Cloud-based Development Platform for Next-Generation Monozukuri

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Product development is becoming increasingly demanding in terms of design constraints on power consumption, heat generation, various noises, and durability. Strict requirements must also be met within very tight margins. Even when these requirements are individually met, much time is spent on coordinating them for overall adjustment. Thus, enterprises require a comprehensive solution that offers multiple approaches combined and executed simultaneously. For this reason, product design tools of computer-aided design (CAD) and computer-aided engineering (CAE) have undergone continuous improvement and enhancement. However, these individual, tool-specific optimizations cannot offer a solution to today's complex design challenges. Therefore, Fujitsu has fundamentally reviewed product development methods, and sought a solution to complex design challenge by integrating all design tools, data and know-how into a single platform. This is a next-generation cloud-based development platform, "One Platform," that facilitates parallel analyses of electricity, heat, electromagnetic field and mechanical structure that strives to go beyond "connectability" to a truly "connected" state.

1. Introduction

Some 50 years have passed since computer-aided design (CAD) began to be fully applied as a product development environment utilizing computers. Since then, in the area of advanced product development, CAD has become an indispensable tool for designers and it can be said to be a system integrated with product strategy. CAD systems generally consist of a combination of electrical CAD, structural CAD, electrical analysis, structural analysis, and further functional subdivisions. For the purpose of optimizing each phase of product design, CAD and computer-aided engineering (CAE) tools have been continuously evolving.

Meanwhile, to build a richer digital society, demand keeps on increasing for products that offer ultra high speed, large storage capacity, small size, low power consumption, and low cost. As the degree of difficulty of product development increases accordingly, product development environments are also becoming increasingly complex. Technologies that were evolved for specific tools are now having to work with one another through "connectability." Fujitsu believes that it is important to create an information and communications technology (ICT) platform to firmly support the increasingly complex product development environments of the future by making these various technologies "connected" and building a new product development environment designed to go beyond simple tool linkage, achieving tool coordination and tool collaboration.

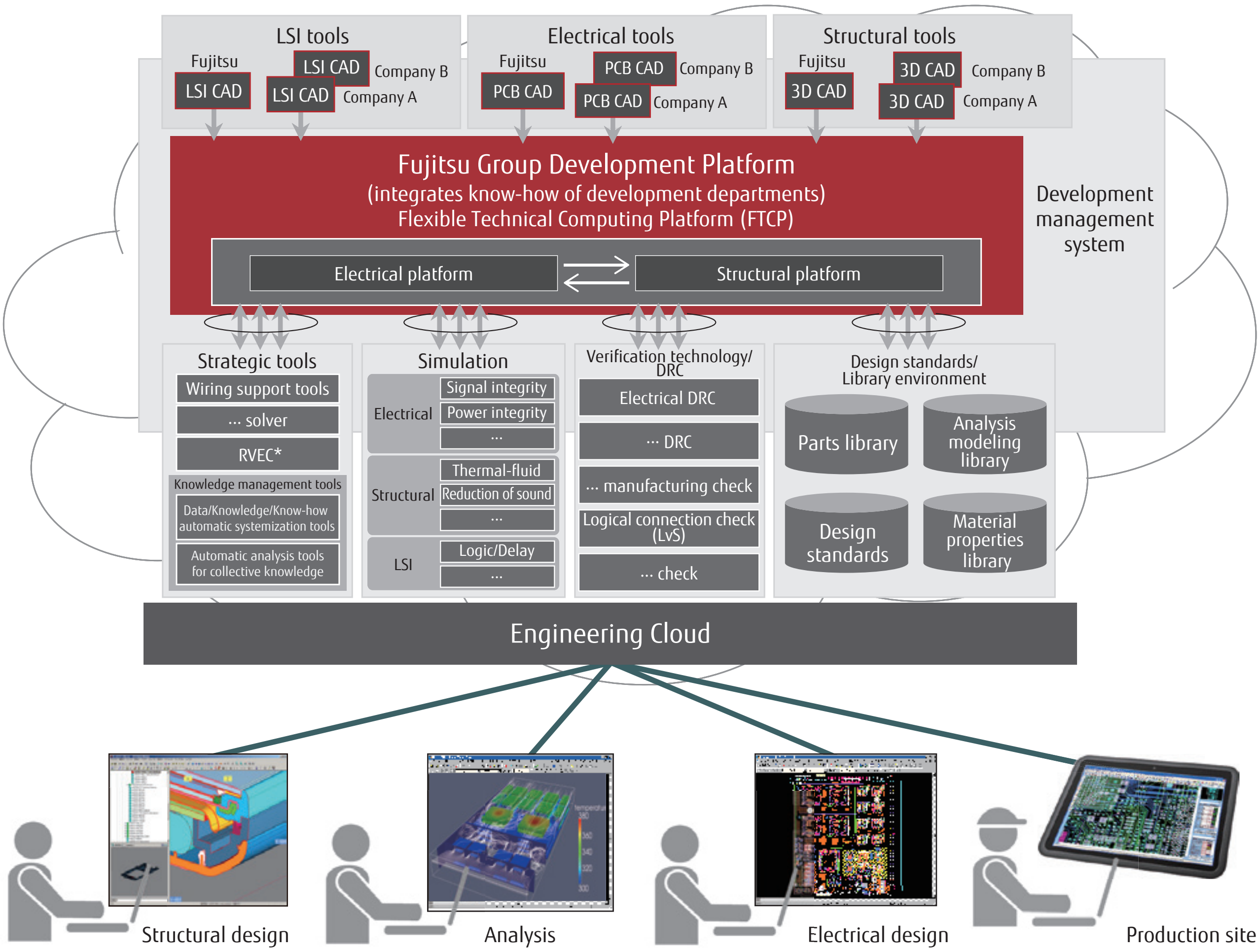
This paper first introduces Fujitsu's product development environment. Next, it describes major challenges in product development, and finally, it introduces the next-generation development platform that Fujitsu is developing to solve these challenges.

2. The Fujitsu Group's product development environment

As a leader in ICT, the Fujitsu Group develops, manufactures, and sells state-of-the-art ICT products ranging from supercomputers to servers, network equipment, personal computers, and mobile terminals such as smartphones. Besides high performance and quality, speedy delivery of products and services when customers need them is also required. To meet all these requirements, The Fujitsu Group has adopted a scientific approach to Monozukuri (Japanese way of manufacturing) and built the Flexible Technical Computing Platform (FTCP), which is a development platform that incorporates the extensive know-how that we have cultivated at our various development and production sites, as well as our development tools.[1)]

FTCP combines LSI, electrical, and structural CAD design tools, analysis tools for design verification, and design rule check (DRC) data files, as well as the design standards, parts DBs, and libraries that constitute the basis of development. All elements necessary for product development, such as a design data management system and project management system, are integrated to realize an environment in which all processes, tools, and data are "connectable" from the upstream design processes to the manufacturing processes. Further, FTCP also aggregates the ICT resources needed to operate all the above, offering them in the form of services as Fujitsu's Engineering Cloud, which offers the same development environment to users everywhere (**Figure 1**).

In recent years, needs related to the Internet of Things (IoT) and cloud services have been growing, and ICT products face increasingly high requirements in terms of functions, performance, and quality. These requirements include high performance, power saving, housing design that uses downsized and fanless heat dissipation measures and electromagnetic compatibility (EMC) measures, and electrical noise countermeasures. Meeting these diverse



* RVEC (Remote Virtual Environment Computing, pron. "rĕ-vĕc'") is a display acceleration technology that improves the operational responsiveness of screen transfer.

PCB: Printed circuit board

Figure 1
Flexible Technical Computing Platform (FTCP).

requirements necessitates coordinated and collaborative design, and conventional product development methods that consist in independent design, verification and, problem-solving, such as electrical design and structural design, increasingly fall short of design that satisfies all such requirements.

To solve this problem, we worked to realize One Platform, a cloud-based development platform that integrates the CAD and CAE tools for electrical and structural design, in a bid to strengthen the product development environment from a "connectability" platform environment to a "connected" platform environment (**Figure 2**). In this way, the graphical user interface (GUI) front-end directly operated by designers and the back-end that runs analysis and automated processing engines can be seamlessly connected, allowing designers to perform electrical and structural design and verification on one screen.

In terms of direction, One Platform is based on the concepts of "as a tool, combining design and analysis into one (optimization of the entire apparatus)," "as knowledge, combining the knowledge of each designer into one (new solutions)," and "as data, collecting various data in one system (utilization of design assets)." The main features of One Platform are listed below.

1) Excellent operability

Simplification of the GUI and consistency of operation reduces the learning costs for mastering the various tools in addition to improving workability.

2) Memory space sharing among applications

Complex processing sharing design models and data in real time on CAD/CAE applications is achieved. Circuit design and board design, electrical and structural design, design and analysis work, and so on, can be carried out in parallel.

3) Utilization of large-scale resources at the back-end

Execution of calculations that require a lot of resources such as coupled analysis, which deals with two or more analyses such as heat and structure, or heat and electricity, and automatic processing, are performed in the cloud, and users can use these resources without being aware of the behind-the-scenes operation.

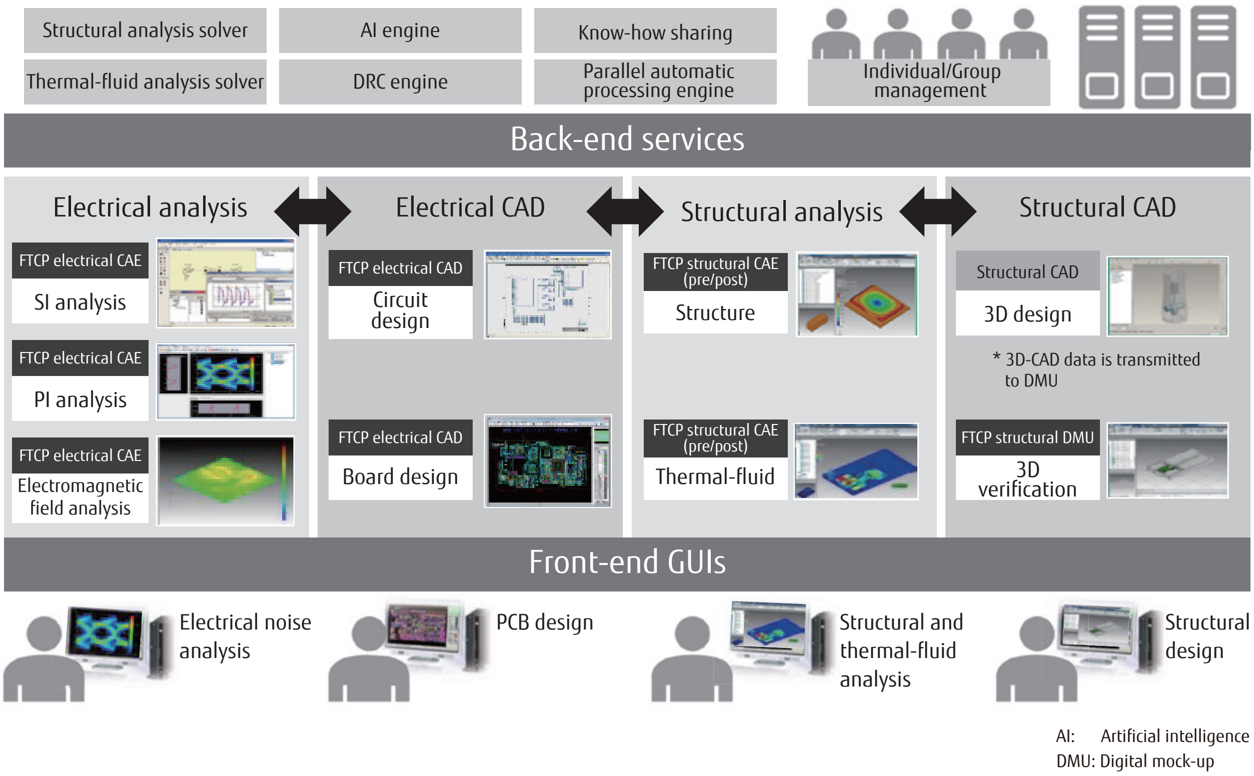


Figure 2
Configuration of One Platform.

3. Challenges in product development

Recent challenges in product development, which is becoming increasingly sophisticated in terms of the functions, performance, and quality demanded, are described below.

3.1 Human error

The following are examples of defects that occurred in structure-related design at Fujitsu.

- 70% of defects already occurred in the past
- 48% of defects can be avoided with a checklist

These numbers indicate that recurrence prevention of defects that occurred in the past was insufficient and that the checklists to prevent defects were not working satisfactorily.

At product development sites, team leaders have been giving team members on-the-job training (OJT), sharing experience and know-how within the team. However, there are situations where OJT does not work due to factors such as frequent transfers of development members and the tendency to preferentially assign tasks to skilled designers.

In addition, continuous improvement activities using 3D digital mock-up (DMU) data, which is thought to be intuitively easier to understand than 2D drawings, was carried out, but as the use of such data became commonplace, a new challenge came to light. That challenge was the fact that it is difficult for people other than the designer who came up with the 3D representation to understand even the DMU data at first glance, causing human errors such as the overlooking of defects.

3.2 Intermingling of design challenges

In the thermal analysis of network products, there was a case at Fujitsu that happened upon changes made to the company's large heat sink specifications for the purpose of improving cooling. It took approximately one month to identify the problem through repeated verification and modification using various design tools including those for CAD and CAE.

The adoption of a large heat sink necessitated moving nearby parts and consequently changing the wiring layout on the printed circuit board (PCB), making it necessary to review various influences such as the impact on the waveform analysis results in transmission line analysis, and interference between parts and the housing due to the relocation of parts. At present, electrical design, structural design, and transmission line analysis are each performed with different tools (electrical CAD, structural CAD, waveform analysis tools), and the measures designed to tackle the various challenges must be repeatedly adjusted to achieve a desirable total outcome. This is compounded by the fact that performance requirements are increasingly demanding and design margins are increasingly thin, requiring a higher number of coordinated adjustments that cause longer design durations. In the thermal analysis of server equipment, there are cases where it took several months to solve problems of the same kind.

3.3 Coordination of awareness among designers

As described above, current product development retains tasks that are dependent on personal experience and know-how, and it is often necessary to solve multiple technical problems within a limited time.

Figure 3 shows the effect on each task when design changes occur. This particular example shows the effect on operations when the swapping of parts is deemed necessary as the result of analysis. In the past, the effect of design changes could be absorbed to some extent thanks to sufficient design margin on the electrical or structural side. By contrast, in recent years with growing and more sophisticated demand, it has become difficult to secure sufficient design margin.

As a result, it is indispensable for designers to make coordinated adjustments. In the design and analysis of electrical systems and structural systems, the development environment differs. This gives rise to increase of information sharing cost and a loop of bug fixes originated from rework.

4. Activities toward One Platform

FTCP, Fujitsu's development platform includes CAD and analytical tools that have evolved independently and have provided the functions and capabilities required for the various products offered to customers. However, as the various margins of product development have shrunk as mentioned earlier, situations in which development platforms originate from tools may actually hinder future product design.

Under such circumstances, the authors are

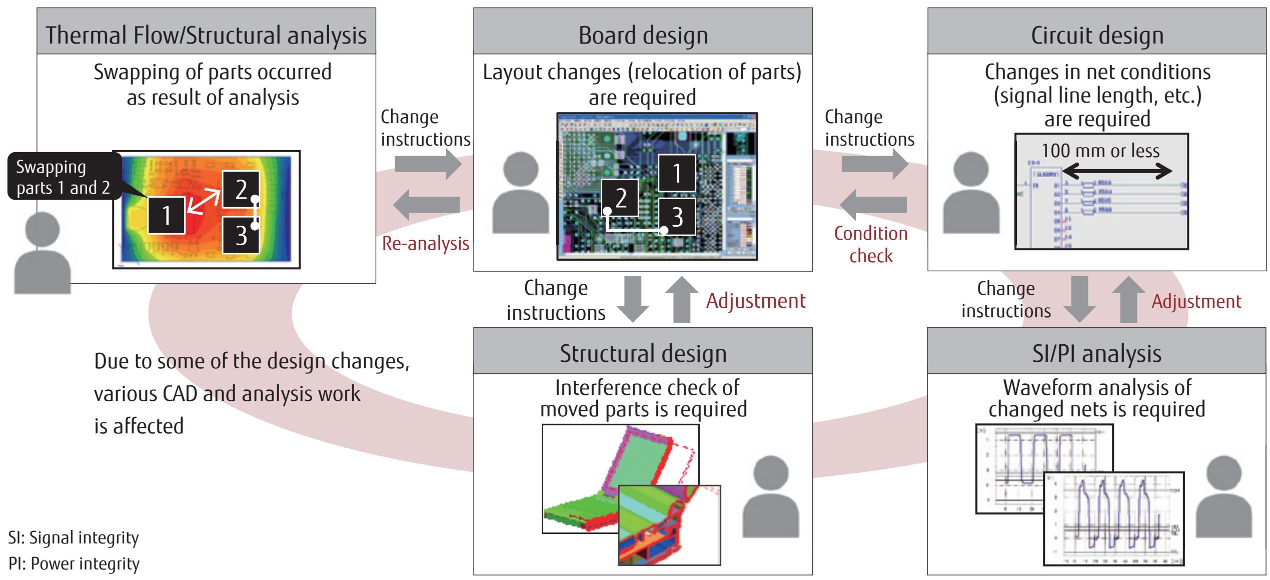


Figure 3
Effect of design changes on design work.

working on the evolution of FTCP based on the concept of One Platform (**Figure 4**). In the case of design development tools, the development of single functions is rapidly emulated by other companies and this makes it difficult to achieve differentiation. For this reason, first FTCP 1.0 was proposed in 2010 as a platform for integrating the development tools for electrical and structural design.[2] Next, we worked to further evolve FTCP to FTCP 2.0, which is a "connectability" platform that allows the various development tools to share memory as well as data at high speed.

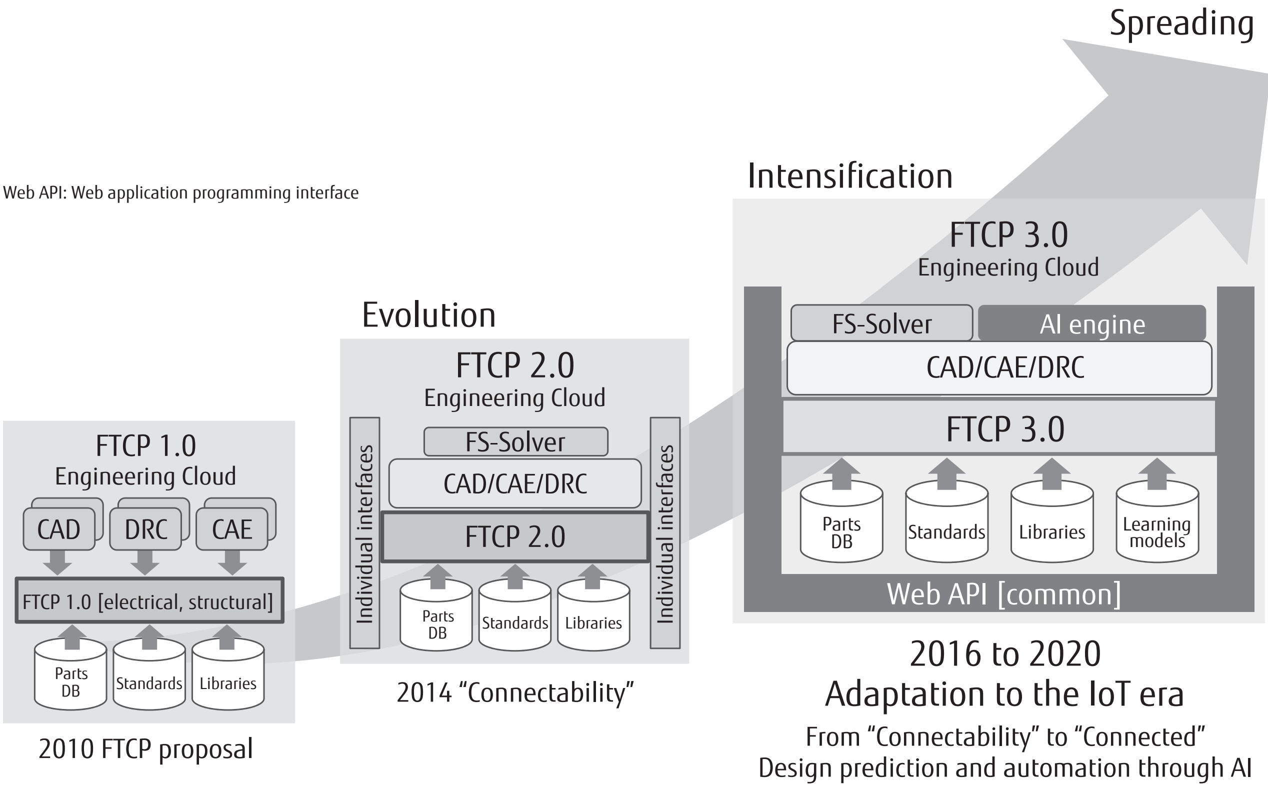
The following describes our activities toward the intensification represented by our move to FTCP 3.0, which embodies the One Platform concept (**Figure 5**).

4.1 "Connected" with design data and know-how

Design data, design verification data and verification results, as well as know-how consisting of findings gained during design, are collected by a know-how sharing system linked to an electrical/structural development platform and project management system, and are accumulated in FTCP. The usage history of the various design tools on the development platform is also collected and accumulated along with the corresponding user information, and the large amount of information generated during product design is aggregated in FTCP.

By making it easy to refer to past verification results and findings, human errors are reduced during new design work. Furthermore, by creating learning models from the accumulated design information and expanding the automation of verification through machine learning, we are aiming to eradicate human error.

We are also aiming for Virtual Obeya (where *obeya* means "large room" in Japanese) where consumers, retired veteran engineers, suppliers, sellers, and many others can participate in Monozukuri in a cyber-physical space that links design offices with actual factories (**Figure 6**). There, it will be possible to share designs as full-size stereoscopic views that make virtual products easy to understand even to those who did not design them. In addition, it will be also possible to utilize various types of sensing information related to the workers, robots, equipment, factories, and the like, as well as to refer drawings, standards, and past verification results. In sections created within the virtual space, novice designers will also be able to receive support from "MONOZUKURI agents" that can give advice and propose better verification methods through big data analysis and artificial intelligence (AI) technology.



Web API: Web application programming interface

Figure 4
Evolution of FTCP architecture.

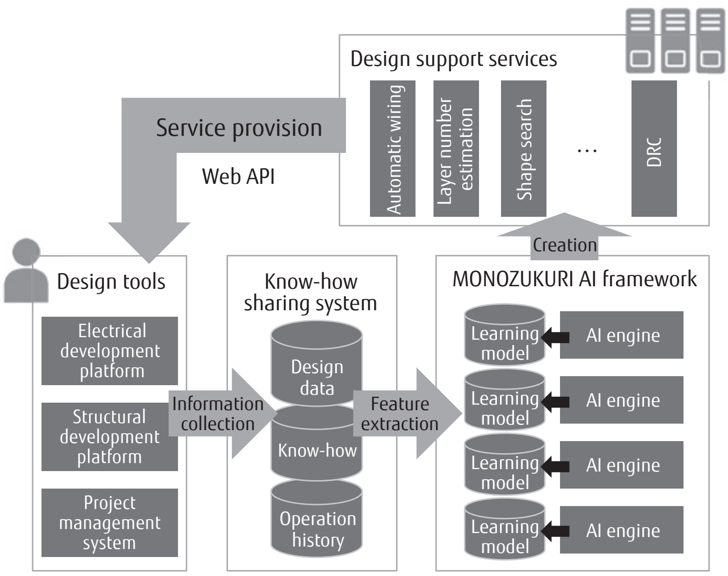


Figure 5
Configuration of FTCP 3.0.

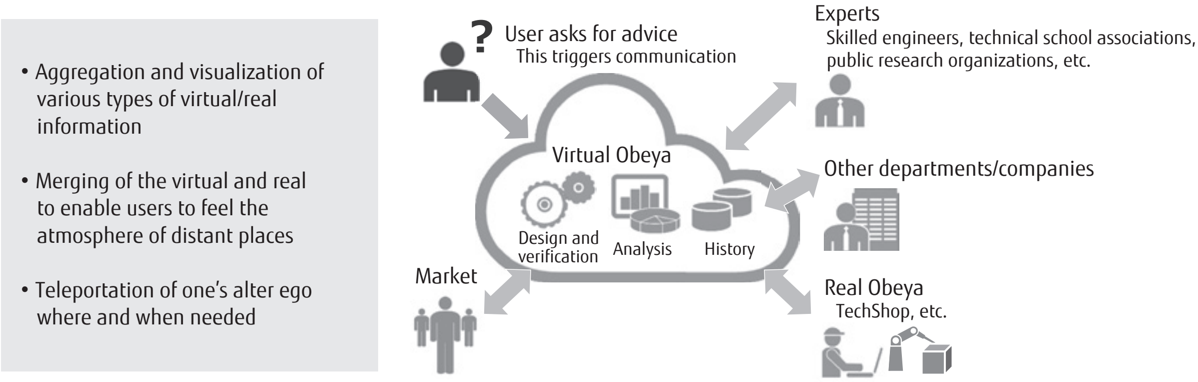


Figure 6
Aim and outline of Virtual Obeya meeting.

4.2 "Connected" with learning models

Design information such as design data and know-how gathered in FTCP will also be used to build learning models for the creation of new knowledge with an AI engine. The necessary parameters will be extracted from the design information collected by the know-how sharing system in order to construct appropriate learning models. We are also working to develop the MONOZUKURI AI framework currently operating on FTCP, as a common platform for supporting new service development using learning models.

This approach is to be applied to Monozukuri as one of the functions of Human Centric AI Zinrai, which systematizes the AI technology that Fujitsu has cultivated.[3)]

4.3 "Connected" with AI engines

Design support services using machine learning will be created by the MONOZUKURI AI framework in the future. We are currently standardizing the calling process as a web application programming interface (web API) to allow use of the services from various design tools. As a result, services will be available for use regardless of whether they are called from Windows or Linux applications, or from a web browser.

This will allow the relationships between the electrical and structural design data to be maintained. For example, it will be possible to invoke structural design support services from tools for electrical designers at the time of design changes, and since it will be possible to grasp the influence of the tools one is using on the other party's side, it will be possible to effectively coordinate the awareness of designers.

4.4 "Connected" with resources in the cloud

We are working on automating a part of design support services using machine learning, but there are cases where a large amount of computing resources is required for practical implementation. Therefore, in FTCP 3.0, we are building also a common infrastructure for job management and load balancing to allow best use of the abundant computing resources in the cloud. This will allow users to use design support services that utilize machine learning without having to be aware of computing resources.

5. Conclusion

Timely provision of complex and sophisticated product development will be made possible by implementing sustainable innovation in the product development environment. This paper has outlined the "connected" development environment derived from the approach to Monozukuri innovation practiced by Fujitsu. Going forward, we will further expand our creation of development platforms that use ICT, developing products that meet the needs of customers and society. We also plan to contribute to the businesses of customers by offering Monozukuri development platforms customized for customers in the manufacturing industry.

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