPS) aimed at the optimization of whole systems by making use of a wide variety of data. In order to realize CPS systems, database systems with high reliability, high scalability, and high processing capacity are essential. However, it is difficult to fulfill such requirements using conventional database systems such as relational databases (RDBs) and Not only Structured Query Language databases (NoSQL DBs).

To rectify this situation, Toshiba Digital Solutions Corporation has developed and released a lineup of GridDB scale-out databases for social infrastructure systems ranging from small to large in scale, utilizing proprietary technologies including a database cluster technology and a high-speed data processing technology. To disseminate GridDB more widely, we are also making efforts to promote the development of technologies to handle petabytes of data as well as activities related to open source software (OSS).

**Renewal of Signal Distribution Systems for TV Stations in Japan**

TATEISHI Isao / YOSHINARI Takashi

TV stations in Japan are now faced with the need for the renewal of digital terrestrial broadcasting systems, which were introduced throughout the country between 2003 and 2006. These systems incorporate a signal distribution system, which plays a role both in receiving video and audio signals fed from hundreds of lines, and in distributing the signals, whose quality is properly adjusted and controlled by the signal distribution center, to various terminals inside and outside the TV station for broadcasting. With the dissemination of 4K (3 840 x 2 160 pixels) broadcasting and Internet channels in recent years, transmission devices and lines in this system are expected to be changed as needed.

In response to the market demand for such renewal and additional functions meeting the specific requirements of individual TV stations, Toshiba Infrastructure Systems & Solutions Corporation has been developing signal distribution systems that allow large volumes of video and audio signals to be efficiently handled by a smaller number of operators, while at the same time achieving space saving and reduced power consumption. As part of these efforts, we have delivered a new signal distribution system to Nippon Television Network Corporation in order to provide the functions required for its key station system.

**Technology Using Metal-Assisted Chemical Etching (MacEtch) Process to Fabricate Silicon Capacitors with High Capacitance**

OBATA Susumu / SANO Mitsuo / HIGUCHI Kazuhito

Silicon (Si) capacitors with a dielectric film formed on a silicon substrate have been attracting attention as a replacement for conventional multilayer ceramic capacitors (MLCCs) in recent years due to their advantageous features including high heat resistance, low inductance, and thinness. Although Si capacitors with high capacitance are required in the field of automotive electronics, fabrication is costly due to the need to form a trench structure on the Si wafer in order to expand the surface area.

Toshiba Corporation has been engaged in the development of a metal-assisted chemical etching (MacEtch) technology applying anisotropic wet etching of Si using noble metal catalysis, which makes it possible to chemically process the entire surface of a Si wafer. Experiments on a prototype Si capacitor chip with vertical trenches formed on a Si wafer of 100 µm in depth and 1 µm in width using gold (Au) catalysis have verified that it achieves a capacitance density of more than 200 nF/mm<sup>2</sup>.

**Surface-Emitting Photonic-Crystal Quantum Cascade Laser Offering Both High Power and Narrow Beam Shape for Gas Sensing Applications**

HASHIMOTO Rei / SAITO Shinji

Attention is being focused on the quantum cascade laser (QCL), a type of semiconductor laser covering the medium- and far-infrared wavelength ranges, as a potential candidate for small infrared light sources to be used in various laser-based applications including gas sensing and medical equipment. However, higher manufacturing costs and lower beam quality are serious obstacle to their practical use.

As a solution to this issue, Toshiba Corporation has been developing a surface-emitting QCL using a photonic crystal (PC) to achieve a balance between high output power and a narrow beam shape, in addition to high mass productivity. We have now designed and fabricated a PC capable of efficiently oscillating a laser beam of high beam quality with a wavelength in the 4 µm band through the use of various technologies including electromagnetic field simulation and high-precision lithography and dry etching techniques. Experiments on a prototype surface-emitting PC QCL have successfully realized the world's first surface-emission lasing at a wavelength of around 4 µm and confirmed that this newly developed QCL achieves high beam quality with a laser beam divergence angle of less than 2 degrees.

## Frontiers of Research &amp; Development

Technology Enabling Autonomous Visual Inspection at Manufacturing Sites Using Deep Learning