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Synthesiology

English edition

Creation of seamless geological map of Japan at the scale of 1:200,000 and its distribution through the web

Development of a small-size cogeneration system using thermoelectric power generation

Realization of a collaboration system for everyone to develop and manage

Introduction to service engineering

A systematic analysis of protein interaction networks leading to the drug discovery

The aerosol deposition method

Synthesiology editorial board

MESSAGES FROM THE EDITORIAL BOARD

There has been a wide gap between science and society. The last three hundred years of the history of modern science indicates to us that many research results disappeared or took a long time to become useful to society. Due to the difficulties of bridging this gap, it has been recently called the valley of death or the nightmare stage [(Note 1)]. Rather than passively waiting, therefore, researchers and engineers who understand the potential of the research should be active.

To bridge the gap, technology integration [(i.e. Type 2 Basic Research – Note 2)] of scientific findings for utilizing them in society, in addition to analytical research, has been one of the wheels of progress [(i.e. Full Research – Note 3)]. Traditional journals, have been collecting much analytical type knowledge that is factual knowledge and establishing many scientific disciplines [(i.e. Type 1 Basic Research – Note 4)]. Technology integration research activities, on the other hand, have been kept as personal know-how. They have not been formalized as universal knowledge of what ought to be done.

As there must be common theories, principles, and practices in the methodologies of technology integration, we regard it as basic research. This is the reason why we have decided to publish "*Synthesiology*", a new academic journal. *Synthesiology* is a coined word combining "synthesis" and "ology". Synthesis which has its origin in Greek means integration. Ology is a suffix attached to scientific disciplines.

Each paper in this journal will present scenarios selected for their societal value, identify elemental knowledge and/or technologies to be integrated, and describe the procedures and processes to achieve this goal. Through the publishing of papers in this journal, researchers and engineers can enhance the transformation of scientific outputs into the societal prosperity and make technical contributions to sustainable development. Efforts such as this will serve to increase the significance of research activities to society.

We look forward to your active contributions of papers on technology integration to the journal.

Addendum to Synthesiology-English edition,

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Synthesiology Editorial Board

Note 1 : The period was named "nightmare stage" by Hiroyuki Yoshikawa, President of AIST, and historical scientist Joseph Hatvany. The "valley of death" was by Vernon Ehlers in 1998 when he was Vice Chairman of US Congress, Science and Technology Committee. Lewis Branscomb, Professor emeritus of Harvard University, called this gap as "Darwinian sea" where natural selection takes place.

Note 2 : Type 2 Basic Research

This is a research type where various known and new knowledge is combined and integrated in order to achieve the specific goal that has social value. It also includes research activities that develop common theories or principles in technology integration.

Note 3 : Full Research

This is a type of research where the theme is placed within a scenario of future society, and where a framework is developed in which researchers from a wide range of research fields can participate in studying actual issues. This research is done continuously and concurrently from Type 1 Basic Research (Note 3) to Product Realization Research (Note 5), centered by Type 2 Basic Research (Note 4).

Note 4 : Type 1 Basic Research

This is an analytical research type where unknown phenomena are analyzed, by observation, experimentation, and theoretical calculation, to establish universal principles and theories.

Note 5 : Product Realization Research

This is a type of research where the results and knowledge from Type 1 Basic Research and Type 2 Basic Research are applied to embody the use of a new technology in society.

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Creation of seamless geological map of Japan at the scale of 1:200,000 and its distribution through the web

— For maximum accessibility and utilization of geological information —

Koji Wakita [*], Toshie Igawa [**], Shinji Takarada [**] and Yuichiro Fusejima[**]

[Translation from *Synthesiology*, Vol.1, No.2, p.82-93 (2008)]

A seamless geological map with unified legend was created at the scale of 1:200,000 covering the entire Japanese Archipelago. This was accomplished by harmonizing regional geological maps that were compiled in various ages. A research scenario from basic geological research to information technology (IT) for distribution of digital geological maps was designed. Type 2 Basic Research was proposed to distribute the interoperable data set of geological maps, which were transformed from the results of Type 1 Basic Research for geological mapping. Seamless geological mapping was finally proposed as a Full Research program in geological research field.

Keywords : Geological map, seamless, web distribution, standardization, GeoSciML, GEO Grid

1 Introduction

Geology has two major characteristics: first, it is a basic natural science that investigates natural phenomena on and beneath the earth's surface; second, it is an applied science that explores natural resources in response to social requirements of the times. The first geological map created at the dawn of geology provided us with valuable knowledge and information about natural resources such as oil, coal, iron, and diamond[1]. It also introduced use to the mysteries of the underground. Today, geology continues to evolve and is accumulating comprehensive knowledge of the earth system. It also plays an important role as a practical science in many fronts such as natural resources, environment, and disaster prevention. This practical role is emphasized in the subtitle "Earth Science for Society" for the International Year of Planet Earth 2008.

In Japan, numerous geological maps were published at different scales by the Geological Survey of Japan (the predecessor of present Geological Survey of Japan of the AIST) since its establishment in 1882. From the Meiji Era (late nineteenth century) to the reconstruction period after the Second World War, the geological maps were used as basic information for exploring mineral resources that contributed significantly to the development of industries. Presently, they are used as basic information for industrial locations, disaster prevention, and environmental studies. Particularly, the 1:200,000 scale geological maps were compiled and utilized as the most detailed maps covering the entire Japanese Archipelago.

Geological maps, which were compiled by elaborate field survey followed by advanced research, provide the latest geological knowledge for the crustal development of the Japanese Archipelago. These maps contain not only basic information of the underground, but also are the distinguished products of Type 1 Basic Researches that contribute to the construction of knowledge system[2][3].

Geological maps are always compiled based on the latest geological model of the time. Since new geological models emerge with the progress of geology, it often happens that two maps compiled at different periods, even though they are adjacent, may be represented by different geological divisions and/or legend, and the distribution of formations may be discontinuous.

Because of such inconveniences, we are faced with growing need to revise and update these geological maps made at different ages with latest model and knowledge obtained in field surveys. Expanding this operation nationwide will make geological maps more useful and helpful in our society. Likening the situation where current research become outdated and inapplicable as time goes by to the "valley of death" in research, we must promote Type 2 Basic Research to make past accomplishments more valuable and escape this situation. The research of seamless geologic maps aims to recreate valuable geoinformation for society.

This study contributes not only to the development and management of useful geoinformation, but it also develops both Internet deliverable technologies that facilitate wider use of geological maps and standardization of interoperation among different spatial information. We also intend to develop, deliver, and utilize the information through the network in and outside Japan to provide Full Research. Up-to-date web delivery technologies can be applied to seamless geological map, to make data compliant to international standards. This is expected to stimulate faster and broader distribution of detailed and precise geoinformation.

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Furthermore, interoperation with other information systems will help establish safer society in terms of infrastructure and disaster prevention.

In this paper, first we present the outline of seamless geological map and its research scenario, which was designed as Type 2 Basic Research in order to actively promote the development of basic intellectual knowledge of Japan. Then we show how to select appropriate knowledge to provide clear and plain geoinformation to the public. Studies of geological maps can be considered as both Type 1 and Type 2 Basic Researches, because they provide various useful geoinformation by integrating broad range of knowledge such as paleontology, structural geology, stratigraphy, and petrology. However, many recent geological maps tend to be thematically specialized, and are published as basic research report with highly advanced research outcomes, stressing the aspect that they are results of Type 1 Basic Researches. In contrast to this recent trend, we shall describe the methodology and features of seamless geological maps as an example of Type 2 Basic Research, which can create great values for society by integrating broader knowledge including Internet delivery technologies.

2 Background and goals

2.1 Revision of previous geological maps with recent geological models

The fundamental, essential parts in creating geological maps are field surveys and field observations. We conduct surveys at outcrops discontinuously exposed along rivers or in mountains to investigate types of rocks and formations and their structures. Developing geological models from observed data, we speculate on the rock distribution underground that are covered by soil and vegetation. How much information we can get from scant field observation and how precisely we can deduce the underground structure depend on the quality and quantity of geological knowledge and models we have. This "analog visualization" technique of extracting as much information as possible from limited field observations and deducing hidden structure beneath has been developed long before invention of computers.

Let us describe the case of Mino area in Gifu Prefecture as a typical example where the neighboring geological maps were drawn based on different geological models. There are four 1:50000 geological maps in this area: "Neo," "Hachiman," "Tanigumi," and "Mino" published in 1964, 1984, 1991 and 1995, respectively[4]-[7]. "Neo" was drawn according to the geosynclinals model[Term 1], which was predominant in geology before plate tectonics was accepted as a new geological paradigm in the 1990s. The geological division and expression adopted in this map are quite different compared to other maps, which were created based on the accretionary prism model[Term 2] formed by oceanic plate subduction. Furthermore, other three maps were made according to different geological models developed under the plate tectonics theory: submarine landslide[Term 3] for "Hachiman," mud diapir[Term 4] for "Tanigumi," and tectonic deformation[Term 5] for "Mino." Consequently, geological divisions and expressions of the four maps are different (Figure 1).

As shown in the above example, knowledge of historical background and transition of theories may be necessary to effectively utilize geological maps. However, most users know little about past geologic concepts and theories even

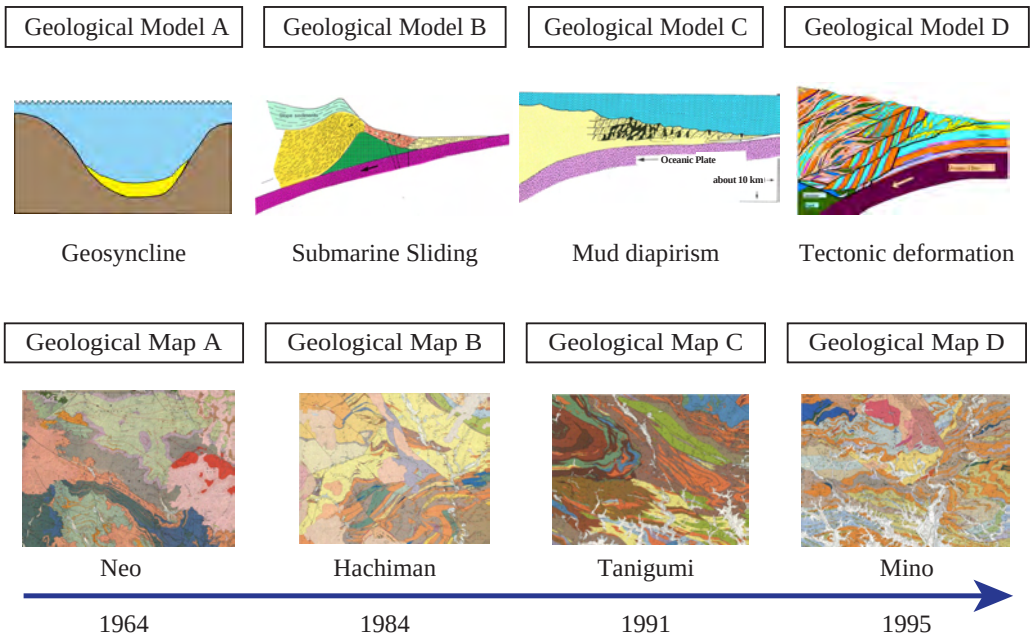

Fig. 1 Changes of hypothesis for formation of geologic bodies in Mino area, Gifu Prefecture.

though they may be acquainted with recent researches. They often become confused by unfamiliar explanations and expressions in old maps. In order to remove this obstacle, we developed a method for seam-smoothing geological maps, and applied it to the 1:200,000 geological maps, because they almost completely covered the Japanese Archipelago, whereas the 1:50,000 maps were insufficient for the purpose.

2.2 Goals and scenarios

Nothing can make geological maps more valuable than their wide spread use in the society. We set our research goal as follows: to contribute to the safety of our society by integrating the geological maps that were created independently and by promoting the use of these maps through effective delivery.

The research scenario to achieve the above goal is as follows (Figure 2):

- Revision of each map drawn according to different geological models, recompilation with the latest integrated standards, and seam-smoothing with adjacent maps
- Delivery of harmonized maps on the Internet, rather than by print or CD-ROM media, to facilitate wide use in the society
- Standardization of the expression of geological information to allow interoperation with other ground information inside and outside Japan

3 Procedures for harmonizing geological maps

3.1 Outline

Harmonization of geological maps involves revision of old geological maps based on past models by applying up-to-date models.

The procedure includes unification of legends and adjustment of geological features such as boundaries and fault lines (Figure 3). In order to give priority to prompt distribution of the results, no extra field surveys were conducted in this project.

The 1:200,000 geological maps, of which 112 maps have already been published, cover about 90 percent of Japan (as of March 2006), and they are most detailed maps that could be harmonized. The revised seamless geological maps of Japan based on these maps are the most frequently used example of seamless geological map[8].

Launched in 2002, the project published areal seamless maps in series as follows. In 2003, Hokkaido and Tohoku regions were completed, followed by the Kanto region in 2004, completing the eastern half of Japan. Three regions of Hokuriku, Tokai, and Kinki were completed sequentially in the same fiscal year. In 2005, Chugoku and Shikoku regions, Kyushu region, and Nansei Islands were completed, covering the western half of Japan. Adding several areas of southern Kanto region (Izu Northern Ogasawara, Izu Southern Ogasawara) and eastern area of Hokkaido (including four islands of the Kuril), as well as the revision of Hokkaido region, the first edition of the national seamless map was published. This digital geological map was drawn with unified legend and consisted of massive amount of data involving 149,081 polygons and 371,528 lines (as of May 12, 2007)[9].

3.2 Unified legend

The first step in seam-smoothing geological maps was unification of the legend. As legend gives all description of geological features in the map, it was necessary to develop a common legend applicable to all neighboring maps under the latest geological model. However, limited amount of information in old geological maps makes it impossible to apply the latest legend to all maps. Most up-to-date yet most widely applicable legend was chosen based on recent geological model.

The unification was carried out in two stages, applying the existing legend system and applying it to the 1:200,000 maps.

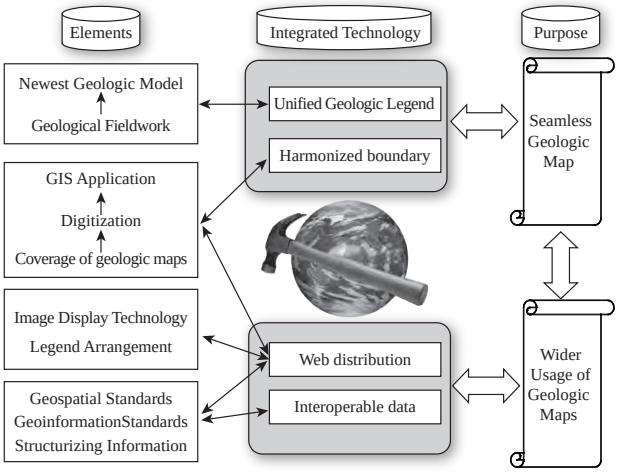

Fig. 2 Elemental technology and scenario for Japan Seamless Geological Map Project.

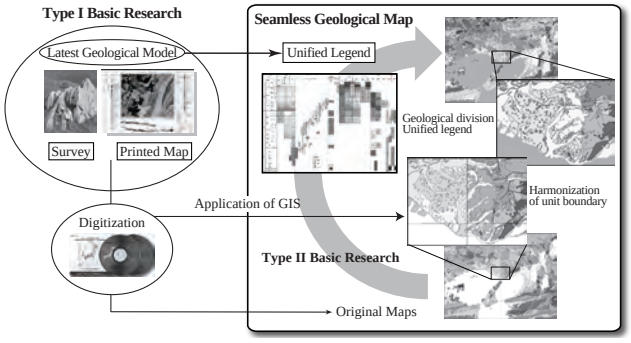

Fig. 3 Concept and process of Seamless Geological Map of Japan 1:200,000.

Every geological map has unique geological divisions or local formation names to describe the geological information of the area. However, a common legend must be applicable to all formations and rocks in Japan. Consequently, only two criteria - lithology and age of rocks - were employed in the legend. Similar legend system had already been developed and adopted for the first time in the third edition of the 1:1,000,000 scale geological maps of Japan (1992)[10]. It was the only nationwide legend created from the most precise geological model in 2004 when the project started. Applying this legend (basic version) as standard, we published the seamless 1:200,000 scale map on the web as the first stage. However, the legend for the 1:1,000,000 scale maps was too rough for the 1:200,000 scale maps to provide sufficient information, due to far greater quantity and quality of information in the latter. To solve this problem, improved unified legend with more detailed geological division was developed in the next stage (Figure 4).

A criterion for nationally consistent petrological and stratigraphical divisions for the larger scale map was reviewed and discussed in five categories (sedimentary rocks, accretionary prism, volcanic rocks, plutonic rocks, and metamorphic rocks). Metamorphic rocks were further classified into three categories: 1) metamorphic conditions, 2) age of metamorphic rocks, and 3) original lithofacies[11]. Accretionary prism was subdivided into two categories for rock types in each structural unit. Legend for sedimentary rocks was reviewed according to detailed subdivision of geological ages based mainly on regional stratigraphic correlation. Besides geological age, classification by chemical composition was carried out on volcanic and plutonic rocks. Holocene sediments in densely populated plain regions were subdivided by sedimentary environment including dune, wetland, alluvial fan, natural levee, lake, and artificially altered land.

Though the above classification was ideal up-to-date legend for the harmonized 1:200,000 maps, not all regional maps could adopt the above classification, as they were compiled during varying periods. Listing all the legends used in each map and comparing them with the ideal legend, 384 geological divisions were adopted as optimum combination for the new geological map. The number of divisions nearly doubled from 194 divisions in the 1:1,000,000 maps. The new legend allowed the seamless geological map to provide more detailed information. Figure 5 is an example of the map of Shikoku region.

3.3 Application of unified legend and establishment of single attribute table

After replacing the former legend with the new legend, reassembly of attribute data in digital geological maps was carried out with the aid of geographic information system (GIS)[Term 6]. Polychromatic analog maps were digitized, and original classification was given to each geological province, followed by permutation by correlating with the unified legend. Adopting vectors[Term 7] to digitized geological data enabled independent calculation within each area as well as automatic slimmer, and resulted in both rapid data compilation and cost reduction, while maintaining the location accuracy of geological boundaries.

As stated above, correlation of each classification in original maps to the most recent maps was very complicated and specific task, because the geological models of the maps differed by time of their production. Compilation of geological maps required cooperation of several researchers specializing in different research fields such as volcanology and sedimentology, or formation of different geologic ages. They usually had their own fields of specialty in certain locality where they conduct research. Consequently, one or more geologists who were specialized in the region participated in the correlating procedure. For example, one geologist handled volcanic rocks in northern Kyushu while another worked on compiling sedimentary rocks in southern Tohoku region. Each specialist examined the old and new data, and correlated them with the aid of other references including relatively recent geological maps of neighboring areas or maps of different scales and the latest paleontological and/or radiometric data. More precise correlation was possible when sufficient data were available to make regional stratigraphic correlation tables and/or columnar sections. Some of the recent 1:200,000 maps were drawn with legend showing almost equivalent geologic ages to the basic version, and these allowed easier correlation.

3.4 Boundary smoothing and compilation

The next procedure was to maintain continuity of geological boundaries and fault lines between neighboring maps. This involved adjustment of precision and interpretations of the maps, by making old map data consistent with latest geological and topographic information (Figure 6). It also involved reviewing geological classifications and boundaries based on the latest geological model.

Combining neighboring maps is widely used procedure to create integrated geologic map. Wide-area geological map is usually made from larger scale maps. For example, the 1:200,000 geological map is made by combining 1:50,000 maps. However, no attempt has ever been done to create integrated map from original maps of the same scale. In compiling a smaller scale map from larger scale maps, one of the most common methods is reducing the large scale maps using a copy machine and joining the boundaries by hand. However, this is applicable only in cases where the accuracy of locality data may be sacrificed.

To create continuous geological map in same scale as the

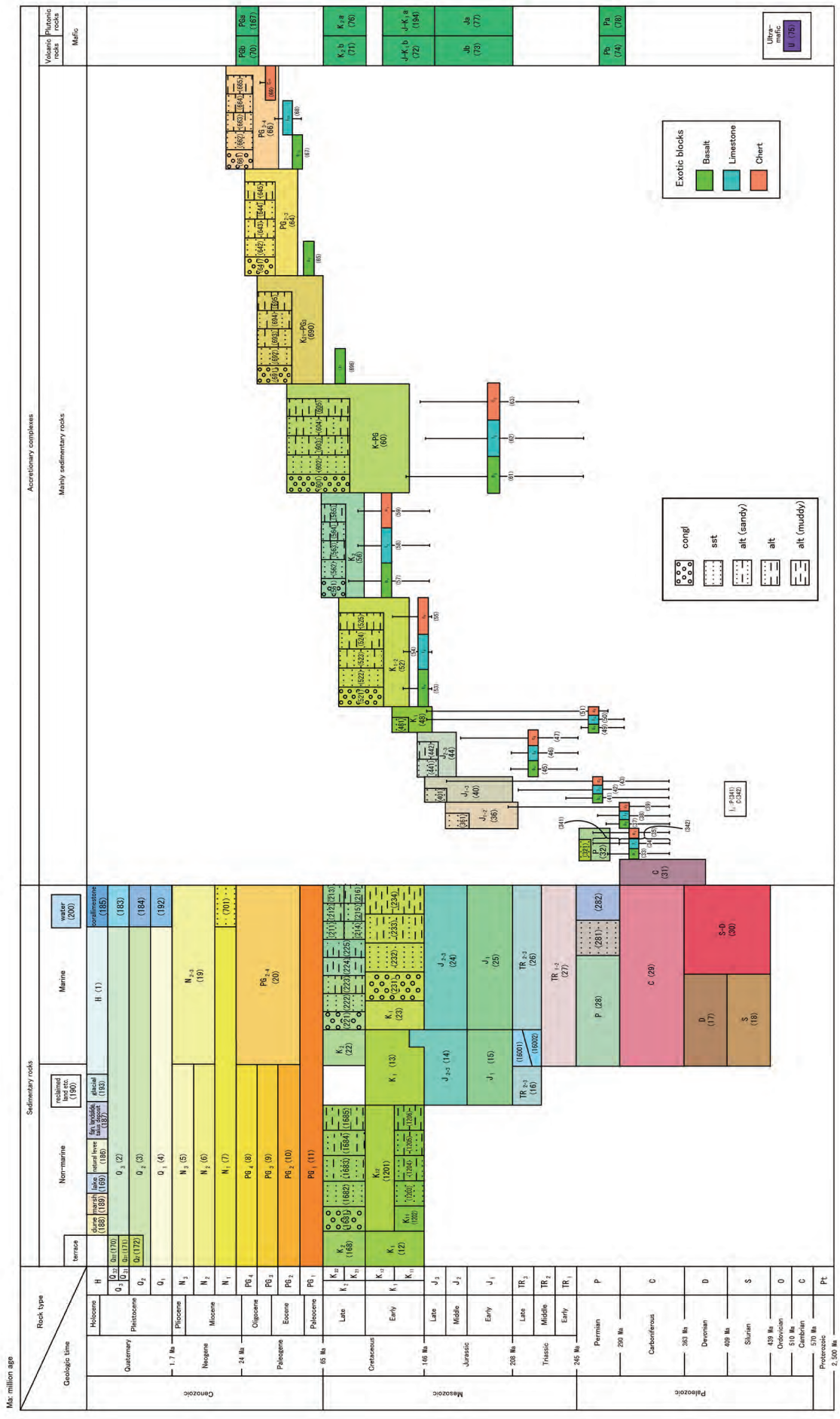

Fig. 4(a) Universal national legend of the Detailed Version of the Seamless Geological Map of Japan 1:200,000.

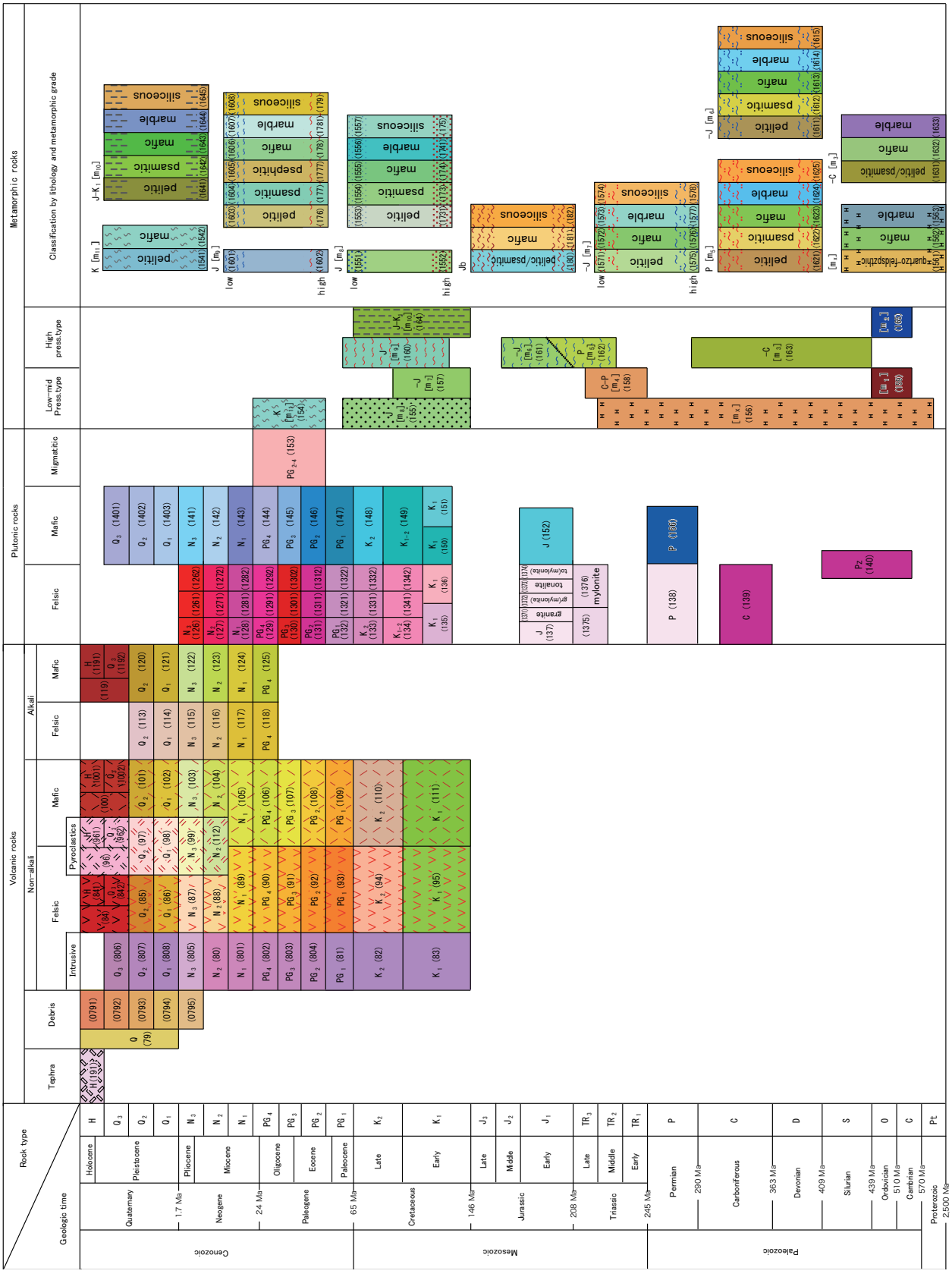

Fig. 4(b) Universal national legend of the Detailed Version of the Seamless Geological Map of Japan 1:200,000.

original maps, it is very important to maintain positional accuracy. Therefore, GIS was employed actively in digital geological map where possible. After the attributes in neighboring maps were replaced with the unified legend, the areas of same geological divisions in both maps should share the attributes. However, it often happened that single geological body seemed discontinuous or different, because the information were independently compiled and published in different times. In such case, extra procedure as described below was necessary to maintain continuity.

Generally, amount and accuracy of information in a map increase with time. In many cases, recent map contains more detailed and correct information of distribution of rocks or formations. In maintaining continuity of the boundary, the lines in old maps were altered to accommodate the lines in new maps. The latest geological information from the 1:50,000 geological maps or academic papers were employed to ensure better smoothing.

Since old geological map is drawn according to old topographic map, superposing an old geological map on latest topographic map often caused slight positional mismatch. In such case, position of terraces or alluvial fans was corrected so it would be consistent with the latest topological data. Coastlines often posed more difficulties. Positional adjustment of island coast was accomplished using affine transformation[Term 8], by establishing several benchmarks. In other cases, geological boundaries were extended or shortened to match older data to the present coastlines using GIS.

In addition to rock or formation boundaries, faults were reexamined to determine whether they were exposed or concealed based on latest research results. Specialists of the area and recent papers were consulted in making judgments on whether a geological boundary was a fault or not.

4 From analog to digital, then from CD-ROM to the Internet

4.1 The significance of digital geological map

Geological maps were generally printed on paper. Since the 1990s, with the development of GIS technology, social demand for digital geological maps increased. Therefore, we started to systematically examine the “publishing procedures by electronic media” in 1993, and published the first digital geological map on CD-ROMs in 1995. In contrast, seamless geological map has been distributed mainly on the Internet at present. The main reasons are: 1) it allows easier access to data and facilitates utilization, 2) it enables frequent data update, and 3) costless publication enables free (or low price) information provision.

In 2006, there were 600,000 accesses to the Seamless Geological Map of Japan published in 2002, while sales of other printed maps were only about 900 copies a year. Although it is difficult to directly compare printed maps that are used repeatedly, three-digit difference is substantial. Moreover, wide range of users such as consulting firms and real estate companies, as well as researchers have accessed our website (Figure 7).

4.2 Distribution on the web

In 2003, the National Institute of Advanced Industrial Science and Technology(AIST) started to offer seamless geological map on the web as one of research information database (RIO-DB, http://riodb02.ibase. aist.go.jp/db084/index.html). In the beginning, data were offered as images, although the original maps were created in vector format (Figure 8). Primary reason was because the public preferred to use maps in graphic form mainly to view and search and they were used to the printed version. Another reason was inadequate infrastructure for smooth browsing of vectorized data at that time.

The total size of the current 1:200,000 Seamless Geological

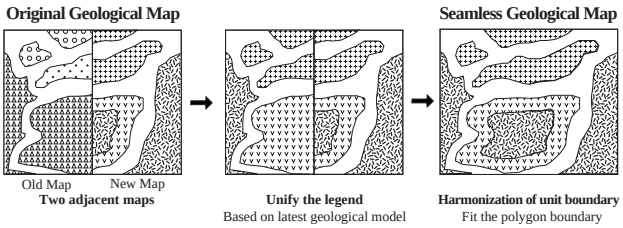

Fig. 6 Harmonization process for seamless geological map.

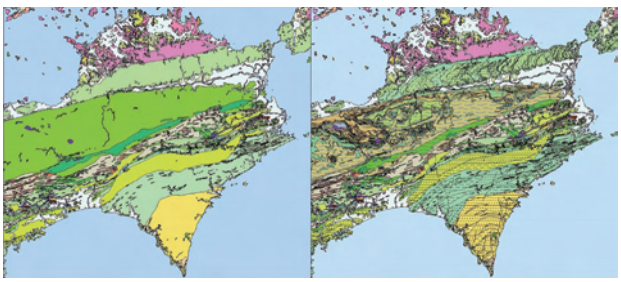

Fig. 5 Two types of the Seamless Geological Map of Japan 1:200,000.
Basic Legend Version (left) and Detailed Legend Version (right).

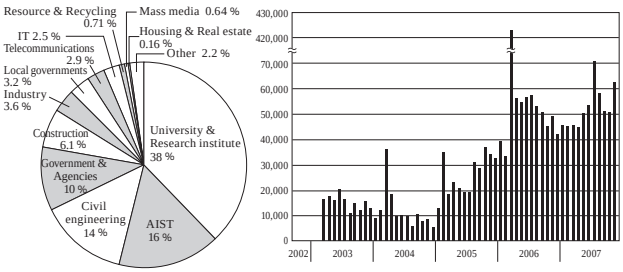

Fig. 7 User category (left side, reference to November 2007) and change of number of access to the homepage of Seamless Geological Map of Japan 1:200,000 (right side, from September 2002 to November 2007).

Map of Japan provided on the web will be 3 m x 7 m if printed in scale. Almost 4 gigabyte file size is necessary to provide image that is clear enough to be enlarged on screen (400 dpi). Since this data size is too large for users to download at once, it became crucial for us to develop a transmission system to instantaneously deliver required data to where they were needed. Although several software for this purpose were already available commercially, we decided to develop our own program, J-GeoView, to reduce cost and to optimize representational function. It enabled continuous zooming in/out and displayed geological explanation at the position of the cursor. Along with academic description, we provided plain and simple explanations without complex technical terms for general users.

5 Further development of seamless geological map and challenges for the future

5.1 Refinement of geological information and integrating technology

The seamless geological map was created without conducting field surveys. However, field surveys and mapping are essential to improve the accuracy of geological maps and to update the geological information such as distribution of rocks, faults, and other geological features. To accomplish this task, we must collaborate with specific research groups who are in charge of making geological maps at 1:200,000 and 1:50,000 scales. We are planning to revise the already published 1:200,000 geological maps in order of their publication date in the second business term of AIST (April 2005 ~ March 2010), and compile new maps in the third term or later (from April 2010). The above plans will significantly improve the contents of the seamless geological map.

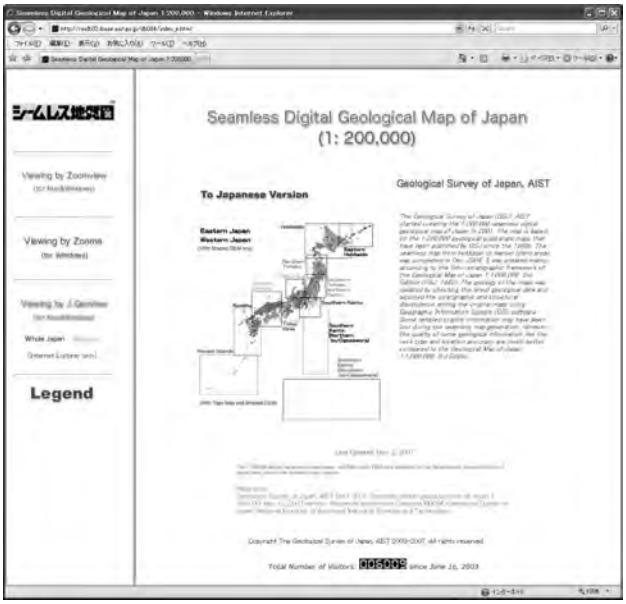

Fig. 8 Homepage of the Seamless Geological Map of Japan 1:200,000.

Data in the seamless geological map are delivered in vector format by GeoMapDB developed in 2006 at http://iggisl.muse.aist.go.jp/ja/top.htm. One of the features of vector format is that it can separately manage corresponding data by cutting each element that composes the ground surface based on object-oriented concept. It allows continuous zooming in/out and arbitrary change of color and size. It also enables addition of attributes for rocks or faults such as age, thickness, and lithofacies. The method adopted in seam-smoothing geological map fully exploits the above features. In the future, strict standardization of data and development of data model to standardize the structures among data sets will lead to deployment of the maps as spatial relational database, and consequently will result in convenient usage including flexible search, analysis, drawing, simulation, and automatic control[12].

Combination of these features will enable us not only to use the seamless map as a planimetric map, but also allows us to draw geological profile and multi-dimensional map, and create geologic time scale using a single set of data in the seamless geological map. We have started normalization and standardization of geological data, data model establishment, and development of the data to achieve these goals.

5.2 Seamless geological map as an information infrastructure

The seamless map aims not only for greater convenience and broader delivery via the Internet, but also aims to make geological maps shared and widely used in society as a common national property. We shall continue our efforts in making the map available to everyone through the Internet.

One example is the mutual use of data between engineering geological map and surface geological map of the Ministry of Land, Infrastructure, Transportation and Tourism (MLIT) and seamless geological map of the AIST, and this is making major contribution to the reciprocal exchange of the latest geological map information (Figure 9), as well as to cost reduction. Actually, engineering geological map[13] was used as reference in the compilation of the seamless map of Shikoku region. On the other hand, vector data of the seamless geological map were used to create the engineering geological map of Tohoku region[14]. Interoperation between other geospatial information is another important aim of the seamless geological map. We are currently promoting joint researches in environmental field with Nagoya University, Tohoku University, and others. Within AIST, the seamless geological map is utilized as basic geological information in the study of active faults and soil contamination.

Creation of the 1:200,000 Seamless Geological Map of Japan triggered the research project called “Basic Research on Development of a Highly Information-Interoperable Database for Integrated Geoscience Atlas” in which other

geoinformation will be improved and integrated at national scale. In this project, geophysical (gravity and aeromagnetic) and geochemical maps[Term 9] are developed at 1:200,000 scale. They will be revised and published as a nationwide seamless geoscience atlas in set with seamless geological map. These maps are recognized as part of intellectual foundation of geoscience, and are expected to facilitate interoperation of information with other fields (Figure 9).

5.3 International standardization and interoperation of geoinformation

New system for "cloud computing" is necessary to mutually exchange and utilize geological map information on the web[15]. It is also required that any people and any system around the world share common understanding of definition of the terms. The Geography Markup Language (GML)[Term 10] and its operational specifications WFS and WMS[Term 11] are some examples of international standards for geospatial information proposed by the Open Geospatial Consortium, Inc. (OGC), the international organization for development of international standard for geospatial interoperability[16]. To become interoperable with other geospatial information of different fields and forms, the seamless geological map must conform to these international standards (Figure 9).

In order to realize interoperation among various geological information including geological maps, we joined the Commission for the Management and Application of Geoscience Information (CGI) under the International Union of Geological Sciences (IUGS) to discuss the development of GeoSciML, which is one of the international standards for geological information[17]. Similar to GML mentioned above, this is one of the XML vocabularies whose data model is described in terms of XML, and is compliant with GML for geospatial information[18]. We intend to provide interoperable geological data in the form of compatible parts, by splitting geological digital documents including digital maps into small pieces, and then embedding metadata using various GeoSciML tags (Figure 10). Applying XML vocabulary including GeoSciML requires arrangement of data based on each data model. We also aim to rebuild the 1:200,000 seamless maps into spatial relational database by applying GeoSciML (Figure 10).

In utilizing geological information such as the seamless geological map, framework for secured utilization will be necessary in the future. The GEO Grid[Term 12], one of AIST's integrated issues, is an initiative that will allow this to be practicable (Figure 9). The GEO Grid project was started to study international data sharing among Asian countries as well as Japan. The seamless geological map has become one of major contents in the project, and it will enable interoperation among similar geological maps and related information in Asian countries (Figure 9). Natural resources and environment are borderless issues, and the geoinformation of surrounding countries are important for Japan to ensure stable economic development and secure society. Interoperation of geoinformation using the GEO Grid is expected to play an important role in the security of the society such as response to various disasters like earthquake and volcanic eruption in Asia.

6 Conclusion

We described the innovative methods of transforming traditional analog maps to the seamless geological map and the interoperation technology that allows the information to be used interoperably on the web.

Seamless geological map, which allows the public to use geological maps and information easily, can be regarded as an example of Type 2 Basic Research. The nationally harmonized 1:200,000 map was distributed over the Internet and accessed 600,000 times in 2006. The figure demonstrates wide utilization of the digital geological map. However, for broader dissemination of geological information to the

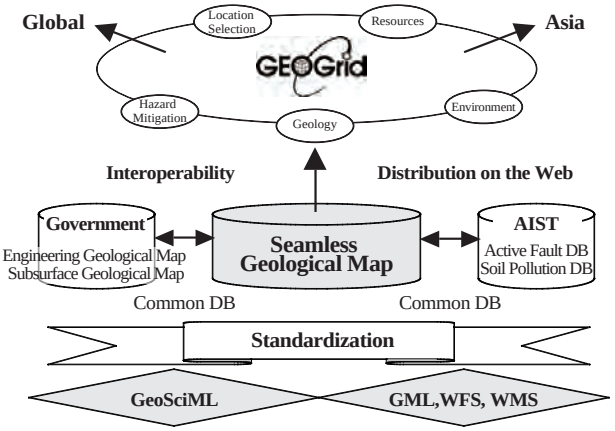

Fig. 9 Future model of Seamless Geological Map Project.

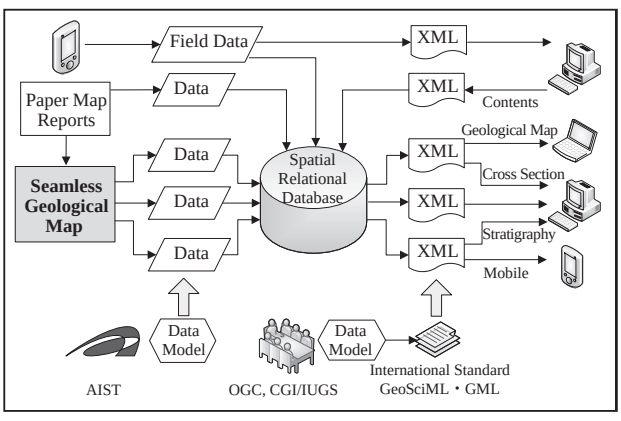

Fig. 10 Interoperable workflow based on the standardization of geoinformation.

public, it is necessary to present finer geoinformation at larger scale. We started making seamless geological maps at scales of 1:50,000 to be utilized mainly in engineering and construction, and 1:25,000 to be used mainly for industrial and residential location survey. We ultimately aim to provide flexible services to general users by making these detailed contents accessible from cell phone or car navigation system. We shall continue to promote information and technology for safer society through our researches - creation of seamless geological maps and its interoperational technology - as Full Research of geoinformation.

Acknowledgement

We would like to thank the members of the Geological Mapping Group, as well as Mr. Jun-ichi Miyazaki and Dr. Joel C. Bandibas of the Geological Survey of Japan, AIST for their kind cooperation to our research.

Terminology

Term 1. Geosynclinal Model: An ancient geological model for hypothetical huge sedimentary basin. This was a major model for the origin of mountain building from late 1800s to 1960s.

Term 2. Accretionary Complex Model: A recent geological model for the origin of orogenic belts. The basic components of orogenic belts were derived from accretionary complexes that were caused by the interaction between subducting oceanic plate and continental margin. According to this model, the rocks that compose the foundation of Japan are composed of accretionary complexes.

Term 3. Submarine sliding origin: Major theory in the 1980s where submarine sliding caused fragmentation and mixing to form mélanges.

Term 4. Diapiric origin: A hypothesis to explain the ocean bottom around the Barbados Islands in Middle America, where extraordinary high pore fluid pressure caused mud diapirism to form mélanges.

Term 5. Tectonic origin: Theory that states tectonic shearing between subducting oceanic plate and overlying plate of the continental margin caused fragmentation and mixing to form mélanges.

Term 6. Geographic Information System (GIS): Any system for capturing, storing, analyzing, managing, and presenting data and associated attributes which are spatially referenced to earth. In narrow sense, it is an information system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information.

Term 7. Vector format: Object-oriented data format that expresses spatial information consisting of polygon, line, and points. Spatial information is defined by location and attributes information.

Term 8. Affine transformation: A transformation method using linear transformation and parallel movements (eg. Euclidean geometry). Relationship between geometric lines is preserved after the transformation process.

Term 9. Geochemical map: Map showing distribution of 53 chemical elements based on the chemical analysis of about 3,000 samples from 10 km grids covering entire Japan.

Term 10. Geography Markup Language (GML): A standard for spatial and geographical data defined by the Open Geospatial Consortium based on XML.

Term 11. Web Feature Service (WFS) and Web Map Service (WMS): WFS is interface standard for geographical vector features, and WMS is spatially referenced information, defined by OGC.

Term 12. GEO Grid (Global Earth Observation Grid): A system to facilitate the integration of earth observation data and other spatial information using grid technology.

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Discussions with reviewers

1 Feedback to Type 1 Basic Research

Question (Akira Ono)

I highly appreciate this research as one of the most significant Type 2 Basic Researches. You integrated original geological maps of quadrangle areas (the result of Type 1 Basic Research) into nationwide seamless map.

Although this study is outside my field, it seems to me that each original geological map is a unique and distinctive product that reflects the interests and abilities of individual researcher, as well as being presentation of research result based on the latest model of the time. I suppose the meaning of this study is reevaluation of these unique researches under a common standard called the unified legend.

While the study was conducted as a Type 2 Basic Research that required several years to harmonize the original geological maps, is there any possibility that it will positively influence future Type 1 Basic Researches, such as in compiling original geological maps? I expect the creation of the seamless geological map will inspire unique and distinctive geological researches in the future.

Answer (Koji Wakita)

Smaller amount of geological information and less positional accuracy in the original maps may affect the content of the neighboring areas in the seamless map, because it is harmonized according to existing 1:200,000 geological maps. The seamless map, which is the result of a Type 2 Basic Research, indicates the direction of our future research: in which area we should promote further Type 1 Basic Research or what kind of researches we should undertake. Also, because the seamless map contains much more detailed regional geological information than the past maps, it helps us narrow down the issues and subjects of research.

2 Past seam-smoothing

Question (Akira Ono)

I think the smoothing technique had been applied in maintaining continuity and consistency of geological data between neighboring geological areas before digitization and web distribution of geological information became common. Are you saying that development of digitization techniques and wide usage of the Internet facilitated full-scale map smoothing?

Answer (Koji Wakita)

Although combining and harmonizing same-scale maps have been attempted over the ages, but it was no more than "compilation" in which smaller scale map was recreated by combining larger scale maps. One of the greatest challenges of the study was to harmonize geological maps into same scale map.

3 Comparison of this seam-smoothing method to Google Earth

Question (Akira Ono)

I imagine that one of the major obstacles in developing and launching Google Earth, which is now commonly used on the Internet, was how to smooth boundaries. Can you indicate any common and/or different points in smoothing images for this study and Google Earth?

Answer (Yuichiro Fusejima)

Smoothing really didn't matter in launching Google Earth. That is because the information in Google Earth consist mainly

of satellite images and aerial photos, which are ground surface information collected in short range of time. Their space-time distribution density and accuracy are much more uniform compared to geoinformation. Of course, there still exist some elements that must be harmonized (data matching) in satellite images and aerial photos, such as photographic equipments and weather conditions. However, the vast amount of information enables application of statistical approach to data matching, and the problems are being solved gradually. The purpose of our challenge in harmonizing geological maps is to improve limited underground information so we may utilize them conveniently as ground surface information.

4 Research trend in other countries

Question (Akira Ono)

I think seamless geological maps are attracting attention abroad. What are the research trends in other countries? And what is the level of Japanese research in comparison?

Answer (Koji Wakita)

Opinion on harmonization is divided among Asia, Europe, and the United States. France is promoting harmonization not only at 1:200,000 scale but also at 1:50,000, while the UK advocates using original maps. Some of the Eastern European countries like Czech Republic and Asian countries like Korea are conducting harmonization at around 1:200,000 scale. However, there is essential difference in geology of Japan compared to these countries. Japanese geology is much more complicated and unique, because Japan is part of active island arcs. This geological condition requires us to develop unique models. Thick vegetation and soil layer hamper us from obtaining sufficient information. We must revise geological maps drastically as advances are made in research. We face these difficulties today. On the other hand, geological maps of Europe and the United States, where most of their lands sit on stable continental crust, are relatively simple, and do not necessitate major revisions with advancement of earth sciences. Their geological maps can be harmonized easily, or in many cases, simply combined without seam-smoothing. This doesn't mean our research level is inferior. In Japan, because of its unique geological situation, advancement in basic research directly affects the quality of geological maps. In my opinion, we cannot provide more detailed and more comprehensible geological information to the public unless we create seamless geological maps. Considering this unique geological condition, I believe our level of research for seamless geological maps is quite high compared to other countries.

5 Researches on geological maps

Question (Eikichi Tsukuda)

I completely agree with your opinion that the study shows new direction for Type 2 Basic Research. However, I see problems in the logic that you consider all past geological surveys as Type 1 Basic Research. I understand that geological survey consists of both researches, while geological maps are created mainly by Type 2 Basic Research. I don't think geological surveys are conducted only for the sake of scientific discovery. The past geological maps were made by amalgamating the results of Type 1 Basic Research, adding latest knowledge, and were individually optimized, but also went through the "valley of death."

It seems to me that you are overcoming the second "valley of death" by promoting the research of seamless geological map to conquer new obstacles in research. What is your opinion on this point?

Answer (Koji Wakita)

I completely agree with you that geological map research has both aspects of Type 1 and Type 2 Basic Research, as I described in the paper. However, I do not share your view that geological map research mainly focuses on Type 2 Basic Research. In my view of the present geological map project, current 1:50,000 scale maps are research reports, while 1:200,000 scale maps should be recognized as comprehensive thesis published when results are sufficiently accumulated. They reflect individual idea of the authors, so they may have quite different interpretations and descriptions on same formations or rocks, even if they were published around the same time. In case the researcher decided not to publish a geological map of an area, or couldn't get enough information to publish, the area is left unpublished, even if there is great social demand. Stratigraphic division units are also independently named by each researcher and are not unified. This is why I said we haven't made enough effort to increase social value of geological maps. In the study of geological maps, we don't even have a general methodology to create social values, which is the principle of Type 2 Basic Research. This is the main reason that motivated us in the research of seamless geological map.

Having discussed geological map study for years, we concluded that geological maps, especially the 1:50,000 scale, emphasize their feature as research results of field geology containing the latest outcomes of specialized academic fields. The basic stance of the study is to offer our product, the standardized technologies for field geological surveys, to the society by making the best maps with which scientists can conduct advanced researches in their respective fields.

I realize that we simplified the role of Type 1 Basic Research to highlight the significance of seamless geological map that has aspect of Type 2 Basic Research. However, we recognize that this is a realistic description of research, considering the fact that the role of geological maps have greatly changed today from the first map that was created in Meiji Era.

Development of a small-size cogeneration system using thermoelectric power generation

— Recovery system of high-temperature waste heat by new thermoelectric oxides —

Ryoji Funahashi * **and Saori Urata** **

[Translation from *Synthesiology*, Vol.1, No.2, p.94-100 (2008)]

As energy and environment issues become serious, there is an urgent need to improve efficiency of industrial energy use as well as to alter lifestyles. To realize thermoelectric conversion technology that allows power generation from waste heat, we newly discovered thermoelectric oxides that possess high safety and durability at high temperatures. We then developed a prototype of a small-size generation system that functions at temperature range of 773~1173K in collaboration with a private company

Keywords : Thermoelectric power generation, oxides, module

1 Background of research

The production of fossil fuel, our mainstay of energy, is expected to reach its peak in a few years, and humankind is faced with challenges to find early solutions for stable supply of energy and environmental problems. Therefore, many research institutes are actively tackling R&D of new heat and energy conservation technologies. One of the solutions to these serious issues is efficient use of waste heat that is unused and disposed of into the atmosphere. Japan consumes and imports several hundred million kiloliters of primary energy in crude oil equivalent every year. However, about 70 % are disposed into the atmosphere as heat energy (Figure 1)[1]. Using this unused waste heat and improving energy efficiency are extremely important issues along with the development of alternative energy to oil.

Even though the total quantity of waste heat is massive, there is actually little energy disposed by a single heat engine. Waste heat energy is dispersed widely and thinly.

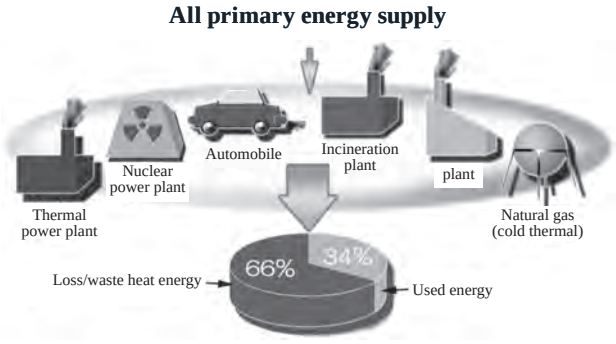

Fig. 1 Huge amount of waste heat.
In Japan, about 70 % of all primary energy supply is unused and disposed into the atmosphere as waste heat.

Thermoelectric power generation is drawing attention as the best candidate for technology that allows conversion of waste heat into electric power. This is because, since there is no scale effect in thermoelectric conversion, however small the heat energy, electric energy equal to the thermoelectric conversion efficiency spent on the heat energy can be obtained. For example, it is calculated that if 20 % of waste heat disposed from automobiles, plants, garbage incineration plants, and others could be converted to electricity, we can obtain 35 thousand GWh of power a year[2]. This figure is equivalent to power produced by a medium-size nuclear power plant. Also, thermoelectric generation system does not produce CO_2 or radioactive material, has no moving parts such as a turbine, and is a clean, maintenance-free, and long-lasting energy conversion system.

Thermoelectric power generation has been studied for quite a long time, and there were great expectations each time new materials were discovered followed by great disappointments. Therefore, users often regarded thermoelectrics with cold eyes: “Oh, thermoelectric again….” This was because even if a material had excellent properties, when putting it to civilian use, it often ran into major problems of safety, durability, cost, or of manufacturing technology. Also, in the United States, 10 years ago, civilian use of thermoelectric power did not arouse enthusiasm due to the attitude, “Gasoline is cheap so we don’t need thermoelectric power” , thus retarding its civilian use. However, expectation for thermoelectric power is rising again because of the shift in consciousness for energy and environment issues. It is rising from the demand from users rather than researchers of thermoelectric materials. One of the triggers of such movements was the discovery of excellent thermoelectric oxides by Japanese researchers including the Authors.

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2 Strategy for realization of thermoelectric power generation

As the energy issue is becoming serious, the expectation for effective use of waste heat is increasing. Waste heat includes a wide range of temperatures from cool waste heat of about 80 K to high temperatures of over 873 K, as well as various forms of heat in gas, fluid, and solid phases. The most convenient form of thermoelectric power generation that employs temperature difference is to use high-temperature waste heat. In general, high-temperature waste heat at a certain energy level can be recovered by heat converter using boilers. Therefore, in thermoelectric generation research, the main focus was on the development of material that functioned below 700 K. However, since the exergy[Term 1] decreases with decreasing temperature of waste heat, the thermoelectric generation system to recover heat will become large in scale. Diversification of energy conversion with such systems as medium- to-small-scale cogeneration system and boiler using biomass being in progress, effective use of waste heat was difficult from efficiency and cost aspects since practical amount of waste heat could not be obtained using the existing heat recovery system. In other words, in using waste heat for small systems, high temperature waste heat was preferred. However, this might decrease the efficiency of the thermal system to which the thermoelectric generation would be installed. The Authors, therefore, considered recovering energy through thermoelectric conversion at higher temperatures than required by the thermal system, and then operating the thermal system afterwards. Thinking from a different angle, we proposed a topping heat recovery system in which waste heat from thermoelectric generation was used in the "main house" thermal system (Figure 2). This system would improve energy efficiency of the entire system by optimizing energy use in thermoelectric generation and thermal system. In the development of the topping system, the Authors looked at water heaters using natural gas.

In home-use gas water heater, the combustion temperature of natural gas reaches 1473 K, while the hot water obtained is only about 323 K at the most. It is very wasteful when looking just at temperatures. Therefore, the Authors conducted joint research with Osaka Gas Co., Ltd. to create a cogeneration system where topping heat recovery and water heating can be done simultaneously through thermoelectric conversion in gas water heater. Moreover, we attempted generation of superheated steam as well as hot water in this cogeneration system.

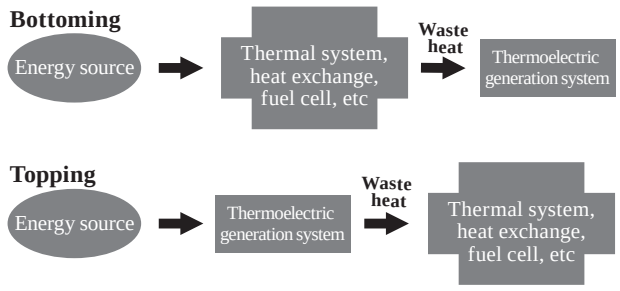

Fig. 2 Concept of bottoming and topping waste heat recovery.

3 Necessity of thermoelectric power generation in gas appliances

Gas appliances used in homes including water heater, cooking stove, and fan heater require electricity for ignition or control of the device. Users are faced with inconveniences such as requirement of a power outlet in addition to a gas valve, inability to heat the house or make hot water during power outage, and having to pay for electricity . If the gas appliance can generate its own power so self-sustained operation is possible without power supply from an outlet, the usability will increase dramatically. Also, household use of superheated steam is becoming common such as for cooking and sauna. With the development of small steam generator, electrical appliances are ahead, but considering energy efficiency and instantaneity of heating, steam can be generated in high volume and a short time if gas combustion is used. However, due to issues of heat deterioration in heat exchangers and incomplete combustion from a decrease of flame temperature (production of CO), small steam generators using natural gas combustion have not been widely used. In other words, the key to development of small steam generator using natural gas is the development of technologies that protect the surface of the heat converter and prevent the decrease of flame temperature. To solve the above problems, it is effective to coat with material with excellent heat durability such as oxides, just to a level that does not compromise heat exchange property. If thermoelectric conversion function can be added to this coating layer, both steam and electricity can be generated simultaneously by gas combustion, and a new cogeneration system that is extremely useful to the user can be developed.

4 Technological issues for gas-hermoelectric cogeneration system

Figure 3 shows the technological issues for constructing small cogeneration system using natural gas. We started our investigation from "downstream." To produce superheated steam and hot water by gas combustion, it is necessary to heat cool water by heat conversion. Therefore, we decided that the thermoelectric module should be in pipe form, and the temperature difference would be created by heating the exterior of the pipe and by running water inside the pipe to conduct simultaneous thermoelectric generation and heat exchange. In the main-stop type water heater for home used in this study, the heat converter was located 15~20 cm above the burner, and the space between was empty. To generate superheated steam, it was necessary to bring the pipe-type

module close to the burner. The thermoelectric module was installed in the space between the heat converter and the burner. Technologies necessary to manufacture the pipe-type module included technologies for: manufacturing thermoelectric element; joining of p- and n-type elements at low resistance and high strength; junction of element and pipe with high heat transfer, sturdiness, and electric insulation property; heat collection to transfer gas combustion heat into the module; and low cost manufacturing. To synthesize these technologies, "upstream" technologies were necessary for materials that not only possess high thermoelectric performance but also have high durability in natural gas combustion and high temperatures both chemically and mechanically, as well as materials to stably join electrode to element in high temperatures. Moreover, the material must not contain toxic and/or rare elements due to safety and cost concerns. Basic researches such as physics to design such material and chemistry for nanotechnology were also necessary. In this paper, basic research undertaken by the Authors to develop a small gas cogeneration system using thermoelectric power generation, intermediate integration technology that combines the technologies, and the power generation performance of pipe-type module installed in a water heater will be explained.

5 Basic research: birth of new material

In 1998, the Authors started a search for safe, inexpensive thermoelectric oxides that were stable in high temperatures and air. The design concept of the material was a low-dimensional material or a layer structure that was drawing attention at that time[3]. One of the Authors, Funahashi, has been working on superconducting oxides with layer structure, and has synthesized Co layered oxide derived from that research. However, this was removed from the list of development material since no significant property was found. Fortunately, upon assessing the thermoelectric property, it was discovered it had good p-type property in high temperatures and air. The composition of this oxide is $Ca_3Co_4O_9$ (Co-349), and Figure 4 (a) shows the diagram of its crystal structure[4]. This oxide has a layer structure where CoO_2 layer composed of octahedron with 6 Os arranged around Co and Ca_2CoO_3 layer with rock salt (NaCl) structure are stacked alternatively. The dimensionless thermoelectric figure-of-merit (ZT) [Equation(1)] at 973 K for oxide monocrystal was about 1.1.

$$ZT = S^2T/\rho\kappa \quad \text{... (1)}$$

Here, Z is called thermoelectric figure-of-merit, and when it is multiplied by absolute temperature T, it is called dimensionless thermoelectric figure-of-merit. S, ρ and κ represent Seebeck coefficient, electrical resistivity, and thermal conductivity, respectively. Greater the ZT, better it is as thermoelectric material.

ZT for Co-349 is normally at the same level as the highest figures for compound semiconductors in bulk, but these values are measured in vacuum, and only Co-349 shows high thermoelectric performance in high temperatures and air (Figure 4(b)).

To construct an efficient thermoelectric generation system, development of n-type thermoelectric material was necessary. However, since it was extremely difficult to find excellent material as in the above case, the Authors developed high-efficiency search technology for thermoelectric materials using sol-gel synthesis to increase chances of discovery. Using this technology, $LaNiO_3$ (Ni-113), an n-type material stable in high temperatures and air, was discovered, although its ZT was about 0.01 in 973 K and its performance was still insufficient[5]. We also succeeded in manufacturing thermoelectric generation module that brought out the performance of these oxides to a maximum, but the conversion efficiency was still about 1.5~2 %.

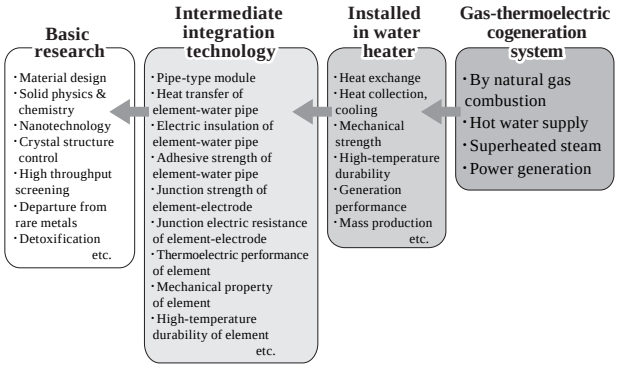

Fig. 3 Technologies needed for gas/thermoelectric cogeneration system.
We constructed "upstream" technology to respond to demand from "downstream".

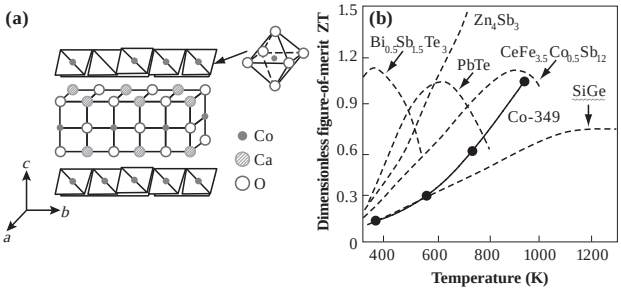

Fig. 4 Crystal structure of $Ca_3Co_4O_9$ (Co-349) (a) and temperature dependence of dimensionless figure-of-merit ZT (b).
Co-349 has a structure where electrically conductive CoO_2 layer and insulating Ca_2CoO_3 layer are stacked alternatively. The ZT of monocrystal of this oxide was 1.1 at 973 K. This is equivalent to conversion efficiency of over 10 %. The performances of metal materials with high ZT are also shown in the graph. Excluding Co-349, ZT of all other materials were measured in vacuum.

However, we believe that we will be able to construct a heat recovery system by utilizing high-temperature durability, which is the greatest advantage of oxide materials, and we are continuously working on the thermoelectric generation system for efficient use of high-temperature energy.

6 Intermediate integration technology

6.1 Joining technology

To obtain good thermoelectric module, it is necessary to form junctions with excellent heat durability, high mechanical strength, and low electric contact resistance between thermoelectric and electrode (generally metal) materials. However, for joining metal (Ag in this research) and oxides, problems of high contact resistance and detachment occur due to differences in Fermi energy and thermal expansion (Figure 5). More work is needed on joining materials to solve these problems.

6.1.1 Manufacture of element

The element was created by joining a pair of sintered Co-349 and Ni-113 onto alumina substrate of which the surface was metalized with Ag, and the electric contact resistance and the heat resistance were assessed[6]. The joining material was Ag paste containing powder of Co-349 or Ni-113 at 0~10 wt.%. Normally, it would seem better to use the same powder for both p- and n-type elements, but since application of Ag paste using screen printing required a "2-color printing" technology, in this research, we created an element using one of the composite Ag paste with either p- or n-type powder. The oxide composite Ag paste was applied on the surface of a sintered oxide compact, and placed on a metalized surface of alumina substrate. The Ag paste was solidified by heat treatment at 1123 K while applying uniaxial pressure 65kg/cm^2 vertical to the junction surface, to create a thermoelectric element composed of a pair of p- and n-type sintered compacts. The compositions of sintered compact were $Ca_{2.7}Bi_{0.3}Co_4O_9$ and $La_{0.9}Bi_{0.1}NiO_3$, where part of Ca and La of Co-349 and Ni-113 were replaced with Bi. The sintered compact was made by hot pressing the powders. The reasons for replacing Ca and La with Bi were: for p-type, S, ρ and κ [Equation(1)] were improved[7]; and for n-type, ρ only could be reduced while maintaining S constant[8].

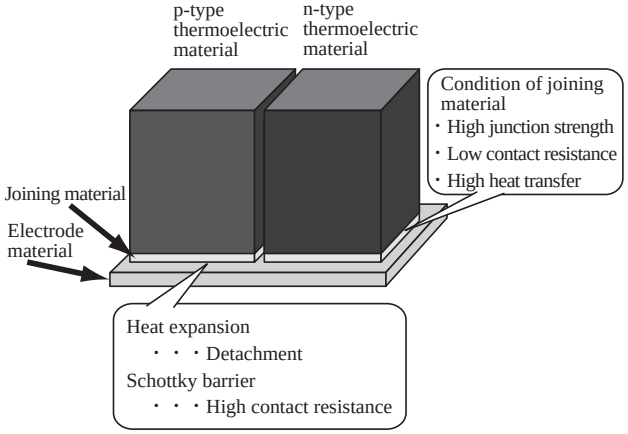

Fig. 5 Issues in joining technology.
Joining technology is mandatory for creating module with high durability and power generation performance. Particularly, developments of joining material and method to realize strong junction strength and low contact resistance are important for practical application.

6.1.2 Property assessment

Compositing Co-349 powder into Ag paste was found to be effective for reducing internal resistance (R_I) of the element[6]. Lowest R_I was obtained when Co-349 powder content was 6 wt.%. This reduction was caused by a decreased contact resistance between Ag paste and sintered oxide compact. Although the mechanism is not clear yet, it is thought to be due to a reduction of the effect of Schottky barrier and an improvement of contact by increasing wettability between the Ag paste and the surface of the sintered oxide compact.

The smoothness of the joining surface of sintered compact was important to strongly and closely connect the oxide material and the Ag electrode. The surface of sintered oxide was buffed before applying the Ag paste, and was joined to the alumina substrate using Ag paste composited with Co-349 powder at 6 wt.% and at the same condition as above. The smoothed surface of sintered oxide was effective in forming good junction.

Next we shall describe the durability of thermoelectric element against the heating and cooling cycle. The thermoelectric element was placed in an electric furnace, temperature raised to 1073 K over 3 h in air, kept in that state for 1 h, removed directly out of the furnace at high temperature, and cooled rapidly to room temperature. This procedure was repeated 5 times, and R_I before and after the heating/cooling cycles were measured and variations were calculated. In elements connected only with Ag paste, R_I increased significantly after the cycle at 600 K or less. On the other hand, in elements using oxide composite paste, R_I increase due to heating/cooling cycles became extremely small[6]. It was found that compositing of oxides into Ag paste was effective in improving durability against heating/cooling cycles. As a result of observation under scanning electron microscope (SEM), large cavities were found in the Ag paste in the element made with Ag paste only. On the other hand, in the thermoelectric element using Ag paste composited with 6 wt.% Co-349 powder, it was found that alumina substrate and sintered oxide were joined closely, although some fine holes were observed. The improvement of fine structure was the reason for controlling the R_I increase in heating/cooling cycles. The reasons for production of cavities are thought to be: contraction due to sintering of Ag, difference in heat expansion bet dispersal ween Ag and oxides, and exfoliation due to poor wettability.

6.2 Electric insulation technology

Thermoelectric module to be installed in gas cogeneration system must convert water used for cooling into superheated steam at the same time as generating power. To accomplish this, both high heat transfer and electric insulation must be maintained between the water pipe (stainless steel) and the thermoelectric element. Water pipe and thermoelectric element were insulated by insulating paste and ZrO_2 coating formed by thermal spraying on the surface of the water pipe. Here, the problem was breach in insulation due to of Ag from Ag paste that joined the element and electrode. The dispersed Ag pierced the ZrO_2 layer and reached the water pipe. This dispersal was prevented by adding other elements to the Ag paste. Since technology for preventing Ag dispersal by adding Pd particles was already used in industry, we investigated the effect of compositing Pd paste into Ag paste composited with Co-349 powder.

6.2.1 Sample manufacturing and assessment method

The assessment method for breach of electric insulation due to dispersal of Ag to insulating paste is shown in Figure 6(a). Ag paste composited with 0~10 wt.% Pd paste was applied and solidified on an alumina plate. Insulating paste and silver sheet were layered on top, and the paste was solidified. After heat treatment of a layered sample at 1023 K for 30 h, conductivity was assessed with a tester. Five samples with varied Pd contents were assessed, and the insulation property was calculated.

6.2.2 Electric insulation property

Figure 6(b) shows the insulation property at different conditions. Insulation increased with increased amount of Pd paste, and in case of 10 wt.%, all samples maintained electric insulation property even after heat treatment at 1023 K for 30 h. Upon observation of fine structure under SEM, it was found that Pd composite prevented Ag from dispersing into the insulation paste.

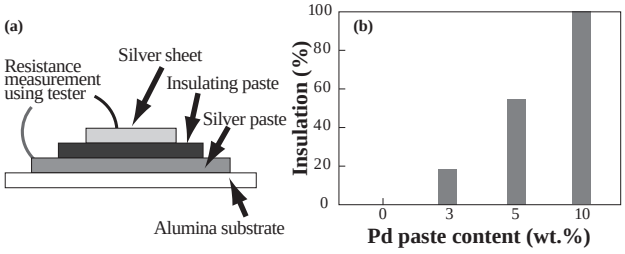

Fig. 6 Assessment method for electric insulation of multilayer structure (a) and dependency on Pd paste content for insulation of multilayer sample after heat treatment at 1023 K for 30 h (b).

Five samples were created with varying contents of Pd paste composites. The insulation property between Ag paste and Ag sheet mediated by insulating paste after heat treatment was assessed.

6.3 Structure and manufacture of pipe-type module

The structure of pipe-type thermoelectric module manufactured in this research is shown in Figure 7. The pipe-type module has a structure where 2 rows of elements composed of 27 pairs of elements sandwich the stainless steel water pipe. $Ca_{2.7}Bi_{0.3}Co_4O_9$ was used as sintered compact for p-type element, and $CaMn_{0.98}Mo_{0.02}O_3$ for n-type element. In this research, we installed this module in a small water heater. The combustion room of the water heater was small, and the module had to be kept compact, so the number of thermoelectric elements was limited. However, numerous elements were necessary to obtain high voltage by thermoelectric generation. To solve this dilemma, we manufactured the module using $CaMn_{0.98}Mo_{0.02}O_3$ which had higher S values than $La_{0.9}Bi_{0.1}NiO_3$. ZrO_2 coat of 60~70 μm was formed on the surface of the water pipe by thermal spraying to provide insulation between water pipe and thermoelectric element. Commercial insulating paste was applied over this to bond the element rows and the water pipe. The thickness of insulating paste after solidification was 150~300 μm. To create the element row, the thermoelectric element was formed into arch shape by grinding the sintered oxide, and using Ag paste composited with 6 wt.% Co-349 powder, it was joined at 1123 K under pressure of 50 kg/cm^2 on the arch section. The element row was joined to the water pipe whose surface was insulated, to create a pipe-type module with a length of 30 cm (54 elements in pairs)[9].

7 Construction of small gas-thermoelectric cogeneration system[10]

Two of the above modules were bundled and installed in the main-stop type water heater (Figure 8). By gas combustion of water heater, exterior of the module was heated, and hot water (about 313 K) was supplied to the water pipe at flow

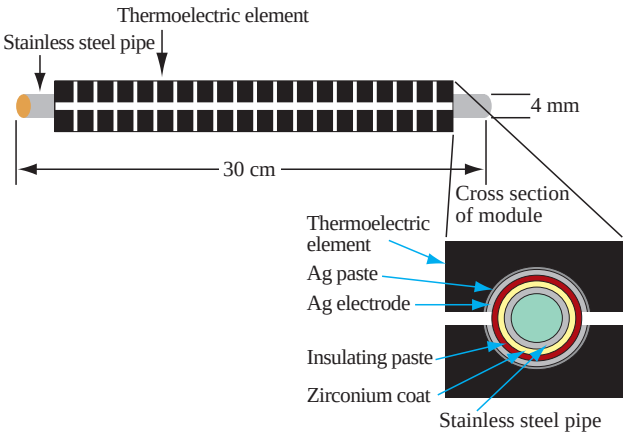

Fig. 7 Schematic diagram of Pipe-type module.

The total length of the pipe is 30 cm. The space between thermoelectric element and stainless steel water pipe is multilayer of Ag paste, Ag sheet, insulating paste, and ZrO_2. Although having thin structure is desirable to increase heat transfer, it is necessary to prevent breach of electric insulation by dispersal of Ag from the Ag paste.

volume of 16 cm^3/min from the water heater to produce temperature difference in thermoelectric element to generate power.

During gas combustion, temperature around the thermoelectric module reached approximately 1473 K. When the water heater was burned at full force, open voltage (V_o) and maximum output (P_{max}) reached 1.3~1.5 V and 0.28 W, respectively. After continuous generation for 1 h under heating condition where the V_o of the module reached 0.6 V or 1.0 V, combustion was stopped, allowed to cool to room temperature, and generation property was measured repeatedly. As a result, there was no deterioration of generation property by repeated heating and cooling for 1 h. Also, superheated steam of about 473 K was obtained from the end of the module water pipe. By installing pipe-type thermoelectric module that allowed direct heat conversion, an ordinary water heater became a multifunctional cogeneration system (Figure 9). Moreover, exhaust gas temperature was higher and CO partial pressure was reduced when gas combustion was done with pipe-type thermoelectric module installed in the water heater, compared to when water pipe without thermoelectric elements was installed. This was probably because by covering the water pipe with oxide thermoelectric element, incomplete combustion was prevented by halting the decrease in gas combustion temperature that occurred when water pipe with low surface temperature was installed.

In general, waste heat recovery is considered to be the use of exhaust gas after completion of heat engine cycle (bottoming). Although natural gas burns at about 1473 K, the temperature of hot water that comes out of the water heater is 323 K at the most. This means that the heat energy produced by combustion is not efficiently used. Therefore, heat use with high total efficiency becomes possible if unused high-temperature heat energy (potential waste heat) can be used for thermoelectric generation while the water is heated using waste energy from thermoelectric conversion (topping). Heat recovery by topping is possible due to oxide material that can be used in high temperatures, and this is a new method for using thermoelectric generation.

8 Future prospects

The development of oxide thermoelectric generation system for efficient use of high-temperature waste heat was explained. It was necessary to start from thermoelectric material to construct this system. We were fortunate in this aspect, and were able to find Co layered oxide with excellent conversion efficiency and durability. This substance not only enabled practical application of thermoelectric generation in high temperatures and air, but also was highly acclaimed in the academic society as a demonstrative example of high thermoelectric performance by nano-block integration with different functions. However, for construction of a generation system, various technologies and know-hows for joining, electric insulation, and heat transfer described in this paper must be integrated and mass production technology must be developed along with the development of new high-performance materials. Also, reduction in use or alternatives to rare metals must be sought for Co for p-type material, La of n-type, and Pd used in paste to widely diffuse thermoelectric generation in the future.

The market for thermoelectric generation is being developed at this moment. For practical application, we must create value for the users in thermoelectric generation using waste heat. To do so, it is necessary to give added function to the module in addition to thermoelectric conversion, or provide

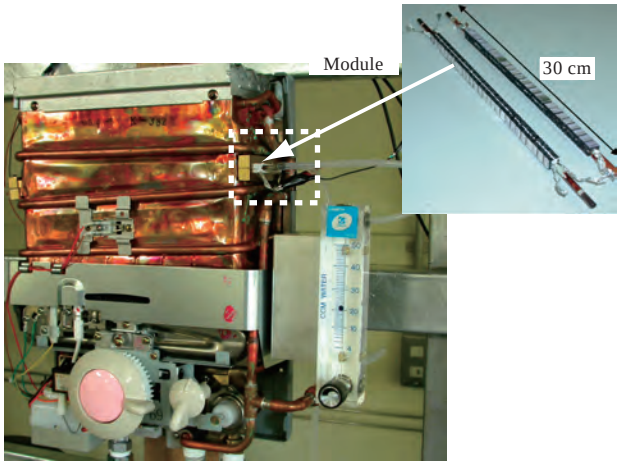

Fig. 8 Pipe-type module and main-stop water heater equipped with module.
By gas combustion in main-stop water heater equipped with pipe-type module, the water heater produced hot water and the module produced superheated steam and electricity simultaneously.

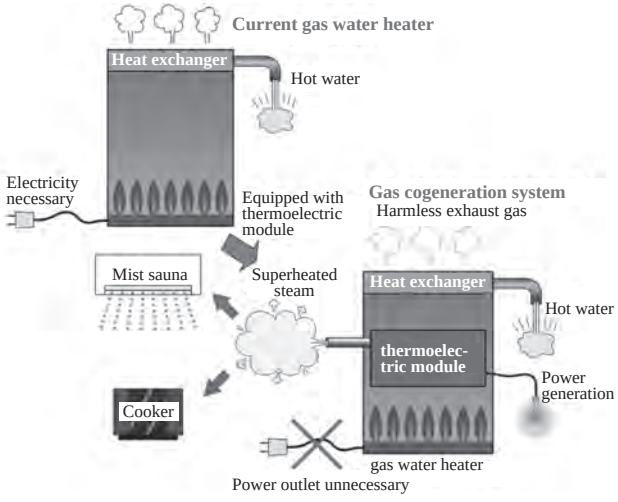

Fig. 9 Home water heater becomes cogeneration system.
By installing thermoelectric module and conducting topping heat recovery, it was possible to produce electricity and superheated steam in addition to hot water. Also, the CO content in exhaust gas was reduced.

added value to the system to which the thermoelectric module is installed. In oxide thermoelectric module, since the temperature on the low side can be set high, waste heat can be used efficiently by topping heat recovery. Using this concept, we expect improvement of total heat efficiency of heat conversion and energy conversion devices such as boilers and fuel cells. Also, high power density, an advantage of thermoelectric conversion, is excellent for application to mobile objects such as automobiles and power sources for cell phones. The Co-349/Ni-113 thermoelectric element can produce about 2 MW/m^3 power density.

By installing the thermoelectric system developed by technological integration described here to heat engine so waste heat can be used effectively, new value can be provided to users who were waiting for this, and great contribution can be made to solve the energy issues.

Some of the results described here were presented in other journals[10].

Acknowledgement

We express our gratitude to Yoshinori Hisazumi, Senior Engineer and Akeshi Kegasa, Senior Engineer of Energy Technology Research Center of Osaka Gas Co., Ltd. for their useful advice in manufacturing the pipe-type module. Also, part of this research was conducted under NEDO Industrial Technology Research Grant (ID06A39002d).

Terminology

Term 1. Exergy: effective energy that can be converted to other energy.

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Discussion with reviewers

1 Greatest difficulty in this R&D

Question (Naoto Kobayashi)

I see that you were engaged in a series of significant R&D with a strategic vision toward the development of small-size gas cogeneration system, with a basic research including search and development of materials, an intermediate integration technology that combined with know-how, and a power generation by pipe-type module installed in a water heater. What was the most difficult point? And how did you overcome that?

Answer (Ryoji Funabashi)

The most difficult point technologically was material development. Discovery of a new substance cannot be planned beforehand, and one must be blessed with luck to succeed. We were able to discover Co layered oxide for p-type material, but we are still struggling for n-type material. I feel that the research for

module realization, as described in the paper, went smoother than expected due to various collaborations and information gathering. Rather than technological matters, the real difficulty in realizing thermoelectric generation was to create value for thermoelectric conversion technology. We did not suddenly come up with small gas cogeneration system. We looked at the merit and demerits and listened to opinions of users in several fields, and finally arrived at the idea of topping, with specific application to a small gas cogeneration system.

2 Future research topics

Question (Naoto Kobayashi)

As described in the paper, I think a major contribution can be made to energy conservation if the waste heat recovery becomes possible through an efficient thermoelectric generation system at high temperatures. I think this R&D effort is a milestone, but what is the greatest issue that must be overcome in the future?

Answer (Ryoji Funahashi)

They are mass production and improved reliability of the module. Of course, search for new materials is necessary because of the current low conversion efficiency, but I think the immediate task is to build a market for thermoelectric conversion that can be realized at the current performance.

3 Prospect for n-type thermoelectric material development

Question (Naoto Kobayashi)

I understood that in this R&D, compared to the high-performance p-type thermoelectric oxide material, the performance of n-type thermoelectric oxide material is not so good, and this is a major issue in the future research. Please explain the strategy and prospect for the future development of n-type thermoelectric material.

Answer (Ryoji Funahashi)

We have two strategies for material development. One is development of material to be used in the thermoelectric conversion market that will be developed in the near future. This is not development of totally unknown material, but we plan to improve the performance of Ni and Mn oxides that were described here through element addition and process technologies. Moreover, current performances of both p- and n-types are insufficient to expand the thermoelectric conversion market. It is necessary to create a totally new substance using crystal structure control by nanotechnology or high-efficiency search by combinatorial technology.

4 Efficacy of heat recovery system from high temperatures

Question (Naoto Kobayashi)

For the development of small cogeneration system, I think it was highly significant that you conducted verification of the system. Also, this small-size verified system is most likely effective for general heat energy use such as electric conversion at high temperatures, heat use in medium temperature, and use of high-temperature steam. In actual practical application, other than water heater, how do you the think heat recovery from high temperature by topping can be used?

Answer (Ryoji Funahashi)

Basically, I think it can be installed in any system that involves heat exchange with water. For example, I think it can be used for boiler fin, which is much larger than home water heater. The important point is not to depart from the main objective of the original system. Also, I think solid oxide fuel cell (SOFC) is a candidate. The operating temperature of SOFC is decreasing every year with technological progress. Therefore, the temperature margin is formed on the high temperature side. I think this margin can be used effectively for thermoelectric conversion.

5 Effect of the result of this research on thermoelectric generation market

Question (Naoto Kobayashi)

Concerning the effect of the result of this research on thermoelectric generation market, what level of innovation do you think will be introduced to the market compared to current technologies and products?

Answer (Ryoji Funahashi)

There is no market for thermoelectric generation yet. Therefore, as explained in the paper, we must assess the value of thermoelectric generation from a different angle to build the thermoelectric market. We are planning to establish a venture company to do this.

Realization of a collaboration system for everyone to develop and manage

— Practices of communication patterns using qwikWeb —

Kouichirou Eto [*], Masahiro Hamasaki [**] and Takuichi Nishimura [**]

[Translation from *Synthesiology*, Vol.1, No.2, p.101-110 (2008)]

To realize a new collaborative communication system, we propose qwikWeb which has a design philosophy based on communication patterns where a user can easily build a system that matches the group's activity. Adequacy and efficacy of this system were demonstrated by designing, implementing, operating, improving, and conducting analysis of operation data.

Keywords : Collaboration system, groupware, pattern language, Wiki, mailing list

1 Introduction

With the advance of communication and Internet technology, we now possess the means for sharing information over time and space. As of 2005, there were estimated 69.23 million users of portable terminals such as cell phones, and estimated 66.01 million people used personal computers[1]. If we can provide a system that can be built collaboratively within an organization, organizations, interest groups, and local areas can more actively engage in creative and economic activities. However, currently available systems were difficult to manage, and users could not efficiently accumulate and structure knowledge.

In this paper, we propose qwikWeb[2], a collaboration system for user groups who wish to have a system that does not require complex access control, is easy to manage and learn, and enables accumulation and structuring of knowledge, as shown in Table 1. Communication patterns were employed as background design philosophy that enables construction of a system to a user's preference. Adequacy and efficacy of the system were demonstrated by designing, implementing, operating, and improving the system, and conducting analysis of the operation data.

In this paper, Full Research of the web system is discussed in Chapter 2. Corresponding to this development process, present status analysis of the collaboration system is described in Chapter 3. Service design of qwikWeb is discussed in Chapter 4, and implementation of qwikWeb in Chapter 5. Data analysis and discussion of qwikWeb in operation are discussed in Chapter 6. Related studies are discussed in Chapter 7 to clarify the positioning of this study, and summary and future directions are presented in Chapter 8.

Table. 1 Comparison of existing collaboration systems and qwikWeb.

	Ease of management	Accumulation and structuring of knowledge	Complex access control
Cybozu[3] and others	×	△	○
qwikWeb	○	○	×

2 Full Research of the web system

In the Full Research for developing and realizing the web system, it is important to develop the system by understanding user behavior and by utilizing user feedback. The basic design and development procedure involves the participation of the users as well as the designers and the system developers, as shown in Figure 1.

First, in the phase for analyzing the current situation, outline of service and target users are selected, and current problems are analyzed. Since service outline and target users

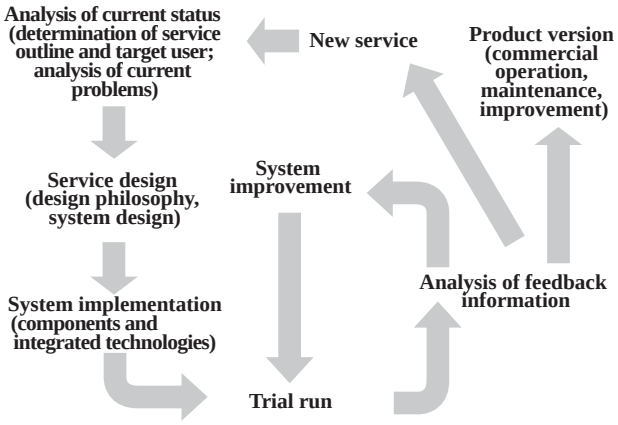

Fig. 1 Development process of web system.

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can be identified by understanding the current problems, analysis of the current situation can be done simultaneously. Extraction of problems in the current system is done on a concept level as well as on a functional level. New service is designed based on these results. In this design, design philosophy including service vision is determined to create a system design incorporating selection and improvement of component as well as future scalability and linkage with other systems. System implementation follows system design, and cost performance in terms of software engineering is taken into account. Next, test run is done with a certain number of users. In this phase, not only is it necessary to accumulate system log to collect user feedbacks, but it is also necessary to hear direct user comments. Gathered information is analyzed and the design is improved as needed, and the commercial version is completed as the system is continuously improved on the test run. During the analysis and improvement processes, hidden demands may become uncovered and findings that enable implementation of new services can be collected. The commercial version will be sold or licensed to a management company for commercial operation, but maintenance and system improvement must be continued throughout the operation.

Described above is the user participation process in Full Research for the web system. qwikWeb was developed according to this process, and currently, the test operation is almost complete. The development process of qwikWeb will be discussed in the following chapters.

3 Analysis of the current state of the collaboration system

In cooperative and collaborative work in organizations such as companies and interest groups, e-mail plays an important role, and communication and collaboration using the mailing list (ML) is done very actively. However, in collaborative work, information may not be structured, and it requires time to confirm the latest information in many cases. On the other hand, collaboration tools or groupware such as Lotus Notes[3] and Cybozu[4] are used since they have functions for schedule adjustment, table making, and collaborative document creation. However, set-up procedure and operation of such systems are complicated, and the managers are heavily burdened by maintenance work. Also, since communication method within the groupware is different from e-mail address used regularly, there is extra work of data transfer when building document and knowledge collaboratively by e-mail exchange. Flexible cooperation with members outside the group is not easy.

For a user who must keep the costs of start-up and operation low, and wishes to have a collaboration system that does not place a burden on certain managers, it is necessary that he/she can understand how to use the system just by looking at it, without extensive training on the system. Also, the system must have expandable structure that enables gradual construction of user's ideal information environment, built up from the environment with which the user is already familiar. For such a user, detailed access control (for example, which user can edit which document) for each document and knowledge is unnecessary. This is because, while systems like Cybozu[4] assume several thousand users, a user who cannot rely on a manager needs a collaboration system for just a few dozen people.

As an example of target users, the Authors looked at collaborative work by researchers who could not spare time for groupware management. The researchers used e-mail regularly as a main mode of communication. However, they did not spontaneously use groupware in collaborative work unless ordered by the supervisor to create documents. This was also true even in a situation where it was much more efficient to do collaborative document writing. Why was this? Okada[5] positioned communication at directly below collaboration in his hierarchical model of cooperation to emphasize the importance of communication. Kitagawa[6] divided the online community by three functions – obtain information, establish relationship, and collaborate – and stated that although majority of the communities existed simply to obtain information, the members became close in some communities, and some of them developed into collaborative communities. Close communication is necessary as background of collaboration, and collaboration is only possible through information exchange and agreement through communication. In fact, although collaborations such as report write-ups are done over e-mail, there is a problem in terms of structuring and sharing knowledge because all mails must be read and everything must be corrected and integrated to comprehend the latest information. Therefore, we saw a demand for a system that enabled structuring of intra-group knowledge and writing of collaborative document based on natural intra-group communication flow.

The issues were "easy management," "easy learning," and "accumulation and structuring of knowledge."

4 qwikWeb service design

4.1 qwikWeb design philosophy

4.1.1 Basic philosophy

As a result of considering the collaboration system issues mentioned in Chapter 3 from the standpoint of users, we set the basic philosophy of qwikWeb as: "users can freely design the system and the ways it is used."

Since it was not possible for general users to alter the system in Lotus Notes[3] and Cybozu[4], it was difficult to incorporate this basic philosophy. Therefore, we studied Wiki, which was developed by Ward Cunningham, and found it was designed

with a philosophy that closely resembled our proposal. We call Wiki's design philosophy "communication patterns"[7] [8], and we present it in the next chapter, and also discuss the design philosophy of qwikWeb.

4.1.2 "Communication patterns" - Wiki's design philosophy

The philosophy of pattern language[9] proposed by architect Christopher Alexander is reflected in Wiki. Pattern language is a summary of language-like expression of architectural forms that appear repeatedly in architecture. This enables the user of buildings to participate in the design process, which is expected to result in good architecture. In 1987, Wiki developer Ward Cunningham became interested in pattern language, and tried to apply it to software from the perspective of user participation in design. Several patterns were extracted as user interface, and it became possible to design excellent software in relatively short time by providing these patterns to users[10]. This experiment developed into a large movement for creating design patterns that served as common language among developers[11]. Cunningham used HyperCard launched in 1987 from Apple Inc., and created the browser to record and edit the discovered patterns[12]. This pattern browser later grew into Wiki. Wiki was originally developed as a base for recording and editing pattern language.

In 1995, Cunningham recreated the pattern browser as a system on web based on the contents accumulated so far, and called it WikiWikiWeb. This was the origin of Wiki. The greatest difference between the pattern browser on HyperCard and Wiki was the real time connection to the Internet. Wiki was no longer merely a place to accumulate information, but also became a place to discuss accumulated information.

In general, a system used for communication is managed by organizing information into some uniform format. A typical example is the bulletin board. An article is stored by breaking it down into several items such as author's name, date, document title, and text. Authorization is attached to the article, and usually only the author can edit the article. It is like sharing a piece of paper in contrast to the storage of information in Wiki. In Wiki, there was no set format of information and any document could be written freely. Anyone could edit any document since there was no concept of authorization. However, when several authors edited the same documents, confusion occurred inevitably. Local rules were created to solve such confusion. For example, "one must leave one's name at the end of a comment." Gradually rules were created within Wiki, which was in a state of anarchy in the beginning. Rules of communication developed spontaneously among user relationships, and they seemed to have a similar structure to the development of patterns in architecture. Therefore, in this paper, rules of communication that arise in this manner are called "communication patterns."

Although the initial objective of Wiki was to collect patterns that were necessary to create information systems, it soon became a place of communication among people who were interested in patterns, a place to discuss the rules (communication patterns) of communication, and also a place to record and collect communication patterns that were generated spontaneously. Wiki developed as a place not merely for collecting patterns but a place with a higher-level function of collecting the rules for collecting information (communication patterns).

The most important communication pattern in Wiki can be categorized into a thread mode and a document mode. The thread mode is a mode in which discussion is in progress using that page, and the user comments are presented in bulletin board form. In contrast, the document mode is a mode where only objective descriptions are presented on the page and subjective comments are excluded. In practice, most pages use a hybrid mode where objective descriptions are presented at the top of page and a discussion goes on in the lower part. Each page starts with a short document that describes the topic of the page, and comments on this topic are added in the thread mode. Individual differences are gradually absorbed as discussion progresses, and finally it grows into one objective statement (the document mode). It was expected that all pages would ultimately reach the document mode.

Here, rather than setting rules and communicating along the set rules, the stance is emphasizing spontaneous rulemaking where the rules on how to carry on communication are decided through communication. This stance is the most distinct characteristic of Wiki. If the essence of Wiki's design philosophy is described in one phrase, it is "emphasis on communication patterns."

4.1.3 Communication patterns in qwikWeb

Investigating the design philosophy of qwikWeb based on Wiki's design philosophy "communication patterns" which was restated in the previous section, it is a "system that enables the user to construct collaboration system appropriate for the group by combining various communication patterns." Adding the user's standpoint that it "can be used with current knowledge only, without explanation," it is a web system where one can practice expandable communication pattern to gradually develop one's ideal information environment, starting from a communication environment of e-mail that is very familiar.

4.2 System design of qwikWeb

4.2.1 Basic design

Considering "easy management," "easy learning," and

"accumulation and structuring of knowledge" that were discussed above, we investigated the routine communication method used by our target users. They were mainly telephone, facsimile, cell phone, e-mail, and web browsing. Among these, e-mail and web browsing were communication means of digital information such as text information which is compatible for distribution on the Internet. Since Wiki, whose design philosophy was adopted as described in the previous section, was an extension of web browsing and did not alter the way of using e-mail, it was assumed that a user would use mail in a conventional manner. Therefore, e-mail and Wiki were combined for structuring knowledge and for collaborative work. It was designed as a web system that enabled communication patterns in which the user could freely edit and set convenient rules including the image of the entry page to Wiki. Specifically, the following points were emphasized in the design.

- Ease of management
  It can be set up by sending e-mail, and then responding to the mail from the system. Anyone can add or delete members, thereby enabling collaboration with members outside the organization, which was difficult to do with the conventional system. Members of the system and Wiki can be matched so anyone can easily take on managerial work.
- Ease of learning
  Starting with simple communication using e-mail, one can gradually build up a desired information environment.
- Accumulation and structuring of knowledge
  Exchanges of e-mail are accumulated in Wiki, and necessary knowledge structuring and collaboration can be accomplished. Notification about who did what in Wiki is transmitted (distributed by mail).

Therefore Wiki and ML that distributed mails to the group were combined. ML is a mechanism whereby e-mail can be sent to several people simultaneously. When a person sends e-mail to the ML, it is then sent to all registered members. ML can be categorized as an asynchronous communication system. There are many server softwares for ML such as fml and majordomo, but a hosting service such as Yahoo Group[13] and freeML[14] is frequently used due to the ease of set-up.

When setting up a ML, the user, who will act as the ML manager, sets the mail address for the ML, and then registers the members. In general, participation and withdrawal of members are managed by the ML manager, and participation or withdrawal is done by sending a request to the manager. This endows authority to the manager, and while it enables removal of troublemakers, it also places a heavy responsibility on the manager.

Therefore, QuickML[15] was employed as our ML. QuickML is a ML system that enables set-up and operation with simple maneuvers.

4.2.2 QuickML

QuickML is a ML management system developed by Satoru Takabayashi and Toshiyuki Masui. It enables easy set-up and operation. In QuickML, all members have authority to determine participation/withdrawal of members, so the problem of placing a burden on a single manager does not occur. Mail sent in by a member is forwarded to all members, so each member will manage the mail as a client.

5 Implementation of qwikWeb

5.1 Implementation method

For implementation of qwikWeb, QuickML and Wiki were used as component. Implementation was done so the users would not be conscious of QuickML or conventional Wiki, and the system looked like an ingenious combination of the functions of ML and Wiki to users. In qwikWeb, knowledge structuring was promoted by registering all mails sent to ML as Wiki pages.

User can set up ML and Wiki site by simply sending e-mail to the qwikWeb system. First, the user selects a name for ML, and sends e-mail to "name-of-ML@qwik.jp." If the name is not already used, confirmation mail will be returned. By responding to this mail, ML and Wiki site is set up (Figure 2). If such ML and Wiki sites remain unused for one month or more, they are automatically deleted after issuing warnings. Almost no burden is placed on the user for starting and closing a site, and the user can start-up ML and Wiki by simply throwing in an e-mail.

The e-mail sent to the ML is automatically stored in the Wiki site as a new Wiki page. The title of the mail becomes the page name of the Wiki page, and in the case where the same page name already exists, the new mail is added to the end of the already existing Wiki page. Response to that mail is also added on to the end of the Wiki page of the parent mail. The mails within the same Wiki page are displayed divided by date and user name. Related mails are stored on one Wiki

Fig. 2 Newly set up Wiki.
Exchange on ML directly becomes Wiki page.

page. The Wiki site can be accessed only by members of the ML. Addition of members can be done by mail or Wiki. Addition of members can also be done by sending mail to the ML with cc mail addresses of members to be added. From Wiki, members can be added by directly editing the the member list of the Wiki page. Any member can take part in this member management maneuver, so no single manager is burdened.

In qwikWeb, Wiki plays the role of archiver, but unlike ordinary ML archiver, it can be edited because it is Wiki. For example, minor typing error that does not have to be notified by mail can be easily corrected by directly editing the Wiki page. Also, when mail "We want to set a date, so please check the day which is convenient for you" is sent to the ML, one can check the convenient day directly onto the mail on the Wiki page, rather than responding to the mail. When a file is attached to the e-mail, that file is shared on the Wiki.

With qwikWeb, exchanges on the ML can progress seamlessly to collaborative editing. Unlike e-mails, however, since not all members check the Wiki, some users may not notice that editing has taken place. Therefore, qwikWeb has a function where the system automatically and regularly sends update information of a Wiki page (of the name of user that did the update and the update time) to the ML. All Wiki pages are version controlled, so items can be recovered even if someone deletes them accidentally. Also, there is time machine function that allows the editing status of the Wiki page to be viewed easily. This is a function where one can see the sequential change over time of a Wiki page by moving the slide bar to left or right.

In user participation, there is always a concern for security. Therefore this system was designed with utmost care. For example, a mail address is used as ID and a password is automatically generated by the system. The password cannot be obtained by typing in someone else's mail address, so impersonation is difficult. In case one forgets the password, it is sent when one enters the mail address, but it is sent to the mail address entered so only the owner of the address may receive it. Of course, if the password is stolen or accidentally sent to someone else, impersonation becomes possible as in other systems. However, if the impersonator alters the website, the alterations are notified to the members, so the actual person will know someone else has engaged in unauthorized maneuver. Since all web pages keep past history, the undesired change can be restored to a desired state, and future impersonation can be prevented by deleting the ID registration. Recovery is also easy in case wrong entries are made since past entry history is stored.

5.2 Points of implementation

qwikWeb was developed, not just as a mere practical web system, but as "the ideal solution for a web system" and we tried to get close to the ideal as much as possible. Specifically, we followed the REST architectural style by Roy Fielding. In the beginning of qwikWeb development, there was no web application framework that could be used easily, so we created parts of the framework including templates and plug-ins. To keep installation and maintenance simple, we selected mechanism of using a file system only as storage rather than database.

In general, increasing stability as a system for practical service and adding functions occasionally as a system for research are two contradicting activities. If functions are added, bugs occur and the system becomes unstable. However, both must be done simultaneously to satisfy both research and practical aspects. To accomplish the two contradicting properties, we attempted to decrease bugs as much as possible by thorough function test descriptions. Since we created the web application framework ourselves this time, and also created the test framework, it was easier than usual to describe the function tests for the web system. Since a function test was described beforehand at all times during the development, there was almost no function without a function test. Hence, we were able to operate the system with hardly any length of downtime. For both development and operation, the Author (Eto) alone has been able to continue the operation for four and half years.

6 Operation of qwikWeb

6.1 Access analysis of qwikWeb

Using the implemented qwikWeb, research operation started in August 2003, and the system continues to be in operation as of present. Users must agree to the terms and conditions (such as data will be used for research purposes without identification of individual users) when using the system.

Figure 3 shows the cumulative values of the number of MLs, the number of closed MLs, and the number of MLs using Wiki. As of May 2007, there were 3,110 MLs and 18,519 users (excluding data for ML set up by developers). Maximum number of users in a single ML was 648 people,

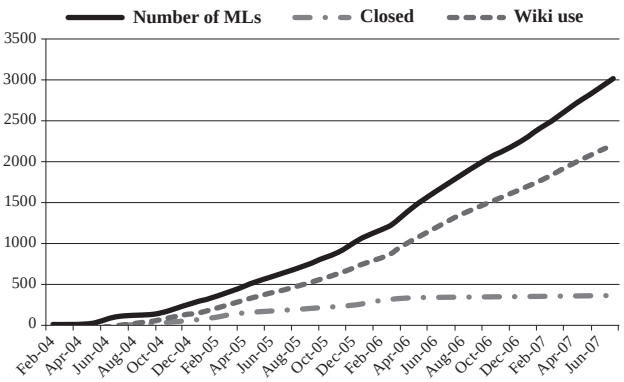


Fig. 3 Time transition of number of MLs.

and the average was 7.7 people. The majority were MLs with 10 or less people, and this matched the design intent of a ML to be used by a small number of people. Wiki was used in about 70 % of the MLs, and many users selected qwikWeb since Wiki can be also used. While the average active period of MLs using Wiki (2,235 MLs) was 145.1 days, it was 42.4 days for MLs without Wiki (875 MLs). It can be seen that Wiki was employed for long-term use. The number of closed MLs is currently about 10 %, and this is low compared to 50 % closed ML for QuickML, and a longer use is expected to promote more accumulation of knowledge.

The cumulative values of users are shown in Figure 4. Number of users, number of Wiki users, and number of users who created MLs all increased. About 70 % were MLs with Wiki, and about 40 % were users of Wiki. This is probably because many users started using Wiki by induction through the ML. About 10 % of users created MLs (1,909 people). Maximum number of MLs created by one person was 40 MLs, and the average was 1.6. As seen from the fact that there was a single user who created 40 MLs alone, the cost to the manager is relatively low. About 25 % or 505 people created 2 or more MLs. On the other hand, looking at the number of MLs in which the users participated, of the 18,519 people, the maximum number of participation was in 48 MLs, and the average was 1.3. About 20 % or 3,515 people belonged to 2 or more MLs. Participating in several MLs may be due to that fact that the users considered qwikWeb to be useful to some degree.

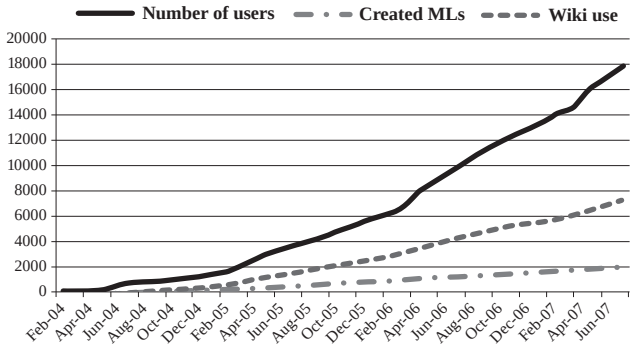


Fig. 4 Time transition of number of users.

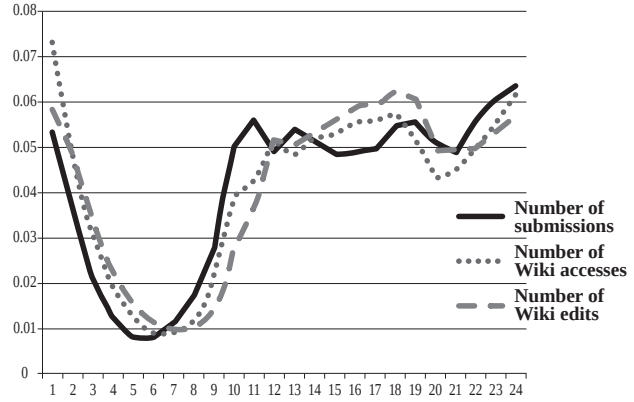


Fig. 5 Difference in use status of ML and Wiki by time zone.
The solid line of the graph shows the percentage of submissions by time, when the number of submissions throughout the day is set as 1.0. The same is applied to numbers of Wiki access and Wiki edit.

The difference between Wiki and ML was studied from the difference in use by time zone. Figure 5 shows the number of submissions, number of Wiki accesses, and number of edits to Wiki by time. It can be seen that peaks of submission to a ML occurred during 9:00~11:00, 12:00~13:00, 17:00~19:00, and 23:00~24:00. The time zones corresponded to start of work, after lunch break, end of work, and before retiring for the evening. In contrast, the number of Wiki accesses and edits increased from start of work in the afternoon to end of work, and reached a peak at 17:00~18:00. The reason for this is, since submission to a ML is communication, it was done most often at start and end of segments in daily routine, while access to and editing Wiki are part work so it was done during work in the afternoon, and as summary at end of work and before retiring for the evening.

Next, we looked at the use by groups that use both Wiki and ML. Here, we focused on MLs with over 50 submissions, 50 times or more editing of Wiki page, and durations of 1 year or more. Of the total 3,110 MLs, 64 MLs met this condition. Comparing the number of submissions and number of edits by month, about 80 % or 54 MLs had more months with higher number of submissions than edits. Figure 6 shows the cumulative values of number of submissions and edits in some MLs. Figure 6(a) is mainly ML and Figure 6(b) is mainly Wiki. Overall, the first few months were most active (with many submissions and edits) and the activities tended to decrease afterwards. Particularly Wiki showed that trend, and it tended to subside after initial heavy editing. In some MLs, the number of edits to Wiki suddenly increased. Figure 6(c1) and 6(c2) show steadily growing number of submissions, while the number of Wiki edits increased suddenly at some point and then subsided. It is thought that both ML and Wiki are regularly used if they are used for communication in daily work and for collaborative knowledge structuring, but when they are used for a particular event only, use increased suddenly before and after the event.

The use of qwikWeb and the difference in how ML and Wiki were used was discussed based on operation data. Although this was a research operation, the efficacy of qwikWeb design and implementation was demonstrated.

6.2 Example of qwikWeb in practice

Articles on Wiki appeared over 12 issues of Software Design of Gijutsu Hyoronsha, from August 2005 to July 2006. One article of the series was “Complete Guide to qwikWeb”[16]. At the same time, qwikWeb was used as a collaboration system to create the article series, and the actual process of

editing using qwikWeb was presented in the final article[17]. The qwikWeb group used in the article series was opened to public to serve as reference for similar users[18]. According to the article, the reasons qwikWeb was selected were: "overview of the project can be readily seen by members who joined later" and "both mail and document can be viewed." Here, the objective of qwikWeb was realized. From this example, it can be confirmed that qwikWeb reached a quality that could be used at a practical level even though this was a research run.

7 Related researches

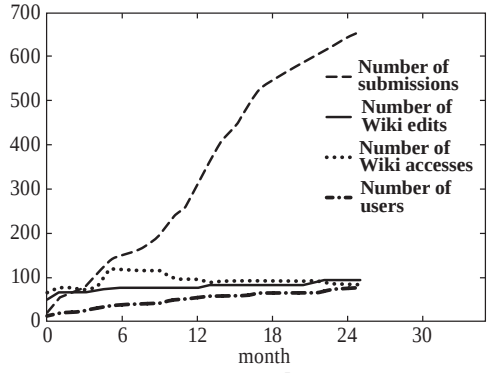
The basic concept of Wiki is that anyone can easily edit the contents, and there are several similar systems called Wiki clones that have adopted this concept. There are Wiki engines equipped with a function of linkage with mail to enable more convenient use of Wiki. In JotSpot[19], a Wiki page can be updated by sending e-mail to the mail address corresponding to each Wiki page. PukiWiki[20] allows an addition of a function of handling the mails received as entry to the page. Hiki[21] has a function of notifying updates by mail. All these use e-mail as a supplementary function of Wiki, but qwikWeb is different in the point that it is joined closely to ML. There are also Wikis with specialized purposes. Perhaps the most famous one is MediaWiki. This is a Wiki engine used in Wikipedia, the online encyclopedia. There are also several proposals for a Wiki engine called Semantic Wiki, a tool to easily create semantic web data[22][23]. There are Wiki engines for educational purpose. Guzdial et al developed a Wiki engine called CoWeb which is used in education[24]. In 2 years of operation, over 120 Wikis were started up in schools and are operated on 10 servers. Wang et al added extensions needed for learning environment such as page ownership, writing authorization, and invisible mode[25]. Brereton et al constructed an educational support environment based on Wiki[26]. However, there is no proposal of a system fused seamlessly with ML as in qwikWeb.

8 Summary

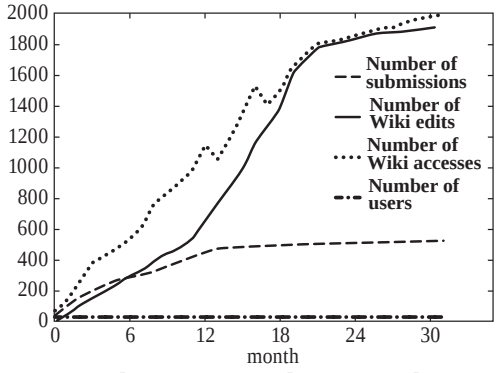
We proposed qwikWeb that smoothly fused information communication, accumulation of knowledge, and structuring technology to realize a collaboration system that can be built and managed by anyone. We described the process for realizing Full Research of such a collaboration system. As a result of designing, implementing, and operating this system, about 18,000 users used about 3,000 MLs. Adequacy and efficacy of this system were demonstrated by analyzing the operation data.

Future issues include commercial operation by companies, improvement by focusing on target users, and improvement for use in diverse information environment such as cell phones.

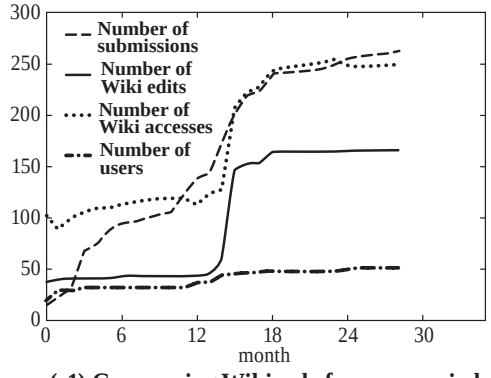
Modulobe, or virtual organism construction environment,



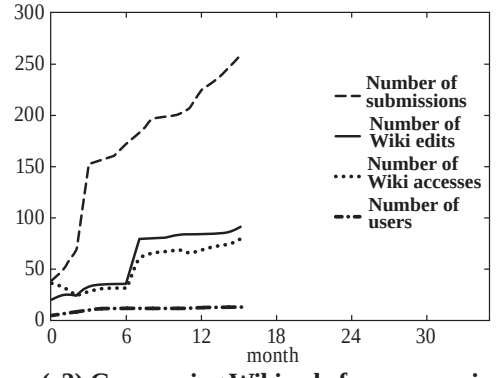
(a) Group mainly using ML



(b) Group mainly using Wiki



(c1) Group using Wiki only for some period



(c2) Group using Wiki only for some period

Fig. 6 Difference in use status by group.

is another project of the Author (Eto). In Modulobe, virtual organism created by the user is shared on the net, and other users can create new models by adding changes to the model. ID attached to the parts of the model allows the relationship of re-use of models to become visible. It is similar to qwikWeb since it is an attempt to seek findings by running a system that supports communication among users.

Both qwikWeb and Modulobe have common points of "design by subtraction." The most essential function for the user is considered, while extraneous functions are deleted completely. Therefore, the target users can understand the system more readily. In qwikWeb, comprehensibility was achieved by deleting functions that normally exist such as functions to assign managers or to change editing authority for each page. Although this may make qwikWeb unusable in some situations, we were able to create a system that new users can understand and use immediately.

In the future, we shall continue research that supports communication among users and contributes to knowledge sharing on the network.

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Discussion with reviewers

1 On improvements for user participation

Question (Kazuhito Ohmaki)

I think the perspective that "it is very important to have a mechanism where end users can become directly involved in system design" is important, and I think this point should be clearly stated.

Answer (Kouichirou Eto)

As you indicated, since the improvement process with involvement of users is important in information systems, I explained further in "2. Full Research for web system." Although direct involvement of end users is very important, in this development, we employed a method where the users use the system, we, the developers, observed them carefully, and then we thought of the necessary functions based on our observations. Since users are novice of the system, they cannot necessarily propose truly necessary functions. However, since end users are specialists in their own respective work, the developers determined the necessary functions based on their work processes. This point was described in Chapter 2.

2 On rights of software

Question (Kazuhito Ohmaki)

Have you clarified the rights for qwikWeb?

Answer (Kouichirou Eto)

The people who were involved in direct development of qwikWeb were AIST researchers only, and the relationship of rights is clear. Although QuickML had been used as part of the system, it is disclosed as free software based on General Public License (GPL). qwikWeb also is under GPL, there is no rights issue.

3 On learning how to use softwares

Question (Kazuhito Ohmaki)

Having used Wiki, the Reviewer feels that although simple, one must learn "pattern language" to some point. I would like to hear your comments on what you think of the trade-off.

Answer (Kouichirou Eto)

Thank you for pointing this out. First, although pattern language is background philosophy of Wiki, it does not mean that one cannot use Wiki without learning it. Anyone can start using it by learning the simple maneuvers. To make full use of Wiki, one must learn pattern language to some extent, as you point out. That means that one must learn the background philosophy of Wiki, but one can learn it gradually. In other words, by using Wiki, one can gradually become acquainted with the philosophy of pattern language, and that is one advantage of Wiki.

In Wiki, it is necessary to express the sentence structure by using Wiki syntax, which is its unique mark-up language, and the time required to learn this could not be ignored. However, by writing sentences using Wiki syntax, one becomes conscious of the sentence structure. In fact, when I teach Wiki in college courses, by teaching Wiki as well as advantage of structuring sentences at the same time, the students were able to learn Wiki syntax naturally. Such trade-off does exist for Wiki syntax.

As you pointed out, concerning this point, I added explanations.

4 On goal of development, scenario, and selection process of component

Question (Motoyuki Akamatsu)

In the last part of Section 2.3, you mention four points. Explanations assumed the fusion of ML and Wiki, except in the first point. I think it will be better to write a scenario by describing the four points as four goals of system design, and then to write that the Authors decided to fuse ML and Wiki after considering how to achieve the goals (Description of Scenario). Also, there must have been a selection process of component, and I think you should write the "selection process" where certain technologies other than ML and Wiki were not employed.

Answer (Kouichirou Eto)

The scenario, as you point out, was not clear in the original paper, so the chapters were arranged according to the process in Figure 1, and changed to reflect the flow of development from problems and solution strategy of current collaboration ("ease of management" and "accumulation and structuring of knowledge"), basic philosophy toward solution, selection of Wiki that had concept close to our basic philosophy, and employment of QuickML in basic design of the system. For selection processes, the reason for selecting Wiki as component is explained in 4.1.1, Wiki is explained in 4.1.2, the reason for selecting Quick ML as component is explained in 4.21, and Quick ML is explained in 4.2.2.

5 On process of improving operation

Question (Motoyuki Akamatsu)

In "4. Operation of qwikWeb," you present the result of user data analysis. I think this section corresponds to the cycle of analysis of feedback information, system correction, and system operation, but there is no description of how the correction to the system was done according to this cycle. Can you clarify so the relationship with the improvements can be seen?

Answer (Kouichirou Eto)

I explained an example by adding "6.2 Practical example of qwikWeb." The feedback here corresponds to the explanation in Figure 1.

6 On difficulty of research and development

Question (Motoyuki Akamatsu)

Reading this paper, I get the impression that qwikWeb was created easily. I imagine that there were various problems, and it could only be created after solving those problems. I think it will benefit the readers greatly if you include descriptions of technological difficulties and how they were solved.

Answer (Kouichirou Eto)

I described the problems we had in implementation and operation in Section 5.2.

Introduction to service engineering

— A framework for theoretical study of the service engineering —

Hiroyuki Yoshikawa

[Translation from *Synthesiology*, Vol.1, No.2, p.111-122 (2008)]

This paper proposes a framework for a theoretical and systematic study of service engineering. In this framework, primitive service is defined as a person (donor) donates a service to another person (receptor), and the service effect occurs when the receptor receives the service donated by the donor. The conventional service is amplified primitive service through some medium. The service industry is a complex system composed of those conventional services, in which primitive services are amplified and organized by diverse tools and various social mechanisms.

Keywords : Service science, theoretical framework, function, amplification, service industry

1 Introduction

This paper describes a system necessary to discuss service from an engineering perspective. The system is synthesized as a "product" that is to be usefully utilized for improving real services, and the synthetic process of the system is clarified as explicitly as possible within this paper. The system must clarify objectives, range, and related disciplines of service engineering, as well as extract concepts that are necessary to address the service theoretically and to clarify relationships among concepts. Also, the service engineering must promote reconsideration of society and industry from a perspective of service, creation of new service and its industrialization, extraction of elemental technologies for service and their improvement, and improvement of service productivity in the current industry *etc*.

The basic stance of this paper for considering service is stated here. Although the following points have been discussed earlier by the Author *et al*[1]-[3]., they will be summarized to set a starting point of the paper.

(1) Human possesses an ability to manifest function[1].
(2) All things have functions[1].
(3) A function is recognized as being meaningful or valuable to human[1].
(4) Both natural and artificial things have functions, but the function of artifact contains the intent of the manufacturer[1].
(5) A value of thing is not in the object itself, but is in its function[2].
(6) A function is latent and becomes manifest through an action or a use. However, a different function is manifested depending on the mode of the action or the use[1].
(7) A service is manifest function[3].
(8) A service is unique to human, had existed before the establishment of industry, and was the major motivation for human to form a society[3].
(9) Because, as an artifact, industrial product manufactured is a carrier of an intended function, manufacturing industry and service industry are not separated but are mutually and complexly related[2].
(10) Because the purpose of products made by manufacturing industry is to strengthen or amplify services, service industry ideologically includes the manufacturing industry[3].

Here, service is identified by its meaning or value to human, and therefore it cannot be discussed in terms of physics, and must be discussed in terms of function study. However, there is no study of function that compares the consistency of physics, and since function study is an emerging discipline[4][5], service engineering must evolve side by side with the basic function study or contribute to its advancement. This is a difficult issue revealed in this paper. However, if this issue is encountered frequently, it may mean service research has a great potential to contribute to the advancement of function study.

In the service engineering, functions and values are discussed separately. The function is thought not dependent on personal subjectivity. On the other hand, the value lies within a person because it is dependent on human values, and thus the value cannot be discussed without considering the fact that people seek different values in a certain object. Human value is an issue that transcends service engineering, and this issue will not be addressed here, although it must be inevitably addressed when discussing specific service. However, when the word "value" is used to mean some agreement within the society, it will be specified in this paper as "a social value."

Currently, the perspective of nature providing services to

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human is drawing an attention, as exemplified by ecosystem service[6] and the value of nature[7]. Although this is an important perspective, in the stance of this paper, it will be discussed elsewhere and later as an issue of function. The basic premise here is that service is donated "by a person to another person."

Any strict definition of service will not be given here, and it is simply stated as a manifest function. Rather, we shall state that this paper itself presents a definition of service. However, when "service" is simply mentioned in the text, it means a service in general terminology except otherwise noted.

2 Basic Framework

2.1 Service in general

Service action is an action taken by a person with some intent or motivation to influence another person (or other people) in some way. In general, it is a time-series or a temporal process. It does not happen when a person lives alone. It occurs when people form a society, and thus service is a fundamental reason of forming a society. There are also a service to oneself and a service as a blessing of nature, but these services will be considered special or degenerated service.

A person donates service to another person. This is a service-donating action. Then the other person takes a certain action in response to the service received. This is a service-receiving action. The person is the donor of service and the other is the receptor of service. In general, each action is time-serially characterized by temporal element. When all the service actions are completed, a change occurs to the external world as well as to the donor and the receptor. The summation of changes is called a service effect. The series of process may be called a service phenomenon.

When only one person donates a service to another person, it is "a primitive service." Figure 1 shows some examples. A primitive service is donated directly or through some medium (called "vehicle"). In case of a primitive service that can only be donated through medium because it cannot be donated directly, the medium may amplify the service as described later, and therefore it is necessary to set a standard medium for a primitive service. Primitive services may form a chain. If the service is not a primitive service, the following terms are used. In case there is one donor and two or more receptors, it is called a distributed service; in case there are two or more donors and one receptor, it is an integrated service; and in case there are two or more donors and receptors, it is a socialized service. Through a chain with those combinations, the services form a network.

When each action which is taken for the purpose of donating a service is completed, the temporal sum of these actions up to that moment is called the amount of service donated. A change that occurs to the receptor is a result of the donated actions motivated by the donor, and this is called a main service effect. The main service effect is temporal sum of changes that occur as a result of receptor's receiving action, and this can be divided into physical, corporeal, and mental.

Changes that occur to subjects other than receptor includes those that occur to donor (for example, fatigue) and change in medium or tool used (for example, wear). Such changes are called sub-effects. The change in the external world that results from service donating actions by donor (for example, the environmental pollution) is called a ripple effect. Each change is the result of respective action (reaction in case of change in object). Such a change is diverse, and it can be divided into corporeal and mental in human, and physicochemical for object.

The above definition of service is consistent with the conventional stimulus-response concept. The service-donating action is stimulus whereas the service-receiving

D: Donor R: Receptor effect: ① Body ② Mind ③ Material

	Meaning (Contents)	D's preparation (design & planning)	D's providing action	R's receiving action	R's effect (Function level)	Example of D	Example of R
①	Medical care	Diagnosis	Treatment	Accepting	Health level	Mother	Child
	Elderly care	Judgment	Elderly care	Dependence	Action level	Youth	Elderly
	Assistance	Request	Assistance	Cooperation	Achievement level	Strong man	Weak man
	Transfer	Designation	Transportation	Obedience	Distance	Driver	Passenger
	Eating & drinking	Cooking	Serving	Eating & drinking	Satisfaction level	Husband	Wife
	Beauty	Decision	Make-up	Make-up	Appearance	Person	Self
	Lodging	Preparation	Providing	Sleep	Rest	Innkeeper	Customer
②	Education	Evaluation	Preaching	Listening	Learning level	Parent	Child
	Information	Creation	Transmission	Reception	Information level	Person	Acquaintance
	Consultation	Analysis	Proposal	Solution	Problem solution	Wise man	Troubled person
	Music	Direction	Performance	Hearing	Excitement	Performer	Listener
	Story	Production	Speaking	Listening	Entertainment	Storyteller	Listener
	Entertainment	Direction	Performance	Viewing	Relief	Person	Family
③	Storage	Evaluation	Maintaining	Entrustment	Volume x Time	Keeper	Entrustee
	Transportation	Packaging	Delivery	Entrustment	Volume x Distance	Truck	Receiver
	Maintenance	Diagnosis	Repair	Reception	Recovery & performance	Fixer	Non fixer
	Production	*Design*	*Manufacturing*	*Use*	*Convenience*	*Skilled person*	*User*

Fig. 1 Example of primitive service.

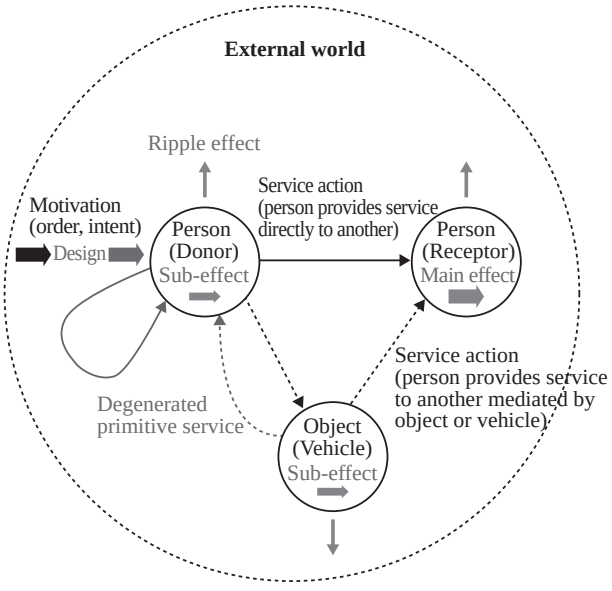


Fig. 2 Basic system of primitive service.

action is the response. However, as it will be explained later, service structure that is equivalent to stimulus-response possesses unique structure as shown in Figure 2, and true nature of service cannot be discussed without clarification of this structure. The stimulus-response model may be applied if the service is discussed in a macroscopic or phenomenal perspective without considering this structure.

2.2 Donor of service

One who donates service is called a "donor" and takes an action according to some motivation. Motivation can be diverse, but it can be divided into autonomous or intent and heteronymous or order. Intent and order indicate the main effect to be extended to the service receiver called "receptor". When an intent or an order is expressed, the service action that is useful for realizing the effect is designed. Sometimes it can be designed by the receptor who places the order, but in most cases it is designed by the donor. As it will be mentioned later, a specialist who is called a (professional) service designer may emerge as the service is socialized, but this may weaken the communication between the donor and the receptor, which is often a major issue in the service. This must be discussed separately (an issue of ready-made service in manufacturing industry).

In case the donor handles the design, the donor acts according to the design, and part of this action is delivered to the receptor as a useful service. Here, a gap may form between the order and the service, depending on the excellence of the design to fulfill the intent or the order, mastery of maneuver or expression of donor's action, and the communication efficiency. This gap arises from the donor, and depends on the donor's total ability, and the ability to control this gap is called the service-realization ability of the donor. These will be defined later.

2.3 Receptor of service

When a receptor receives a service from a donor, he/she takes a certain action and the result of this action becomes the effect. Effect includes a physical change (such as a change in the situation or the location), a corporeal or a physiological change (such as a recovery from disease), and a mental change (such as an increased knowledge). The latter two are changes in the status that cannot be expressed in terms of a physical quantity. The receptor who will receive a service has an expectation previously for the main effect that will result from the reception, and this expectation is expressed as an order.

It should be emphasized that in this paper, the change in receptor's status is not given heteronomously, but is caused by the own action of the receptor. That is, the flow is as follows:

Service donated → Receptor's action → Change in the receptor's status

The action here is not necessarily receptor's voluntary action. For example, a patient who underwent a surgery is taking action as he/she recovers even while anesthesia is still in effect. Whether voluntary or not, recovery will not take place unless there is a physiological action of the patient. Such action of receptor includes physical, corporeal, and mental aspects.

This implies that the potential ability within the receptor is brought out by the external stimulus or service, becoming a receiving action, that causes an effect on the receptor. The fact that the effect of service is caused by the action of the receptor themselves, makes the issue of service return to an issue characterized by the basic property of living matter.

The reason for above thought process is because the concept where the service donated by the donor directly changes the receptor's status is similar to the concept of human as a passive machine. This blurs the independence of the receptor which is the main subject of the service. In other words, the essence is to position the receptor's action as an exertion based on the independent decision according to the receptor's potential ability caused by donor's stimulus, and then to think about the effect which this own action will have on the receptor. In this case, we must be careful not to lose sight of the essence of the service by ignoring the intrinsic structure of response. When a donation of the service and the realization of main effect are considered macroscopically to be stimulus-response phenomenon, the direct relationship between the two can be called a service receptivity, and the numerical value can be called a reception sensitivity.

Based on the above thinking, the service donated to oneself can be understood as follows. A person has an expectation that a certain effect will occur, and he/she takes a certain action to realize it. This is a donating action, and the receiving action occurs simultaneously or sequentially. The receiving action brings about an effect. Here, the donor and the receptor are the same person. This is a case of a degenerate service, whereas a service is normally donated by one person to another. Under this premise, the reason for receiving service from another is because the degenerate service cannot be donated or a person does not want to donate a service to themselves. The fact that there may be situation where the service cannot be donated themselves or a person does not want to donate the service to themselves is the exact reason that the service exists socially.

For a receptor, the quality of the service received can be measured by how much the service donated meets the receptor's expectation. This is called a fulfillment level of service. The receptor's expectation is reflected in the receptor's order. The most difficult point in the service issue is the fact that the receptor him/herself does not completely understand this order. It is usually decided by the receptor's values and sensitivity as well as the receptor's circumstance

of making a decision or motivation to place an order. However, these are subjective in nature and are difficult to express objectively. In this paper, we shall avoid considering the internal structure or the content of subectiveness, and just state that the receptor's expectation is "the effect that the receptor wants to happen."

In general, the expectation becomes starting point from which the service originates. It is composed of the following transitions:

Receptor's expectation (effect that receptor wants to happen) → Donor's design → Service donated → Service received → Receptor's action → Effect on receptor

Here, definitions about the individual "excellence" of each transition are given, which can influence the service productivity to be discussed later. Improvement of the productivity occurs when the above chain forms a loop, and then the circulation of information in this loop causes the service to evolve.

(1) Excellence of design (ability of the donor or the service designer): Relationship between the receptor's expectation expressed as an effect and the projected effect caused by the service designed to realize that effect. This includes a relationship between the receptor's ability to express his/her expectation as an order, and the donor's ability to understand the effect that the receptor wants to happen.
(2) Skill mastery of donating the service (donor's ability): Relationship between the service donated by the donor according to the design and the actual design.
(3) Communication efficiency (quality of medium between the donor and the receptor): Relationship between the service donated by the donor and the service received by the receptor.
(4) Coefficient or function of receiving an action (receptor's property): Relationship between the service received and the receptor's action.
(5) Coefficient or function of effect realization (receptor's property): Relationship between the receptor's action and the effect achieved.

Obtaining quantitative measures for the above indicators will become a major work in the service engineering research.

2.4 Supplementary concept

We have explained basic concepts needed to discuss the service, and supplementary concepts will be mentioned next. In a real service, it is necessary to consider the relationship between the effect achieved and the effect one wants to happen. In practice, this can be called a service fulfillment level. Since an expectation (an effect which one wants to happen) is transformed into an effect in the order of

(1) → (2) → (3) → (4) → (5),

the fulfillment level is the relationship between (1) and (5). Since (1) and (2) are donor's ability, and (3) is usually selected by the donor, (1), (2), and (3) can be called donor's ability to realize the service. On the other hand, (4) and (5) are receptor's property. They are abilities to receive the service, so they can be called receptor's sensitivity. Then, setting the effect on receptor as the main effect, the following relationship can be obtained:

Main effect = Donor's ability to realize ∗ Receptor's sensitivity ∗ Effect wanted to happen

Currently, ∗ is unknown, but it is an important relationship in discussing the service. Here, when {Donor's ability to realize ∗ Receptor's sensitivity} can be obtained, it will represent the level of achievement of the expectation provided from the donor's viewpoint, and the fulfillment level of the service from the receptor's viewpoint. This is a useful expression when discussing service as a phenomenon.

The service realization level (from donor's viewpoint) and the service fulfillment level (from receptor's viewpoint) are the same, and this is integrated characteristic that contains both properties (abilities) of donor and receptor. The receptor's coefficient of receiving action and quality of the service donated are not necessarily independent, and are, in most cases, dependent on each other. A practical or phenomenal expression for the above main effect holds clear meaning when the two are independent, and is not very useful when they are dependent. Therefore, it is necessary to select properties so that the two are independent, and this is a research topic for the service engineering. Also, when

Donor's ability to donate service ∗ Receptor's sensitivity to receive service = 1

The service can be called perfect because levels of the achievement and the fulfillment are both 1. While this can be realized with a perfect design, the highest skill mastery, a communication without loss, an accurate response, and a proficient exertion of function (a sufficient condition), it is not realistic. The issue of service engineering is to seek a maximum realization under limited conditions.

2.5 Temporal consideration in service

As mentioned in 2.1, a service is a time-series. Although this was not stated explicitly in the above discussions, it did not mean that time can be ignored. One of the characteristics of the service is time course, and this discussion is one of the most important elements. The reason that time was not taken up until now is because the consideration of time in function study has not yet been established, and to discuss the temporal aspect of the service implies the discussion on time in function, which adds an extremely complex underlying issue. Therefore, let us attempt to consider the time aspect in

a topical manner limited only to service.

(1) Relationship of function and service
Human action and the use of things bring out potential ability, and the activation of the ability is considered to be an exertion of function, so the potential ability can be called a latent function here. Then the function manifests "slowly" through the action and the use. The relationship can be described as follows. The latent function is L, the manifest function is F, and the speed of manifestation is f with following relationship:

$$L_{d0} = L_{d1}(t) + F_{d1}(t)$$
$$f_d = -k_d \cdot d(L_{d1})/dt$$

d represents the donor. L_0 is the initial value of the latent function, and the service can no longer be donated when this reaches 0, and it determines the donor's lifespan for donating a service. f is a speed of appearance of the function, and is a time-speed for donating service, and service in general meaning falls into this category. k is a parameter which includes diverse meanings, and must be defined separately.

(2) Relationship between effect and service
Definition is necessary for receiving actions of receptor. Reception is a situation where the function flows in at a certain speed. However, the function that flowed in at f_r does not immediately become receptor's latent function, but some part is wasted. The latent function L_r that the receptor already possessed does manifest as f_r' to generate effect. This is service effect e. Then, we obtain some relationships as follows:

$$f_r = k_r \cdot d(F_{r1})/dt$$
$$F_{r1} \neq L_{r1}$$
$$L_{r0} = L_{r1}(t) + F_{r1}'(t)$$
$$f_r' = k_r' \cdot d(F_{r1}')/dt$$
$$f_r' = -k_r' \cdot d(L_{r1})/dt$$
$F_{r1}(t)$ = (Excellence of design, mastery, communication efficiency) $*$ $F_{d1}(t)$
f_r' = (Coefficient of receiving action) $*$ f_r
e = (Coefficient of effect realization) $*$ f_r'

r is for the receptor. The service F_d becomes F_r when delivered to the receptor, and flows into the receptor at f_r. Receptor who received it exerts function from L_r at speed f_r', and increases F_r'. These relationships are possible, of course, when both are quantitatively expressed, but quantitative expression is conventionally not easy. However, quantitative considerations are sometimes done unconsciously in an actual practice, so precise consideration of this unconscious quantification is useful. This is an important topic of the service engineering, and the outline of the issue will be presented using an example.

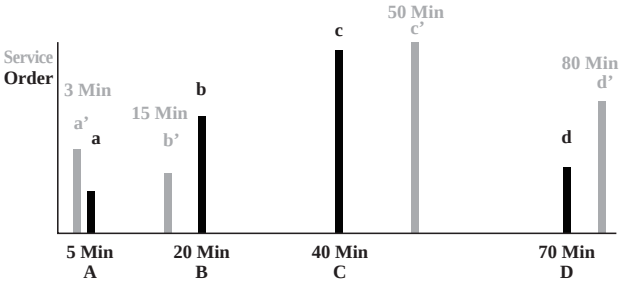
Example) Dining at a restaurant

A person goes to a restaurant to have a meal. He sits down; looks at the menu, and selects aperitif (A), appetizer (B), main dish (C), and desert (D). Then he places an order. This is an order by the receptor. The cook who hears the order considers the customer's preference (service design), cooks (service maneuver), and serves the dish (service donation). It is immediately apparent that timing for serving the dish is important. First, the order of aperitif, appetizer, main dish, and desert must be observed strictly. Also, the time interval between each meal elements is extremely important. However, the customer usually does not designate the interval. Therefore, estimation of the receptor's expectation by the donor is a part of the service design. In this example, the donor's motivation of providing action is an order. To simplify, let us assume that the receptor sets the order time, and his expectation is completely fulfilled when the order is provided as designated, or in other words receiving action and effect realization are perfect, that is both coefficients are 1. The result, for example, may be as shown in Figure 3. There is a gap between the order and the providing action. The gap consists of quality or quantity between expectation and provision (the Figure evaluates quality; it is quantified as x and x') and gap in time (expectation t, provision t'), and results in decreased level of achievement. Of course, the fulfillment level also decreases. The value can be calculated as follows:

Fulfillment level or Achievement level =
$1/4\Sigma\,(\,xx'/x^2\,)\,(1-(\,|t-t'|/t\,)) = 0.69$

The fulfillment level is about 70 %. As in this example, the problem cannot be solved practically unless the service is considered as a time course. In this example, only the time of serving dish is shown, and this is an approximation by discretization.

Originally, donation and reception are considered to be a continuous function of time. If the individual service is



R's order: Wants to enjoy good meal. Selects items A, B, C, and D from menu. Expects that the items will be served according to time course a, b, c, and d, and places order.

D's service: Makes preparation, i.e. cooks, to meet R's order, and serves items at appropriate timing a', b', c', and d'.

Fig. 3 Dining at restaurant.

designed and analyzed in terms of engineering by observing the behaviors of the donor and the receptor, it is necessary to describe the service more microscopically and consider it as a continuous process. In the above example, the cook or the donor has time course of designing dish and preparation involving movements (included in the donation), while the customer or the receptor has a time course of reception including the expectation until the dish arrives, eating and drinking, and resting between dishes. Although it is not easy, it is possible to express the time course with some conditions. For example, the donor increases the "latent function for the donation" through preparations ("function for cooking" has been already exerted). When the providing action occurs through serving of dishes, the function for the receptor is exerted, and it becomes a manifest function or service, and the cumulative latent function decreases. In this sense, service is change (temporal differentiation) in latent function accumulated by preparation. The time course is as follows: receptor's reception increases rapidly on arrival of the dishes, this leads to the receiving action of dining, the fulfillment increases, and a new fulfillment occurs as the receptor enjoys the afterglow of meal. The elements of the donor and the receptor are not independent, and, of course, the relationship that characterizes the service exists between the two elements. Therefore, the service issue is a mutual relationship between limited continuous processes with autocorrelation.

3 Amplification of service

Here, let us address the amplification of the service. This is an important issue related to the fact that the service is drawing attention as an industrial or an economic problem. It is also related to the productivity of service industry. These issues will be discussed in the future, and here we shall describe only the basic concepts that must be understood to enter into the discussion.

A service can be amplified. The amplification can be accomplished by a medium (or a vehicle). Setting a primitive service in which a person donates a service to another person as a basic unit of the service, the rate of service amplification can be expressed as the ratio of (amount of) service to (amount of) primitive service.

There are two modes of amplification. The first is strengthening by a medium within the condition of primitive service. When one person donates a service to another person, not directly, but through a medium (in most cases, through tools), the service may become higher in speed or wider in range (when transporting a person, higher speed service can be donated using a motorcar rather than carrying the person on back), and this is called a strengthened primitive service. The primitive service in which the person is carried on back is amplified through strengthening medium (tool) called motorcar. The second mode is the proliferation. The amount of service is increased when a network is built using media and the service is delivered to many people without losing the amount donated per person. One service donor can donate the same service to several receptors (Rakugo, a Japanese traditional art for telling humorous stories, told to one person can be heard by tens of thousands of people through the television media). The delivery of the service in this manner is called amplification by proliferation.

The medium (vehicle) that bridges relationship between the donor and the receptor includes tools such as devices and machines, circumstances such as stage and building, and social system such as laws, regulations, rules, and customs set by nation, government, region, or organization. Examples are shown in Figure 4. In order to calculate the amplification quantitatively, respective consideration must be taken for each case. Using the aforementioned example, number of television sets can be used as rate of amplification due to proliferation. In terms of strengthening, if the transportation service can be donated in 5 min by car while it is 30 min by carrying the passenger on back, the rate of amplification by strengthening is 6. However, it cannot always be measured, and along with qualitative improvements, the quantification is not easy. For example, in the restaurant example, the fulfillment for the cooking (taste, for example) was quantified, but this is not necessarily accurate. In this point, effective measurement method must be determined by employing the knowledge of related disciplines and by introducing new points of view to the each field of service.

When considering the cost of amplification, the perspective shifts to economy. There are many issues including the productivity of service industry. Many issues that are currently drawing attention and are being investigated belong to this topic.

4 Summary: related disciplines and research topics

Amplifying media	Types of media	Example of service amplifying media
Tool	**Tool, device, machine, database, software, *etc*.**	**Television, message device, automobile, word processor, search engine (all devices are service amplifiers)**
Circumstance	**Structure, spatial configuration, network, *etc*.**	**Theater, hotel, recreation hall, information network, road**
Social system	**Law, system, rule, organization, custom, *etc*.**	**Government, ward office, police box, bank, store, communication system, traffic system, hospital, school, company (administrative, financial, distribution, communication, transportation, medical, and education services)**
Integration	**Integration of above**	

Fig. 4 Example of service media.

Above is the description of a basic framework for discussing service with assumption that it can improve service in the real world. It is a basic model for the service, and the work to verify this model is to follow. For a model to become a scientific or engineering model, it must follow the formality that can be objectively verified. Although the model described in this paper is proposed as having such formality, its verification cannot be done by the laboratory experiment. In this case, the following process is necessary for verification.

First, related fields must be defined. There are many fields as discussed below. In respective fields that are extracted, items that can be explained with an existing knowledge and those that require a new knowledge must be distinguished. If the new knowledge is necessary, that is within a research on scientific or engineering discipline of the service. Next, the relationships among disciplines must be clarified. Since the general method for integrating different disciplines are still under investigation[8], at this point, it must be solved as a problem unique to the service, and this can be called a systemic research on service.

Described below are the related fields that are necessary for creating the framework explained in the above section, together with the reason for the extraction of those fields, the completeness and incompleteness of knowledge in them, and what we shall do in respective fields as the research into service. Let us start them, keeping the primitive service and its amplification in mind. Then, we shall identify the direction of the systemic research on service. This will also be an overlook of synthesiological research for how we shall build a good service based on scientific investigation of the service elements.

(1) Function

As discussed in Section 1, a service is assumed to be a manifest function, so if we understand what function is, then we will be able to understand the service. However, although the function has been addressed in various fields over the history, it has been difficult to define what it is exactly. It is not systematized to be called as "functionology", and the quantification of function has been unsuccessful [1][4][5]. Therefore this discussion will proceed without seeking a general expression of function, but by provisionally defining a functional content of the individual service. As a simple example, as discussed in Section 2.5, the latent function of serving dish to customers is increased when the cook creates the dishes, and the latent function is accumulated by the cooking time. The properties of the service as a temporal differentiation become realistic through such quantification.

Yet generally, the function is more complex, and it can hardly be simplified as in this example. This will become clarified through discussions relying on the basic structure of the service described below.

(2) Service-donating action

We have discussed the service design and following service action responding the motivation of service, that is, own intent or the order from another person. Each has the excellence of design and the mastery of maneuvers. The intent or the order consists of mental, corporeal, and physical components, and from another perspective, it consists of immediate personal motivations to wider social motivations, and thus understanding them requires a diverse perspective. Since an immediate order is met in real time, education and training to understand the person's unique receptivity are necessary. A specialized knowledge in diversified specific fields is necessary. For example, the pedagogic knowledge is needed for the education service, while knowledge of medicine, physiology, pharmacology, and others are essential for the medical service. On the other hand, language, psychology, and semiotics are useful as a general background. Of course, learning by experience is necessary. Sociology, behavior science, and market survey are necessary for the social service, and the methodology of social science is useful.

There is unique design method for each specific field, but the study of general design theory will be basic. Also, an original method for the service design is necessary, and the data accumulation for the service and development of service CAD[9] are useful. Creation of a perfect digitized expression of human form including its movement[10] is a useful information source for the service design to be applied to various fields.

The service maneuver based on the design is a discipline in itself. Mastering language and physical expression are necessary, and expression science and sports medicine are also related fields.

(3) Service-receiving action

When a person to whom the service is donated receives it, reception is not passive but active as mentioned in Section 2.3, and therefore receiving action is selective. There is a unique selection by the receptor. This is an important characteristic of the service, and also a point that makes service complex. What is the selection in reception including the rejection when the service is donated? It is necessary to clarify the factors that determine the nature of service, including influential factors and influencing mechanism in the selection. An action taken by the receptor and the mechanisms of exertion of effect must be understood in those terms. Here, knowledge from psychology, physiology, behavior science, and life science including brain science, which is yielding many interesting findings, may be useful. However, knowledge and method for understanding the receptor and improving the receiving action are currently

extremely insufficient. As reasons, in response to the current social situation where the professionals become donors, conventional specialized knowledge is employed only for the preparation of providing action and is not considering the receptor. This point must be addressed in the future as a subject about the structure of academic knowledge for service engineering research. For example, although the perspective of accessible design is gaining attention[11], academic maturity of this field is urgently requested..

(4) Delivery of service

A service may be delivered directly from the donor to the receptor in a primitive service, but it is mediated in many cases. It not only travels through the network as information, but it is communicated riding on various objects (products). A service takes on several forms when it rides on objects, and we have no organized knowledge for this. This may be a function of the object, and here again is the relationship of the service and the function.

A service that is communicated over network as information characterizes the modern society. There are countless researches and its diffusion as a real technology is dramatic. Its further development is desired, but considering the impact on the society, perhaps we have reached a stage where "information ethics" must be considered from the service viewpoint. On the other hand, the service that rides on the media must be understood in terms of the service amplification of manufacturing industry, which will be discussed later.

(5) Ripple effect of service

Some kind of effect occurs in the external world when the service phenomenon takes place in the real society. Although this can be ignored in case of a primitive service where one person donated a service to another person, it becomes an issue when it involves the industry, and must be dealt as environmental load. This point is not considered sufficiently and left as a future issue.

(6) Amplification of service

A service issue is drawing attention because the influence of the service industry on economy has increased particularly in advanced countries and is increasing in developing countries. In Japan, it has been pointed out that the productivity of service industry is much lower compared to the productivity of manufacturing industry. Actually, except in information field, the service industry has not been able to increase quality and productivity by using the results of rapidly advancing basic scientific research like in the manufacturing industry.

In the information field, diverse information technologies are widely available, as symbolized by the term "information society." These information technologies contribute to the increased productivity of the service industry. As a result, the view became prevalent that the advancement of the service industry is achieved by the advancement of the information industry. However, the service is not only for the information field as shown in the example of the primitive service in Figure 1, Section 2.1. The productivity in wide-ranging service fields can be improved by the combining the knowledge of social sciences with knowledge of diverse science and engineering fields including life sciences, material sciences, environmental science, and physics. However, when considering the productivity of service being affected by those diverse science and technology, it is more convenient to consider the issue of the service amplification before considering the economic issue in order to discuss the service without losing the track of its nature.

In modern society productivity of the service industry is important, and thus opinions that service science is necessary for the improvement of the productivity have grown stronger[12]. These discussions start by setting the service as an economic issue and therefore take a different stance from this paper. IBM, where Spohrer works, has triggered the current widespread interest in service, and the service science described there is an integration of several disciplines. In fact, IBM uses the term SSME (Services Science, Management and Engineering). More multi-dimensional discussion is expected in the future.

Here, I must address the "mystery" that Japan is currently called a backward country in the information industry and the service productivity. Japan has improved the productivity by introducing information processing into manufacturing such as CAD-CAM (computer assisted design and manufacturing), FMS (flexible manufacturing system), and IMS (intelligent manufacturing system), and succeeded in taking a superior position in the international competition. Then, what is the relationship between this success and the backwardness? First, it should be noted that the information technology never ventured outside the factory. In fact, the informatization in the factory was amplification of the service action within the factory, and this could have been applied to the amplification of service action outside the factory if it was scrutinized in an abstract manner. Unfortunately this did not happen because the evaluation was done only from the economic viewpoint. However, a more fundamental reason is because the isolation of industrial sectors became the barrier.

Although the information technology was still in infancy at the factory compared with modern level, it pioneered a new territory by fusing with mechanical, electric, and material technologies, as exemplified by mechatronics[Note)], a term coined in Japan. This allowed Japan to become a leader of international manufacturing industry. Japan will now introduce wider-ranging advanced technology into the service industry that is currently dominated by the information technology, hoping to become a good contributor

to realize the sustainable service industry.

Developing the theory of the service amplification and increasing the productivity of all industries including service and manufacturing industries, or "global productivity," are necessary conditions for building a sustainable world.

(7) Issue as an engineering theory

The objective of this paper is to create a knowledge system that maintains consistency within the system, that is compatible with other disciplines, and that provides a useful method to improve the real service. This can be called the "service engineering theory." The achievement of this objective depends on the future study, and some of the issues extracted in this paper will be summarized here.

(A) Definition of service

In this paper, it is assumed that a service is an expression of latent function (discussion of time as a function being differentiable is one example, and needless to say, it is necessary to discuss more generally without limitation). Although this is a basic definition, the service issue is replaced by the issue of the function as mentioned in the text, and it contributes to discussion of the function by identifying which properties must be clarified as a function in order to discuss the service. The function is a broader issue, and it is assumed that the function will be expressed in the form of mass and free energy (information), but there is a higher possibility of reaching the root of the issue if it is viewed as a service issue. Here, there is a major issue of accepting the "law of conservation" for the function, and this is a serious viewpoint for the service economy. It is necessary to continuously update the definition of the service while referring to the definition of the function.

(B) Uncertainty of service

In this paper, we purposefully called the provider a donor and the receiver a receptor. The provider is a donor because this provider does not consider the effect on him/herself and provides without seeing whether the service will be received by another. The receiver is a receptor because this receiver selectively receives what he/she wants. This can be called a social model of service, and the terms were chosen to reflect the actual service phenomenon. As a related basic model, the paper presents the following model of service reception. In this case, the service flows from the donor to the receptor, but the inflowing service does not generate a direct effect, but the receptor's latent function manifests to cause an effect on self. In addition to the aforementioned social aspect, this model incorporates compatibility with the life maintenance of organisms, guarantee of receptor's independence, and an explanation of real service phenomenon. These results imply that the service in society cannot be solved determinately, but must be reviewed from the viewpoint of the evolution theory.

(C) Factors that influence service

In order to approximate theory to reality, the necessary condition is to extract the influencing factors as faithfully as possible. This has not been done sufficiently in this paper, and must be relegated to the future research. In extraction, it is necessary to select factors that are mutually independent. Although statistical tests on data are useful, it is important to derive effective model (by abduction). This is a major work for future researchers.

(D) Quantification

In this paper, various properties of service are often handled quantitatively. However, as mentioned herein, in the service issue in which the major factors are function, human decision, and action based on the decision, discussion of quantification must be carried on carefully. Simplistic quantification or building theory based only on questionnaire and market survey must be avoided, although it may be sometimes useful to obtain figures using survey based on non-specialist models. One of the main roles of the service theory is to draw an insight from elements that are currently unobserved and to encourage observation of new elements. Quantification or measurement is necessary for refinement of the theory. However, it must be undertaken alongside the refinement of the model.

Note Mechatronics: Japanese English word coined by Tetsuro Mori (Yasukawa Electric Corp.) in 1969.

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Discussion with reviewers

1 Compatibility of the paper with *Synthesiology*

Question (Motoyuki Akamatsu)

This paper was submitted as a paper on *Synthesiology* , but I think it will be better to mention the positioning of this paper within "synthesiology". I think the study of the service engineering is "synthesiology" in two aspects. One is the service itself is synthesiological; the other is that the service engineering is synthesiological because an academic system must be created by integrating related disciplines. If there is a description that this paper is synthesiology in the beginning of the paper, I think the positioning of the paper will be clearer.

Answer (Hiroyuki Yoshikawa)

Type 2 Basic Research is a study to extract general inference, knowledge, and methods that underlie the activities to synthesize meaningful artifacts by integrating available knowledge, and I believe a *Synthesiology* paper is to present this process comprehensively. Therefore, it is necessary to consider its position as an academic journal for paper written by "person who makes (or synthesizes) theory (or an artifact)."

Colossal scientific knowledge system is composed of partial systems that are called disciplines. Science includes physics, chemistry, and biology each of which forms a closed and consistent system within its own discipline, which are also mutually consistent. Of course, each discipline includes phenomena that cannot be explained by other disciplines, harbors issues that cannot be explained within its discipline, and solution to such issue is the motivation to do research. Type 1 Basic Research conducted from this motivation is the normal science as described by Thomas Kuhn.

What is the theoretical research that is not so? Kuhn called research that is not normal science "research that causes paradigm shift" and positioned it as the most important undertaking in the history of science. There is also research that is not research within discipline like normal science, and although not at history-of-science level, it may spin off theory that offer conclusion that has a direct impact of the real world. It also exists more frequently, at wider range, and on daily basis than paradigm shift study. Since theory that has effect on real world is a kind of meaningful artifact, the research to create such theory is synthesiological study. Moreover, such study has common theoretical structure as study that causes a paradigm shift. Of course, in the history of science, a research that causes a paradigm shift produces a theory that solves the problem that becomes publicly known an inconsistency of that age. On the other hand, the theoretical research of daily issues deals with issues that are interest of the age but has no common basis for consideration, and its motivation is the expectation to create a theory to build such basis. It is different, but isomorphic.

If research to create theory is explicitly stated and considered as a paradigm shift research, there arises question of whether it is necessary for the new journal *Synthesiology* to take up synthesiological research to create the similar theory on mundane level. However, it is necessary to recall the following fact. Taking the example of Newton's Principia that influenced the history of science, Newton had a magnificent originality that generated disciplines, but he offered no explanation for "synthesis" of the central three laws (absolute coordinates, acceleration, and action-reaction). In Principia, after describing the laws, he simply states, "The above was a description of principles that were recognized by mathematicians and verified by abundant experiments" (Sir Isaac Newton, *Philosophiae Naturalis Principia Mahtematica*, translated into Japanese by S. Nakano, Kodansha, 977, p. 38). This is followed by 600 pages (in Japanese version) of theorems derived from the laws. This became a major theme of the abduction study by C.S. Peirce, but it was unknown how Newton could "synthesize" such wonderful and useful laws.

Although the importance of the intellectual "synthesis" of creating theory is explicitly stated, neither theoreticians nor science historians could explain the mechanisms. Therefore, it is the work of researchers at AIST who are attempting to extract Type 2 Basic Research, to clarify the secret of theoretical synthesis, and I believe *Synthesiology* is the place where this should be attempted.

Of course, there are many additional matters that must be considered. There are conditions that must be met regardless of whether it is theory or not, as follows.

(1) Is the goal necessary and appropriate? It is now understood that service theory is necessary.
(2) What about the trends of research to be disciplinal? We should actively remove them.
(3) Is the explanation for knowledge integration sufficient? We made effort.
(4) How about the compatibility of explanation in theory? This is the main objective of this paper.

As a theory, the main subject is basically to define the concepts and to create relationships in the synthetic process. Since the theoretical basis of this paper is set as a hypothesis building, the paper itself is an abduction. Therefore, the propositions must be verified. The main issue is whether there is a format for verification,, and to enable this, variables (concepts) are to be employed by rejecting concepts that are thought non-measurable.

As the Reviewer points out, it is necessary to consider that service itself is synthesiology, but it is difficult theoretically to consider them simultaneously, so please refer to the Author's paper, "Introduction to general design" (*Seimitsu Kikai*, 1979).

2 On terminology

Question (Motoyuki Akamatsu)

Since the formulation of service is the main subject of this paper, I think it is important to clarify the definition of terminologies and variables as much as possible. When read from this viewpoint, there seems to be lack of unity and unclearness in terminologies. For example, terms "latent ability" and "latent function" seem to be used interchangeably to express similar concept.

Answer (Hiroyuki Yoshikawa)

Latent function is an expression of a latent ability, so (1) of Section 2.5 is changed to: "Human action and use of things bring out potential ability, and here activation of the ability is considered an exertion of function , so the potential ability can be called a latent function. Then function manifests 'slowly' through action and use." Other terminologies were unified.

3 On latent function of receptor

Question (Motoyuki Akamatsu)

In Section 2.5 (2), there is description: "Latent function L_r that the receptor already possessed is exteriorized as f_r and regenerates effect. This is the service effect *e*." However, this is not presented explicitly in the equation presented below. Since the fact that receptor's latent function influences service effect is major point from viewpoint of service, I think the formula should be revised to express this point.

Answer (Hiroyuki Yoshikawa)

Since the point indicated is important issue in service, I shall explain specifically and in details. Taking the example of restaurant, it is probably as follows:

f_d: Speed of provision of dish (food)

f_r: Speed on intake of dish (food)

L_r: Volume that can be consumed (hunger volume)

f_r': Speed of consuming dish (food) perceived to be tasty (meaningful service for receptor)

F_r: Amount consumed

F_r': Volume of tasty dish among dish consumed $\leqq F_r$

Therefore,

$L_{r0} = L_{r1} + F_{r1}$'

This equation means that initial hunger volume is filled with good food only. It raises question of whether one can be filled with bad food, but here, let us say that that does not happen. In this case, there is a problem to be considered because to reach satisfaction or to make the hunger level 0, the cook (donor) must make preparation

$L_{d0} > L_{r0}$.

As indicated by the Reviewer, the relationship of L_r and f_r' is important, and there is basic problem of psychology of dining where food tastes differently depending on hunger level. However, at this stage this will not be addressed explicitly, and the possible future consideration can be expressed as:

f_r' = (coefficient of receiving action) $*$ f_r

and is included in "$*$".

The Author thinks that one of the purposes of the framework theory is that such problems become apparent, and I look forward to future study.

4 On f_r and F_r, and f_r' and F_r' in temporal discussion of service

Question (Motoyuki Akamatsu)

Since f is defined as differentiation of latent function F, f is speed of appearance, and it is stated, "f is speed of service provision, and equivalent to service in general." Here, I can understand what f_d and F_d represents. However since f_r and F_r, and f_r' and F_r' are only described in the equation, the meaning of " ' " is difficult to understand, so I think it should be explained with words.

Answer (Hiroyuki Yoshikawa)

In the example of dining, it is as follows. The dish is served by the donor (provided service F_d), receptor recognizes it (F_r), and consumes it (f_r). At that time, receptor's hunger (L_r) sets off the action of receiving service or eating the tasty food (f_r'). As result, hunger (L_r) decreases and fullness (F_r') increases. Therefore the following explanation was added: "The service F_d becomes F_r when delivered to the receptor, and flows into the receptor at f_r. Receptor who received it exerts function from L_r at speed f_r', and increases F_r'."

5 On difficulties and issues on systematization

Question (Masaaki Mochimaru)

In this paper, service engineering is systematized into basic framework (provider, receiver, and time concept) and service amplification, to point out difficulties and technological issues in building specific engineering system and to seek hints for solution. I read it as a scenario for systematization to realize service engineering and to achieve goals, and a discussion of necessity to select, newly study, or integrate technological elements listed as topics. Therefore, I think by systematically organizing and describing the "difficulties and technological issues" that are discussed in "4. Summary," the objective of this research "to propose systematic methodology to advance Full Research for service engineering by selecting and integrating elemental technology" will become clearer.

Answer (Hiroyuki Yoshikawa)

At end of "4. Summary," I organized and described the issues in "(7) Issues of engineering theory: (A) Definition of service, (B) Uncertainty of service, (C) Factors that influence service, and (D) Quantification."

6 On "Receptor's expectation → ⋯→ Effect on receptor" in Section 2.3

Question (Masaaki Mochimaru)

Five factors from (1) to (5) are defined according to "excellence" of transition influencing service productivity, and I understand that "Receptor's expectation → ⋯→ Effect on receptor" circulates and spirals upward. In this case, promoted by the effect that occurs to the receptor, receptor gains new (higher level) expectation, the receptor expresses (orders) that or donor does so (understands intent), and the next spiral is set off. I think the process within "excellence of design" in (1) includes the process of donor learning the receptor's expectation by communicating with receptor, and then expressing this as effect wanted to happen. It is implied in Section 2.2 that this kind of communication is important. If so, I think this should be clearly state in (1).

Answer (Hiroyuki Yoshikawa)

It is exactly as the Reviewer indicates, so I described the process in which transition becomes loop. I also described the fact that "excellence of design" includes "ability of donor (understanding intent) and receptor (order) to express the receptor's expectation as effect wanted to happen to receptor, and the relationship between receptor's true expectation and expressed effect wanted to happen to receptor," as well as "relationship between ability to design to realize the expressed effect, and the projection of effect that will be caused by the design."

A systematic analysis of protein interaction networks leading to the drug discovery

— Development of ultra sensitive mass spectrometry analytical platform —

Shun-ichiro Iemura and Tohru Natsume *

[Translation from *Synthesiology*, Vol.1, No.2, p.123-129 (2008)]

Inside each cell that constitutes organism, over 100 thousand different types of proteins function for vital biological processes. The proteins form groups and organizations that function as networks. We were able to achieve large-scale protein network analysis with high sensitivity, high reproducibility, and high efficiency, by newly developing liquid chromatography system with extremely low flow rate of 100 nL/min. The large scale data set obtained using this analysis contributed not only to the discovery of new cellular systems, but also to the understanding of development mechanism of diseases at molecular level. Our research developed into Full Research that led to the development of new diagnostic and treatment methods as well as new drug discovery targets.

Keywords : Proteomics, mass spectrometry, protein network, drug discovery, protein microquantative analysis

1 Background of research

Human body consists of about 30 trillion cells, and each cell contains over 100 thousand different types of proteins to sustain life activity. These proteins do not function separately, but form groups and organizations and function as networks. The work of mapping the network of proteins in the cell is called protein network analysis.

Network analysis is important not only for the clarification of biological processes, but also for the understanding of development mechanism of diseases at molecular level, and contributes to the development of new diagnosis and treatment methods and to new drug discovery targets (Figure 1). However, protein network analysis is technically not easy. There was no established methodology, because the demand in actual protein network analysis was to analyze several hundreds or several thousands of proteins at once.

It was practically impossible to meet this demand with technology of the 1990s. However, the technology came to a turning point in the 21st Century, with the maturity of ionization mass spectrometry for protein invented by Koichi Tanaka of the Shimadzu Corporation. Analysis work that previously required dozens of hours to identify just one protein could be accomplished in a few minutes or even a few seconds using the new mass spectrometry method. Also in theory, the sensitivity increased several hundred times, and it seemed that the researchers were released from the limiting requirement of purifying large amount of samples. However, even after protein researchers obtained their high-tech mass spectrometers, high-sensitivity analysis did not necessarily become instantly available. That was because each of the hundred thousand types of protein possessed different form and size, varied in chemical properties, and were unstable. Microquantity protein degraded and denatured in the test tubes, and became undetectable as they became adsorbed into the test tube wall. Although mass spectrometer was an ultra sensitive “detector,” evanescence of samples determined the real limit of analysis sensitivity and throughput. Therefore, unless this problem was solved, it was impossible to conduct microquantative protein analysis by fully employing the performance of the state of art mass spectrometer. Even if the performance of mass spectrometer increased in the future, there is concern that its advantage would not be utilized fully.

2 Real problem that must be solved (liquid chromatography technology)

The most important method when treat microquantity protein is to maintain the sample in micro-space at concentrated condition as much as possible. However, this is not easy since desalt and washing processes are necessary to analyze protein from organic samples by mass spectrometry. The conventional practice was the on-line reverse phase high-performance liquid chromatograph (HPLC) and the mass spectrometer. A sample was concentrated and desalted in the HPLC column, an elution fraction of liquid chromatograph was ionized, and introduced into the mass spectrometer. However, commercially available HPLC devices had low sensitivity and throughput that did not satisfy our objective of protein network analysis. Particularly, the minimum limit of the pump of conventional HPLC was a flow rate of several microliters per minute and had poor analytical reproducibility, and it was impossible to conduct large-scale, repeated and stable analyses. One of the greatest reasons was because homogenous mixing of solvents was difficult at a low flow rate of several microliters per minute.

To conduct liquid chromatography (LC), proteins and

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peptides are adsorbed and concentrated in the column carrier from the initial solvent. After desalt, elution solvent is discarded and the eluted sample is analyzed. Normally, the elution solvent is mixed gradually with initial solvent, and the liquid is delivered by generating a concentration gradient. To accomplish this, flow path for mixed delivery is necessary by connecting the pumps of two systems for initial and elution solvents. Check valve and dead volume of mixer (space to thoroughly mix the solvents) are always present in the flow path. Therefore, single analysis takes a long time, and solvents cannot be mixed evenly at a slow flow rate. In the 1990s, much research was done to decrease the flow rate by splitting the liquid delivery without slowing down the flow speed of the pump. A branch was formed in the flow path, most of the solvent was discarded, and part of the solvent was sent to the analytical column. If the split was 10 against 1, 9 parts of the solvent could be discarded and the flow rate was reduced to 1/10 (upper part of Figure 2). In this method, it was not possible to conduct analysis at a set flow rate unless the backpressure of analytical column and resistance at the split part were always constant. However, in actual practice, the backpressure of analytical column was not necessarily constant depending on load and volume of the sample. Also, the split resistance tended to increase as the frequency of analysis increased. Therefore, it was almost impossible to conduct reproducible microanalysis. This was an issue that must be definitely solved.

3 New scenario and development of elemental technology (issue of LC environment)

The scenario we employed to solve this issue was based on increasing the performance of LC. The first task was to increase the performance of LC, and then individual elemental issues would be solved as they arose, and finally we could achieve efficient high-precision protein analysis.

To increase performance of LC, we created a totally new method in which a single-system pump was used instead of a dual-system to generate concentration gradient in the elution solvent. By using a single-system pump, the flow channel could be dramatically simplified, and the dead volume, which was the greatest challenge of LC at low flow, could be minimized. Also, if this were realized, low speed liquid transfer would be possible without splitting. Here, we devised the novel split-less nano-flow gradient elution system. The system consists of several channel solvent reservoirs connected by a ten-port electrical switching valve and a manifold. Each reservoir was filled with step elution solvent for LC, which was supplied from two separate reservoirs for initial and final solvents by an

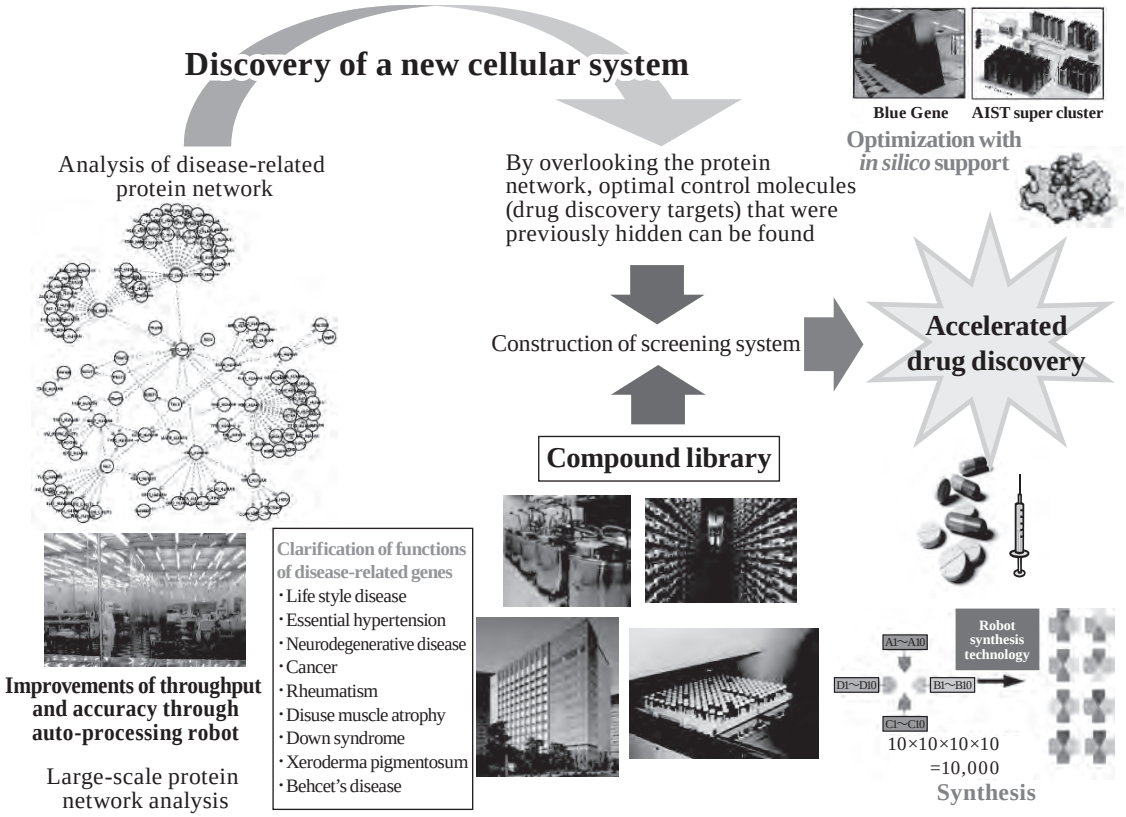

Fig. 1 Drug discovery from protein network analysis.
Proteins interact with each other and form networks. By understanding the protein network, we can discern the function of individual protein. Also, by overlooking these networks, we can find pathogenic mechanisms and new drug discovery targets. Drug discovery screening is conducted based on these informations.

automated high flow-rate mixing module.

Describing this idea in one sentence, it is "mixture is made homogenously in a larger world, and then delivered to a smaller world," much like "Columbus' egg." Although it was important to make sure that the solvents in each step would not mix with each other, we took advantage of the disadvantage of a dual-system pump where the solvents in a microflow channel do not mix (lower part of Figure 2). This method enabled extremely high reproducibility as well as continuous operation and automation of LC. Using this method, HPLC at lower than 100 nL/min with direct flow without split was installed online with mass spectrometer for the first time in the world[1]. As a result, a high sensitivity of 20~50 times the conventional method was achieved.

We also improved the analytical environment to maximize the high sensitive analysis. Even if we achieved sensitivity that allowed analysis of microquantity samples, since massive amounts of human keratin existed in general experimental environment, the signal of microquantity sample would be overpowered by contamination of air-borne keratins. Also, since the analytical channel consisted of a thin capillary with internal diameter of 10 micrometer to eliminate dead volume as much as possible, the channel became clogged readily by dust particles in the atmosphere. Therefore, continuous operation in a general environment where people walk in and out was impossible. Although elimination of dust particles and keratin were not easy, we started to use the prototype system for routine anayses.

In 2000, we started analysis using actual samples at Tokyo Metropolitan University where the technological development was carried out. Since there was no clean room at that time, we evaded the issue of experimental environment by limiting entry and exit of people to the analysis lab. The lab was thoroughly organized to eliminate dust source and covered with antistatic sheet as much as possible to prevent adsorption of dust by static electricity. Entry to the room wearing raised fabric clothes was prohibited. Also, after opening and closing the door of the lab, we waited until the dust settled, and only after then did we start the analysis.

The excitement we felt when over 100 proteins were identified at once for first time using this system was unforgettable. We gradually obtained cooperation of people who appreciated the

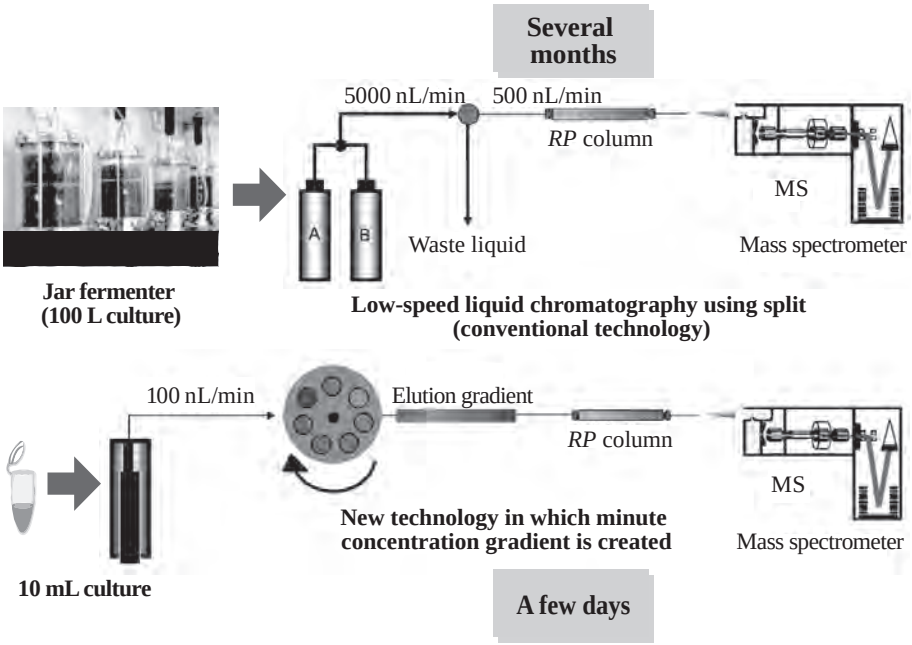

Fig. 2 Comparison of new and conventional technologies.

In conventional technology, elution gradient is created by a dual-system pump. Concentration gradient is created by shifting the transfer rate of pump A that delivers initial solvent and pump B that delivers elution solvent. However in this method, low speed mixing is not possible since the dead volume is large. Therefore, low speed is achieved by installing a splitter between the analytical columns and by discarding most of the liquid. The figure shows that the flow rate is decreased from 5000 nL to 500 nL/min by discarding 1/10 of the liquid (upper part).

In the new technology, reservoirs with multiple branches are filled with elution solvents in steps using a separate pump system. Elution gradient is created by rotating the port valve and pushing out each step with a single-system low-speed pump. There is no dead volume and it does not require a splitter (lower part).

In conventional technology, sample preparation by mass culture was necessary for a single analysis. It was common to conduct 100 L culture using jar fermenter. Several months were required to prepare for an analysis. Using the technology we developed, we achieved sensitivity where several analyses would be possible with samples from 10 mL culture. In this scale, only a few days are necessary for sample preparation, and several different samples can be prepared simultaneously.

superiority of the result, and was able to install a simple clean booth in the analysis lab. However, as a practical problem, heat produced by the mass spectrometer was too large, temperature inside the booth quickly rose to over 35 °C, and it could not be used for a long time, as the device would get damaged. We strongly felt the necessity for a fully equipped clean room to conduct stable and continuous analysis.

In the spring of 2001, the AIST Tokyo Waterfront was newly opened and we obtained the opportunity to install a clean room. We visited several semiconductor plants to learn about clean rooms from basics. However, not until the opening of Tokyo Waterfront annex in 2005 and the construction of second-generation super clean room did we solve the dust issue.

4 Execution of Type 2 Basic Research (issue of sample preparation)

After successfully developing the elemental technology for liquid chromatography, we thought it was important to move on to product realization research in order to make the hardware available commercially. However, as mentioned in the previous section, we discovered that the developed technology was useless unless the analytical environment was constructed properly. My real objective was to construct a mass spectrometry system with the highest sensitivity in the world, to conduct large-scale and high-precision protein network analysis, and to efficiently find disease mechanisms and discovery of new drug targets.

In fact, the effectiveness of developed LC system and mass spec facility was extremely significant. There was no necessity for steps of separating the sample by electrophoresis, and in about one hour, interaction complex composed of over 200 different types of proteins could be completely identified at sub-femto level. Before, sample had to be prepared from several tens to hundreds of liter volume and the analysis took several months, while now it can be done in 2~3 days. Also, since multiple analyses can be conducted, 10~20 analyses can be done simultaneously. Conducting large-scale analysis at high throughput became a reality.

By increasing throughput, it became possible to consider in details the conditions of sample preparation for high-precision analysis. There are various parameters such as affinity refinement of proteins, incubation time, and lysis of cells. To combine multiple parameters, several thousand analyses were necessary, and such analyses could not be accomplished by one researcher in his/her lifetime. Therefore, optimization of conditions for sample preparation was never done at comprehensive and thorough manner, and normally sample preparation designed on trial-and-error based on a researcher's experience and intuition. In fact, we sought sample preparation optimization through several thousand analyses, and developed an extremely precise method eliminating foul positive data maximally.

We investigated diverse parameters, and the conclusion obtained was simple: "work fast." Since sensitivity of conventional analysis methods was low, it was common knowledge to maximize yield of a sample as high as possible. However, more time was required to recover higher yield, and unstable protein denatured and aggregated to produce "dirty" data. As high-sensitivity analysis became possible, it was no longer necessary to concern ourselves with "yield" of a sample. Rather, the most important concern was to increase "quality" or to prepare the samples as fast as possible before the proteins denatured and aggregated. However, it was not easy to do this in practice, and the technician in charge developed thorough protocol for sample preparation. This involved everything from ways to hold the test tube to arrangement of reagents on the bench, and emphasis was placed on the efficiency of the operator. Also, movement of the operator was filmed on video and studied to remove any unnecessary movements. Finally, we created and executed protocol where work, which previously took several hours or overnight, could be completed within one hour.

5 Research results and commercialization

Through these technological developments, we conducted large-scale protein network analyses using 2,200 human cDNA in about 5 years. There were over 16,000 analysis sessions. We were able to discover new cellular mechanisms functioned by proteins. The results were published in nearly 30 papers including twice in Nature and 6 times in Nature affiliated journals. We succeeded in analyzing protein networks of several disease-related genes, more than initially expected. We obtained findings that may lead to discovery and understanding of molecular disease mechanism as well

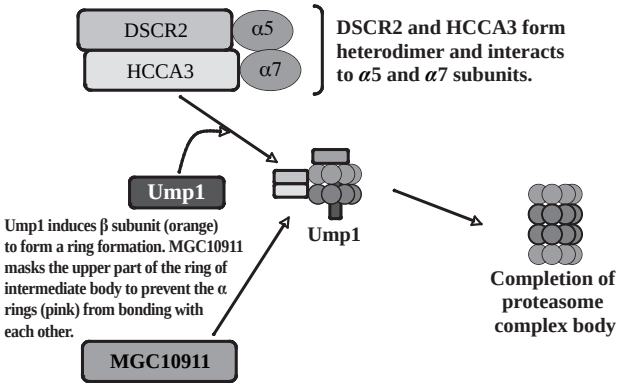

Fig. 3 Discovery of assembly factor of proteasome.
We discovered 4 assembly factors that composed the proteasome. Rather than inhibiting the proteasome itself, there is less side effect and higher possibility of being effective against wide range of cancer cells by inhibiting these assembly factors. They are better drug discovery targets.

as functional analysis of causal and related genes for cancer, life style disease, neurodegenerative disease, xeroderma pigmentosum, Down syndrome, Behcet's disease, and essential hypertension. We also discovered several cases in which proteins that were considered to have absolutely no relationship to disease may become totally new drug discovery targets[2]-[14]. I shall describe a representative example of network analysis in the following section.

There are huge protein complexes called proteasome in the cell, functioning as factories that degrade unnecessary proteins. The complexes consist of over 60 protein components, and it was long unknown how they were assembled. We discovered the assembly factors that assembled the proteasome. This was academically a significant discovery, where huge protein complexes are constructed with collaborative support of other proteins[4][11]. As shown in Figure 3, an assembly factor called DSCR2 and HCCA3 cooperated and arranged the α subunits in α ring form. Next, Ump1 and MGC10911 created the β ring structure, and α and β rings joined in a correct alignment. At the same time, this was a new drug discovery target.

Proteasome not only has a role of "quality control" or breaking down old and denatured protein, but it also has an important function of controlling diverse vital protein reactions. In cells, when new proteins become necessary for some vital reactions, it may be too late if they are synthesized as need arises. The cell continuously makes proteins that are expected to become necessary until the situation arises, and proteasome continuously degrades them. When the moment arrives when proteins become necessary, the degradation is halted and the necessary proteins can appear immediately.

For example, when cells divide, several proteins must cooperate in one direction and work closely together. This is lead by proteasome. Cancer cells that continue to divide indefinitely are thought to require more proteasomes than normal cells. It has been known that drugs that inhibit the action of proteasome possess powerful anticancer effect. However, severe side effects appear when such inhibitory drug is used, since proteasomes are necessary for a normal cell function. Therefore, this inhibitor is used only with special cancers with no other treatment. However, when the function of assembly factor of proteasome that we discovered was inhibited, the amount of newly created proteasomes decreased, and there was hardly any effect on normal cells although it was fatal for cancer cells. Since normal cells do not require as much proteasomes as cancer cells, they are less susceptible to some decrease in proteasome level. Also, we expected that that there will be fewer side effects, unlike complete inhibition of proteasome function. This assembly factor would be a new and more suitable drug discovery target.

Since these results could be directly applicable to drug discovery research, we suggested corroboration research with pharmaceutical companies in 2006. As a result, we started a drug discovery research project in which almost all Japanese major and medium pharmaceutical companies participated. The initial grand design of this project was based on protein network analysis of disease related or causative genes or proteins in which each pharmaceutical company was interested, for drug target discovery. However, the project was taken further, and aimed at establishing drug screening platforms under corroboration of pharmaceutical companies based on the information of protein network analysis. When the project finds 'hit' compounds, AIST provides the hit information for corroborative companies for developing therapeutic drugs. To do this efficiently, Computational Biology Research Center[Note] in AIST Tokyo Waterfront also got involved in the project to bridge hit compounds and combinatorial chemistry by in silico simulation using the hyper parallel computer system. Eventually, to enhance activity of the industry, the project was designed[15] to provide research resource and facility which can not be equipped in each single private sector, such as mass spec facility, large-scale natural compound library and computatonal resources like Blue Gene[Term 1].

6 Discussion: strategy toward Full Research

The most basic strategy that we implemented when we planned and started the protein network analysis project was: "we shall not aim for eccentric and extraordinary innovation." Even if we created a wonderful technology or technique, it normally takes at least 10 years before it is standardized as a analysis method and begins to generate data. In fact, it was in the early 1980s that Mr. Koichi Tanaka ionized peptide protein using matrix and conducted mass spectrometry for the first time in the world. This discovery led to the development of MALDI mass spectrometry, which the protein chemists and biologists around the world started to use in the late 1990s to 2000.

At the time, we thought spending 10 years developing analytical technology was unrealistic. We adhered to the most realistic, most down-to-earth, and "straightforward" way of doing things, that is, to minimize the greatest bottleneck in current mass spectrometry. The "straightforward" method was to "transfer microquantity of sample to mass spectrometer without loss," and we focused thoroughly on this issue. We decided not to dip our hands into new innovations such as improvement of mass spectrometer or increasing efficiency of ionization. The mass spectrometer itself was already highly sensitive, and we placed our bet on a hope that if ionization could be accomplished without loss of sample, we could obtain the target sensitivity.

If we could achieve ultra high sensitivity, large-scale analysis at high throughput would become possible. The

greatest bottleneck of protein experiment was, needless to say, the preparation of samples. Therefore, we decided to challenge the big projects that required 50~100 people in Europe and US with just a few people and limited time by improving throughput of analysis through "attainment of ultra high sensitivity." In fact, we achieved high sensitivity "that surpassed our expectation" by creating new elemental technology called gradient method, but it was not useful in practice. That was because the S/N ratio worsened due to noise from the environment. We painfully realized that improvement of S/N ratio is necessary to implement 'real' high-sensitive analysis by MS, or battle against noise, and we also understood the reason why development of micro liquid chromatography was not undertaken elsewhere in the world.
The developed prototype lacked durability, was damaged easily by dust particles, and required much time for maintenance. One success was the beginning of the next suffering. However, we have been using them, rather than improving ease of maintenance of the LC system. This was only possible since we designed the entire device all the way to its screw. Although our device and system was full of defects, we believed it was more important to "use it and get data," and set that as priority. The subject of analysis was initially narrowed down to known molecules that were very well characterized, in spite of analyzing unknown molecules. We had two reasons to this. First, if the analysis system we developed had truly high sensitivity and high throughput, there must be a new discovery even in an area that was already thoroughly characterized. Second, if there was a new discovery, we could validate and publish the data, because there is plenty of information and knowledge for well known molecules. These were our aims.

7 Conclusion

To claim a new system to be "high sensitive" or "high throughput," the system has to generate large-scale and highly accurate data. And the only way to demonstrate this is by publishing such data in as many high quality journals as possible. We thought there was no other way of objectively demonstrating the superiority of our newly developed system. This was particularly true because our strategies were steady improvements and gradual accumulation of know-how. We were unable to demonstrate our results as intellectual property by publishing papers that claimed novelty or innovativeness of methodology. In fact, the only thing we can call innovation in our development was a single-pump gradient method, and all other technologies were adaptation of existing elemental technology of other fields (semiconductors and industrial robots). We simply utilized them and thoroughly optimized the classic biochemical experiment method. Fortunately, these strategies and tactics turned out successful, and we realized the "flow" of microquantity of 100 nanoliters or less per minute. We hope this flow initiate new mainstream of drug discovery.

Acknowledgements

We received support of the Japan Science and Technology Corporation for the development of new gradient method, and support of NEDO for protein network analysis. We express our deepest gratitude.

Note Participation of Takatsugu Hirokawa, Research Team Leader, Drug Discovery Molecular Design Team, Computational Biology Research Center.

Terminology

Term 1. Famous episode in which massively parallel computer with 8,000 CPU beat a chess master.

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Discussion with reviewers

1 On integration of elemental technology

Question (Noboru Yumoto)

The originality of this paper is the success in integrating the elemental technologies including 1) construction of new system of liquid transfer, 2) improvement of analytical environment, 3) adjustment of analytical flow passage with minimum dead volume, and 4) optimization of sample preparation, toward the objective "to construct ultra high-sensitivity mass spectrometry system for protein network analysis." Please explain 2), 3), and 4) as you did for 1), and how you achieved the objective by integrating the selected elemental technology.

Answer (Tohru Natsume)

The technologies for 2), 3), and 4) were basically accumulation of know-how and introduction of other technologies, and they were optimizations and combinations of existing technologies. I abbreviated them because they may sound like side stories. However, they may be important, as you indicated, so I added some stories taking care not to distract from the main theme of the paper.

2 On relationship between research objective and society

Question (Hisao Ichijo)

Research for problem solving is very detailed and convincing, but I feel there is some lack of "relationship between research objective and society" and "evaluation of result and future development."

I think it will be easier to understand if you add some description that the objective "to find pathogenic mechanisms and new drug discovery targets by conducting large-scale high-precision protein network analysis" has been partially achieved.

Answer (Tohru Natsume)

The specific story of new dug discovery target was described taking the example of proteasome assembly factor that was published in *Nature*.

The aerosol deposition method

— For production of high performance micro devices with low cost and low energy consumption —

Jun Akedo * , Shizuka Nakano, Jaehyuk Park, So Baba and Kiwamu Ashida

[Translation from *Synthesiology,* Vol.1, No.2, p.130-138 (2008)]

AD (aerosol deposition) method is one of newly developed technologies for spray coating powder materials. It is a revolutionary coating technology in which high-density consolidation of ceramic powder can be obtained at room temperature, without sintering at high temperature as in conventional ceramic formation. By using AD, it is expected to improve device performance, to greatly reduce energy consumption and to decrease the number of steps during fabrication process that ultimately result in cutting production costs. How the characteristics of AD method are positioned from the perspective of technological competitiveness and reduction of environment load, as well as its potential, is investigated from the viewpoint of Full Research, along with description of principles and specific case studies.

Keywords : Aerosol deposition, AD method, optical scanner, on-demand, energy conservation, electronic ceramics, piezoelectric, MEMS

1 Introduction

The circumstances surrounding the manufacturing process of electronic devices and their implementation are rapidly changing due to industrial globalization and concern for environmental overload. Shortening product(ion) cycle and multi-product variable production have become non-negligible issues. Currently, product specifications are rapidly becoming diverse in the market, and this is affecting mounted products such as connectors, sensors, and actuators. Multi-product variable production with extremely short delivery time is now in demand, in contrast to the age of single-product mass production. The demand in the manufacturing industry is changing greatly due to diversification of market requirements. For example, over 1 billion yen investment in manufacturing line is required to mass produce MEMS device starting from the R&D phase, even when existing LSI manufacturing line is used. Usually, long time is needed for product development, and substantial production volume is required to lower the cost through mass production at device level. For these reasons, the business risk for commercialization is considerable even for a major corporation. It is also the basis for the adage: “killer application is necessary to commercialize MEMS.” On the other hand, MEMS devices are considered as parts (components), and flexibility for multi-product variable production is needed when considering practical application. Although only a hypothesis first, this trend is expected to increase as integration level of modular functional parts increases. Demand for multi-product low-volume production develops when black boxing and customization are conducted to control commoditization of product to maintain its competitiveness. To lower cost in such conditions, further evolution of process technology from perspective of manufacturing will become necessary.

Considering the manufacturing process of advanced devices in the future, demand for high performance by achieving thinning and high integration of oxide electronics material with multiple functions is expected to increase. In the integration process of electronic devices such as MEMS, various R&Ds are conducted using vacuum thin film processes including sputter and CVD methods due to their manufacturing application potential. However, there are surprisingly few cases where thin film technology has reached a practical level through integration of semiconductor parts. This is due to the fact that, as, for example, in the cases of capacitor and filter parts fabrication, the property of material and the cost of production process in device application are at trade-off, and at this point, ingenious utilization of bulk material is more feasible in terms of cost, facility, and energy consumption. Highly pure raw material and ultra vacuum environment are necessary and

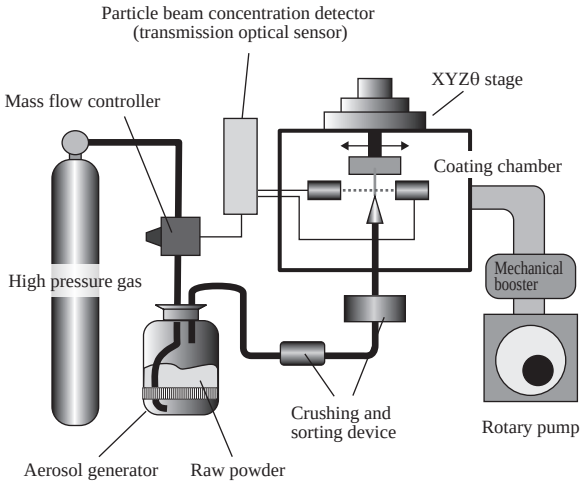

Fig. 1 Basic components of aerosol deposition (AD) device.

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there are several issues that must be tackled including facility cost, energy consumption, and environment load to realize a mass production level. Making breakthroughs to solve these issues will be important. Therefore, construction of on-demand manufacturing process and system that can address these needs is expected to become important in the future from the perspectives of strengthening industrial competitiveness and reducing environment load. Investigations of such issues are made using small-scale cell production systems at assembly level including implementation of circuit substrate for sensor device[1].

In the background of high performance device manufacturing described above, the R&D stance of not only "How do we realize the function?" but also "How should it be made to ensure resources and low costs?" will become more important. In this paper, the potential for on-demand manufacturing process based on aerosol deposition method is investigated along this stance.

2 The aerosol deposition (AD) method

The aerosol deposition method (hereinafter AD method)[2] is a technology in which fine or ultra-fine powder is mixed with gas to form an aerosol, that will be sprayed through a nozzle to form a film coat on a substrate. The motion energy of material particle accelerated by gas carrier is converted to local heat energy by colliding with the substrate, and substrate-particle and particle-particle bonds are achieved. However, the mechanism of energy conversion has not been sufficiently understood.

Figure 1 shows the basic structure of the coating device. The device is composed of an aerosol generator connected to a narrow delivery tube and a coating chamber, which is vacuumed to 50~1 kPa using a vacuum pump. The dried fine or ultra-fine powder that makes the raw material is stirred and mixed with gas in the aerosol generator chamber, carried to the coating chamber by gas flow caused by pressure difference between the two chambers, accelerated through the slit nozzle, and sprayed onto the substrate. Normally, mechanically grounded sintered ceramic powder with particle diameter 0.08~2 μm is used as raw material. The gas carrying the ultra-fine powder can be easily accelerated to several hundreds m/sec by passing through a nozzle with micro opening of 1 mm or less. Since coating speed and density of film coat depends greatly on particle diameter, aggregation state, and dryness of ceramic fine powder, crushing and sorting devices are installed between the aerosol generator and the coating chamber to ensure high quality powder flow.

Recently, using ceramic powder in AD method and selecting appropriate coating condition as well as adjusting particle diameter and its mechanical properties, room temperature impact consolidation (RTIC) was observed. This is a phenomenon where high density, transparent ceramic film was formed at room temperature at high speed, as shown in Figure 2[2][3]. The substrate was not heated when the powder material was sprayed onto the substrate, and no heat processing was required after coating. This phenomenon occurred not only for ceramic materials but was also observed for metals.

Amorphous layer or heterophase between crystalline particles in the microstructure of ceramic film formed by RTIC using the AD method was not observed and the dense films obtained at room temperature consist of non-oriented microcrystal with size 10~20 nm or less. Clear lattice image has been observed in microcrystals 10 nm or less in diameter. Although some distortion occurred in the interior of the film, the texture of the films remained the same from substrate interface to film surface. The powders used in AD deposition have monocrystalline structures with average particle diameter 80~100 nm or more; however, smaller fine crystal texture was observed in the coated films. From the results of XRD and EDX analyses, the coated film maintained the crystal structure of material powder with small compositional variations. From measurement of particle speed and assessment of motion energy, it is considered that the material powder crystals are mechanically crushed by collision, become finer by plastic deformation, and nanocrystal thin film is formed as bonds between particles[1]-[3]. These are not seen in the conventional coating method using particle collision.

Compared with the conventional thin film processes, the AD method shows the following unique characteristics:

1. Binderless, dense coating/film are obtained at room temperature;
2. High coating rate of 5~50 μm/min (conventional method: 0.01~0.05 μm/min);
3. Film coat of same composition and crystal structure as powder used for complex composition system can be obtained with substantially different pressure;
4. Wide variation of film thickness can be obtained (0.5 μm~1 mm);
5. Without etching process, micro pattern can be obtained using direct rendering, mask method, or lift-off method;

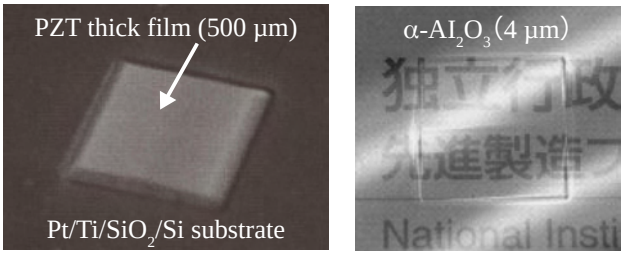

Fig. 2 Ceramic film created at room temperature using the AD method.

6. Film formation is possible even at low vacuum (several hundred Pa ~ atmospheric pressure).

During the film formation by RTIC using the AD method, absolutely no increase in substrate temperature due to collision was observed. Macroscopically, ceramic material was consolidated at room temperature. Since it did not undergo firing process, AD consolidation process could be considered as binderless, ultra high-density ceramic green fabrication process.

3 Comparison with current thin film technologies and energy conservation

3.1 Difference in principle with conventional thin film technologies

If ceramic film with high density and good crystallization can be formed accurately at low temperature, at low cost, and at high speed, the issue of mass production discussed in Chapter 1 can be solved. The AD method is a non-heat equilibrium process, and unlike thermal spraying, the material powder is bonded and a thin film is formed in solid state at room temperature. Compared to the conventional thin film method, the coating speed is extremely fast since it is a build up process at a particle level, and the crystal structure of material powder is almost completely preserved in the film coat. Therefore, one major characteristic of AD method is that it can be used for film coating on any substrate material, and film coatings from powders with complex compositions such as composite oxides can be formed. Due to the characteristics of the AD method, drastic reduction in process temperature can be expected compared to other coating technologies. Moreover, the AD method is also readily applicable for compounding and integration of different ceramic, metal, and polymer materials, as well as for development of nanostructure compound materials.

From the perspective of process energy conservation, coating with conventional technologies is normally possible only in vacuum environment of several hundred Pa or less, while, with AD method, coating can be done in atmospheric pressure depending on the material and use. In conventional thin film technology, material is broken down to atomic and molecular levels, and then crystallized on the substrate. Therefore, to obtain highly pure crystal formation without defects and with high-performance film properties, it is necessary to maintain ultra high vacuum to control adhesion and bonding of contaminating atoms before reaching the substrate. As shown in Figure 3, in the AD method raw powder material is already in crystallized form. AD method has a fast powder supply speed to the substrate and, because the surface of material powder is inactive before collision with the substrate or the coated film and the activation for bond formation occurs only due to collision with the substrate, the need of ultra high vacuum is not necessary to control inclusion of impurities during the coating process. Since adhesion of impurities can occur on the surface of material powder, it is necessary to clean the surface before use to obtain ultra pure crystals. However, in the NEDO Nanotechnology Program / Low Temperature Formation and Integration Technology of Nano level Electronic Ceramics Material Project (FY2002~FY2006)[4], film property equivalent or better than that achieved with current vacuum thin film technology was demonstrated in many electronic ceramic materials without the cleaning process.

For industrial application, the innovative point added by AD method is that although high performance material is involved, coating can be accomplished in low vacuum. Compared to the conventional vacuum thin film process, it is expected to reduce cost of building manufacturing facility, energy consumption, and environment load.

3.2 Energy conservation by using the AD method in electrostatic chuck manufacturing process

Investigation has been conducted on how much energy could be conserved in the whole product manufacturing process and to what degree product function would be improved by employing the AD method in the NEDO Energy Research and Development Project for Core Technology for Efficient Energy Use (Leading Energy Conservation Research FY2001~FY2003)[5] through joint research with a private corporation. The subject of investigation was electrostatic chuck, which is currently used to lift up wafers by adsorption in semiconductor manufacturing, and product with high adsorptivity is in demand to support large wide size Si wafers or heavy components such as flat panels. Electrostatic chuck has a structure consisting of a ceramic thin plate added on as isolator to generate static electricity on a metal jacket that acts as radiator and electrode, as shown in Figure 4. The thinner the ceramic plate is, the higher the adsorptivity per applied voltage. Aluminum nitride material with good heat conductivity is generally used due to its radiation property. In

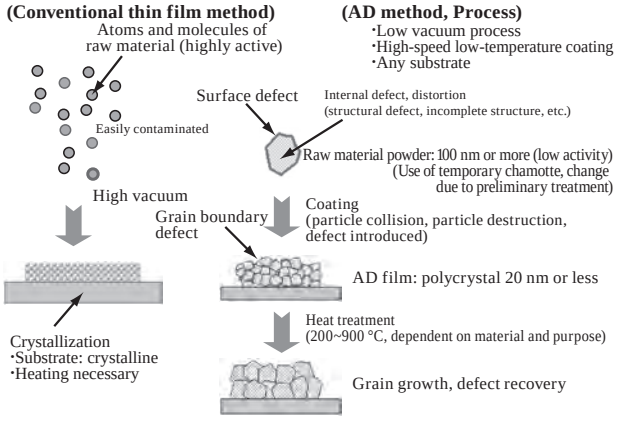

Fig. 3 Difference between the processes of AD method and conventional thin film method.

the NEDO Project, aluminum nitride thin plate was replaced with ceramic coating on a metal jacket using the AD method, and the improvement in performance and energy consumption reduction throughout the entire manufacturing phase were investigated. By replacing the insulation layer with AD coating, thickness was reduced to 1/10 or less, adsorption per applied voltage increased about 20 times, and heat conductivity and speed of adsorption response to a metal jacket also increased dramatically. Since heat conductivity can be improved by replacing aluminum nitride with other materials, ex. yttria, new functional improvements such as increasing corrosion resistance against plasma can be expected.

For the manufacturing of electrostatic chuck through introduction of the AD method, approximately 80 % reduction in energy consumption could be achieved for the entire manufacturing process, as shown in Figure 4. The manufacturing process time was also reduced to 1/10 or less. For this particular application, the energy reduction was obtained not only by the removal of sintering process that is required in conventional manufacturing to be performed at high temperatures, but also for further removal of other fabrication process steps present in the conventional manufacturing process. Particularly, the reduction in energy consumption of polishing process needed to gain evenness of adsorption surface, which determines the performance of electrostatic chuck, contributed greatly to the reduction of total energy consumption. When ceramic thin plate is made using conventional ceramic process, there is substantial contraction and warping during firing, and energy consumption needed for planarization is quite substantial. Using ceramic coating by the AD method, sufficient pressure resistance can be obtained since the film is dense even if it is thin, and warping of adsorption surface is greatly reduced because of its thinness. The energy reduction in manufacturing process is relevant to mass production design, and we believe that the efficacy of the AD method in energy conservation should be further investigated.

Although the above case study was for the particular case of electrostatic chuck, energy conservation can be achieved by employing AD method in ceramic coating in many other ceramic products, when ceramics with properties such as corrosion resistance, insulation, and hardness are demanded.

Improvement of resistance to plasma corrosion by using yttria film coated using the AD method in inner walls of chamber and components in semiconductor manufacturing device is currently in the process of commercialization. Because by using CVD, separate devices are needed for each material and/or process step, an alternative method using a single device needs to be investigated. It may eventually become possible to optimize scale, facility cost, and energy consumption of semiconductor manufacturing plant according to production volume.

4 Possibility of lower cost and energy conservation by application to MEMS optical scanner

4.1 Application to Si-MEMS scanner and simplification of process

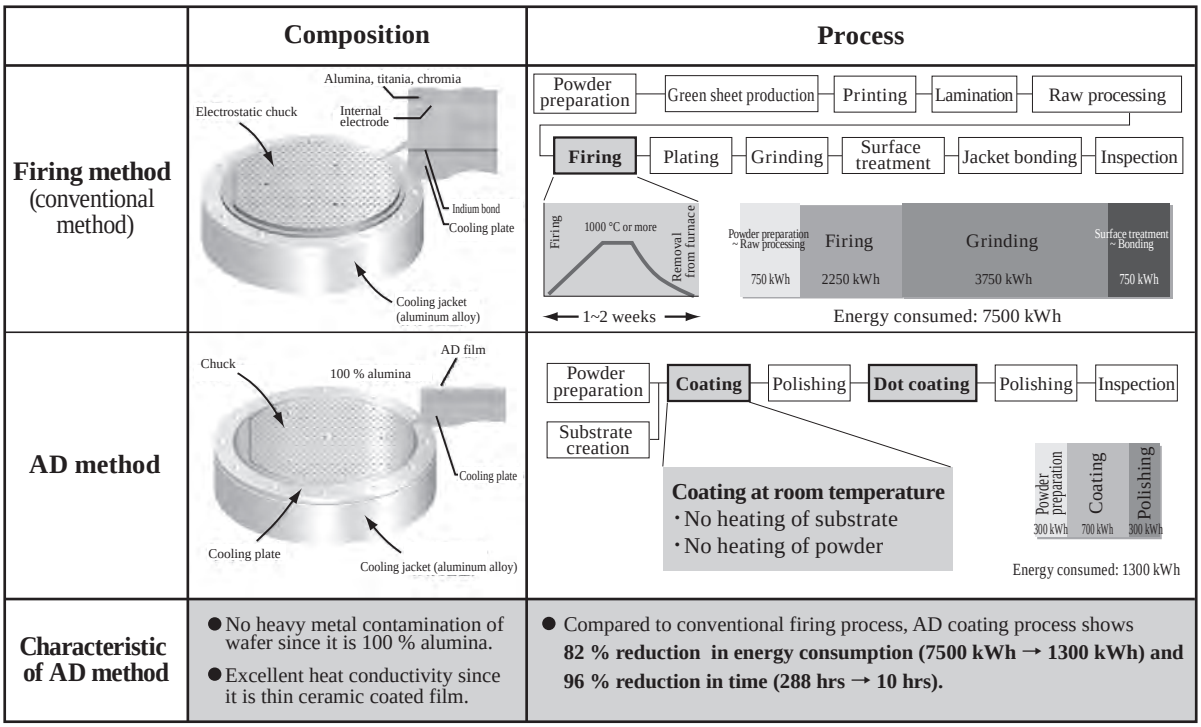

Fig. 4 Structure of electrostatic chuck and comparison of energy consumption in manufacturing process using AD method.

In response to demands for "necessary amount at necessary places" or "multiple product variable volume," we investigated the on-demand application of process and manufacturing system. Since the AD method is a nozzle spray process, it has the potential for an on-demand process similar to the ink jet technology.

As case study, we investigated the application of the AD method to piezoelectrically actuated Si-MEMS optical scanner, as shown in Figure 5. This scanner is expected to be used in next-generation laser printers, barcode readers, and ITS laser radars, and will become a key component of next-generation display devices such as micro projectors and retinal projection displays. Therefore, requirements include high-speed scanning of tens of kHz, scanning angle of over 20°, millimeter size mirror, reduced distortion during motion, and low voltage drive[6].

In the manufacturing process the scanner structure was formed using Si micromachining, and an active film, which would be the driving source, was coated only in required areas. Conventionally, to create such actuator structures, upper and lower electrode layer and piezoelectric layer were deposited using the sputter method, CVD method, or sol-gel method after forming the structure by bulk micromachining using wet and/or dry etching. The substrate has to be heated to crystallize the piezoelectric layer and the patterning is usually done by etching. An expensive microfabrication device, a coating device, and processes involving over 20 steps were necessary. In contrast, using the AD method, the piezoelectric layer could be formed accurately only in necessary areas of the microfabricated Si scanner structure. The etching process for piezoelectric and electrode layers became unnecessary and this enabled drastic reduction of processes and facilities along with improved coating speed. Device performance has been also improved, scanning frequency of 33.4 kHz and optical beam scanning angle of 30° were obtained, and the resulting optical scanner had higher speed and larger amplification than conventional electrostatic driven, electromagnetic driven, and piezoelectric driven MEMS optical scanners[7]. These results were possible because the thickness of the piezoelectric film was easily thickened in the process, and as a result, the generative force of drive source was increased and a Si torsion beam structure with high rigidity could be employed.

4.2 Application to metal base MEMS scanner and reflection in device design

Because high performance piezoelectric film could be formed on any substrate material using the AD method, we investigated the fabrication of a metal base device for a less expensive, highly impact resistant, and practical small-size actuator[8]. Figure 6 shows the manufacturing process of Lamb wave resonance type high-speed micro optical scanner that was created by replacing Si with stainless steel

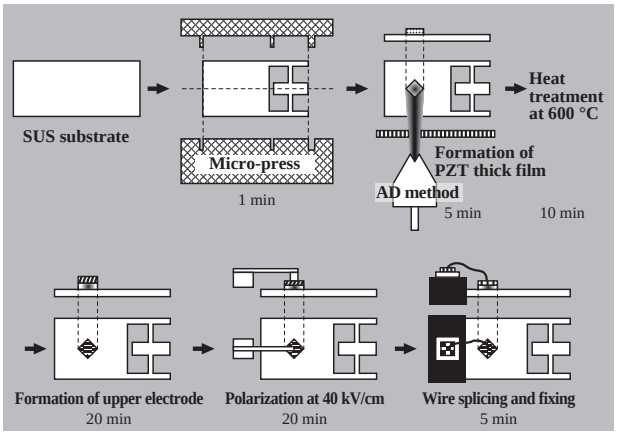

Fig. 6 Metal-base optical scanner driven by AD piezoelectric film and manufacturing process.

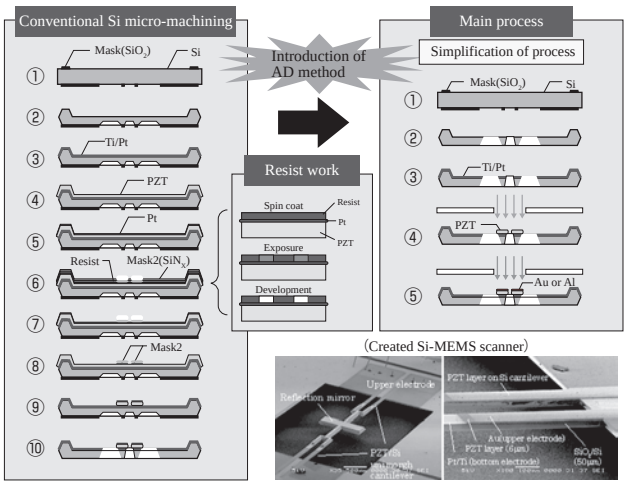

Fig. 5 Comparison of Si-MEMS optical scanner driven by AD piezoelectric film and conventional manufacturing process.

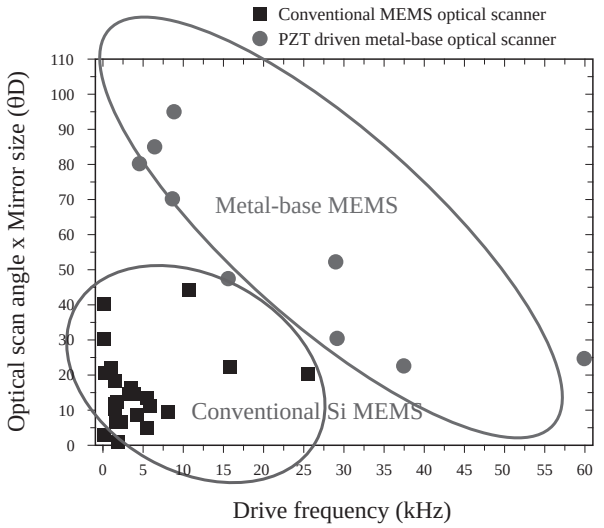

Fig. 7 Comparison of performance of metal-base optical scanner based on Lamb wave resonance principle and conventional Si-MEMS scanner.

material for the body of MEMS optical scanner shown in Figure 5. The whole scanner structure including mirror and torsion beam was formed by a punching process, and the piezoelectric film was directly formed on the structure using the AD method. As the AD piezoelectric film formed on the substrate undergoes expansion and contraction by external electric field, bending deflection is induced in the entire substrate (function as uni-morph actuator), Lamb wave is produced, mirror is excited by resonance, and laser light reflected by the mirror is scanned at high speed. Figure 7 shows the performance comparison with an optical scanner manufactured by conventional Si-MEMS when same driving voltage has been used. The horizontal axis shows the resonance frequency and the vertical axis shows the mirror size x scanning angle of light beam as standard assessment index for the deflection angle of the mirror. The resonance frequency could be designed at wide range between 100 Hz ~ 90 kHz in air, and maximum 95° was obtained as scanning angle of the light beam. Also, by using stainless steel material that was treated by ultra-precise polishing process, punch processed mirror achieved flatness of about $\lambda/4 \sim \lambda/8$ for 1 by 1 mm^2 mirror size, making it applicable for this optical scanner. When Si wafer is used, it is impossible to achieve mirror scanning angle at 10 kHz or more, because the torsion beam is damaged when the yield limit is surpassed and resonance frequency decreases. As shown in Figure 8, as a result of continuous motion test at maximum scanning frequency of 61 kHz and at maximum light beam scanning angle of 75° for over one year, there was no decrease of resonance frequency or deterioration of light beam scanning angle, confirming that practical durability was achieved from perspective of metal fatigue. Also, impact resistance was significantly improved by using stainless steel material, making possible its implementation in mobile devices and vehicle-mounted devices. Moreover, the stainless steel structure allowed the scanner itself to be used as a lower electrode, manufacturing process being greatly simplified compared with Si-MEMS or other optical scanners that require the fabrication of lower electrode. Since the initial cost for facility could be kept lower compared to conventional Si microfabrication facility, the cost of a device is expected to be also reduced.

These results indicate that, for realizing high-speed optical scanner with large scanning angle, both high performance and cost reduction could be achieved when conventional design philosophy based on silicon micromachining could be exceeded by maximizing the advantage of the AD method which enables direct formation of excellent quality piezoelectric films[9] on metal substrate, and by combining this advantage with conventional mechanical processing technology.

4.3 Application to multi-product variable production system

To investigate the efficiency of the AD method in the above-mentioned optical scanner manufacturing at production level and, as an attempt for application to sensor and actuator parts for custom-made medical micro-devices for which multi-product variable production is required, we developed

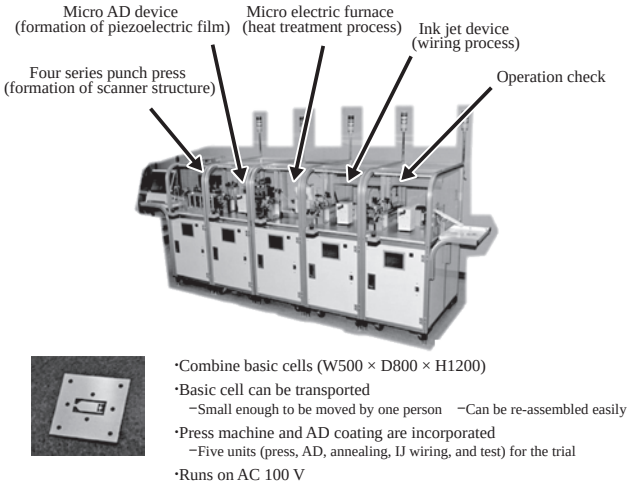

Fig. 9 On-demand MEMS manufacturing system.

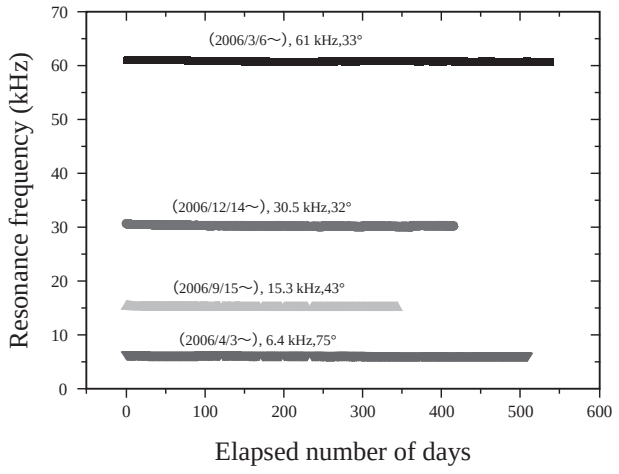

Fig. 8 Durability of metal-base optical scanner.

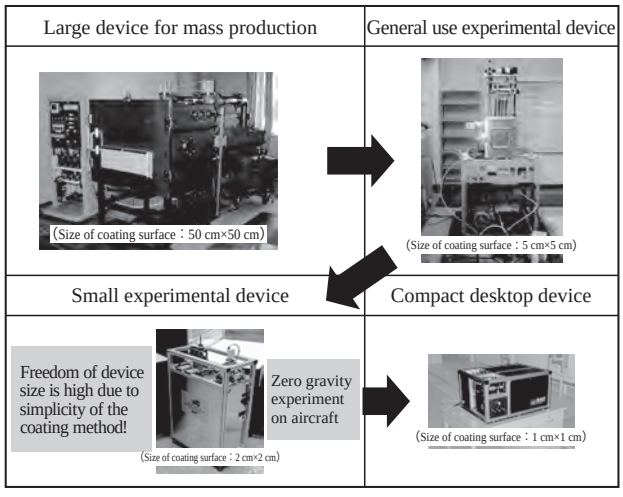

Fig. 10 AD devices in various scales.

a manufacturing system using forming and processing technologies for functional material with immediate demand which includes the AD method, laser process, and ink jet method, that allows speed and diversity of mechanical processing as shown in Figure 9. We aimed for a manufacturing process that can handle multi-product variable production masklessly even though the manufacturing process was for electronic functional devices. Below are described the results of these investigations.

Due to simplicity of its principle, the AD method holds potential of shifting the scale of device from role-to-role to desktop. Figure 10 shows some AD device prototypes at various scales. Currently, the largest size is a device with coating surface of 50 cm square, while the smallest is less than 1 cm^2 in size. A small AD device has performed successfully in trial coating in zero gravity aircraft for potential use in a space station.

For the equipment that includes AD created as prototype for manufacturing of aforementioned metal base optical scanner (Figure 9), the chamber size was optimized so as a single device would fit into 2 cm square area. In the actual production system, as shown in Figure 11, since mechanisms for automatic delivery and automatic alignment of sample must be added, the sample holder was installed in the chamber lid to enable reduction of tact time for transfer and positioning of the samples. The chamber lid with holder can be moved vertically by piston cylinder driven by compressed air. This allows the conveyor arm to set the sample, the lid to close, and vacuuming to start in less than 0.2 sec. The prototype system seem to be advantageous since high vacuum level is not required for coating using the AD method; and evacuation and vacuum leak time of the coating chamber are significantly reduced by down-scaling the coating device.

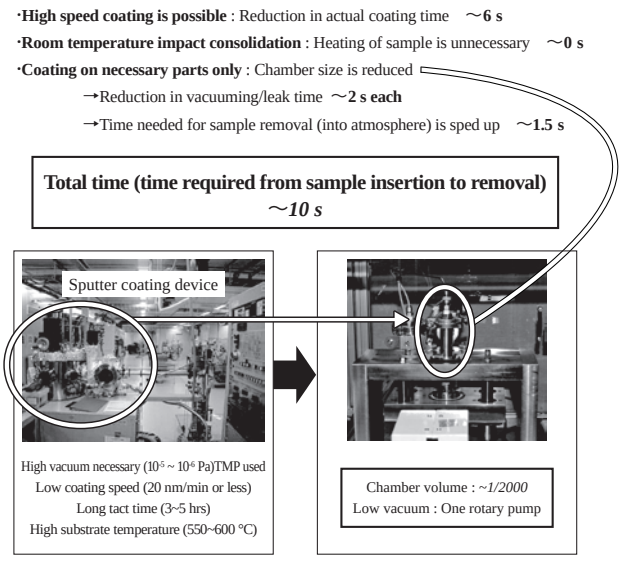

Fig. 11 Improvement of tact time by downsizing.

Since the vacuum level necessary in AD method was about 100 Pa (during coating), high-speed evacuation at low vacuum range was necessary. By designing the whole chamber volume (up to gate valve) at extremely small scale, about 75 cm^3, to match the sample size, coating became possible in about 3 sec after using a single small size rotary pump with 15~20 m^3/min throughput to achieve 2 Pa. Atmospheric pressure after AD deposition was reached in 0.7 sec from about 0.1 Pa. Coating speed depends on the performance of the aerosol chamber. Although it is not satisfactory at this point, a coating rate of around 1 μm/sec can be achieved under current conditions.

In the above design, for coating PZT thick film of 3 micrometers on 5 mm square surface area, time required for the processes of substrate insertion → evacuation → coating → vacuum leak → substrate retrieval was reduced dramatically to about 10 sec, as shown in Figure 12. This revolutionizes the conventional understanding that vacuum process must be done as a batch process, and is a major point in achieving on-demand production.

In the punching process for forming the scanner body structure, 4 progressive divisions were set for mirror, torsion beam, entire scanner frame formation, and positioning holes. 4 micro-press mechanisms punched out the stainless steel

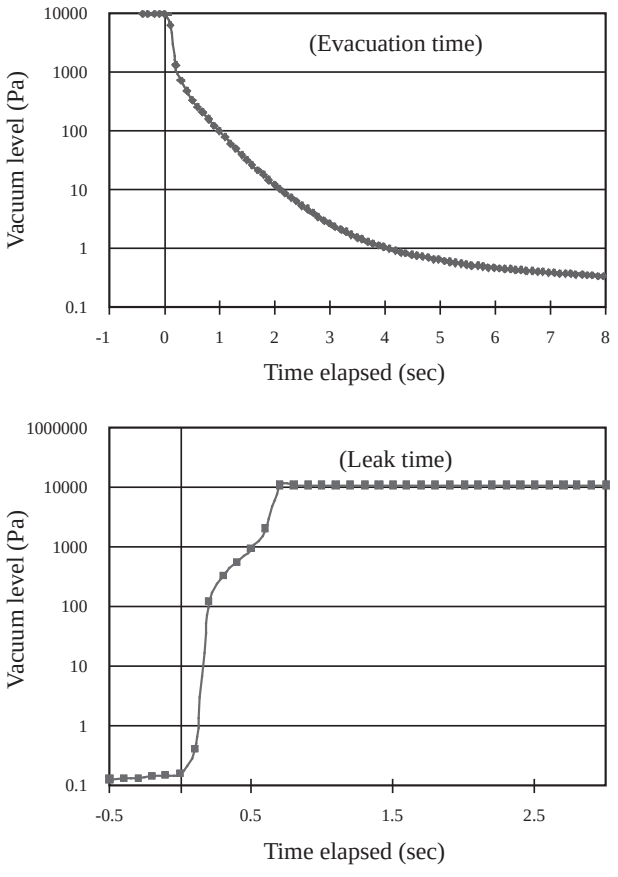

Fig. 12 Speed required to reach vacuum level where coating is possible, and leak time in a small AD device.

hoop material. This construction allowed exchanging the molding parts and selection of several kinds of combinations for manufacturing of scanners with different resonance frequency and different mirror size for relatively low cost production. Prototypes for process unit for small heating processing device and ink jet device for wiring were also created, and we were able to construct a system that enabled manufacturing from material to device. Currently, several revisions and improvements are necessary before the unit can be used for practical manufacturing, but we believe there is an advantage in simultaneous optimization and evolution of manufacturing facility development and device design.

The metal based optical scanner discussed in the previous section was optimally designed and created by trial-and-error using the prototype production system and computer simulation. As a result, production speed of 1 device/min per line has been achieved. This means that a production level of about 20 ~ 30,000 units per month can be easily obtained. By replacing the conventional Si microfabrication facility manufacturing process with the one described above, great reduction of energy consumption, facility surface area and manufacturing time has been confirmed and the reduction in environment load became possible, as shown in Table 1.

5 Summary and future prospect

Maximizing the characteristics of the AD method, we investigated the construction of on-demand manufacturing technology with low environmental load that realizes both high product performance and cost reduction. The AD method is making possible coating at room temperature, has a high coating speed, and allows localized coating of functional materials without the need for etching to achieve the desired pattern. In the investigation of manufacturing of electrostatic chuck and optical scanner, simplification of device structure and manufacturing process, improvement of process tact time, and simplification of process device worked effectively. By reviewing the device design from material level, improved function, cost reduction, and decreased environment load were realized in the manufacturing process. Moreover, increase in as mass production device was obtained, and simultaneous optimization of manufacturing facility development and device design can be achieved. This is an example of the vision of "minimal manufacturing" with least input (resource and energy consumption) yet with high practicality (high productivity, low cost) and maximum function (new function, high performance). Of course, MEMS device used as example here cannot be effectively optimized by introduction of the AD method alone, but large-scale optimization (minimization) is possible for wider use if there are further advances in currently known elemental processes.

In the future, we will continue the investigation of the effect of introducing new processes, while reconsidering the manufacturing process from the material to device levels.

Table 1. Comparison of MEMS manufacturing systems.

	Silicon lithography MEMS factory	On-demand factory
Floor area	300 m^2 (1000 m^2 including ancillary facilities)	10 m^2 (*1/30～1/100*)
Electrical power (kWh/year)	360000	8000 (*1/45*)
Manufacturing time	About 12 min/piece (process time/number per wafer) About 1.2 min/piece (10 per batch)	Designed target value 1 min/1 piece (*1/10～1/1*)
Environmental load	Disposed material such as resist Process gas Cleaning process	Hardly necessary **(big reduction!)**

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Shizuka Nakano
Joined Mechanical Engineering Laboratory, Agency of Industrial Science and Technology in 1989, and has worked on development of micromachine technology using ion injection technology and others. Investigated useful function of material surface. After working at NEDO (New Energy and Industrial Technology Development Organization) in 2001, has been involved in aerosol deposition method, and worked on microgravity experiment and developed on-demand manufacturing technology. Doctor of Engineering from The University of Electro-Communications in 2003. In this paper, worked mainly on development of device for on-demand manufacturing system including small AD device.

Jaehyuk Park
Joined AIST in 2004. Works on practical application research for ultra high-speed micro MEMS scanner and development of on-demand MEMS small-scale manufacturing device for this optical device, by conducting R&D for transparent nano-composite for magneto- electro-optics using AD method for the development of new optical material and for its application to optical device. Completed electronic information engineering course at Graduate School, Toyohashi University of Technology in 2003. For this paper, worked mainly on development of metal base optical scanner.

So Baba
Joined AIST in 2003, after working as researcher of pre-venture business, Japan Science and Technology Corporation. Has worked on development of laser aided aerosol deposition method to create high performance piezoelectric film actuator on metal substrate, which was very difficult to achieve, in NEDO project. Currently working on development of on-demand manufacturing and process enhancement technology using aerosol deposition method. Completed doctorate in material application engineering, Graduate School of Engineering, Osaka University in 2001. For this paper, worked mainly on development of heat processing (laser aided AD method) for on-demand manufacturing system.

Kiwamu Ashida
After receiving doctorate from Graduate School, Chiba University in 1998, joined the Mechanical Engineering Laboratory, Agency of Industrial Science and Technology, Ministry of International Trade and Industry. Based on concept of “micro factory” where “small things are made with small machines,” works on developing prototypes of “small processing machines” such as portable factory. Also works on micro nano-scale machine processing technology for “small machine processing.” In this paper, designed system architecture and delivery device, where production line can be freely constructed and reconstructed by joining small unit cells, in the on-demand manufacturing system. Also worked on micro-press processing cell that was the initial process.

Discussion with Reviewers

1 Overall composition

Question (Kazuo Igarashi)

This paper describes how the AD method and its application will lead to innovation in manufacturing, and it is appropriate for the objective of this journal. However, the subtitle and the content do not necessarily match, and this hinders understanding. I think by selecting an appropriate subtitle, the relationship to low cost and energy conservation manufacturing stated in the title will become clearer.

Answer (Jun Akedo)

It is exactly as you indicated. I revised the subtitle according to your indications.

2 Problems in introduction and practical application of AD method

Question (Kazuo Igarashi)

In the manufacturing of electrostatic chuck, it is stated that by using the AD method, 80% reduction in energy consumption and 1/10 of manufacturing time was achieved, but how is this technological innovation actually used in actual manufacturing line? If it is being employed somewhere, I think you should mention this. If it is not being employed, what are the factors that prevent that from happening?

Answer (Jun Akedo)

As mentioned in the text, major commercialization is about to be started in the plasma corrosion resistance coating material (announced in The Chemical Daily, April 13).

Reduction in process energy consumption and shortening of process time cannot be assessed easily because they are dependent on production volume and number of AD devices installed. Here, we give estimates based on initial facility cost and production volume projected by the company. For energy conservation, it is extremely complicated since other factors such as product yield are involved, so practical use will depend on the final product cost.

Also, for introduction and deployment of new manufacturing process without previous record like our AD method, substantial time must be taken on sample production to confirm reliability, even if it is satisfactory in terms of performance and cost. Therefore, it took time before practical application. The optical scanner discussed here took about a year and a half for durability tests.

3 Relationship to minimal manufacturing concept

Question (Kazuo Igarashi)

In “Summary and future prospect,” you refer to “totally optimized (minimal)” and “drastic optimization (minimization),” but I feel that the meaning of “minimal” cannot be understood

well. If this is referring to minimal manufacturing, I think you should add a note to clarify.

Answer (Jun Akedo)

As you indicate, this research aims for minimization. Therefore I added the sentence: “This is an example of vision of “minimal manufacturing” with least input (resource and energy consumption) yet with high practicality (high productivity, low cost) and maximum function (new function, high performance).”

Hope for *Synthesiology*

— Discussion with Prof. Lester —

[Translation from *Synthesiology*, Vol.1, No.2, p.139-143 (2008)]

Prof. Lester has outstanding original ideas based on plentiful and profound investigations on the role of the industry and academia in the course of innovation. He emphasizes the importance of interpretive approach where the direction of an issue will be cleared by communication, in addition to the conventional analytical approach where a solution is achieved by setting distinct problems. Here we present a discussion with Prof. Lester on the newly published *Synthesiology* which includes scientific papers based on Type 2 Basic Research.

***Synthesiology* Editorial Board**
Interviewer; Naoto Kobayashi (Senior Executive Editor)

Interview of Prof. R.K. Lester by Kobayashi on March 3rd, 2008 at MIT.

(Kobayashi)
Thank you for joining this discussion on *Synthesiology* today, at Professor Lester's office.

Today we would like to introduce our new journal named, Synthesiology, which we launched in January this year. This journal aims to publicize papers not only on analytical basic research, (we call this Type 1 Basic Research), but also on what we call Type 2 Basic Research based mainly on synthesis or integration, and also on product realization research. We are very happy to have this journal and we would like to extend this journal so that it would attract more attention in the world.

My first question is, what do you think of this journal, or what is your impression of this new journal?

(Lester)
I think that it serves a very valuable role. My understanding of the purpose of the journal is that it addresses a type of research that is normally quite difficult to publish for a number of different reasons; one reason is that existing journals often find the motivation of achieving some practical objective not appropriate for them and this is, I think, typically true of academic journals where the objectives have to do with advancing the discipline or advancing the state of knowledge without any particular reference to practical objectives. So that's one reason why publication of this kind of research is different. Another reason is that often this kind of research is carried out in companies or in other organizations where it is treated as being proprietary. The information may not actually be proprietary, but because all of the other work that goes on in that organization is proprietary, it is just assumed that this too should be proprietary, and so it doesn't typically appear in the public domain.

So there are two reasons why this kind of research is typically not published. As I understand it, the objective of this journal is to provide an opportunity to publish this kind of work, so I think it's a very welcome addition to the field.

(Kobayashi)
Thank you. Have you ever seen any similar journals or papers?

(Lester)
I think that it's possible to identify some publications that perhaps serve a similar purpose but they tend not, I think, to be peer-reviewed. There are a number of research organizations that have a particular practical mission, such as the Gas Research Institute or the Electric Power Research Institute (EPRI) in the United States. These organizations publish journals, and the contributions are directed towards a particular practical objective, but I don't think these are quite

the same as this new journal, *Synthesiology*. One of the reasons is that, as I said, the articles aren't typically peer-reviewed. And in some cases also they tend to be less fundamental, less basic in character. So they may be more oriented toward product realization, or service realization or whatever.

(Kobayashi)
Later we would like to discuss more about peer review or reviewers because this is also very important. But, I'd like to go to the second question. We have made some requirements for the paper. Every paper should have some kind of objective toward society, a scenario to realize the objective, and elements of synthesis—this can be taken from Type 1 Basic Research, and the assessment and the future work. And among these, we also selected two main items: one is the scenario, and the other is the synthesis. To make a practical application, the objective and the scenario are very important. The second is the methodology to realize this scenario. We must take things and make a synthesis, and it is very important how to realize this synthesis. This is up to the author's originality. So we selected these requirements for the papers. What do you think of them?

(Lester)
Let me ask you a question before I answer your question. What exactly does "scenario" mean in this context?
When you ask the authors for a scenario, is it that you are really asking them to show how the development they are presenting can be reduced to practice, how it can be implemented -- how to get from here to there, how to get from where the development currently is to the actual use in practice?

(Kobayashi)
Yes, it is just a scenario and not an actual realization.

(Lester)
But might there be another way to say this? The author is asked to provide a sort of roadmap, to show that there is some pathway that could be followed in order to achieve implementation. Is that it?

(Kobayashi)
Yes. President Yoshikawa says that it needs a logical chain.

(Lester)
So each step must be related to the previous one. Now I understand. So now let's get back to your question. These four things (objective, scenario, element and synthesis) are required of the author. And your question to me is what is my thinking about those, how do I think about those things. That's the question, right? So clearly, these items differentiate articles published here in the new journal from a typical article published in an academic journal. In the latter case there may be a statement of objective, but there is rarely a statement of relevance to society, and there is almost never a statement about how one is likely to be able to move the development to practice. The elements, I think, probably do appear in other publications, but the focus on integration is different, because, in most cases, academic journals are organized around disciplines and so integration tends not to be part of the tool kit. And then assessment and future work, I think these maybe are somewhat similar to what appears in existing journals. So I think that the distinctive items here are relevance, scenario, synthesis; and it seems to me that those requirements are going to lead to a different kind of publication, practically speaking.

(Kobayashi)
Whether these are accepted among the researchers or not, that is a problem, right?

(Lester)
For some researchers, they will probably welcome these requirements because they are very much motivated by the desire to produce work that is somehow relevant to society. So I think these items will be received differently by different researchers. Some researchers will look at them and say, "I don't think I have anything to say about these issues. But other researchers will say, "I'm very happy that these items are required because these are things that have motivated me and they describe how I do my research. So I think those requirements will be received differently by different scholars or researchers.

(Kobayashi)
One problem is how to review whether the objective, scenario and relevance are good or not. The review should be objective.

(Lester)
You are suggesting that there may not be an objective standard to apply to determine whether a particular statement of objective or a particular statement of relevance or a particular scenario is of high quality or not. Whereas in the case of a more traditional publication, your point is that you don't have to justify the contribution by its relevance or even by what the objective is because the objective speaks for itself in a traditional journal. If the frontier knowledge has been expanded or extended, then that is a sufficient condition to judge that it is a good contribution, whereas in this case, the criteria for judging whether it is a good contribution may be subjective. But in fact I don't think that's quite true. I think that the judgment of whether an objective is good, or whether something really is relevant, or whether a scenario is a good one—I don't think that these judgments can be made only by people who are working in the same technical field. Actually I don't think they can be made by people working in the field

at all. They can only really be made by practitioners. It's no use asking a theoretical chemist whether a contribution is relevant to the development of, let's say, some industrial advance because that theoretical chemist may not know what industrial development matters or not. In some ways there probably is an objective measure of what's good or what isn't good, but it's not a measure or standard that is necessarily going to be known by researchers in the field. A peer in the same discipline or in the same field may not be able to make a judgment about how good these statements are.

(Kobayashi)
If the reviewer is not in the same field, he or she may be able to look at the objective, relevance and scenario in terms of logic. If it is logically not good then, I think, it is not accepted as an article. An important element is a good chain of logic.

(Lester)
I think you can judge the logic without necessarily having deep knowledge of the field. If the scenario is supposed to consist of logical steps, then I think maybe it's possible to judge the strength of the logic without having deep knowledge of the technical field.

(Kobayashi)
Let's look at an example. Take the environment problem which is very important in the 21st century. To reduce carbon dioxide is a very high priority work and most people will agree that this is a big objective. If the steps to achieve this goal are logical, then the scenario is OK.

(Lester)
So that's an example of a scenario. If I understand you correctly, the ultimate objective here is to see an emission reduction, but to get that you have to do something here, and to get this you in turn have to do something there. One of the requirements that the editors have identified is that the author has to lay out these stages in order to get to objective. Is that right?

(Kobayashi)
If this is logically OK, then that can be acceptable. But, of course, we have many alternatives.

(Lester)
So you want to have what we might call "an existence proof". You want to show that it's possible to get to where you want to be logically.

(Kobayashi)
Also the originality of the synthesis of technology is important. In this journal, we have selected six papers and the individual authors synthesize for the realization of some results, I think, with an originality. But if anyone can easily think of the method then it doesn't have much originality.

(Lester)
It has to be non-obvious -- is that the point? It should not be obvious. If the combination or synthesis is obvious, then it's not a good contribution.

(Kobayashi)
Yes. In this paper—"To the Low Cost Production of Highly Functional Optical Elements" by Dr. Nishii(see *Synthesiology*, vol.1 no.1 p24-30)—Dr.Nishii has proposed the use the mold method of glass, lens or optical components. The old method is not sufficient to make good devices. Imprinting to make some structures on the lens is needed, but imprinting on optical devices has been very difficult. Recently some people in their companies have developed a method, so he joined this mold and imprint methods together in order to make very good optical devices like this. This is a good combination of mold method and imprinting. This is a very original combination.

(Lester)
If I understand this example correctly, it's a case in which the author brought a rather conventional method together with a new method and combined the two things. And the contribution that the author made was to identify the new advance in imprinting and see that it could be combined with a traditional method. So that was considered to be a good contribution. I think there is maybe also a higher level of contribution, one that also involves integration or synthesis, in which the author actually proposes a modification to one or more of the items that are being integrated, so that they actually can be integrated. In other words, the author sees an opportunity to integrate two elements or two components but only if one or both of those components are somehow modified, and the author actually proposes the modification prior to the combination. That might be an even more valuable, original contribution.

(Kobayashi)
In discussing with the authors, I have thought of some kind of different way of synthesis. Maybe you are more familiar with this. My idea is that the first type is, in German, "aufheben", a Hegel thesis, to make a new concept with the combination of the different thesis. The second one is a breakthrough type. There is a very important key technology, like this here, with many peripheral knowledges. But this cannot make good on its own and so, in the process, something is combined to, as shown here, here, here…

(Lester)
And these things are known?

(Kobayashi)
No, but they should be modified. The third is more objective or scenario-driven or strategy-driven type. It might be a little bit different from manufacturing things. These have an equal

weight, but make some integration or combination.

(Lester)
So the contribution here is to identify the elements that are needed to achieve the objective, whereas here the contribution is to develop this new important thing.

(Kobayashi)
I thought these six papers in *Synthesiology* are related with these three types of synthesis. This is my selection and I don't know if it is appropriate or not.

(Lester)
I think this is helpful. But perhaps one can say – although maybe you will disagree -- that all of these things could be done in a Type 1 Basic Research setting, but what differentiates Type 2 Basic Research from Type 1 Basic Research is that in Type 2 Basic Research, you actually start at the end. Or maybe you don't start there but at least you have an idea of some practical objective that you want to achieve, and here, and here, and that motivates the synthesis, whereas in Type 1 Basic Research, I would argue -- maybe you will disagree with this -- that even in Type 1 Basic Research, it's possible to have a synthesis but in that case it's not driven by some practical objective in the world. My understanding of the difference between Type 1 and Type 2 is not that you only have integration in Type 2 and you never have integration in Type 1. I think you can have integration in both cases. But the difference between Type 1 and Type 2, in my understanding, is that in Type 2, it's the motivation for the integration that is different. In Type 2, the reason for the integration is to accomplish some practical objective. So you have to move between the practical objective and the opportunity for integration, whereas in Type 1, you are not motivated by the practical objective. You just are motivated by the opportunity to synthesize or the opportunity to integrate. This is just the way I see this. We can identify a number of areas in Type 1 Basic Research where different disciplines come together: for example, biochemistry. There, you have integration or a synthesis of two disciplines. But what's happening is that the frontier of knowledge is being advanced but not because of a practical objective, but because there are opportunities in the two fields to bring them together. And I think that in the case of Type 2 Basic Research, what's driving the integration is some practical objective. So that's how I see the difference.

(Kobayashi)
I agree with you that the motivation, or driving force or the objectives are different. I think you mentioned something in your book about innovation*, and you make some description on analysis and interpretation. Is there any relationship or similarity?

(Lester)
What is the relation between Type I and Type II research, on the one hand, and the analytical/interpretive distinction, on the other? I think this is not so obvious but still it's possible to talk about this. So let's say we have Type 1 and Type 2 and I think we understand the difference between these types of Basic Research. It's a little bit difficult because the distinction we developed in our book between analytical and interpretive approaches is a distinction that applies to the development of a new product or a new service rather than to basic research. So in order to address your question I have to translate a distinction that was developed for one context into a very different context. I think that perhaps the best way to do it is to say that, in each case, i.e., both in research and in product development, there are only two situations that can arise. In one situation, the problem is well understood and the task is to solve the problem. Maybe it's a very difficult problem; let's say you have a theorem in mathematics that has never been proved, and it might take ten years or it might take fifty years to prove it. But even though the problem is a very difficult one, it is still a well-defined problem that has to be solved. This example of a theorem in mathematics is, I think, a Type 1 Basic Research problem. But you can have situations in which the problem is well understood in Type 2 situations as well. Let's take one of the examples here. Maybe the problem is to establish a measurement scheme for ranking health risks -- that's the problem. So we have to develop a scheme which we can use to compare different kinds of health risks. That's a practical problem. It's a difficult problem but we can state what the problem is and we can work hard at it and maybe

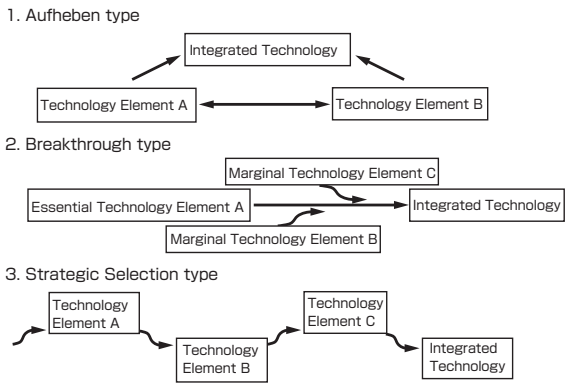

Fig. Different types of synthesis.

Prof. Richard K. Lester

we will solve it. But there's also another kind of setting in both Type 1 and Type 2 research where the problem is not understood -- where we don't exactly know what the problem is. We don't have a problem; we have a 'situation'. Let's imagine that in mathematical research we have a number of branches of mathematics which are addressing a given situation and that maybe they are not consistent with each other. But the different researchers in the different branches of mathematics each see only part of the situation and they don't recognize the inconsistencies in their approach. But when they talk to each other over a period of time, the nature of the problem becomes clear. There is a process that goes on that brings together the different researchers in different fields, in different branches of mathematics. They talk to each other, and over time, they discover that there is actually a problem there. They didn't realize that there was a problem initially. They didn't realize there was a paradox. But as they talk to each other with each one bringing a somewhat different perspective to bear, they discover that there is a problem that needs to be solved. Similarly in Type 2 Research, the situation might be that a company or the scientists or engineers within the company are in discussion with a regulatory body about setting a standard for, let's say, a chemical or something that the company is making, for which the company needs regulatory guidance. So the engineers in the company go to the regulators and say, "we need some guidance here, we need you to tell us what we can do and what we can't do". And the regulator starts to look at the chemical that the company is developing, and he might think, "that chemical is actually quite similar to another chemical that somebody else is developing. And are they similar enough that we should be thinking of them in the same way or in different ways? And a conversation starts, bringing in the other company. And maybe over time, as the companies and the regulator start discussing the situation, they see the possibility of developing a ranking scheme for different chemicals or for ranking the risks from different chemicals. But when they started talking about this, they didn't see that possibility. So this is a very different kind of situation. This second type of situation can apply in both Type 1 and Type 2 Research. Its characteristic feature is that the problem isn't well-defined, and maybe isn't even defined at all at the beginning. And the distinction that the book makes between analytical and interpretive is that the interpretive process is what happens when you move from not understanding the problem at all to having a clear picture of what the problem is. And you encounter these situations in both Type 1 and Type 2 Researches. In both cases you want to move from a situation where the problem isn't well-defined to a situation where the problem is understood. That is the interpretive process. And then once the problem is understood, then you use analytical methods to solve it. And what the book argues is that in innovative organizations it is important to have both processes. It's important to have the interpretive process and it's important to know how to manage it, because it involves a very different kind of management from the management of the analytical process. And it's important not to cut the interpretive process short, not to shut it down too quickly. And so to go back to this situation here, I think the distinction that's made here applies to both Type 2 and Type 1 Basic Researches. We would argue that you need to have both of these things going on, in both cases. So that's why, as I said at the beginning, it's not so obvious how this translates. I think that this distinction difference of analytical from interpretive is relevant in both Type 1 and Type 2 Basic Research. And it's also relevant, I would say, in product realization, because there too you need both interpretive and analytical processes.

Interviewer: Naoto Kobayashi

(Kobayashi)
I have a question. You have shown a diagram of Bohr type, Pasteur type and Edison type for the nature of the research. Does this correspond to some process?

(Lester)
I think it does. I think it is very closely related to what you are talking about. I think Pasteur is really more Type 2 and Bohr is Type 1.

(Kobayashi)
Some people think that in Type 1 the analytical method is more usual than interpretive. Is that so?

(Lester)
No, I think both play a role in each case. This is an important point.

(Kobayashi)
So even in Type 2, we have analytical method and interpretive method.

(Lester)
Yes. But I think the difference is, in the interpretive process in Type 2, you have to bring –we talk about this as being a conversation. The interpretive process is like a conversation. It may not exactly be a conversation, but it's like a conversation. And the difference is that in Type 1 Basic Research, the conversation is between—the question is who

is involved in that conversation. The people who are involved in that conversation in Type I Basic Research are generally within a given discipline or, in some cases like biochemistry, for example, they are in two disciplines. But in the Type 2 case, I think the people who are involved in the conversation, some of them are from scientific disciplines but some of them are from the world of practice. So that's the difference. The difference is who is involved in the conversation.

(Kobayashi)
We would like to consider the reviewers and readers. With Type 1 Basic Research, the readers are within the discipline and most of the readers know where the frontier of knowledge is. In case of Type 2 or in *Synthesiology*, the readers are in many fields, outside the field, of business etc. Also we need different kinds of reviewers. As you said conversation is important.

(Lester)
Also in order to judge the relevance, you need reviewers who can assess the relevance. I think that one of the challenges for the journal is that you have a very broad readership because you have multiple disciplines and you also have multiple application domains. For example, in this first issue, in one case you have health care, in one case you have environmental regulation, in one case you have personal health. So you have multiple application domains, as well as multiple disciplines. So the challenge is how to appeal to readers who might know a lot about personal health care but may know nothing about environmental regulation. And also you've got to bring in people from different disciplines. But that maybe is less important because your researchers are people who actually bring multiple disciplines together. The challenge is that the reader is unlikely to know more than one application domain, and so the question is going to be how is a paper in another application domain going to be for (the reader). Here is health care, and here is environment, to take two examples from the first issue. A reader who knows a lot about health care probably isn't going to know much about the environment and will that reader be interested in articles about the environment? Maybe the thing that would make such a reader interested in an article about the environment would be if the article was really about how to do a certain kind of synthesis. Then it might appeal to readers with knowledge of other domains.

(Kobayashi)
This is what we would like to aim at. Now, the reviewers for this volume are all from inside AIST because people who think about Type 2 Research are very few, but we must extend it to the outer world. Next time we will invite some reviewers from the outside who know about Type 2 Basic Research. In the future, we would like the reviewing process to be done outside AIST like other academic journals.

(Lester)
I think one of the opportunities for this journal, perhaps, is to make it a place for people in companies who are doing Type 2 Basic Research, because there are many people in companies who do Type 2 Basic Research, especially in Japan, perhaps, but also in other countries too.

(Kobayashi)
The final question; even up to now, in private companies, they have many technological reports non-public or made public like in NTT, Fujitsu, Toshiba that are very useful for the engineers. But these are probably not reviewed by peers. This *Synthesiology* aims at the academic. What is the barrier that we must remove?

(Lester)
I think one of the barriers, if you're hoping to attract authors from companies, is going to be a concern about disclosing proprietary work. Another problem or challenge is going to be to bring peer reviewers. I think some of the peer reviews have to be done by practitioners, people who understand the goal. I think that's going to be the key. And some of those people are going to be people in AIST who have a very good understanding of the goal. But if you want to broaden this, maybe you have to bring people from the outside.

(Kobayashi)
Also some of the professors, for example at MIT, or Harvard, or Stanford, know how to solve the real problem and make it in the application field?

(Lester)
Yes, certainly at MIT the culture is one in which people are motivated to work on practical problems. So some academics will have that knowledge.

(Kobayashi)
So the conclusion today is that to make a good journal, especially in Type 2 Basic Research and product realization research, conversation or communication with many fields is important, even with reviewers and with readers. With academic journals, they are also based on conversation among people in many different fields.

(Lester)
Yes. One last point I would make: if this journal succeeds, I think it will make easier the movement of researchers into and out of universities, which I know is an important objective in Japan. If you have a journal that is academic -- a peer-reviewed journal -- but that addresses this Type 2 Basic Research, it might make it easier for researchers in industry or in AIST to move into universities, and back from universities into industry. I think the journal might help to promote migration across that boundary which, I think, is very important in Japan.

(Kobayashi)
You can do that in the United States.

(Lester)
You can do that. Why can we do that? I think partly because it is possible for people in industry to publish in Type 1 Basic Research journals, so there is an opportunity for those people to move back and forth. But in Japan, I don't think it is so common for people in industry to publish in Type 1 Basic Research. It doesn't happen so easily.

(Kobayashi)
Lastly, do you have any future advice for the journal?

(Lester)
I hesitate to offer advice as you have been thinking very hard about this and I don't think I have very much to add. In terms of the strategy, what may be valuable—although I hesitate to say this because it may not be the right thing for you—but I wonder whether a valuable step would be to highlight certain areas of application over others; in other words, to say, "this journal is about Type 2 Basic Research, but we are going to emphasize certain areas of application". I think that the challenge is to move this beyond AIST. That's where, in the long run, you want to go. So the question is how to do that. You can't go directly from the current situation where the reviewing is conducted entirely within AIST to "involving everybody". I mean, in a sense, it's like President Yoshikawa's point about describing a logical progression or scenario. The goal here is to have a general journal that is read very widely. But to get there you will have to move in stages. And the question is how to think about these stages. One way to think about them would be to say that the first step you are going to take when you move beyond AIST is to focus on a particular domain of applications –maybe the environment, or health or energy. Then draw in a readership and a reviewer-ship around those areas and then maybe the next step is to increase the number of application areas. I think the same scenario method you are calling for in the preparation of articles may also be used to plan the development of the journal itself. In some sense, the journal is also a 'product', or the practical realization of a research activity.

(Kobayashi)
Thank you. Today's discussion is very fruitful and helpful to us. And in thinking of the future of Synthesiology, it is valuable. We would like to express our sincere gratitude for joining our discussion.

(Lester)
My pleasure. I'd like to congratulate you on the publication of your first issue.

(*)R.K. Lester and M. J. Piore, "Innovation"; Harvard University Press 2004.

Profile of Prof. Richard K. Lester

Director of the Industrial Performance Center (IPC) and a professor of nuclear science and engineering at the Massachusetts Institute of Technology (MIT). Born in 1954 and graduated from Imperial College (UK). His research focuses on industrial innovation and the management of technology. He has led several major studies of national and regional productivity, competitiveness and innovation performance commissioned by governments and industrial groups around the world.

The Toyota Motor approach from basic research to product realization

— Interview with Dr. Umeyama, General Manager, R&D Management Division —

[Translation from *Synthesiology*, Vol.1, No.2, p.144-148 (2008)]

Toyota Motor Corporation is a world-class automotive manufacturer and unquestionably one of the most successful manufacturers in Japan. The company has been introducing new technology to society without being caught in the conventional concept for cars. Foreseeing the shape of an ideal society, their vision is reflected in the creation of the world's first hybrid automobile. The automobile is a compilation of diverse technologies, and there is hardly any technology that is not used in cars. The R&D Management Division is an integrator of technological development of all automobiles in the Toyota Group and includes the Toyota Central R&D Labs. We interviewed General Manager Umeyama of the R&D Management Division, and asked him about the flow from basic research to product realization at Toyota Motors, as well as his expectations for *Synthesiology*.

***Synthesiology* Editorial Board**
Interviewer; Motoyuki Akamatsu (Executive Editor)

Interview of Dr. Umeyama, General Manager, by Akamatsu on February 14, 2008 at Toyota Motor Corporation.

What does Toyota Motor wish to do?

(Akamatsu)
Seen from corporate side, national research centers and universities mostly conduct basic research. There is considerable lag time before the results of the research reach society and much research is buried and forgotten. Ever since the inception of the AIST, we have been concerned and carried out discussions on how to overcome this"valley of death" or "period of nightmare" in research so our results and development efforts can be put to use in industry. There are many types of research. Although certain kinds of research pursue one topic deeply, it is often necessary to combine several different technologies to create a viable product.

What processes are taken from basic research to product realization at Toyota Motor?

(Umeyama)
First, we face the basic issue of what we are trying to achieve in the automobile business. Not only should we make nice cars; we must consider "environment," "safety," and "comfort" to achieve a harmonious relationship between humans, urban centers, and the automobile. We try to set goals that people may question, "Is that really possible?" Like "a car that cleans the air as it runs," "a car that can go around the world on one full tank," "a car that will never crash," or "car that makes the passengers healthier as they ride." To achieve these goals, we look over all the technologies that are necessary and define the core elemental technology.

The R&D process includes advanced research, preceding development, and product development.
Effort in R&D – Rotating the key man

(Akamatsu)
You mentioned three phases: advanced research, preceding development, and product development. How are they related? I don't think the results of advanced research can be used directly in preceding development.

(Umeyama)
There is an image that advanced research flows smoothly into preceding development, and a product is developed and is shipped out into the world. Actually it is quite difficult. Often, advanced, preceding, and product research are isolated

and on their own. The preceding developer thinks, “Advanced research is complicated, and there’s nothing I can do,” while a product developer may think, “Preceding development can think freely, but can’t come up with a product.” It is important how well these three phases rotate. I think in many cases, we see success by rotating the key man who will act as the core.

I used to do research on gear, so I speak from my experience. I had success by setting up a system where the advanced researchers worked jointly with preceding developers on noise and vibration problems in automobiles. Demand and practical methods were available in the workplace of preceding development. People of research worked hands-on, actually saw what were the problems, and ran experiments to see for themselves. Then they realized when research had to be stepped up here and there or expanded in range, or they saw some different form of application. They learned to pick things up.

When advanced research and preceding development talk to each other, they see the limit and potential of their theories, and I think that allows them to set the course of research.

(Akamatsu)
I see. From the opposite standpoint, solutions to problems that the preceding developers run into may be found by talking to the advanced researchers.

(Umeyama)
Yes. And if the researchers can realize that they can pick up new research topics there, they can appreciate the fact that development is a hotbed of exciting new topics.

(Akamatsu)
Do preceding development and product development have similar relationship?

(Umeyama)
The way things are done when going from preceding development to product development is quite different. Preceding development is a place where people investigate composition to meet the performance criteria set as goal. Since the goal cannot be achieved by thinking only about constraints, preceding development can work on the generation of a breakthrough idea to achieve the goal, and when they get something good, they hand it over to product development.

In product development, the concern becomes production technology conditions, weight, reliability, cost, and requirements as a product. Product development receives the results of preceding development, but in a way in which the receiving side handles the work done by preceding developers, who are emotionally attached to their own accomplishments, is very difficult. The results are not necessarily handed over to product development with all issues cleared, so if a preceding developer hands over a high-level demand saying, “You do the rest,” the product developer will have to suffer. If it is handed over suddenly without sufficiently communicating the relevant development information and without shared passion for development, one’s left to say, “I can’t do that!” So, I think it’s important to have a leader with passion to go from preceding development to product development, work together, encourage people, create the product, and then go back to his place. Therefore, I think it may be useful to rotate people between preceding development and product development on a three-year cycle.

Integrated research at Toyota Motor Corporation

(Akamatsu)
In automobile technology, I understand that product realization is achieved by the integration of several types of R&D. Has there been there any case where a single core technology directly evolved from basic or advanced research into a product?

(Umeyama)
For example, continuing my example of gears, if we wish to put a research result into practice and directly come up with a product, no, that doesn’t happen. A gear is attached to a shaft. If we don’t figure out the appropriate shaft and bearings, it can’t become a product. For automobile parts, I don’t think a single core technology can become a product.

(Akamatsu)
So, integration is necessary.

(Umeyama)
For research that requires integration, in the future I think it will become necessary to conduct physical and mental analyses of how a person riding in a car feels, and to clarify the relationship between the behavior of the driver and the control of automobile as hardware.

(Akamatsu)
I see. It is integration of technologies including the human user.

(Umeyama)
A car was made to be a tool used by humans, but why does it have this form? Is this form optimal for this tool? And, how do we add attractiveness beyond it being just a tool? Those fields have not yet been sufficiently researched. In such an integrated field, perhaps we can come up with different ideas by setting high goals based on “What are we aiming for in the first place?”

Barriers that must be overcome when integrating research results

(Akamatsu)
What do you think is the barrier to integrative research? Is it that people of advanced research intrinsically are unable to understand how people of preceding development see things?

(Umeyama)
When people of advanced research and preceding development talk, they often both think that the other is speaking a different language. For example, it's a battle between a researcher who bring up a research theme and think, "What, this guy doesn't understand this?" and developer who thinks, "He's making things complicated so I won't understand." This is a barrier, if you wish to call it so. I do think that there is a "language" barrier.

But, this is same old story. For example, the moment we see "R&D," I think Dr. Akamatsu and I have different meaning for the term. I don't think we can communicate unless we replace words with objectives and tasks such as "do what with for what and how," rather than relying on one word.

(Akamatsu)
Certainly. Making a roadmap with vision is one way of doing it. By sharing the goal, people will face the same direction and may start talking in common language. I think this may be the way to go.

(Umeyama)
Yes. It's hard to find exact match of words, so we must rephrase expressions several times and check meanings carefully "This means that, right?" and then finally common language is built between preceding and advanced teams. What are we targetting for? How are we doing it? How far are we taking it? If this sort of common understanding becomes eye contact communication like in sports, this is best. Nonverbal communication will then be possible and I think things will be progress much more rapidly.

Become a connoisseur of technology and incorporate technology

(Akamatsu)
The work of a research manager is important in overcoming barriers. Toyota Motor's chief engineer system is very famous. I think it can work for this purpose.

(Umeyama)
When making an automobile, the chief engineer coordinates the fabrication of the various parts and builds the car. For example, we made a good engine. We also have good drive transmission. The chief engineer thinks day and night how they can be combined to make something better. But in practice it's full of conflicts. The engine people make some demand, the transmission people say they can't, and the chassis people say that's impossible. Then, the chief engineer steps in and says, "Well, I understand your problems, but will you please think along this line so we can create a car?" He gets the developers to talk to each other beyond their expertise. He gives his own expertise and says, "If the pressure for this part is going to be 3 times normal, you can design this part assuming 3 times normal pressure." "I can't do that." "Why not?" "We'll have other problems." "Then let's get the engineer to re-design this with different conditions." He offers a type of intermediation.

The chief engineer tries to build a common language by setting up a common discussion. He listens to each pearson's claims, extracts common issues, and then throws back a solution. If it is an engine and a transmission, rather than fitting everything to the engine, he might suggests task of raising the performance of the engine through a system for transmitting torque. Then conflict subsides and collaborations begin.

To make a car today, we need a coordinator that can "fuse various fields together" who can understand each researcher's viewpoint systematically.

(Akamatsu)
In conducting such work, what do you think are the required abilities? Or what kind of human resources are necessary?

(Umeyama)
The person we need is the person who can climb half way up a mountain, but can stop and think that there may be something that can be used even if the final goal is set to be the mountain top. A person who thinks that he can get something better if he climbs a meter higher. A person who thinks how to utilize the results in hand at all times. It is ideal if the person works as a connoisseur to incorporate preceding development with product development. I really wish it would be possible for someone on the coordinating side could become a key person to bring out that sort of ability from researchers. I think a system where the leader says, "Hey, we can use this," and the researcher responds, "Yes, you may be right. Then let's try it." That kind of cooperation is necessary. In most cases, a researcher says, "See, here's something," but rarely does the "something" fulfill the

Dr. Mitsuhiro Umeyama

conditions for production, so he does not get listened to. If he is told, "Considering the total balance, that's not necessary," the researcher will be very discouraged.

I have stood between preceding and product development, and worked on incorporating various technologies to seek a specific solution. I have worked on development of hybrid cars with one main motor. If there were two main motors, one motor could be used to run the car and the other to start-up the engine, but that was not possible, so we added a separate starter system for engine start-up. There was a person who was developing stop-and-go engine (idling stop), and when I heard about that, I came to the conclusion that the deficiency in my system could be covered by introducing and combining this technology, and the combination was able to solve the problem.

Wide-ranging knowledge for connoisseurs; a story for the narrator

(Akamatsu)
That is a connoisseur. How does one learn to become a connoisseur, and what do you think is the education of a connoisseur?

(Umeyama)
I think that a person who knows a lot about diverse area should look at specific technology. In the research report meeting in our company, the researchers are very enthusiastic about talking about their research. People who listen build a story based on what they hear, and think, "This field may become an important focus field for Toyota Motor in the future." I think this is one kind of connoisseurship.

(Akamatsu)
Do you think a connoisseur should have research experience? Or do you think someone can become connoisseur without research experience?

(Umeyama)
Perhaps a connoisseur should have research experience, even in a slightly different field, to understand the behavior and personality of researchers, such as to understand "being totally engrossed in research." On the other hand, a researcher also must make an effort. For others to understand their research, they must learn to tell the "story" of what is the objective, what kind of approaches they have taken, and the results that were learned. I have researchers do a short presentation with a storyline that can be understood readily, and I think that helps others understand the research.

The receiving side must have a wide-range of knowledge to be a connoisseur, while the explaining side must have a story.

(Akamatsu)
I see. But I think there is a danger of being unable to communicate at all if the researcher fails to make a good story. Things may fall in place if there is story that attracts the connoisseur, but if the researcher writes story with the wrong characters, the storyline may get lost. What do you think about this?

(Umeyama)
I think it is important that the objective is clear and the direction of approach is told in simple steps. If the story gets lost, the explainer must work harder to promote the understanding of the listener, but I think the gap will narrow if both the explainer and the listener take time to talk with each other patiently and repeatedly.

On journal Synthesiology

(Akamatsu)
To change the subject, who would be the reader of the journal *Synthesiology* at Toyota? Who would find it most interesting?

(Umeyama)
First, it will be the connoisseurs. I think it will be useful for people who must have knowledge of a wide-range of fields. The journal presents both objectives and the underlying stories.

(Akamatsu)
Yes. We call the final goal the "dream," and how to conduct research to achieve that goal "scenario."

(Umeyama)
It will be very useful if the scenarios showing the development process of a research project are presented as in order and discussed systematically. For example, a certain discipline is working on such-and-such, and its objective is so-and-so. If this process is presented visually, I think I will able to read further into it.

(Akamatsu)
We ask authors to draw diagram of what they want to do, and what are need to accomplish their goals. When people write scenarios, I think they realize where they stand in the process, and the positioning of current results.

Interviewer: Motoyuki Akamatsu

Companies have technological reports that describe technologies that became the actual products, but it seems they are mostly elemental technology. I think an article on how a connoisseur combined technologies is suitable for *Synthesiology*.

(Umeyama)
Stories of achieving success including blockade and detours are encouraging. They serve as a record of a researchers' activities. Such articles are rare. What we emphasize are stories about someone decides to do something, he doesn't succeed with his initial approach, but gives it another try from the other side and succeeds. There is another way of looking at things. It will be great to have such articles.

(Akamatsu)
I think so too. I think it will be great to have article that shows the thinking process of how a person involved in R&D runs into a wall and how they go about solving the problem. For example, a researcher one day realizes that the person next door is working on a research topic that may solve his problem, decides to use it, and is finally successful.

(Umeyama)
I think it will be great to have a story about research done with a clear objective and with feet on the ground. I understand your intent, and I hope the work done at AIST can be widely communicated and will contribute to society.

(Akamatsu)
I think integration and synthesis of technology are mandatory to create automobiles, which are a combination of diverse technologies. Today, I was able to hear very valuable stories about effort as organization and necessary human resource to achieve the goal. Thank you very much for taking time to talk to us.

Profile of Dr. Mitsuhiro Umeyama

Completed masters program at Faculty of Engineering, The University of Tokyo in 1982. Joined Toyota Motor Corporation in 1982. Appointed to Transmission Design Division, worked on design of clutch operation system. In charge of preceding technology for a damper to reduce torsion vibration and development of driveline vibration analysis technology in 1985. Started research on adjustment of teeth surfaces for low noise gears in 1994. Obtained a degree for this research from the Tohoku University in 1997 (Doctor of Engineering). Placed in charge of development of the transmission unit for a hybrid car in 1997. Became general manager of the Technology Management Division in 2005, and manages R&D.

Round Table Talk by Reviewers of the New Journal

Reviewing papers in the new style

[Translation from *Synthesiology*, Vol.1, No.2, p.149-156 (2008)]

Reviewing the *Synthesiology* papers was exciting but hard task for the reviewers because of the new style unseen in the other scientific journals. A round table talk with the reviewers of Volume 1 No. 1 and 2 issues was held to provide frank comments on diverse issues including their impressions on the new journal, the new role of reviewers, the originality of the papers, and the practicality of the requirements to the authors.

***Synthesiology* Editorial Board**

(Kobayashi)
We have asked you to review the papers for *Synthesiology*, the journal for Type 2 Basic Research featuring papers in a new style, and I believe reviewing the papers for this journal has been quite different compared to reviewing Type 1 Basic Research papers. What are the points that you felt most strongly about in doing the reviews?

Impression of reviewing for *Synthesiology*

(Yumoto)
These were original papers for which originality was required, and I found it was very difficult to emphasize originality. It must have been much more difficult for the authors themselves, but as a reviewer, it was very difficult devising ways to bring out originality.

Another point is, I have heard direclty from authors that there were limitations due to patent and joint research conditions with companies, and many things couldn't be written up in the paper. Perhaps we should wait for the full story when the authors are formally permitted to write, but I also felt it was useful to read about research in progress. However, it is difficult to determine originality if the details of technology remain undisclosed.

(Igarashi)
If originality is sought as in Type 1 Basic Research, this journal may be insufficient. The President had said, "There are many things that cannot be written in the journals for Type 1 Basic Research when conducting research along a set scenario. One of the important functions of this journal is to describe that process fully." I felt this was not presented sufficiently. I think the reviewers must emphasize this point with the authors. Of course, the range of what can be described may be limited due to nondisclosure concerns, but I do feel it is necessary to stress this point.

(Ono)
I think the reviewers share the standpoints of both authors and readers. Compared to Dr. Yumoto and Dr. Igarashi, I have a rather optimistic impression. The authors seem to have a driving passion to write Type 2 Basic Research papers. They tried to show their passion here, and I felt they attained it. Talking with the authors, some mentioned, "For the first time I was able to write things that I couldn't in the other journals." This made me believe that authors will be able to show their vision. I may be too optimistic, but I thought we succeeded in showcasing their insights.

I reviewed two papers that did not relate to my own research discipline. In fact, it was my first experience that I read original research papers in disciplines other than my own. In my duty as a reviewer, I more or less forced my way through the manuscripts, but I was surprised that as a reader I could read it more smoothly than I though. I might be so optimistic, but my first impression is that the journal was a success, and I have high hopes for it.

(Mochimaru)

The papers submitted here are quite different in style compared to the ones in conventional scientific journals. I am satisfied with the requirements, and the papers I have reviewed were undertaken with the understanding that diverse styles are acceptable. On the other hand, it's a different story when it comes to whether the readers will accept this diversity. How do we make the readers, who are accustomed to old-style papers, understand the points the authors are trying to make in new-style papers. We must bring around a change in the consciousness and attitudes of readers. We must convince the readers that the new-style papers are also scientific papers, and point out where the originality of the papers lies along the way. To be honest, I think this balance was hard to maintain. Communicating what the authors were trying to say was the hard part.

(Kobayashi)
We placed the section for discussion with reviewers after the paper. What did you think about that?

(Mochimaru)
We received several comments from readers that "the discussion with reviewers was interesting," and I believe it was effective in delivering the message that *Synthesiology* is created by a collaboration between the reviewers, readers, and authors. I sincerely think it is a good plan because we can clearly show the process of synthesizing a scientific paper to the readers.

On the other hand, the reviewers must put in extra effort to read the papers because their comments will be published. If we have two reviewers and one is caught making off-the-mark comments, we must really do our jobs knowing that our names will be published out in open.

(Kobayashi)
In a peer review, the reviewers are usually anonymous, but we disclose our names, and I do feel that increases the weight of our responsibility.

(Ono)
We have received several responses from readers stating that "the discussions with reviewers were most interesting," though I'd prefer if they'd say the papers themselves were interesting. It seems that readers sometimes read "Discussion with Reviewers" before anything else, and if they find it interesting, then they read the main article.


Dr. Kazuo Igarashi

(Igarashi)
I've also heard the comment: "Although the content is difficult and the research is not so-called Type 1 Basic Research, it was very interesting that when a reviewer asked how the author will make changes to parts of a manuscript that were ambiguous, the author responded sincerely in the discussion session."

(Kobayashi)
Perhaps the discussions with reviewers may serve as a bridge between authors and readers.

Shift in role of reviewers: from reviewer to coauthor

(Akamatsu)
Talking about first impressions, I do think the discussion with reviewers is important. Maybe I said too much, but I did say a lot. I made plenty of suggestions, almost to the point of being a coauthor. First, I read a manuscript from the perspective of a reader, and think about what the readers should get out from the article. When I feel that "the paper doesn't say enough," I comment on everything from the structure of the paper to its logic, which is quite different from reviews done in ordinary journals.

The primary objective I have in doing my review is whether "the author can describe a good scenario." Specifically, what was the issue or reason for starting the research, and what was the focus. If there is clear description of what the issues are and what research has to be done in a certain field, I think people from other fields will be able to see that, "The people in this field are thinking this way when they do their research."

(Kobayashi)
I reviewed one paper on optical devices and another on standards in issue no.1, and a paper on materials in issue no.2. Since they were all physics related, the individual elements were clear, and I could readily see the scenario and synthesis of how things were combined to achieve the goal. However, a common problem was since the authors were in the process of product realization, not everything could be written due to nondisclosure agreement with companies, and I found that frustrating at times and I'm sure the authors felt this as well.

Another point is the originality as mentioned by Dr. Yumoto. I saw originality because the papers I reviewed were written by people in similar fields to my specialty. I do feel that people of other specialties may find it difficult to judge the originality of synthesis because the component technology may not be original.

The reviewers of conventional journals decide whether the knowledge presented in an article is truly innovative from the standpoint of their respective disciplines. However, in *Synthesiology* we look at how knowledge can be used, and I felt in this context the role of the reviewers is quite different.

Next, do you think the points that the authors wanted to appeal to in their papers were presented appropriately? As readers, were they useful or interesting and what do you expect in the future?

Useful papers

(Igarashi)
I think there are three points that make the readers feel that a "paper was useful." One is the reader can see a useful scenario as required by the journal. Second, the description is useful in terms of technological content because points that were not written up in Type 1 Basic Research were presented. And third, it is useful to show that AIST is engaging in the new movement.

I reviewed two papers, and I thought the scenarios were developed in a style which would be useful to readers.

(Mochimaru)
I really had no idea how *Synthesiology* was advertised. Suddenly, several partners in joint research said they wanted to read it, so I gave them copies of the first issue. I think they learned somewhere that "AIST put out a new journal." People commented "I read your paper" or "it's pretty interesting." They were not eyeglass people.

As Dr. Akamatsu said, the reviewers are like representative of readers who give advice on how to communicate the message of the paper to a wide-range of people. Although I don't necessarily mean that a paper has to be popular among readers, I think whether the intent of an author is communicated effectively must be checked at some point. As a proposal, we can set up a "designated reader," who doesn't necessarily have to be fixed, and get comments from that person. It is necessary to check whether the intent of the paper is being effectively communicated from time to time.

(Akamatsu)
The "scenario," as mentioned by Dr. Igarashi, is a major element that allows people of other fields to understand papers content more deeply. Another point is whether it is useful to researchers in the field. I expect that when knowledge, which researchers of Type 2 Basic Research maintain as implicit knowledge or things that they figure out among themselves and believe are important in conducting their research, are organized in a thesis form to discuss "why this was done," knowledge presented in such a style may eventually become a part of formal knowledge. By engaging in discussions relating to these issues, researchers may come to realize flaws in their logic. People in the same field can understand the thinking process of the authors involved or how the target was set in progressing to the next step.

We heard only positive comments from the authors, but I think there should be more "awareness" about problems in their own research, such as this was no good or this was not good enough when writing up their research in a paper.

(Ono)
I think authors are aware that. Type 1 Basic Research can be written up as a 100% complete story, but they cannot present a 100% complete paper in this journal for Type 2 Basic Research. The story here is "my first target was this, but we've reached only this level," and such an incomplete paper will not be accepted by the existing journals. I do feel that some authors have come to accept the fact that a paper could be incomplete, while others were unable to write a paper on their results because they could not accept the concept of writing a paper in an incomplete manner.

(Kobayashi)
I did get a similar impression. I said to a certain researcher, "Don't you think you can write a scenario about how your research can help lead to a sustainable society?" but the person responded that can't be written so he'll write only up to a certain point. A scenario is "a chain of hypothesis," as President Yoshikawa said, but I think there's a nature hesitation on the part of a researcher in how much hypothesizing one can do. The readers, on the other hand, want the authors to present a birds-eye view for the 21st century, so I hope the authors will go ahead and do it.

(Ono)
I think such scenarios are discussed hotly within a research group. A research group can't function without discussion of such scenarios. But the results of such discussions remain within the group and don't make it outside. I think this journal is trying to bring such discussions into broad daylight. The reason they never came out before was partly because there was no path for them to do so, but the main reason is there was fear the results may be stolen when disclosed. Such scenarios are an asset of researchers and

Dr. Motoyuki Akamatsu

research groups. This time, the authors spilled out the scenarios in their head for us, and although this is good for society, I was a little bit worried that it might disadvantage the authors who were sincere enough to do it.

(Mochimaru)
Dr. Ono's concern and Dr. Akamatsu's comments are very true to an author like me. I do become aware of things when knowledge is formalized within myself by writing it out. When I write, I can qualify "whether the method used here was optimal or not."

How much can a specific case be generalized? This is something that cannot be stated with confidence. I write a bit more only when the reviewer comments, "How about it?" Therefore in my paper, much is written in the section describing the discussion with the reviewers. It was important to get advice from the reviewer. In that sense, although in a sense it is spilling one's brains out, I feel it is a useful exercise for the researcher to write out their thoughts in an organized manner.

(Yumoto)
Speaking about scenarios, I think biotechnology is slightly different. Rather than a set scenario, it develops from a certain breakthrough. To find the objective of their research, rather than shooting straight at the center of the target, the biotech researchers try for a breakthrough by at first elaborating the periphery of the target, in the so-called a shotgun style. Since it is an emerging field, such individuals may not admit having a specific scenario in mind when they are asked, "Did you start out with that scenario?"

In conventional journals, we wrote as if we aimed at the result from the very beginning, but if we make the future scenario too clear, we can't apply for patent, and that is very difficult.

(Akamatsu)
I think that leads to the discussion of originality. The originality of Type 1 Basic Research is "novelty of individual elements," and it requires a third party to appreciate that originality. From the perspective of Full Research, I think diffusion of science and technology to society is delayed when it is carried out by a third party. That is, there may be problems with the paradigm of evaluating the value of researchers according to the novelty of the individual elements of their research. Until now, the thing that has been most secretly and jealously guarded from others has actually been the process of creating the "thing," and I think hiding this process weakens the driving force for the product to be used in the society.


Dr. Noboru Yumoto

In other words, knowledge must be used by others. If the synthesis process is disclosed to all, the successor can go on to the next step. I think that is one of the values of knowledge. Therefore, I think the steps of synthesis should be considered as originality.

Were the requirements described logically?

(Kobayashi)
Dr. Akamatsu's comment just now refer to the specific requirements for a paper. Were the "establishment of research objective," "presentation of scenario," "selection of elemental technology," "combination of elemental technology," and "evaluation" described logically? Please comment including the practical aspects.

(Ono)
They depended pretty much on the authors. Some authors described every elemental technologies evenly and explained what they did with them, which is what I expected in the beginning, while others, particularly biotechnology researchers, described the main-and-sub relation where one elemental technology was overwhelmingly important so the next steps could be made only by making a breakthrough in that area. And they described how they added a sub elemental technology later to create the "product."

(Igarashi)
Many people looked at the scenario as a backtrack rather than a forecast, and when authors conduct their research, they do not necessarily have the scenario as described in the paper in their head. They ran into dead ends, took detours, and then they picked up the track and marched forward. If we track their routes, it is irregular, but looking at the flow from a larger perspective, I feel the authors went in the direction as described in the scenario.

On the appeal point of the journal, the content of each paper is fine, but seen from the viewpoint of the reviewer, I feel the author should set the main theme. Reviewers may have diverging opinions, and I don't know how to handle this aspect in the future. Perhaps the committee chairman can ultimately dictate what should be.

(Mochimaru)
Since there are two reviewers for each paper, the authors are confused when the reviewers' comments are in conflict.

"What should I do?" I think it will be good to have a principal reviewer who will make the final decision while listening to the comments of other reviewers.

Normally, in submitting papers to a journal, the author thinks, "A reviewer is someone with the power of life and death over my research paper." Therefore, the common practice is to succumb to whatever the reviewer says. The author feels that his/her prose becomes a thesis only if he/she agrees with whatever the reviewer says. This must be changed gradually.

(Kobayashi)
Currently, the reviewers and the authors are acquainted with each other and can discuss things between them, but in the future, we will be receiving submissions from outside AIST and we must review papers of people we do not know. Also when we ask outside people to do the review, we need to have some sort of ground rules. As Dr. Mochimaru suggests, perhaps it is better to have a principal reviewer who can integrate the comments of the reviewers.

(Akamatsu)
In the requirements, I think the most difficult point is to determine "what is the result?" When we hear "result," we tend to write up the result as in Type 1 Basic Research, but it is doubtful whether such a result is the type of result required by *Synthesiology*. We must consider this. Although we still do not clearly, perhaps they must express their results in terms of *Synthesiology*.

(Mochimaru)
There is the matter of "significance of a scientific journal," and it is accumulating *Synthesiology* through the vehicle of journal. Dr. Akamatsu wrote, "Each paper is an archive of case study of *Synthesiology*, and *Synthesiology* is created from that archive." However, from the standpoint of the editor of the journal, it does not happen automatically, and we must make an active effort.

(Ono)
Synthesiological methods are actually present, but I feel we are still far from generalization of the methods. I want to focus on the level of "product" that goes out into society and how the "product" is useful to people.

(Akamatsu)
I think it is not easy to draw the line clearly between Type 1 and Type 2 research. One of the important points is to find value for people who progress from Type 1 to Type 2 Basic Research. We must build a path to encourage people engaging in Type 1 to move on to Type 2 Basic Research.

I think we should present how one can move from Type 1 to Type 2 Basic Research by writing papers in *Synthesiology*.

(Ono)
Perhaps that's what is expected by us. I agree with this totally. I hope the results of Type 2 can be clearly presented, even if they are minor

(Akamatsu)
When we ask, "Please write upon the result of your Type 2 Basic Research," will the author be able to describe it? As mentioned earlier, it is matter of "what is a result?" The result of Type 1 Basic Research is a discovery or invention with great impact. If a discovery has great impact, the underlying knowledge must be useful to other researchers.

When the result of Type 2 Basic Research is explained in the form of a specific product, it may be at the point a product exerts influence on people in society. But if we consider the problem from the perspective as to whether it can have a great impact on other people doing Type 2 Basic Research, there may be some doubt. Even if it is extra work for the the authors, we should ask, "What are your result in terms of *Synthesiology*?".

(Mochimaru)
I think that the journal should ask the authors, and authors and reviewers to engage in a discussion with an open-ended question. We do have a place for an open review, so we can take a moment to think over abstract concepts.

Relationship of papers and companies

(Kobayashi)
Next, let's move to the subject of the relationship with companies when writing the paper. The authors mentioned that there were many things that couldn't be included in their papers due to the patents and know-how nondisclosure agreements. Regarding how this should be dealt with in the future, we can't say much. When the author says, "I can't write about it," I don't know what to do as a reviewer. This problem also arises in hearing and evaluation, and when a researcher says, "I can't talk about it," then we'll have to respond, "Well, then we can't evaluate it."

(Igarashi)
Companies are very sensitive about the disclosure of know-how. I think that this will be a frequent source of questions.

Dr. Naoto Kobayashi

(Yumoto)
If we receive more submissions, I think that part will soften a bit. If papers are submitted and the authors say they want their articles published, we can say, "Can you describe a bit more?" If the author says, "No, I can't do that," then we can say, "We can't publish it!"

(Ono)
Since I don't have that much experience doing joint research with companies, this may be a wild-pitch comment, but there were instances when I was reviewing papers when I felt why they couldn't talk about things. Aren't you overstretching the scope of joint research? If you are relinquishing the originality of your research into joint research and are being limited by nondisclosure agreements, isn't that diminishing yourself as a researcher? I know this may sound unorthodox, but can't anything be done about it?

(Mochimaru)
I've done lots of joint research, but basically I agree with Dr. Ono. My boss has the same opinion. Basically we are public servants at a national institution, and we do not do research for the company. Even if we do joint research with companies, the findings and methods that we obtain in our activities will be eventually publicized. This is the basic premise.

In joint research, though I don't know what others do, I feel there is no precise agreement with the partner about the final academic reporting.

(Igarashi)
In practice, a detailed agreement is made when a contracdt is signed. There are conditions to which we must agree, like waiting a year and half due to patent matters. I understand Dr. Ono's point, but we must make these rules clear, and the researchers must set up the scenario taking the time gap into consideration.

Synthesiology as originality and learning

(Kobayashi)
Now, on the originality of papers, as Dr. Yumoto mentioned earlier, and whether we are heading toward "synthesis as an academic study," which is the heart of the journal. What was the status after publishing issue No. 1? How was it for the review of issue No.2? And what do you think is the general direction?

(Yumoto)
In issue No.1, after more than three exchanges of comments and through revisions by Dr. Ono and Dr. Kobayashi, I realized that certain things that seemed not original to someone in that specialty may be significant as a *Synthesiology* in people of other fields.

Since I didn't have a complete understanding of *Synthesiology*, I initially expected content similar to that of Type 1- Basic- Research- like papers. I feel there is a long way before I can fully understand what *Synthesiology* is and whether the papers fulfill the appropriate requirements. I do think I am making progress.

(Igarashi)
I reviewed two papers. One of the papers was closely related to my specialty, so I read it without considering the synthesiological significance. Now when I look back, I think perhaps I should have considered the synthesiological aspects more. In the other papers, I had strong feeling as a reviewer that the contents should be revised to match the purpose of the journal or to increase its appeal, so I commented frequently, "Why don't you change the paper to follow this direction."

I do feel that authors and readers as well as reviewers will have more awareness for synthesiological concepts as more issues are published.

(Ono)
I think it is not very easy to see where originality lies in the papers. Putting it very bluntly, it would be enough if the authors say, "It was fun writing," and the readers say, "It was fun reading it." There was another point that comes up in talking the authors. To question "Could this paper have been written by another person if he had the same information?" all the authors stated with confidence, "No, this paper could be written only by myself." Perhaps that is the author's originality at the root level. Something that can be written by this author only, that's also fun to write and fun to read.

Dr. Mochimaru Masaaki

Dr. Akira Ono

What else do you need? Sorry for being so simple.

Perhaps that's too wild statement. Then, what's the difference between the papers in the new style and the review papers? Several authors mentioned the review papers aren't expansive enough to write about what was described here in this journal. "If I was writing , I wouldn't put it this way." Also, major companies publish "technical reports" periodically, but these "technical reports" talk about the features of new products in words of science and technology, but they're nothing more. Normally they don't offer the thinking behind the product, failures, or alternatives. Since those are the source of power of a company, they can't disclose them. *Synthesiology* spills that part into open.

There's concern that by spilling it out, won't the researchers lose the source of their power, but I think a community where people can spill out their guts is a good community. When science began to bloom in the 17th century and academic societies were formed, it started with sharing Type 1 Basic Research results among all members of the society rather than keeping it as personal secret. Instead of thinking that the researcher lost something by disclosing their know-how and scenario, researchers were given the honor of exercising influence over society. They praise the researcher's originality. If we can create such a community I think science and technology will take a bigger step forward.

Scientists and researchers in companies should not be limited totally within the framework of the company, and I believe they do desire to contribute to the progress of science and technology. I think it may not be very easy for company researchers to write for *Synthesiology*, but I do hope that they will eventually overcome such limitations.

(Mochimaru)

The basic purpose of a *Synthesiology* paper is to explain the "learning" process such as how the researcher synthesized the story or why they made certain choices. I had difficulty in doing that, but I think I was able to produce a paper that smelled of the author. I think this should be continued with conscious effort. As we archive synthesiological methods, it is very important to describe how the choices were made and how things were synthesized.

I have read other people's papers as well. Although they were not presented at an abstract level, they are original, and I think they are fairly successful for the start of a new journal.

(Akamatsu)

In history, the originality of Type 1 Basic Research was to make a major discovery or an invention, and by publishing them as papers, the patron (or employer) thought, "I think this researcher will find more interesting things."

On the other hand, in seeking originality in building a pathway for research so the result will be useful in society, it is necessary to both show that the author can synthesize things in these ways and is capable of making his/her research result useful in those ways. In *Synthesiology*, there are descriptions of awareness and selection of issues, and I think originality lies in such awareness and selection.

I share Dr. Mochimaru's opinion on synthesiological methods, and I think it will take more time to become abstracted and generalized. But I also think that if it is unattended, it will be a mere pile of knowledge, so we must make an effort to shape them into science.

(Kobayashi)

Although accumulating the knowledge of *Synthesiology*, creating archives, and then analyzing and abstracting them might be the work of an editorial board or AIST, I do believe it is the work of synthesiologists, and I wish we can do it for them. In that sense, I think we have made our first steps towards this goal. In the future, I hope we will have many submissions from industry and overseas as well as within AIST, and people will gradually understand our way of thinking. Thank you very much for today.

Participants of round table talk: Motoyuki Akamatsu, Kazuo Igarashi, Akira Ono, Naoto Kobayashi, Masaaki Mochimaru, Noboru Yumoto.

(February 22, 2008)

Editorial Policy

Synthesiology Editorial Board

Objective of the journal

The objective of *Synthesiology* is to publish papers that address the integration of scientific knowledge or how to combine individual elemental technologies and scientific findings to enable the utilization in society of research and development efforts. The authors of the papers are researchers and engineers, and the papers are documents that describe, using "scientific words", the process and the product of research which tries to introduce the results of research to society. In conventional academic journals, papers describe scientific findings and technological results as facts (i.e. factual knowledge), but in *Synthesiology*, papers are the description of "the knowledge of what ought to be done" to make use of the findings and results for society. Our aim is to establish methodology for utilizing scientific research result and to seek general principles for this activity by accumulating this knowledge in a journal form. Also, we hope that the readers of *Synthesiology* will obtain ways and directions to transfer their research results to society.

Content of paper

The content of the research paper should be the description of the result and the process of research and development aimed to be delivered to society. The paper should state the goal of research, and what values the goal will create for society (Items 1 and 2, described in the Table). Then, the process (the scenario) of how to select the elemental technologies, necessary to achieve the goal, how to integrate them, should be described. There should also be a description of what new elemental technologies are required to solve a certain social issue, and how these technologies are selected and integrated (Item 3). We expect that the contents will reveal specific knowledge only available to researchers actually involved in the research. That is, rather than describing the combination of elemental technologies as consequences, the description should include the reasons why the elemental technologies are selected, and the reasons why new methods are introduced (Item 4). For example, the reasons may be: because the manufacturing method in the laboratory was insufficient for industrial application; applicability was not broad enough to stimulate sufficient user demand rather than improved accuracy; or because there are limits due to current regulations. The academic details of the individual elemental technology should be provided by citing published papers, and only the important points can be described. There should be description of how these elemental technologies are related to each other, what are the problems that must be resolved in the integration process, and how they are solved (Item 5). Finally, there should be descriptions of how closely the goals are achieved by the products and the results obtained in research and development, and what subjects are left to be accomplished in the future (Item 6).

Subject of research and development

Since the journal aims to seek methodology for utilizing the products of research and development, there are no limitations on the field of research and development. Rather, the aim is to discover general principles regardless of field, by gathering papers on wide-ranging fields of science and technology. Therefore, it is necessary for authors to offer description that can be understood by researchers who are not specialists, but the content should be of sufficient quality that is acceptable to fellow researchers.

Research and development are not limited to those areas for which the products have already been introduced into society, but research and development conducted for the purpose of future delivery to society should also be included.

For innovations that have been introduced to society, commercial success is not a requirement. Notwithstanding there should be descriptions of the process of how the technologies are integrated taking into account the introduction to society, rather than describing merely the practical realization process.

Peer review

There shall be a peer review process for *Synthesiology*, as in other conventional academic journals. However, peer review process of *Synthesiology* is different from other journals. While conventional academic journals emphasize evidential matters such as correctness of proof or the reproducibility of results, this journal emphasizes the rationality of integration of elemental technologies, the clarity of criteria for selecting elemental technologies, and overall efficacy and adequacy (peer review criteria is described in the Table).

In general, the quality of papers published in academic journals is determined by a peer review process. The peer review of this journal evaluates whether the process and rationale necessary for introducing the product of research and development to society are described sufficiently well.

In other words, the role of the peer reviewers is to see whether the facts necessary to be known to understand the process of introducing the research finding to society are written out; peer reviewers will judge the adequacy of the description of what readers want to know as reader representatives.

In ordinary academic journals, peer reviewers are anonymous for reasons of fairness and the process is kept secret. That is because fairness is considered important in maintaining the quality in established academic journals that describe factual knowledge. On the other hand, the format, content, manner of text, and criteria have not been established for papers that describe the knowledge of "what ought to be done." Therefore, the peer review process for this journal will not be kept secret but will be open. Important discussions pertaining to the content of a paper, may arise in the process of exchanges with the peer reviewers and they will also be published. Moreover, the vision or desires of the author that cannot be included in the main text will be presented in the exchanges. The quality of the journal will be guaranteed by making the peer review process transparent and by disclosing the review process that leads to publication.

Disclosure of the peer review process is expected to indicate what points authors should focus upon when they contribute to this journal. The names of peer reviewers will be published since the papers are completed by the joint effort of the authors and reviewers in the establishment of the new paper format for *Synthesiology.*

References

As mentioned before, the description of individual elemental technology should be presented as citation of papers published in other academic journals. Also, for elemental technologies that are comprehensively combined, papers that describe advantages and disadvantages of each elemental technology can be used as references. After many papers are accumulated through this journal, authors are recommended to cite papers published in this journal that present similar procedure about the selection of elemental technologies and the introduction to society. This will contribute in establishing a general principle of methodology.

Types of articles published

Synthesiology should be composed of general overviews such as opening statements, research papers, and editorials. The Editorial Board, in principle, should commission overviews. Research papers are description of content and the process of research and development conducted by the researchers themselves, and will be published after the peer review process is complete. Editorials are expository articles for science and technology that aim to increase utilization by society, and can be any content that will be useful to readers of *Synthesiology.* Overviews and editorials will be examined by the Editorial Board as to whether their content is suitable for the journal. Entries of research papers and editorials are accepted from Japan and overseas. Manuscripts may be written in Japanese or English.

Required items and peer review criteria (January 2008)

	Item	Requirement	Peer Review Criteria
1	Research goal	Describe research goal ("product" or researcher's vision).	Research goal is described clearly.
2	Relationship of research goal and the society	Describe relationship of research goal and the society, or its value for the society.	Relationship of research goal and the society is rationally described.
3	Scenario	Describe the scenario or hypothesis to achieve research goal with "scientific words" .	Scenario or hypothesis is rationally described.
4	Selection of elemental technology(ies)	Describe the elemental technology(ies) selected to achieve the research goal. Also describe why the particular elemental technology(ies) was/were selected.	Elemental technology(ies) is/are clearly described. Reason for selecting the elemental technology(ies) is rationally described.
5	Relationship and integration of elemental technologies	Describe how the selected elemental technologies are related to each other, and how the research goal was achieved by composing and integrating the elements, with "scientific words" .	Mutual relationship and integration of elemental technologies are rationally described with "scientific words" .
6	Evaluation of result and future development	Provide self-evaluation on the degree of achievement of research goal. Indicate future research development based on the presented research.	Degree of achievement of research goal and future research direction are objectively and rationally described.
7	Originality	Do not describe the same content published previously in other research papers.	There is no description of the same content published in other research papers.

Instructions for Authors

Synthesiology Editorial Board
Established December 26, 2007

1 Types of contributions

Research papers or editorials should be submitted to the Editorial Board.

2 Qualification of contributors

There are no limitations regarding author affiliation or discipline as long as the content of the submitted article meets the editorial policy of *Synthesiology.*

3 Manuscripts

3.1 General

1) Articles may be submitted in Japanese or English.
Accepted articles will be published in *Synthesiology* (ISSN 1882-6229) in the language they were submitted in. All articles will also be published *Synthesiology - English edition* (ISSN 1883-0978). The English edition will be distributed throughout the world approximately four months after the original *Synthesiology* issue is published. Articles written in English will be published in English in both the original *Synthesiology* as well as the English edition. Authors who write articles for *Synthesiology* in Japanese will be asked to provide English translations for the English edition of the journal.
2) The manuscript should be prepared using a word processor or similar device, and printed on A4-size portrait (vertical) sheets of paper. The category of article (research paper or editorial) should be stated clearly on the cover sheet.

3.2 Structure

1) The manuscript should include a title (including subtitle), abstract, the name(s) of author(s), institution/contact, main text, and keywords (about 5 words).
2) Title, abstract, name of author(s), and institution/contact should be provided.
3) The length of the manuscript should be, about 6 printed pages including figures, tables, and photographs.
4) The title should be about 10-20 Japanese characters (5-10 English words), and readily understandable for a diverse readership background . Research papers shall have subtitles of about 15-25 Japanese characters (7-15 English words) to help recognition by specialists.
5) The abstract should be about 200 Japanese characters (75 English words).
6) The main text should be about 9,000 Japanese characters (3,400 English words).
7) The article submitted should be accompanied by profiles of all authors, about 200 Japanese characters (75 English words) for each author.
8) Discussion with reviewers regarding the research paper content shall be done openly with name of reviewers disclosed, and the Editorial Board will edit the highlights of the review process to about 3,000 Japanese characters (1,200 English words) or a maximum of 2 pages. The edited discussion will be attached to the main body of the paper as a part of the article.

3.3 Format

1) The text should be in formal style. The section and subsection chapters should be enumerated. There should be one line space at the start of paragraph.
2) Figures, tables, and photographs should be enumerated. They should have a title and an explanation (about 20-40 Japanese characters or 10-20 English words), and the position in the text should be clearly indicated.
3) For figures, clear originals that can be used for printing or image files (resolution 350 dpi or higher) should be submitted. In principle, the final print will be 15 cm x 15 cm or smaller, in black and white.
4) For photographs, clear prints (color accepted) or image files should specify file types: tiff, jpeg, pdf…explicitly (resolution 350 dpi or higher) . In principle, the final print will be 7.2 cm x 7.2 cm or smaller, in black and white.
5) References should be listed in order of citation in the main text.

Journal – [No.] Author(s): Title of article, *Title of Journal*, Volume(Issue), Start page-End page (Year of publication).
Book – [No.] Author(s): *Title of Book*, Start page-End page, Publisher, Place of Publication (Year of publication).

4 Submission

One printed copy or electronic file of manuscript should be submitted to the following address:

Synthesiology Editorial Board Office
Public Relations and Publishing Division, National Institute of Advanced Science and Technology(AIST)
Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan
E-mail: synthesiology@m.aist.go.jp

The submitted article will not be returned.

5 Proofreading

Proofreading by author(s) of articles after typesetting is complete will be done once. In principle, only revisions or correction of printing errors are allowed in the proofreading stage.

6 Responsibility

The author(s) will be solely responsible for the content of the contributed article.

7 Copyright

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Letter from the editor

You now have in your hands *Synthesiology-English edition* Volume 1 Number 2. Since the journal was issued, we have received many positive comments and encouragement from readers. In particular, the Discussion with Reviewers section following each paper turned out to be attractive to readers, exceeding the expectations of the Editorial Committee.

As in Number 1, this issue contains six research papers. The readers may quickly notice that the style of the papers are very different each other, since various styles are being tested. The style in describing Type Two Basic Research has not yet been well developed, and we are still at the early stages where variety is being pursued and reviewed. Still some more time may be needed for us to develop an established style.

In the interview section, Professor Lester of the Massachusetts Institute of Technology gives his opinion of *Synthesiology* from the viewpoint of contemporary American science and technology research. As a person who understands well the essence of *Synthesiology*, he makes comments from a stance different from that of the Editorial Committee, and offers rich insight into the future development of *Synthesiology.*

Mr. Umeyama, General Manager of Technology Management Division, Toyota Motor Corporation talks about the R&D process from a corporate standpoint. Private companies certainly also face the problem of overcoming the long gap between basic research and product realization. Although the actual steps taken by companies may differ from those by public research institutes, there are issues common to both. One of the major issues in modern Japan is how to "connect" the R&D efforts of private companies and public research institutes like AIST, and this interview gives us a solution.

In the Round Table Talk of the reviewers, *Synthesiology* is distinctly characterized. I hope that this discussion is informative and instructive for the authors and reviewers of *Synthesiology.*

Editor in Chief
Akira Ono

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