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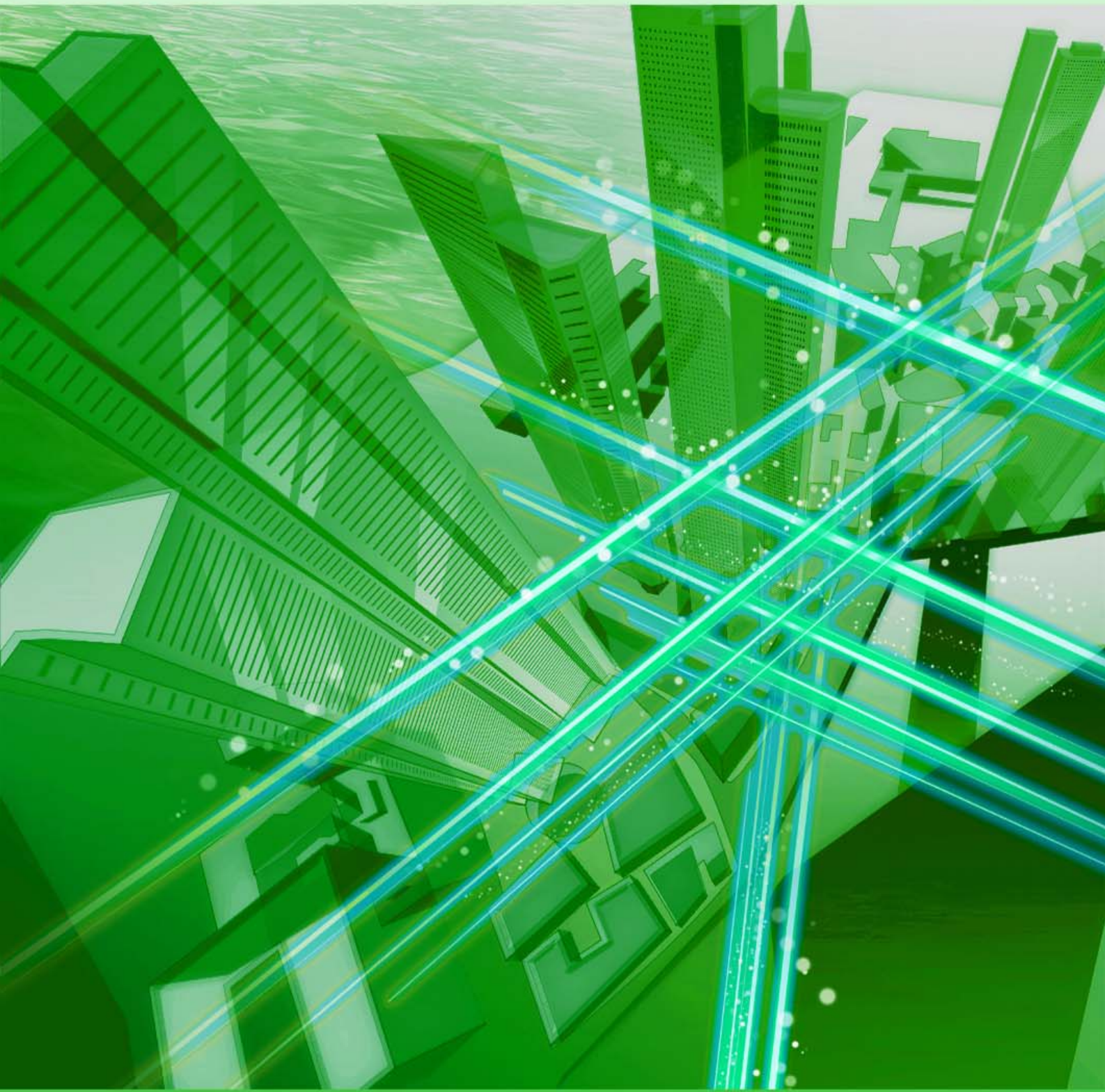

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Improving Productivity of Software Development on the Macchinetta Framework

Hikaru Suzuki

Abstract

The NTT Software Innovation Center aims to provide high quality services in a timely manner while reducing total cost of ownership. To achieve this goal, it is necessary to develop new software rapidly and stably. This article introduces technology for improving the productivity of software development on the Macchinetta framework, which uses the same open source programs as conventional software development.

Keywords: improving productivity, reducing TCO, application framework

1. Introduction

The changes in the revenue structure of the NTT Group over time, as illustrated in *The NTT Group: 30 Years of History*, indicate that voice systems accounted for about 48% of revenue in 2008. In contrast, that proportion had fallen to 21% by 2015, and system-integration-related revenue (including software development) increased from 26% of the total to 46% [1]. The percentage of solutions-related revenue has also increased in recent years, and the work to develop the software to support those systems has come to play a more significant role.

Consequently, by improving the productivity of software development and stably providing high-quality software in a short time period, we will be able to expand services while reducing the total cost of ownership (TCO) and targeting further growth.

At the NTT Software Innovation Center (SIC, hereafter), we have developed Macchinetta as a framework for improving the efficiency of software development. As a result, by improving the productivity of software development as well as eliminating redundant investments and utilizing the created technology in a common manner, we aim to reduce TCO across the NTT Group as a whole.

The Feature Articles in this issue describe our efforts to improve the productivity of software development using the Macchinetta framework [2, 3, 4].

2. Macchinetta

Macchinetta is an application framework targeting enterprise applications. Prescribing the framework of software makes it possible to improve productivity, stabilize quality, and in turn, reduce TCO. In other words, Macchinetta is a software bundle composed of open source software that is used on a global scale, and it consolidates the methods of utilizing each piece of software in that bundle.

In Machinetta, we have collected developmental technology and know-how and consolidated maintenance and support systems in a common framework. Thus, Macchinetta improves the efficiency of software development, stabilizes operations (including handling security weaknesses), and reduces TCO (**Fig. 1**).

Macchinetta is presently being applied to software development throughout NTT Group companies. In fact, almost all new software development projects are utilizing Macchinetta. From now onwards, we will not only apply Macchinetta to new projects but will sequentially apply it to existing systems while also upgrading those systems, with the objective of

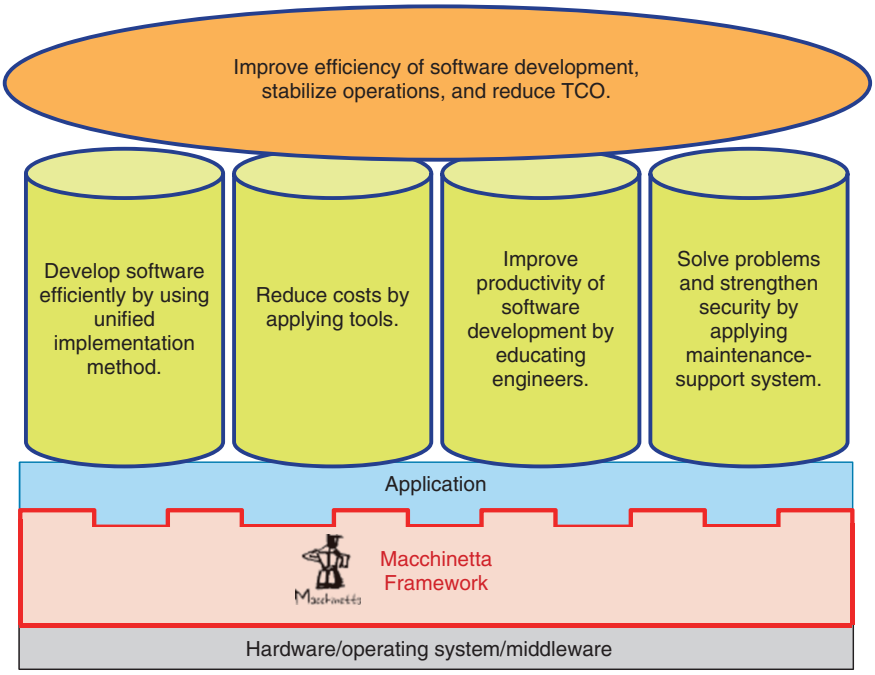

Fig. 1. Benefits of Macchinetta.

reducing TCO across the entire NTT Group.

3. Efforts to improve productivity

To improve the efficiency and stability of software development by applying Macchinetta, it is essential to cultivate human resources with the skills and know-how needed to master Macchinetta. At the SIC, we are preparing study materials by utilizing our experience in developing human resources, and we are striving to nurture experts on Macchinetta across the entire NTT Group and to establish a pool of Macchinetta-related human resources. Furthermore, we will further improve the productivity of software development by establishing tools for supporting software development using Macchinetta and by promoting automation and labor-saving practices. In particular, we hope to improve the efficiency of test processes that significantly affect quality and productivity while advancing research and development (R&D) focused on automation, regardless of the presence or absence of Macchinetta.

4. Efforts to further improve efficiency

The increasingly severe and fluctuating market conditions in recent years mean that it has become necessary to develop services at an ever faster rate. However, at many major companies, so-called *siloization*[*] is continuing, partial optimization has become acceptable, and it is becoming impossible to provide timely and responsive services. In response to such circumstances, we are setting up service development teams that span the business department (Biz) such as the planning and sales department, the development department (Dev), and the operations department (Ops), as well as hammering out services with a sense of urgency and proposing development methods (BizDevOps) that will ensure flexible growth. To ensure cooperation between related departments based on a development style that is both lean and agile, it is essential to ensure smooth communications between those departments. We also propose using data models in order to obtain good communication between departments with differing cultures and complex systems.

5. Future direction

The SIC plans to continue the initiatives described in this article while maintaining acute awareness of

* Siloization: Developing a silo mentality in which people do not share information with other departments.

the status of software development across the NTT Group. Moreover, we will continuously promote R&D aimed at improving the productivity of software development across the NTT Group in a way that will reduce TCO and expand our businesses.

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Hikaru Suzuki

Vice President, Head of NTT Software Innovation Center.

He received a B.E. and M.E. from Waseda University, Tokyo, in 1986 and 1988. Since joining NTT in 1988, he has contributed to the development of the operation and business support systems for various telecommunication services such as PHS (personal handy-phone system), 3G-mobile, Free-Phone, and Next Generation Network. He is involved in developing and maintaining cloud services and software-defined networking services by using open source software such as OpenStack, CloudFoundry, Ryu/GoBGP, and Docker. He was the chair of the Technical Committee on Information Networks of IEICE (Institute of Electronics, Information and Communication Engineers) from May 2010 to May 2012. He is a member of IEEE (Institute of Electrical and Electronics Engineers).

Improving the Efficiency of Application Development Based on the Macchinetta Framework

Gengo Suzuki, Akira Kanamaru, Takuya Iwatsuka, Junya Katada, Satoshi Okada, Seiichiro Mochida, Katsuyuki Natsukawa, Kenji Motohashi, Takanori Hishiki, Takehiko Kaneko, Kenji Tanabe, Hiroshi Izumoto, Miyotaka Sakai, Katsuyuki Yamashita, and Yosuke Iwaki

Abstract

At the NTT Software Innovation Center, we are working to improve the stability and productivity of software development throughout the entire NTT Group by conducting research and development on new software development techniques and making these techniques accessible to developers. This article introduces our work on the Macchinetta framework that we developed in order to produce web-based enterprise applications more efficiently on the Macchinetta tool suite that commonizes development tools, and on the Macchinetta talent pool that provides talented developers to support efficient development.

Keywords: software development, application framework, OSS

1. Introduction

The NTT Group develops software on a very large scale in order to create a diverse range of enterprise applications (enterprise APs) and systems for the management of information about our networks and customers. Increasing the efficiency of this development work is therefore a very important issue. Very little of our software has been developed entirely from scratch or entirely by manual effort in recent years. Development companies and individual developers strive to improve their productivity by making use of frameworks geared towards efficient software development and development tools that allow software to be designed, produced, and tested more efficiently through the use of automation.

However, if individual developers use different frameworks and development tools, they will develop enterprise APs in different ways with different operating methods. This is problematic because developers have to spend a lot of time familiarizing themselves with frameworks, porting systems to new frameworks, and getting disparate frameworks to cooperate with one another. Even if systems are developed using the same framework, operational problems can still arise if the systems use different versions of the framework. Because the NTT Group develops software on a large scale, there are also cases where each company has developed its own set of tools. The inability to share these tools and know-how is a problem with regard to improving productivity.

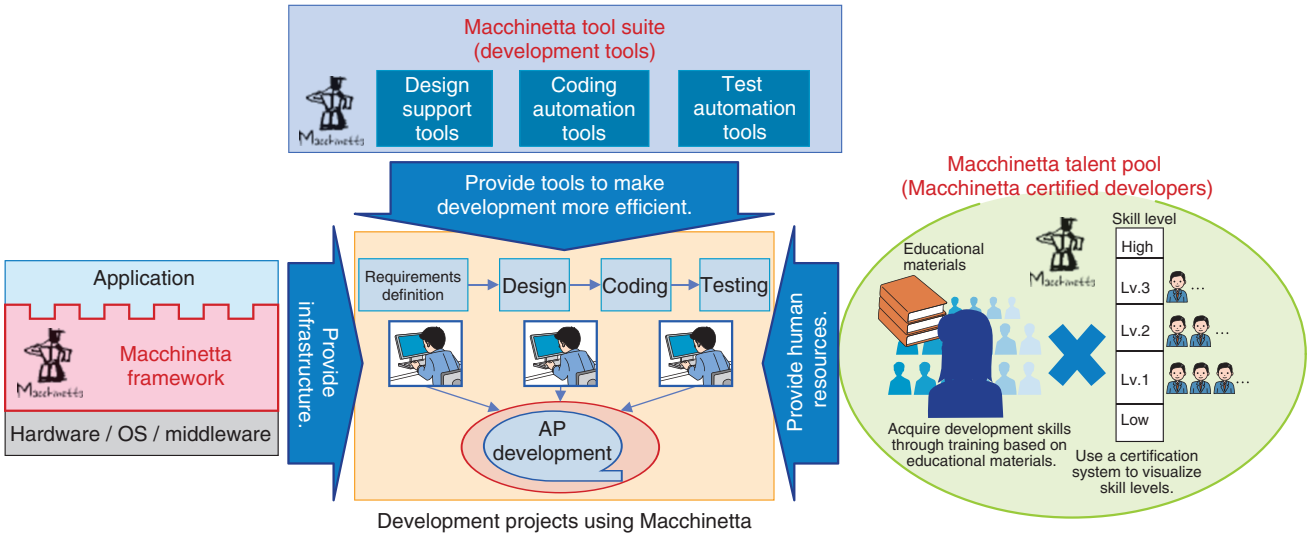

Fig. 1. Efforts to improve the efficiency of application.

To solve these issues, we have developed an application framework to support the development of enterprise APs at NTT Software Innovation Center. Furthermore, to maximize the efficiency of application development based on this framework, we aim to promote the use of a common set of development tools and to cultivate developers who are all skilled in the use of the framework and the tools.

2. Setting up an enterprise AP framework: the Macchinetta framework

When developing enterprise APs, it is becoming common practice to use a software infrastructure called an application framework (AP framework). An AP framework consists of a software framework used by software developers to implement the standard structure of an application using a software development environment consisting of elements such as an operating system, programming language, and middleware. The shared functions of an AP framework make it possible to improve the productivity of software development. Also, by developing systems according to established routines that reduce the differences between individual developers, it is possible to achieve uniform quality. Furthermore, the cultivation of developers who are all experienced with this framework facilitates their understanding of these systems so they can maintain them more efficiently.

However, the following issues have arisen when using an AP framework. First, in order to reap the abovementioned benefits, developers had to learn the established routines for using the AP framework, and had to become familiar with diverse know-how in actual development. In addition, it was necessary to choose from a wide variety of existing frameworks. In particular, even in the NTT Group, there was an issue in that the expansion of similar AP frameworks resulted in duplication of technical development and maintenance costs incurred by each company.

To resolve these issues, reduce the initial training costs, and avoid duplicated maintenance costs, the NTT Software Innovation Center has developed the Macchinetta framework as a new AP framework that can be used in common throughout the NTT Group [1] (**Fig. 1**). The Macchinetta framework uses globally standard open source software (OSS) as a basic principle, and it can be applied to a wide range of different information systems without being tied to proprietary technologies. The Macchinetta framework consists of an OSS stack recommendation model as a common feature that has been verified to be capable of being used stably in multiple APs, and technical documentation to facilitate the smooth implementation of development using the AP framework (**Fig. 2**). By expanding the scope to incorporate online processing, batch processing, client development, and the like, we can use the framework for enterprise APs in a wide range of fields.

The Macchinetta framework has been supplied by the NTT Software Innovation Center to NTT Group companies that carry out system development and has

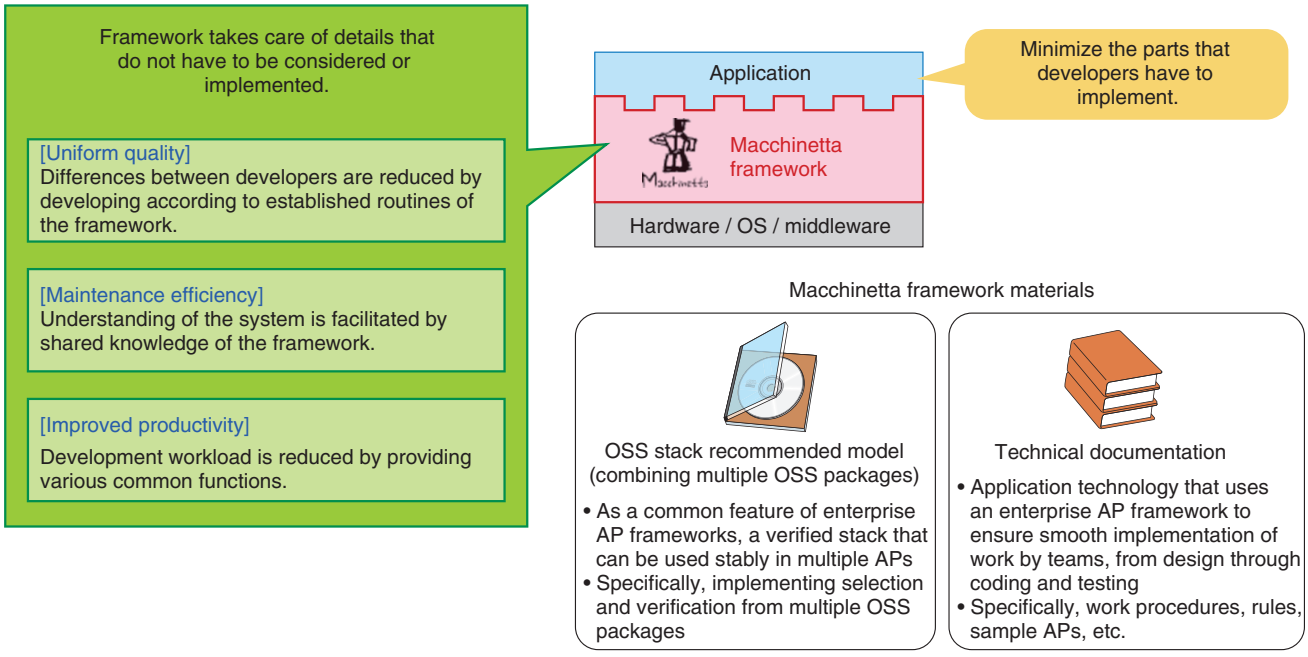

Fig. 2. Overview of Macchinetta framework.

already demonstrated its worth in over 100 projects. In particular, we are not only actively introducing this technology in projects at NTT DATA and NTT COMWARE but are also feeding back knowledge and know-how from these projects in order to promote close cooperative relationships. NTT DATA is deploying the Macchinetta framework with libraries needed for business as the TERASOLUNA Server Framework for Java (5.x) and is applying this framework to large-scale software development in many enterprise systems, which is a major achievement. Also, at NTT COMWARE, we are gaining a lot of experience with applications centered on projects for the NTT Group.

3. Commonization of development tools: the Macchinetta tool suite

In modern software development, various development tools are generally used to improve work efficiency and automate as much of the work as possible in the design, coding, and testing processes. These development tools are often developed separately at various companies, resulting in problems such as duplicated functions and compatibility issues. Even if commercially available technology is used, different companies may use different technologies, resulting in larger training costs for the NTT Group as a whole. We have therefore been working to organize and select suitable development tools to eliminate redundant development efforts and prevent the dispersion of know-how. This selected set of development tools is called the Macchinetta tool suite.

In developing the Macchinetta tool suite, we assessed the effectiveness of commercial tools and existing tools and compiled a list of the development tools that should be adopted. We also compared the functions of these development tools in detail and checked them for duplicated functions. On this basis, we set up the Macchinetta tool suite by deciding whether or not to adopt these tools and continue with their development. An overview of the types of development tools included in Macchinetta and each tool's role in the software development process are presented in **Table 1**. In this way, we were able to prepare development tools to support every step from design to coding and testing, and to make these tools available throughout the NTT Group.

These development tools make it possible to achieve benefits such as improved productivity over a broad range of products, although the characteristics and/or conditions of the products to which they are applied mean that it may not be possible to achieve the desired effect. Therefore, while anticipating advances in development techniques, we will also continue to examine, integrate and develop tools,

Table 1. The Macchinetta tool suite (partial list).

Tool	Target process	Overview of tool
UI design support tool	Design	Integrated development environment that automatically produces source code, settings files, and design documents from UI design information
Automatic code generation tool	Design - coding	Automatic generation of source code from business logic design information
Unit test code generation support tool	Unit testing	Automatic generation of unit test code and test data for source code
Integration test case generation support tool	Integration/system testing	Automatic generation of integration test case list
Continuous integration support tool	Unit - integration/system testing	Automation of repeated build/testing/deploy cycles, support for continuous integration
Source code diagnostic tool	Coding - unit testing	Discovery of memory leaks and other inherent issues in source code
Test execution automation tool	Integration/system testing	Automation of test execution involving the use of UIs
DB access code creation support tool	Coding	Input support for generation of DB access codes

DB: database
UI: user interface

collect and share know-how on the use of these tools among NTT Group companies, and provide feedback through the development of tools that make the greatest possible use of this know-how.

4. Development of human resources to make use of common techniques: the Macchinetta talent pool

The use of a common set of techniques has major benefits in terms of ensuring the availability of human resources. Before these techniques can be used in common, however, it is necessary to have specific technical personnel allocated to each technique. This can make it difficult to ensure that technical personnel are available during busy seasons, resulting in higher development costs, and can also result in development companies becoming entrenched in the use of particular techniques. However, if common development techniques such as frameworks and tools are provided as an infrastructure as described above, then it should be possible to reduce the cost of technical education and make it even easier to secure the necessary human resources. The environment for the education of talented individuals with this common set of skills is called the Macchinetta talent pool. We are working to support the cultivation of this sort of talent pool.

As a part of this initiative, we are working to prepare educational materials relating to these common techniques. An effective way of cultivating high quality developers is to provide them with hands-on access to the frameworks and other technologies in order to learn by building things. However, developers currently have to learn by extracting the required information from large amounts of information such as ordinary commercial primers and web pages, which is a time-consuming and inefficient process. Also, the number of developers assigned to a single development project may run into the hundreds, and training them is no easy task. Therefore, to solve this problem and improve the efficiency of our human resources, we prepared educational materials for the Macchinetta framework.

The Macchinetta educational materials are targeted at beginners with just a basic understanding of Java and are constructed in order to provide a combination of basic instruction and hands-on experience with programming exercises. These materials pick out commonly used functions and arrange them for maximum educational benefit in order to provide a plain description of the recommended implementation methods and rules, thereby facilitating rapid learning. By preparing a hand-made selection of exercises and solutions, we made it possible to gain practical knowledge through simulated development experience. This made it easy to train the human resources needed for Macchinetta (**Fig. 3**). These educational materials are made available to every company in the NTT Group and are used as educational programs for companies involved with development projects using the Macchinetta framework, thereby contributing to a large increase in the efficiency of education.

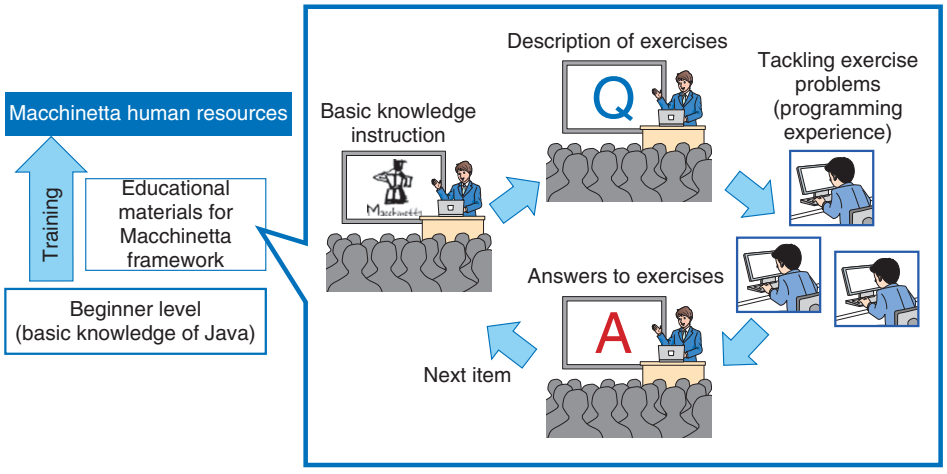

Fig. 3. Educational materials for Macchinetta framework.

5. Future prospects

The environment surrounding software development is evolving every day. By taking advantage of the system infrastructure offered by cloud services, it is becoming unnecessary these days for developers to build their own system infrastructure. However, it is necessary to adapt to a wide variety of client environments with diverse user environments, terminals, operating systems, and browsers. Furthermore, it is expected that application technology will be developed for technical areas with a higher level of difficulty than system development. We therefore aim to continue with research and development (R&D) aimed at expanding the applicable range and operating environment of frameworks and tool suites in order to achieve higher productivity. Also, by modifying these environments, we will further elevate their importance and the opportunities for porting systems to new frameworks and environments. We believe that it will become important to prepare procedures and tools for improving the productivity of migration.

The Macchinetta infrastructure consists of various OSS packages, but in order to provide higher-quality support and improve the reliability of its frameworks and tools, we are actively contributing to the improvement of these OSS packages. In addition to improving quality by providing patches to fix bugs, we are also conducting R&D together with the OSS community to provide new functionality. In particular, we plan to work together with the other NTT Group companies to actively contribute to Spring [2], which is an essential part of the OSS framework.

To cultivate human resources, we are investigating the preparation and operation of a Macchinetta developer certification system. This certification system will make it possible to clearly visualize developers and their skill levels, thereby facilitating the marshalling of human resources.

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Gengo Suzuki
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.
He received a B.S. and M.S. in mathematics from Tohoku University, Miyagi, in 1988 and 1990, and a Ph.D. in computer science from the University of Electro-Communications, Tokyo, in 2013. He joined NTT in 1990. His research interests include database design, multi-database systems, graph data management, and software engineering. He is a member of the Information Processing Society of Japan and the Institute of Electronics, Information and Communication Engineers.

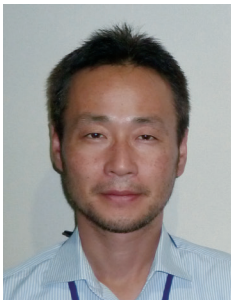
Akira Kanamaru
Senior Research Engineer, Supervisor, Software Engineering Project, NTT Software Innovation Center.
He received his B.E., M.E., and Ph.D. from Tohoku University, Miyagi, in 1996, 1998, and 2001. He joined NTT in 2001. His research interests include computer networks and software engineering.

Takuya Iwatsuka
Researcher, Software Engineering Project, NTT Software Innovation Center.
He received a B.E. and M.E. in computer science from Nagoya University, Aichi, in 2011 and 2013. He joined NTT in 2013. His research interests include programming language theory, program verification, and software engineering.

Junya Katada
Researcher, Software Engineering Project, NTT Software Innovation Center.
He received a B.E. and M.E. in computer science from Tokyo Institute of Technology in 2003 and 2005. He joined NTT COMWARE in 2005. He moved to NTT in 2016. His interests include software engineering.

Satoshi Okada
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.
He received a B.E. and M.E. from Toyohashi University of Technology, Aichi, in 1993 and 1995. His current research interests include software engineering.

Seiichiro Mochida
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.
He received a B.E. in science and engineering from Waseda University, Tokyo, in 2002 and an M.E. in engineering science from the University of Tokyo in 2004. He joined NTT in 2004. His interests include software engineering.



Katsuyuki Natsukawa
Senior Research Engineer, Supervisor, Software Engineering Project, NTT Software Innovation Center.
He received an M.E. from Nara Institute of Science and Technology in 1996. He joined NTT in 1996. His current research interests include software engineering.

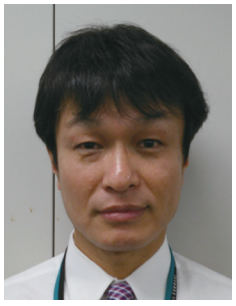
Kenji Motohashi
Manager, System Engineering Headquarters, NTT DATA Corporation.
He received a B.E. in computer science and an M.E. in communications and integrated systems from Tokyo Institute of Technology in 2003 and 2005. He joined NTT DATA in 2005. He is engaged in developing thin client systems, cloud computing systems, and application frameworks.

Takanori Hishiki
Manager, System Engineering Headquarters, NTT DATA Corporation.
He received a B.E. in computer science and an M.E. in communications and integrated systems from Tokyo Institute of Technology in 2003 and 2005. He joined NTT DATA in 2005. He is involved in developing thin client systems, cloud computing systems, and application frameworks.

Takehiko Kaneko
Research Manager, Center for Applied Software Engineering, Production Engineering Department, System Engineering Headquarters, NTT DATA Corporation.
He received an M.E. in industrial engineering from Aoyama Gakuin University, Tokyo, in 1997. He joined the Public System Division of NTT DATA in 1997 and developed a large-scale trading system. He was also involved in developing automated tools. He is currently in charge of R&D and deployment of automated tools including the TERASOLUNA Suite.

Kenji Tanabe
Manager, System Engineering Headquarters, NTT DATA Corporation.
He received a B.E. in electrical engineering from Gunma University in 1988. He joined NTT DATA in 1989. His current work involves technical strategies and public relations in the field of software engineering.

Hiroshi Izumoto
Manager, System Engineering Headquarters, NTT DATA Corporation.
He received a B.E. and M.E. in information engineering from Hiroshima University in 1986 and 1988. He joined NTT DATA in 1989. He is currently engaged in developing technical strategies and working in public relations in the field of software engineering.



Miyotaka Sakai
Manager, SE Department in Core Technology Quality Management and Engineering Division, NTT COMWARE CORPORATION.
He joined NTT in 1985. His main interest is studying best practices for software development projects in order to improve software development methods.

Katsuyuki Yamashita
Manager, SE Department in Core Technology Quality Management and Engineering Division, NTT COMWARE CORPORATION.
He received a B.E. and M.E. in communication engineering from Osaka University in 1997 and 1999. He joined NTT COMWARE in 1999. His main interest is improving the efficiency of software development.

Yosuke Iwaki
Manager, SE Department in Core Technology Quality Management and Engineering Division, NTT COMWARE CORPORATION.
He joined NTT in 1990. He has contributed to the development of the software development environment. His main interest lies in the engineering of software development tools.

Test Automation Technology to Promote Early and Frequent Releases of Software at Low Cost

Haruto Tanno, Morihide Oinuma, and Katsuyuki Natsukawa

Abstract

There is growing demand to speed up the software release cycle while holding down costs in order to rapidly deploy services that meet the changing needs of end users. Considerable interest has been focused on technology for software testing, which accounts for a large share of total development costs, to ensure a certain level of software quality. In this article, we introduce some concrete measures at NTT for supporting test design and verification of test results in software testing.

Keywords: software testing, test design, verification of test results

1. Introduction

Software development is divided into processes, as illustrated in **Fig. 1**. Software errors not detected in the testing phase go out to end users in the release, so testing is clearly very important to ensure the quality of the software. As long as testing is done manually, however, it will be extremely costly. User needs and software/hardware development of the operating environment have been evolving at an ever more rapid pace in recent years, and this requires early and frequent releases of new or revised software to meet these needs (**Fig. 2**). To maintain quality through repeated software release cycles, regression testing must be done to make sure new portions of software—including portions implementing new functions and new operating environments—do not have an adverse effect on existing software capabilities, and this testing of legacy capabilities whenever software is released is also extremely costly.

In order to pursue software development that constantly improves upon quality, cost, and delivery (QCD), the NTT Software Innovation Center is researching and developing technology that contributes to a set of test automation tools as part of the

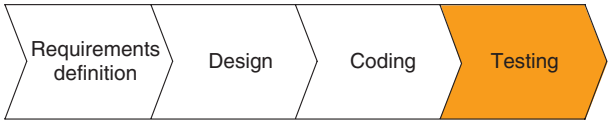


Fig. 1. Software development process.

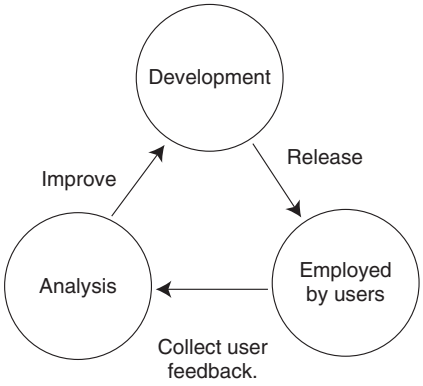


Fig. 2. Feedback loop.

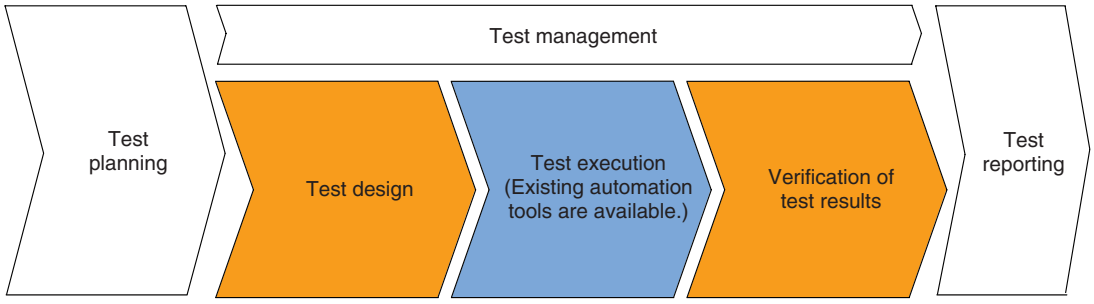


Fig. 3. Testing procedure.

Macchinetta tool suite [1]. The idea is to promote test automation that performs tasks by machine that were previously done manually.

2. Current state of software testing support

The objectives of software testing are to verify that software has been implemented according to the design and specifications, and to reduce the number of defects. The testing process mainly consists of five tasks: test planning, test design, test execution, test reporting, and test management (**Fig. 3**). In test planning, issues such as the time frame and allocation of resources for testing are decided based on the overall development plan. Test design involves clarifying the various tests that must be done, designing test cases comprehensively, refining specific test feasibility procedures for each test case, and creating scripts for automatic execution. In test execution, test data are input for each of the test cases, the software is run, and test results revealing how the software behaves for each of the test cases are recorded. These results are then referenced against verified test results to ensure the software behaves according to design. In test management, management of the state of test execution is carried out as needed, and the test plan is revised if necessary. When all tests have been executed, the results are summarized in test reporting, and the process is complete.

Three of these test processes are especially important tasks: *test design*, *test execution*, and *verification of test results*. Once test cases are produced in the test design, the tests must be implemented precisely with no missing test cases so they can be repeatedly used not only as new tests but also as regression tests in cases where software is patched or improved. Test execution and verification of test results must be carried out repeatedly against all legacy functions when dealing with software enhancements and new operating environments, and the burden increases exponentially as the scale of software increases. Therefore, these three tasks are areas in which the effects of automation are significant for maintaining software quality, cutting costs, and implementing early and frequent releases.

Considerable progress has been made in automating unit testing used to verify the functional operation of small individual units making up software, but automation has made little headway in dealing with integration testing of larger software programs combining multiple modules that include user interface (UI) screens or in dealing with system testing to catch system-level errors.

A number of tools have become generally available in the development workplace for automating integration testing and system testing. One example is SeleniumWebDriver, which automatically executes a web application test based on a prepared test script. However, we note that currently, test design and verification of test results still involve a considerable amount of manual labor. While tools supporting the test design of some functional testing are available, there are major barriers to introducing these tools in the development workplace. Obstacles include the need for testing staff to have specialized knowledge of the tools and the testing technique that the tools use, and the need to write descriptions in an unfamiliar language. In addition, verification of test results requires a great deal of visual inspection by technicians to ensure screens are displayed correctly and so on, and manually checking a large number of test trials one by one is extremely costly.

3. Research vision

With the goal of improving the QCD of test processes,

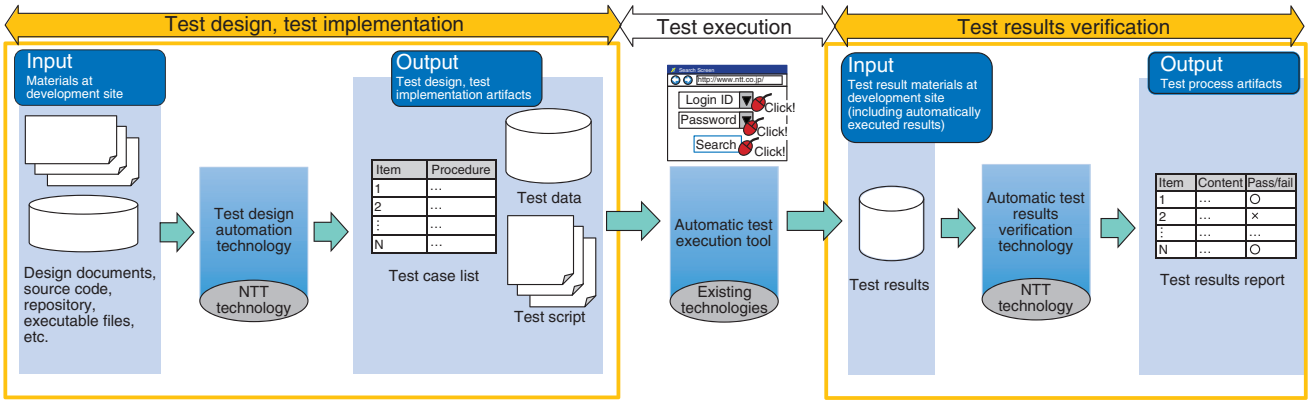


Fig. 4. Research vision.

our vision is to automate all testing during and after integration testing from test design to verification of test results, as shown in **Fig. 4**. We highlight the following two noteworthy features of this approach:

(1) Automating test design using design documents, source code, executable files and other materials available at the development worksite means that everything needed for the test execution—test case list, test data, and execution script files—is automatically generated. This effectively generates tests without errors or omissions at relatively modest cost.

(2) Any problem or error in the test execution results for each test case (application screenshots, etc.) is automatically detected. This markedly reduces the amount of visual verification work, prevents omissions from occurring, and thus improves the quality of applications.

In the following sections, we introduce two tools for automating the test design and verification of test results: the integration testing design support tool *TesMa* and the UI layout test support tool *ULTDiff*. We discuss these tools in the context of an enterprise application featuring a front-end web application developed using the Macchinetta framework.

4. Integration testing design support tool: TesMa

In order for end users to input data in a field on a web application screen, we must ensure that the software behaves as designed no matter what data are entered in the field. For example, if the correct input in the field must be a 10-digit number, the test design must test for correct entries such as “0123456789” but also test for the full range of potential incorrect entries: “012345678a” (violates the numerical requirement), “01234567890” (violates the number of digits requirement), and “01234567890a” (violates both the numerical and number of digits requirements). It is challenging to implement such a test design without errors or omissions even with highly skilled technicians, and the cost can be excessive.

To resolve this issue, we developed the integration testing design support tool called TesMa [2] that automatically generates test cases and test data needed for integration testing enterprise applications from the software design documents (**Fig. 5**). The latest version of TesMa goes beyond generating test cases and test data to automatically generate execution scripts to automatically run the test cases and test data. TesMa has the following features:

(1) The input for the tools is a set of design documents written according to set descriptive rules. These documents are the results of the design process, which is part of the existing development process. It thus has the advantage of being easy to introduce into the development workplace.

(2) The tool generates a comprehensive set of test cases, test data [3], and executable script files [4] based on processing patterns and input data variations. This helps to prevent omissions from occurring in manually created test designs and also generates the test data required to execute each test case, making test execution much easier.

These features of the test tool reduce the cost of integration testing, while maintaining software quality

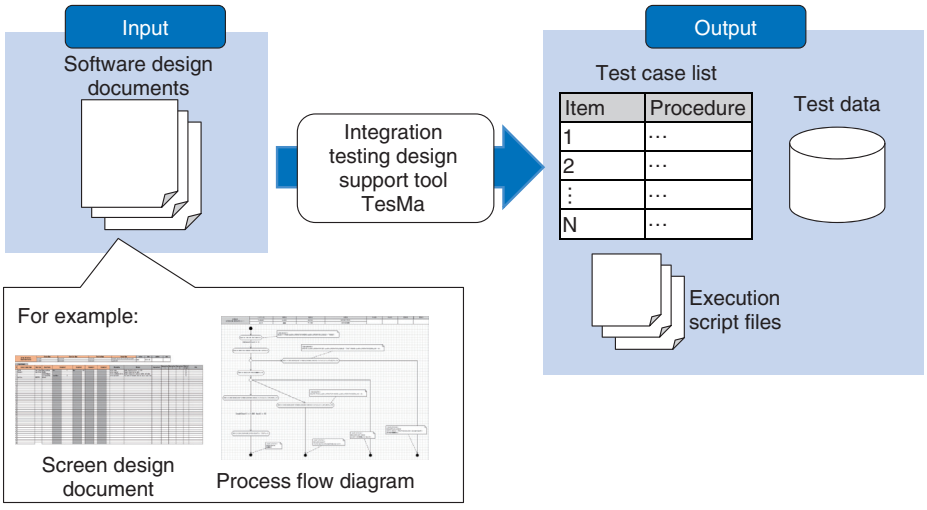


Fig. 5. Integration testing design support tool.

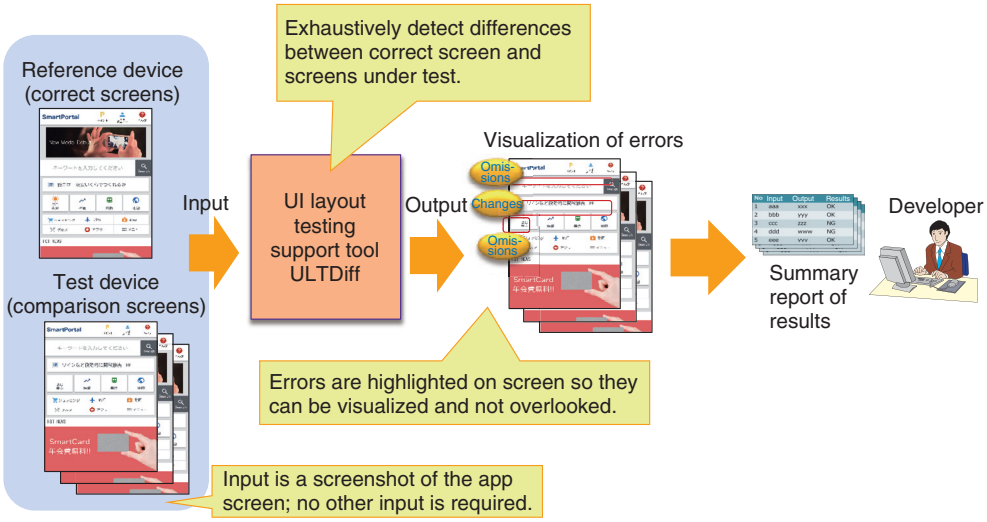


Fig. 6. UI layout test support tool.

through a comprehensive test design.

5. UI layout testing support tool: ULTDiff

Web application testing is done to ensure screens on various types of client devices—smartphones, tablets, and personal computers—display correctly for operating systems (OSs), browsers, and other applications. The test results must also be verified. For example, one might find that screens are displayed correctly on some devices, but buttons have been pushed off screen on other devices. There is an enormous range of terminals available, new model smartphones are constantly being introduced, and OSs are frequently updated. This makes it extremely cumbersome and time-consuming to visually inspect each and every application screen for errors when verifying test results.

The ULTDiff tool addresses these problems, as shown in **Fig. 6**, by automatically detecting missing or displaced screen elements such as buttons. This not only greatly reduces the amount of work required to

visually check for errors across the enormous range and variety of application screens but also catches errors that might otherwise be overlooked, and it improves the quality of applications. The ULTDiff tool has the following features:

(1) ULTDiff reduces the cost of manual detection and prevents omissions by exhaustively detecting the differences between a correct screen and screens under test.
(2) It assists people to effectively decide whether or not each detected difference is an error by highlighting differences on a screen.
(3) It can be applied to many kinds of applications and can be easily introduced to the development process because it only needs screen images as input and does not depend on specific implementation technology.

The combination of these features greatly reduces the amount of work involved in detecting errors and omissions when testing applications under development on a diverse range of client devices and when testing recently released applications on new model devices. Moreover, when revising or adding new functions to applications, ULTDiff can be used for regression testing to make sure the older programming still works with the new changes. ULTDiff significantly reduces the man-hours associated with each release and thus makes it possible to implement rapid release cycles.

6. Future development

TesMa technology has already been adopted in over 100 software projects by NTT Group companies domestic and foreign, and the tool's ability to maintain excellent quality through comprehensive test design while cutting costs is becoming apparent at NTT development worksites. Meanwhile, ULTDiff has been made available to several NTT Group companies, and we continue to refine the tool based on feedback from the development sites, with plans for a general deployment in the near future.

In the future, we will be less reliant on massive design manuals supporting the waterfall development approach and will move toward test design support based on existing resources such as source code for a wide range of development processes. Without depending on a specific development process, we remain actively involved in research and development that helps all of the development worksites. Building on the QCD gains made so far, we are committed to steadily advancing software research and development in the years ahead.

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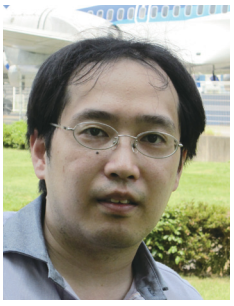


Haruto Tanno

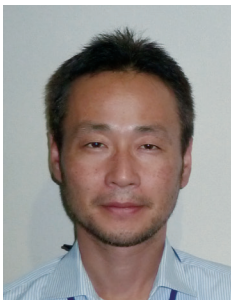
Researcher, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. in computer science from The University of Electro-Communications, Tokyo, in 2007 and 2009. He joined NTT in 2009. His interests include programming languages and software testing. He received the Super Creator Award from the Information-technology Promotion Agency in 2008, paper awards from the Information Processing Society of Japan (IPSJ) in 2009, 2013, and 2016, and the President's Award from NTT in 2016. He is a member of IPSJ.

Morihide Oinuma

Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. in electrical engineering from Keio University, Kanagawa, in 1984 and 1986. He joined NTT in 1986. His current research interests include software engineering. He is a member of IPSJ.



Katsuyuki Natsukawa

Senior Research Engineer, Supervisor, Software Engineering Project, NTT Software Innovation Center.

He received an M.E. from Nara Institute of Science and Technology in 1996. He joined NTT in 1996. His current research interests include software engineering.

A Quick Software Development Method for Improving Competitiveness of Services

Satoru Aihara, Masayuki Inoue, Akio Jin, Yoshinori Furukawa, Takako Tanaka, Nagisa Sekiguchi, Eiichi Oka, and Keitaro Horikawa

Abstract

Environmental changes surrounding our society are becoming more uncertain, and therefore, the development of services must be more flexible than ever. To adapt to such an environment while continuously receiving feedback from the market and our customers, we urgently need to switch to iterative and incremental software development. This article presents an analysis of problems concerning responses to changes in the environment, with a focus on devising effective methods for developing software. First, as an alternative to conventional software development methods, we introduce BizDevOps—an approach that enables rapid development through unified teams. Then we introduce a framework as an alternative to re-engineering, which takes several years. Specifically, we explain a re-engineering model in which multiple *One Team* groups simultaneously develop software in an iterative and incremental manner by working together with other teams while each team shares the same concept model.

Keywords: lean and agile, BizDevOps, early-phase analysis

1. Introduction: BizDevOps

We discuss in this section the concept of BizDevOps and describe ongoing efforts related to its development.

1.1 Competitiveness, speed, and company culture

Globalization and technological innovations have resulted in an environment surrounding business markets that is intensifying in terms of competition to rapidly get products to market (speed of product development). Innovative companies are shortening the time taken to develop services, whereas companies applying entrenched conventional development methods are finding it difficult to release products in an agile manner. For example, the conventional approach typically takes one year to develop new services to full specification and release them with top quality. By the time a product is released, the market may no longer need that product, and as a result, the risk of not getting timely feedback increases (**Fig. 1**).

In the vicious circle of being unable to sell products even if they are made, there is a danger that employees will lose motivation, strains will be put on the organization, and competitiveness will rapidly deteriorate. At present, many system integrators and businesses that develop their own in-house systems use the conventional waterfall approach to development, in which progress flows steadily downward through the different development phases. Although developers are frequently aware that they should adopt a faster way of doing things, it is not easy to do so while expecting to earn profits in the conventional way

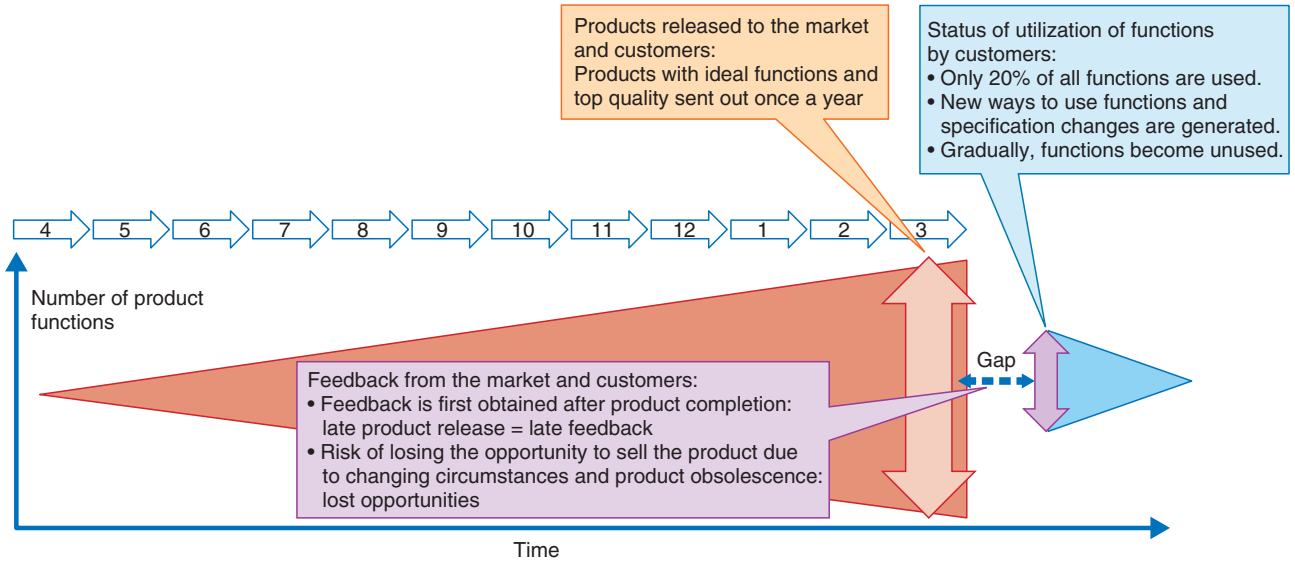


Fig. 1. Traditional service development and utilization status.

because the current situation does not alert them to a sense of impending danger. The track records of successful organizations, and their rules, culture, and customs have actually become factors that obstruct new efforts, and innovative changes are fraught with tremendous problems.

1.2 Necessity of *One Teams* sharing their thinking in a lean and agile way

The concept called BizDevOps was proposed as a means of responding to changes in the business market. The objective of BizDevOps is to foster cooperation among business departments (Biz) such as the planning and sales departments, development departments (Dev), and operations departments (Ops) in order to produce superior services that can adapt rapidly to change. We have formed an approach called *One Team*, which refers to a unified team sharing a common aim to overcome institutional hurdles such as that explained above. This approach is designed to adapt to changes in the business environment and to respond to the market quickly by identifying only functions that are actually used based on *lean thinking*, namely, omitting useless designs and implementations that go unused (such as documentation and duplicated work) (**Fig. 2**).

Typical ways to shorten the development period are to apply concepts such as continuous integration and DevOps and to utilize open source software (OSS). To further speed up product development and achieve a development speed on a par with competitors, BizDevOps can be used to regularly obtain feedback from the market as to whether or not we are heading in the right direction—ranging from the planning stage of new services to hypothesis testing of business and technical problems. Through regular cooperation between Biz and Dev, a new concept can be created, and prototypes can be implemented rapidly.

Whether this concept is correct or not can be determined by applying a way of thinking based on test marketing. Test marketing is done by releasing the product quickly onto the market (from Ops) and seeing how users respond to it and then gathering feedback. The Biz team then analyzes the feedback to determine whether the project (hypothesis) was a success or not. In addition to applying this kind of lean thinking, we must also apply *agile thinking*—namely, considering the ever-changing external environment, upgrading specifications, quickly creating concepts and operational software deemed acceptable by the market and gathering feedback about them from customers, deepening our understanding, and applying shrewd modifications—as an effective measure for team building to closely connect the Biz, Dev, and Ops parts of a One Team. As for what is more difficult about BizDevOps in comparison to DevOps, we can simply presume that it is more difficult to achieve mutual understanding among three groups with differing values than it is to do so between two groups with differing values.

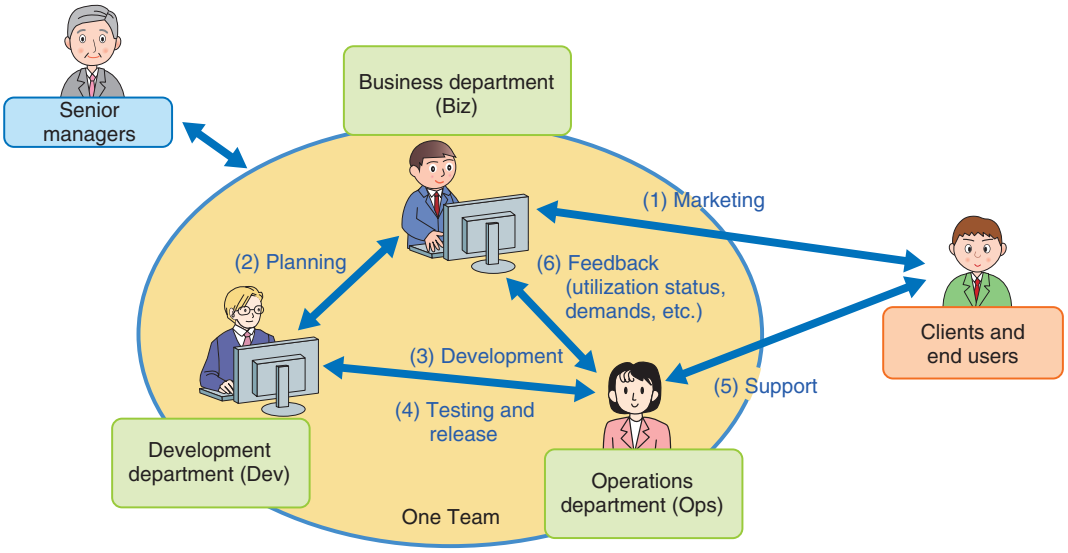


Fig. 2. BizDevOps and One Team.

1.3 BizDevOps

The BizDevOps concept is based on the Scrum way of thinking [1]. Scrum is an iterative and incremental software development approach. It involves cooperative work between people serving in three roles: the development team, the product owner, and the Scrum master. This Scrum way of thinking is extended to include the Biz, Dev, and Ops departments. To build teams that combine players with differing sets of values and cultures from the Biz component as well as the Dev and Ops components, it is essential to attain even more self-organization. Here, self-organization refers to a state in which one's best level can be autonomously mobilized under the environment in which each person is placed. It is a state under which self-motivated deeds are done naturally; everyone does their best to achieve mutual understanding and cooperation from other team members in order to accomplish the objectives of the entire team. Forming a One Team in which each member of a mixed team based on BizDevOps is self-organized makes it possible to substantially improve the success rate of projects.

We are focusing on the start-up stage of projects as the first step in adopting BizDevOps and testing and proposing effective measures for building self-organized One Teams that will have a significant effect on the success or failure of projects. While referencing self-organization and team building based on Scrum, we aim to create mutual understanding among the three representatives in each team and to rapidly change their mindset from the conventional approach (usually the waterfall method) to the new approach.

As a tangible action of this first step, we perform Scrum trials in virtual projects. By looking at how we behave when conventional methods no longer fit, how we choose tasks spontaneously (tasks are not assigned to us), how we ease friction and increase mutual understanding, and how we look back on ourselves (using the KPT (Keep, Problem, Try) method [2] framework that helps us organize and process our behavior), we analyze how we behave when we are self-organized by objectively acknowledging our behavior.

Teams that went through the Scrum trials acquired a lot of knowledge. Later on, they held workshops to teach other teams who needed to learn the knowledge they had acquired. The workshops are condensed into a maximum of ten days and involve not only typical classroom lessons and on-the-job training but also efforts to instill the mindset and skills needed for lean and agile software development. All team members actively participate in a workshop while building up and exchanging know-how in their own team. Thus, the aim of the workshops is to achieve agile team-building that drives a smooth transition to actual projects (**Fig. 3**). Moreover, the teaching team members find out more information and reach a deeper understanding through the efforts passed on to other teams; consequently, this self-organized team-building achieved through repetition can grow and expand.

For those with experience in waterfall development,

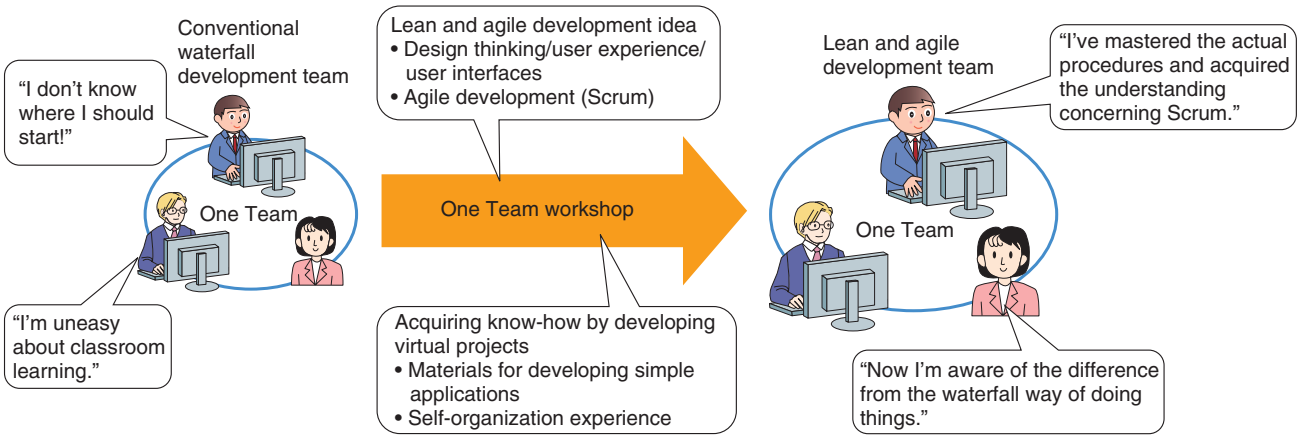


Fig. 3. Depiction of One Team workshop.

switching to a lean and agile thought process involves some confusion and resistance. However, by comparatively analyzing that different experience based on real-life experience and shifting one's thought process in accord with the essence of the know-how acquired, participants derive practical methods that help to formulate an understanding that is a great deal more agile than zero comprehension. Team members who can fully and effectively apply their strong points (including the beneficial aspects of the waterfall approach) are brought together, and methods for quickly starting up a One Team are established.

2. Applying lean and agile thinking to large-scale development

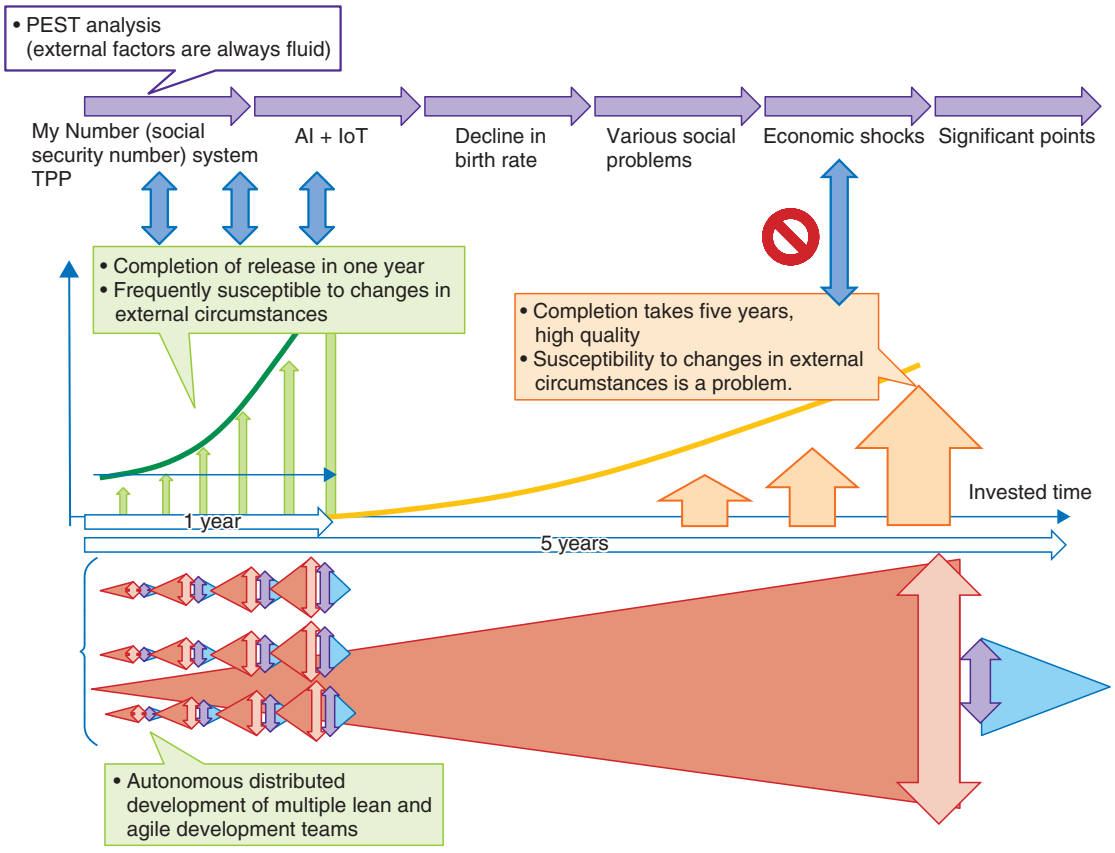
If a project manager in charge of developing an information system were given a task to complete a project that would normally take five years (estimated five years of manpower) in only one year, what methods would he/she use? Such a project would take more time to complete if the design was complicated. However, the longer it took to complete, the less users would be interested by the time the initial detailed design was developed and the product was released onto the market. It is therefore necessary to come up with measures to maintain the interest of users (**Fig. 4**). For a large-scale system to maintain its high added value, we need a new method to quickly review the system.

Hereafter, we describe a framework for linking the lean and agile way of thinking ascribed by the above-mentioned BizDevOps approach and a way of thinking called conceptual data modeling [3], which has been successfully applied to development of large-scale re-engineering.

Differing teams from the Biz, Dev, and Ops departments eliminate duplication and nonconformity between subsystems operated by each team and utilize conceptual data models to understand the *holistic* information (i.e., the big picture) needed to support the development and operation of the system after setting up One Teams. The data model used in this case is an autonomously aligned conceptual model.

2.1 Linkage of autonomously aligned conceptual model

We propose methods to implement large-scale development in an extremely short time in order to quickly adapt to changes in the external environment. In concrete terms, a system under development is divided into subsystems of suitable scale, and multiple teams (one for each subsystem) develop each subsystem in an iterative and incremental manner in parallel. Instead of devoting a long time to designing everything exactly and rigorously, self-organized One Teams are promptly set up, and each team carries out their own development autonomously (but in parallel with the others). Each small independent team develops their partial systems while receiving feedback from concerned users, and this process may speed up the software development. Related users are Biz and Ops (which evaluate and accept functions) as well as other Dev teams in related fields. Fine-tuning is necessary to make sure each subsystem conforms to the others, and efficient communication between the One Teams is essential to do this fine-tuning. Accordingly, a protocol for sharing the autonomously



AI: artificial intelligence
IoT: Internet of Things
PEST: political, economic, social, and technological
TPP: Trans-Pacific Partnership

Fig. 4. Differences between proposed method and waterfall method.

aligned conceptual model (hereafter, simply "the model") was established in order to oversee the big picture (i.e., the whole system) in a short time and plainly comprehend the work of other teams.

The model succinctly clarifies the key concepts of the whole system and the relationships between them, and it is therefore effective because it enables each team developing their own subsystem to work together to: (i) determine pointless duplication, (ii) determine complicated relationships, and (iii) specify areas to be independently managed. An example of detecting overlapping structures in data (*bad structure* detection) (**Fig. 5**) is explained in the following subsection. In general, the people who oversee an entire large-scale system are limited to a few skilled hands. Even so, the application of the model to show holistic information in this manner means that information can be shared rapidly in appropriate amounts. As a result, communication between parallel teams becomes efficient and well suited to simultaneous parallel development.

2.2 Supporting transformation from *bad* to *good* structures

Let us suppose that the whole system is separated into n individual regions (subsystems and development teams). Ordinarily, there are many dependence relationships between n subsystems. In the course of autonomous development, it is likely that interfaces (IFs) between subsystems will be frequently modified. It is thus necessary to pay attention to such modifications, thereby placing a considerable load on each development project. Accordingly, elements that require monitoring of changes to IFs between systems and maintenance of consistency are given over to tools. These tools provide overviews of an entire

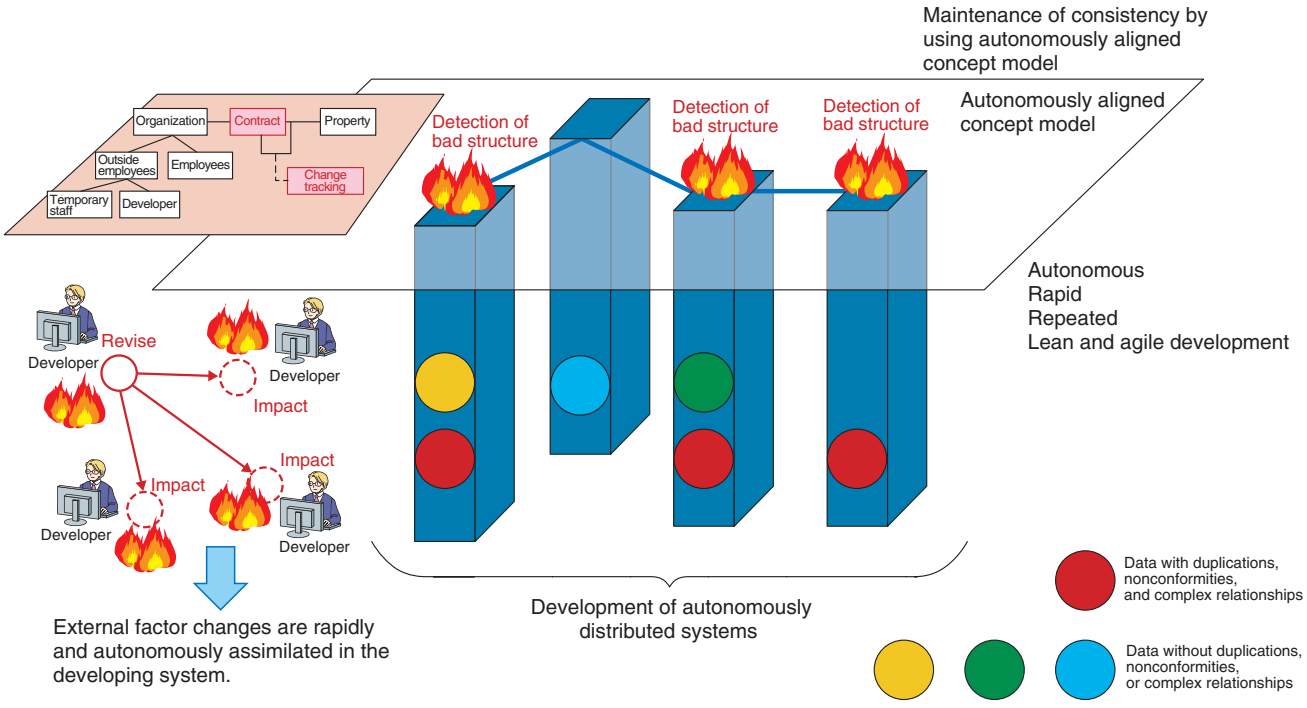


Fig. 5. Lean and agile development utilizing autonomously aligned concept model.

development project for each development team, monitor nonconformities (bad structures) between divided subsystems, and support transformations to consistent states (good structures).

Examples of bad structures are relationships involving duplication of concept model structures, nonconformities, discrepancies, and complications, as shown in **Fig. 6(a)**. In contrast, a concrete example of a good structure is a simply organized structure that is compatible with the concept model, as shown in **Fig. 6(b)**. We prototyped a function for supporting transformation to good structures by automatically detecting bad structures from this overview as a design tool (Fig. 5). By reducing workloads by having the developer orchestrate workloads between workers, each team can concentrate on the development work in their autonomous region, which will improve work efficiency.

Moreover, before and after developing the model transformation of bad structures to good ones, we prototyped a function for estimating initial running costs and evaluating designs. This function makes it possible to rapidly spot nonconformities between data models of the interior and exterior of subsystems and to continuously maintain conformity of the whole system while carrying out the parallel development of each subsystem in a lean and agile manner. The reduction in the initial running costs before and after eliminating nonconformities can be estimated, and that estimate can be effectively utilized as information necessary for making decisions.

3. Concluding remarks

BizDevOps—a development approach used by businesses for analyzing their adaptability to changes in the external environments and for speeding up development through the establishment of One Teams—was described in comparison with the conventional approach. Furthermore, we proposed a method for rapidly coordinating development teams while receiving feedback from the external environment and customers as an alternative to re-engineering for traditional large-scale systems, which requires a long development time.

The main purposes of this proposal are threefold: (i) to increase the speed of development to rapidly adapt to changes in external environments; (ii) to broaden methods for detecting internal and external changes and accommodating those changes into the development scheme; and (iii) to rapidly create services based on the detection results and strengthen

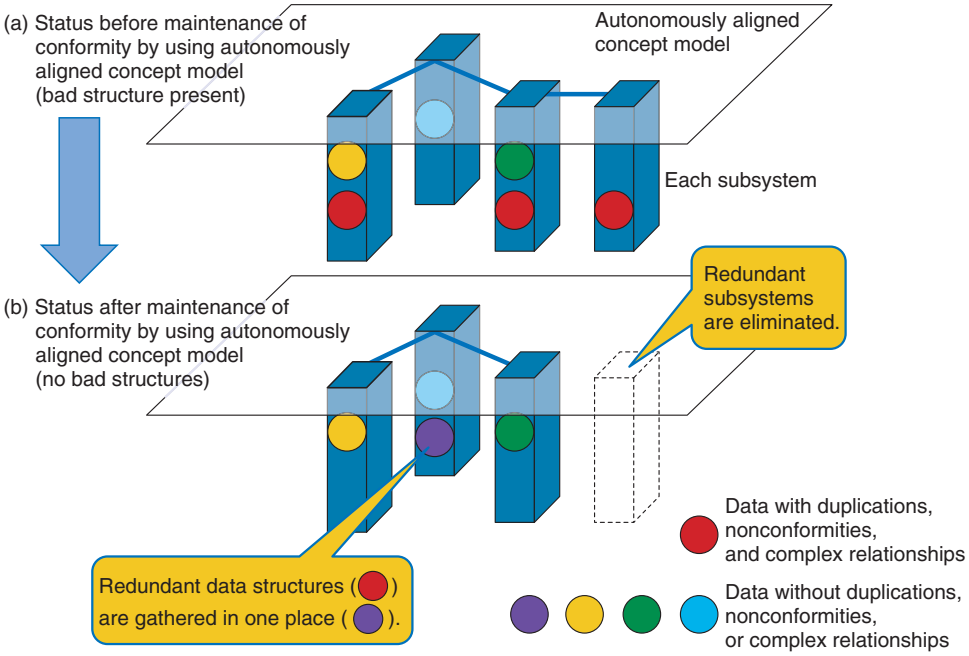


Fig. 6. Transforming faulty structures to ideal structures that can be detected.

competitiveness. As a means of combining a divide-and-rule way of thinking with lean and agile thinking, a development method with which One Teams utilize an autonomously aligned concept model for adjusting overall conformity was devised.

A tool for automatically detecting bad structures and supporting transformation to good structures is being prototyped in order to alleviate operational adjustments to changes in model structures done manually. Furthermore, we will continue to experiment with and evaluate the proposed method as a new development approach that can easily maintain overall conformity while utilizing a cost-estimation function and enabling autonomous and simultaneous work in parallel.

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Satoru Aihara
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. in information technology from Yamaguchi University in 1992. He joined NTT DATA in 1992. His work has focused on the development of search engine and knowledge management systems. His current research interests include software development processes.

Masayuki Inoue
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. in electrical engineering from Tokyo University of Science in 1994 and 1996, and a Ph.D. in engineering from Tokyo Institute of Technology in 2008. He joined NTT in 1996 and worked on the development of 3D cyberspace and video communication systems. He is currently working on system analysis in early phases using stored data in legacy systems. His research interests also include user interaction and video system evaluation. Dr. Inoue is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Akio Jin
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. from Nagoya University, Aichi, in 1992 and 1994, and a Ph.D. from the University of Tsukuba in 2008. Since joining NTT in 1994, he has contributed to the development of the MPEG-4 TwinVQ audio codec, a speech recognition system, and an automatic program generation system. His current research interests include upper software development processes and structure estimation of existing systems. He received the Nikkei BP Technology Award from Nikkei Business Publications, Inc., Japan, in 1997 and the Telecom System Technology Award from the Telecommunications Advancement Foundation, Japan, in 1998.

Yoshinori Furukawa
Senior Research Engineer, Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. from Ritsumeikan University, Shiga, in 1994 and 1996. He joined NTT in 2014. His current interests include software engineering.

Takako Tanaka
Research Engineer, Software Engineering Project, NTT Software Innovation Center.

She received a B.M.I.S in information science from Sanno University, Kanagawa, in 1998. She joined NTT Software Corporation in 1998 as a software engineer. Her current interests include software engineering.

Nagisa Sekiguchi
Software Engineering Project, NTT Software Innovation Center.

He received a B.E. and M.E. from Yokohama National University, Kanagawa, in 2014 and 2016. He joined NTT in 2016. His current interests include software engineering. He is a member of the Association for Computing Machinery.

Eiichi Oka
Senior Research Engineer, Supervisor, Software Engineering Project, NTT Software Innovation Center.

He received a B.S. and M.S. in nuclear engineering from Hokkaido University in 1987 and 1989. He joined NTT in 1989. He has worked on the development of telecommunication services including PHS (personal handy-phone system), 2G/3G-mobile, and the Next Generation Network. His current research interests include software engineering. He is a member of IEICE.

Keitaro Horikawa
Senior Research Engineer, Supervisor, Software Engineering Project, NTT Software Innovation Center.

He received a B.S. and M.S. in information engineering from Niigata University in 1988 and 1990. He joined NTT in 1990. He received the Best Paper Award for young researchers at the Information Processing Society of Japan national convention in 1995. He has a Project Management Professional certification from the Project Management Institute and a TOGAF (The Open Group Architecture Framework) 9 certification from the Open Group. His research interests include software design and architecture, concurrent distributed object computing, meta-object programming and computational reflection, single sign-on for web services, lightweight programming languages, mobile cloud computing and big data processing, machine learning open source projects, computer supported cooperative work, computer supported collaborative learning, game theoretic modeling for decision making, and human factors in research and development.

Graphene p-n Junction as an Electronic Beam Splitter

Norio Kumada

Abstract

N-type and p-type regions in graphene can adjoin without a gap in between. This article explains how such characteristic p-n junctions can serve as beam splitters of electrons. Utilizing the long coherence length of electrons in graphene may make it possible to carry out an electron version of quantum optics.

Keywords: graphene, p-n junction, electron beam splitter

1. Introduction

Quantum optics is a field of research that investigates the wave-particle nature of light based on quantum mechanics, using interferometers consisting of optical elements such as mirrors and beam splitters. Knowledge obtained from quantum optics has been applied to quantum cryptography and quantum teleportation. An electron is also a quantum having a wave-particle nature like a photon and can thus create interference. An important difference between an electron and a photon is whether it is a fermion or a boson. This difference appears in their two-particle interference.

Another important difference is the presence/absence of the Coulomb interaction. The presence of the Coulomb interaction for electrons has both positive and negative aspects; the electron quantum state can be controlled through the interaction, but its coherence is easily destroyed. The resulting short coherence length makes experiments on electron quantum optics difficult to carry out.

Thus far, electron quantum optics has been conducted in the quantum Hall effect regime, which appears under a magnetic field in two-dimensional electron systems formed in GaAs/AlGaAs (gallium arsenide/aluminium gallium arsenide) heterostructures. A narrow channel in these systems called a quantum point contact with an electron transmission probability of 1/2 (**Fig. 1(a)**) is used as a beam splitter. A fundamental problem with these systems is the short coherence length of about 10 μm, which is comparable to the typical size of interferometers, limiting experiments to the basic level. One way to solve this problem and carry out more advanced experiments is to use graphene, in which the coherence length is expected to be longer. However, since graphene is a gapless material, beam splitters based on quantum point contacts made by depleting local electrons do not work.

In this study, a team comprising members from NTT Basic Research Laboratories and CEA Saclay proposed a new beam splitter architecture using a graphene p-n junction and verified its performance. Electrons in graphene that are injected from the n and p regions are mixed in the p-n junction and then partitioned at the exit of the junction (**Fig. 1(b)**). The electron mixing and the subsequent partitioning processes can serve as a beam splitter. The behavior of the beam splitter was verified by measuring the current shot noise.

2. Device fabrication and measurements

Graphene is generally obtained by exfoliating it from graphite. A drawback of this technique is that the graphene size is limited to several tens of micrometers. In contrast, the graphene we used was epitaxially grown by thermally decomposing the SiC (silicon carbide) substrate (**Fig. 2(a)**). SiC substrates were annealed at ~1800°C in Ar (argon) at a pressure of less than 100 Torr. For the device fabrication, graphene was etched in an O_2 (oxygen) atmosphere.

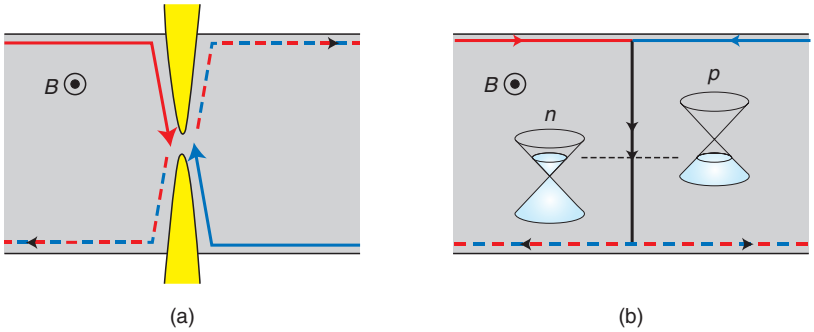

Fig. 1. (a) Quantum point contact (QPC) in a standard semiconductor device, formed by a pair of split gates (yellow). The transmission of the QPC is set to 0.5 so that electrons injected to the QPC are randomly transmitted or reflected to the downstream channels (red and blue dashed lines). (b) Graphene p-n junction. Current channels from the n and p regions (red and blue lines, respectively) are mixed in the p-n junction (thick black line) and then partitioned at the exit of the junction. Therefore, electrons injected to the p-n junction are randomly distributed to the downstream channels in the n and p regions (red and blue dashed lines).

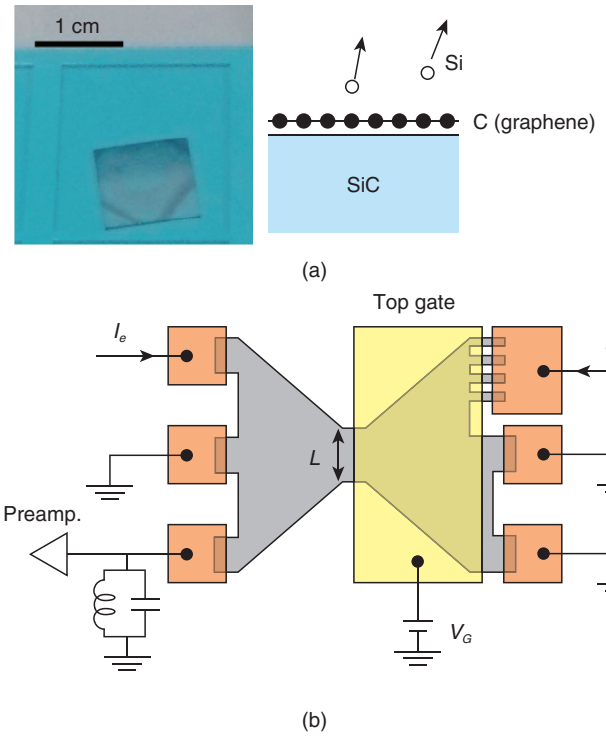

Fig. 2. ((a) left) Photograph of graphene grown on SiC. ((a) right) Schematic of graphene growth on SiC. (b) Device structure of graphene with a p-n junction. Gray region represents n-doped graphene. Tuning the bias of the top gate (yellow region) changes the carrier type in the gated region to a hole, and a p-n junction is formed at the interface between the gated and ungated regions. Orange regions are ohmic contacts.

After etching, the surface was covered with 100-nm-thick HSQ (hydrogen silsesquioxane) and 60-nm-thick SiO_2 (silicon dioxide) insulating layers. A p-n junction was made using a top gate covering half of the graphene. The ungated region was n doped, while p carriers were introduced in the gated region. Therefore, a p-n junction was formed at the interface between the gated and ungated regions (**Fig. 2(b)**).

We were able to fabricate devices with different p-n junction lengths between 5 and 100 μm by exploiting the wafer-size graphene.

All measurements were carried out in a quantum Hall effect regime, which was created by applying a magnetic field perpendicular to graphene at a low temperature of 4 K. The noise measurement involved converting the current noise into voltage fluctuations across one 2.5-kΩ resistor in series with the sample.

3. Behavior of graphene p-n junction as electron beam splitter

Current in the quantum Hall effect regime flows along the edge of the graphene in a direction determined by the polarity of the magnetic field and the carrier type (electron or hole). When a p-n junction is formed, counter-circulating edge channels of electrons and holes are mixed in the p-n junction and then partitioned at the exit of the junction. The mixing and the subsequent partitioning processes serve as an electron beam splitter; electrons injected from the electron channel are randomly distributed to the downstream electron and hole channels (Fig. 1(b)).

We tested the behavior of the beam splitter by measuring the current noise (shot noise) caused by the random electron distribution. The results demonstrate that the random partitioning noise is present when a p-n junction is formed (solid and open cyan circles) and absent when it is not (black circles), as shown in **Fig. 3**. We further found that the amplitude of noise increases as the p-n junction length decreases (**Fig. 4**). This indicates that the energy relaxation length of electrons in a p-n junction is 15 μm. The amplitude of noise in a short p-n junction is consistent with beam-splitter behavior.

4. Future work

The architecture of a graphene p-n junction is simpler than that of a quantum point contact, which is used as a beam splitter in conventional semiconductors. This allows us to integrate several beam splitters within a mesoscopic scale in graphene. Utilizing these beam splitters and long coherence length in graphene would make it possible to fabricate complicated electronic interferometers. Experiments on these devices would reveal the effects of the Coulomb interaction on decoherence. Furthermore, the generation of quantum entangled electron pairs is expected to be achieved in such devices.

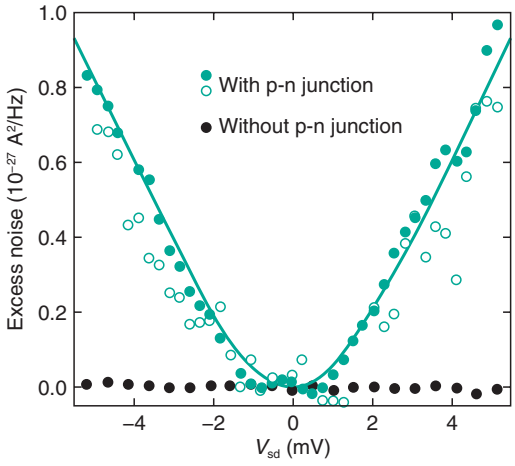

Fig. 3. Shot noise generated by p-n junction as a function of the bias applied to the electron channel V_{sd}. Solid cyan and black circles represent the measured noise in the presence and absence of p-n junctions. Open cyan circles represent the noise in the presence of a p-n junction obtained by applying bias to the hole channel.

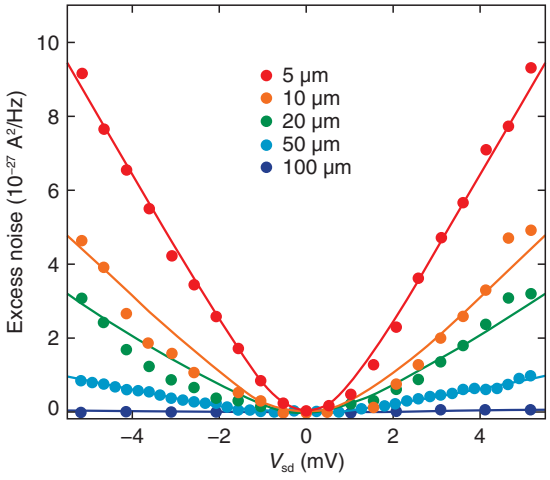

Fig. 4. Shot noise for different values of p-n junction length as a function of the bias applied to the electron channels V_{sd}.

This work was done in collaboration with NTT Basic Research Laboratories and CEA Saclay. Complementary results achieved by a group from Osaka University, Kyoto University, and the National Institute for Materials Science have been published simultaneously [2].

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Norio Kumada

Senior Research Scientist (Distinguished Scientist), Quantum Solid-State Physics Research Group, Physical Science Laboratory, NTT Basic Research Laboratories.

He received a B.S., M.S., and Ph.D. in physics from Tohoku University, Miyagi, in 1998, 2000, and 2003. He joined NTT Basic Research Laboratories in 2003. He has since been engaged in the study of highly correlated electronic states achieved in semiconductor heterostructures. He was a visiting researcher at CEA Saclay during 2013–2014. He was appointed as a Distinguished Scientist of NTT in 2010. He received the Young Scientist Award of the Physical Society of Japan in 2008 and the Young Scientists' Prize from the Minister of Education, Culture, Sports, Science and Technology in 2012. He is a member of the Physical Society of Japan.

World's Highest Density Optical Fiber for Space Division Multiplexing with Deployable Reliability

Taiji Sakamoto, Takashi Matsui, Shinichi Aozasa, Kyozo Tsujikawa, and Kazuhide Nakajima

Abstract

Space division multiplexing (SDM) technology has been intensively investigated in order to substantially increase the network capacity of optical fiber telecommunication. Multi-core or multi-mode fiber is a promising candidate for next-generation optical fiber. In this article, we describe our optical fiber for SDM transmission that can realize 100 times larger capacity than that of standard single-mode fiber while maintaining deployable mechanical reliability.

Keywords: optical fiber, space division multiplexing, multi-mode multi-core

1. Introduction

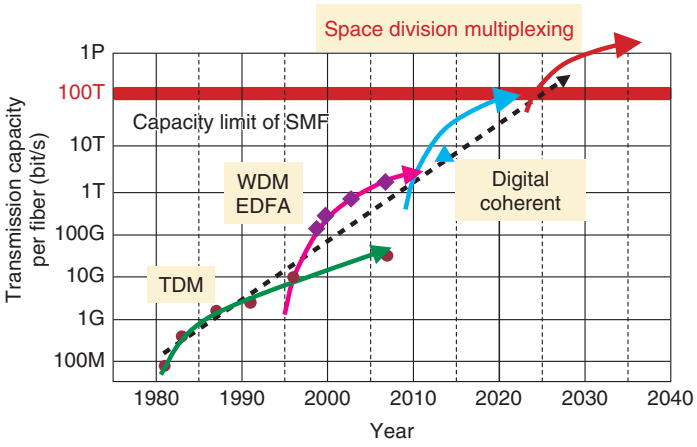
Existing telecommunication networks mainly utilize single-mode fiber (SMF), whose low loss and broadband characteristics have resulted in increased network transmission capacity. The progress in the capacity per optical fiber of the core network in Japan is shown in **Fig. 1**. The transmission capacity has steadily increased year by year, and the rate of increase grew by 1000 times in a 20-year period (from 1.6 Gbit/s in 1987 to 1.6 Tbit/s in 2007). This rapid increase in capacity is due to the development of transmission technologies such as time division multiplexing and wavelength division multiplexing, as well as the development of optical amplifiers such as erbium-doped fiber amplifiers.

A transmission system using digital coherent technology was recently introduced, and 8-Tbit/s capacity has been achieved by using a multi-level modulation format with high spectral efficiency. However, it is expected that the capacity limit of the standard SMF is around 100 Tbit/s [1]. Therefore, it is necessary to develop a new transmission medium to achieve 1000 times larger capacity in the next 20 years. Space division multiplexing (SDM) technology using multi-core or multi-mode fiber has been intensively investigated as a promising candidate for a next-generation transmission system. In the following section, we report our latest research results on the development of optical fiber for an SDM system taking the spatial density and mechanical reliability into account.

2. Optical fiber for SDM system

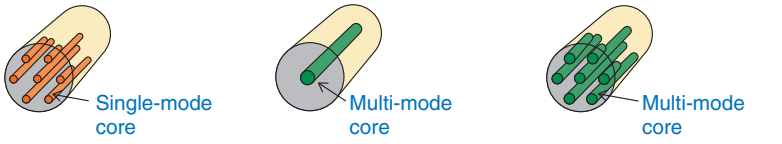
Multi-core and multi-mode fibers are depicted in **Figs. 2(a)** and **(b)**. Multi-core fiber has multiple cores within a cladding, and multiple signals can be transmitted in parallel by using multiple cores. Multi-mode fiber typically has a larger core than that of SMF, and multiple modes can propagate within a core. Each mode is orthogonal to each other and is treated as an independent transmission path. Thus, mode division multiplexing (MDM) is realized, where multiple signals can be transmitted through multiple modes.

Multi-mode multi-core fiber has been studied recently in order to achieve ultra-high capacity transmission. This fiber combines multi-core and multi-mode technologies. The structure of the multi-mode multi-core fiber is shown in **Fig. 2(c)**. There are multiple



EDFA: erbium-doped fiber amplifier
TDM: time division multiplexing
WDM: wavelength division multiplexing

Fig. 1. Progress in transmission capacity per optical fiber.



(a) Multi-core fiber (b) Multi-mode fiber (c) Multi-mode multi-core fiber

Fig. 2. Schematic diagram of multi-core and multi-mode fibers.

cores, and multiple modes can propagate within each core. This enables us to employ MDM transmission using each core. As a result, $m \times n$ transmission channels are obtained with n-mode m-core fiber.

The transmission channels per fiber as a function of fiber diameter of recently reported multi-core fiber are shown in **Fig. 3**. The results for multi-core fiber with single-mode cores and multi-mode cores are respectively plotted as open and solid circles. It can be seen that the multi-mode multi-core fiber makes it possible to achieve substantially more transmission channels compared to single-mode multi-core fiber. In fact, more than 100 transmission channels can be obtained with multi-mode multi-core fiber. However, more transmission channels results in a larger fiber diameter. Next, we describe some important parameters when designing the SDM fiber.

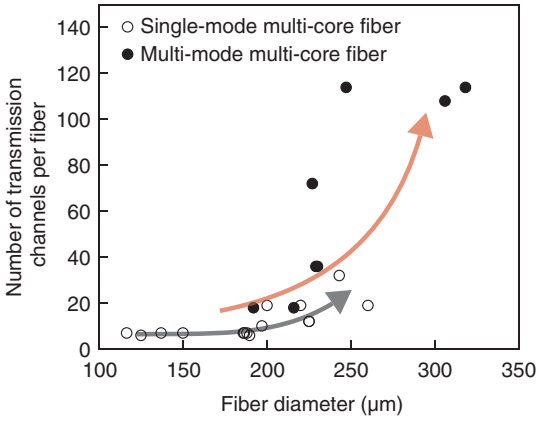
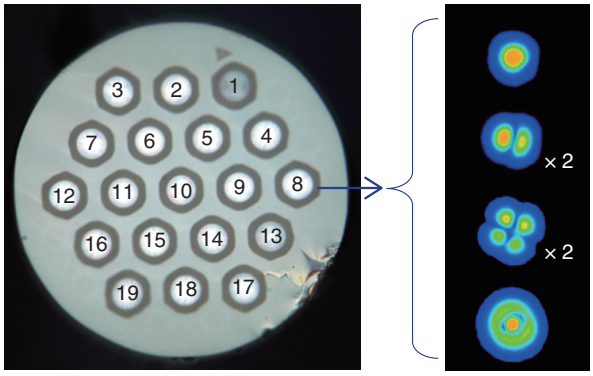


Fig. 3. Relationship between transmission channels per fiber and fiber diameter.

2.1 Mechanical reliability

Failure probability, which means the probability that a fiber will be broken, increases as the fiber diameter increases when fiber is bent owing to the inherent nature of the glass. A failure in a transmission line causes a disconnection of the network service and



Six modes can propagate within each core.

Fig. 4. Cross section of fabricated 6-mode 19-core fiber.

should be avoided so as not to degrade the network reliability. Thus, the fiber diameter cannot be increased in an unlimited fashion in order to deploy a larger number of cores, and a fiber diameter design that maintains flexibility and reliability is required.

2.2 Spatial density

It is important for the telecom operator to design a multi-core fiber with the cores packed as closely as possible because we need to efficiently utilize the limited space of the telecom infrastructure such as the cable duct space underground. The spatial density, namely the number of cores per unit area, is one of the parameters used to evaluate the density.

2.3 Transmission characteristics

The transmission channels in the SDM fiber need to have better performance than those of the SMF. This means that the SDM fiber should have low transmission loss characteristics comparable to the SMF, and the inter-core crosstalk should be suppressed by properly designing the distance between neighboring cores. The differential mode delay (DMD) is also an important parameter for multi-mode multi-core fiber. DMD is the group delay difference between the propagation modes. The propagation modes typically have different group velocities. Reducing the DMD in an MDM system is strongly required because it becomes more difficult to recover the transmitted signals at the receivers when the DMD is large.

3. Fabricated fiber with world's highest spatial density

A cross section of the fabricated fiber is shown in **Fig. 4**. It has a hexagonally arranged 19-core structure with 6-mode cores, and there are 114 transmission channels per fiber in total. This fiber has the following advantageous features.

3.1 Deployable mechanical reliability

Our fiber was designed to have a suitable fiber diameter for maintaining deployable mechanical reliability. The relationship between the fiber failure probability and fiber diameter is shown in **Fig. 5**. It is clear that an increase in the fiber diameter causes an increase in failure probability, which reduces the reliability of the fiber. Fiber reliability depends on the bending radius and proof testing as well as the fiber diameter. Proof testing is a process to improve the reliability of the fiber by applying longitudinal stress to the fiber during the fabrication process. A 1–2% proof level is commonly used in the current manufacturing process, and a bending radius of less than 15 mm is assumed for recent high density optical fiber cable design, so we have targeted a fiber diameter of less than 250 μm to obtain the same mechanical reliability as that of SMF. The fabricated fiber has a fiber diameter of 246 μm. Thus, deployable mechanical reliability for a telecommunication network is obtained.

3.2 Highest spatial density

Our fiber has the world's highest spatial density among reported SDM fibers. To achieve this, we investigated the optimum core structure to incorporate the transmission channels efficiently within a fiber diameter of less than 250 μm. The relationship between the spatial density and the fiber diameter of various multi-mode multi-core structures is shown in

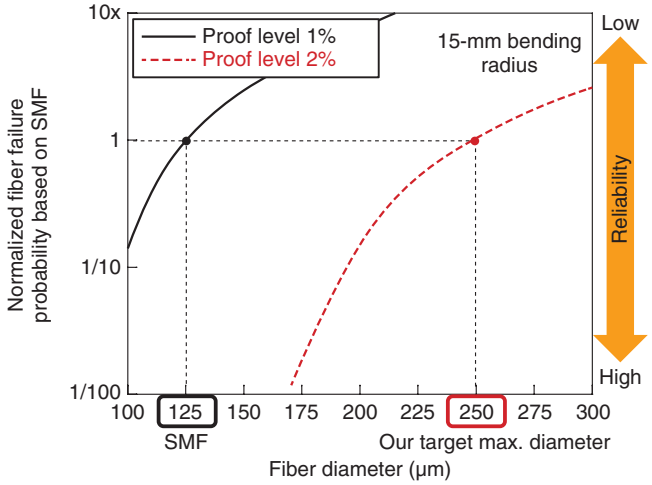


Fig. 5. Relationship between fiber failure probability and fiber diameter.

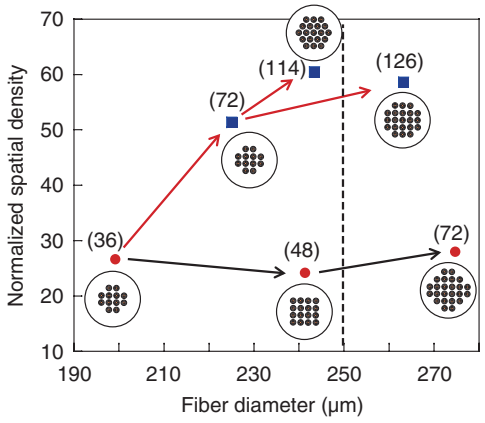


Fig. 6. Relationship between spatial density and fiber diameter of various multi-mode multi-core structures.

Fig. 6. The number of spatial channels is noted in parentheses. Here, the spatial density is the number of transmission channels divided by unit area of the cross section, and it is normalized by that of SMF. We assumed 12–21 core structures with 3-mode cores (red symbols) or 6-mode cores (blue symbols). We found that 6-mode multi-core fiber can achieve larger spatial density than that of 3-mode multi-core fiber, and the 6-mode 19-core structure can be obtained within a fiber diameter of less than 250 μm. We fabricated the 6-mode 19-core fiber as shown in Fig. 4 and achieved the world's highest spatial density of more than 60.

3.3 Optical properties suitable for long-haul transmission

Our fiber has suitable optical properties for long-haul transmission owing to the well-controlled fabrication process. The refractive index profile of the core is shown in **Fig. 7(a)**. It has a graded index core with a low index trench. The graded index core profile enables us to reduce the DMD, and the low index trench can reduce the inter-core crosstalk. The transmission loss as a function of the DMD value of reported multi-mode multi-core fibers is plotted in **Fig. 7(b)**. As shown in the graph, our fiber had the lowest loss (less than 0.24 dB/km) and DMD (less than 0.33 ns/km) among various fibers. In addition, the inter-core crosstalk was suppressed below

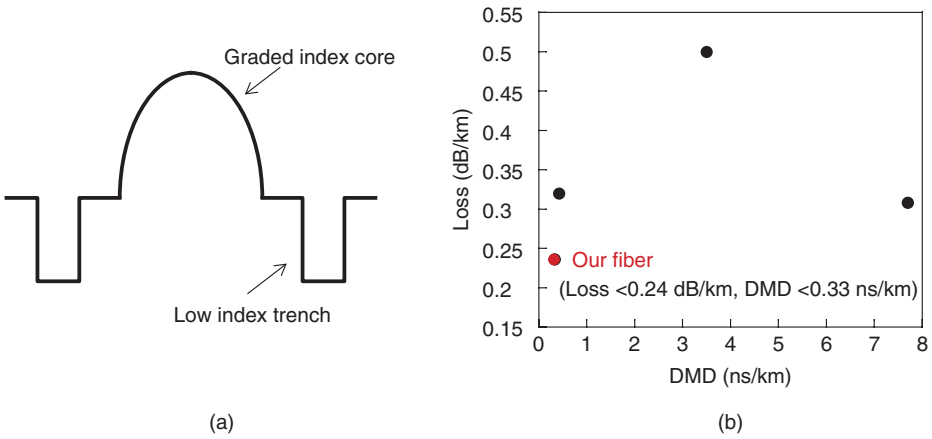


Fig. 7. (a) Schematic diagram of trench assisted graded-index core profile, (b) transmission loss vs. DMD of recently reported few-mode multi-core fibers.

–30 dB/100 km, which corresponded to having the potential to transmit quadrature phase shift keying (QPSK) signals over 1000 km with negligible power penalty induced by the crosstalk. We experimentally confirmed that QPSK signals through 114 transmission channels were successfully transmitted over an 8.85-km-long fiber [2]. This indicates that our fiber has suitable transmission characteristics for long-haul SDM networks.

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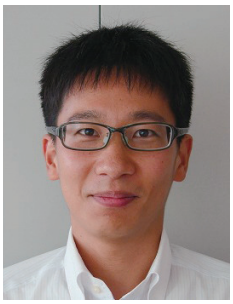

Taiji Sakamoto
Research Engineer, NTT Access Network Service Systems Laboratories.
He received a B.E., M.E., and Ph.D. in electrical engineering from Osaka Prefecture University in 2004, 2006, and 2012. In 2006, he joined NTT Access Network Service Systems Laboratories, where he has been conducting research on optical fiber nonlinear effects, low nonlinear optical fiber, few-mode fiber, and multi-core fiber for optical multiple-input multiple-output transmission systems. Dr. Sakamoto is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Takashi Matsui
Senior Research Engineer, Access Media Project, NTT Access Network Service Systems Laboratories.
He received a B.E., M.E., and Ph.D. in electronic engineering from Hokkaido University in 2001, 2003, and 2008. He also attained the status of Professional Engineer (P.E.Jp) in electrical and electronic engineering in 2009. In 2003, he joined NTT Access Network Service Systems Laboratories, where he researches optical fiber design techniques. Dr. Matsui is a member of IEICE.

Shinichi Aozasa
Senior Research Engineer, NTT Access Network Service Systems Laboratories.
He received a B.S. and M.S. in chemistry from Hokkaido University in 1996 and 1998 and a Ph.D. in engineering from the University of Tokyo in 2008. In 1998, he joined NTT Opto-Electronics Laboratories, where he researched and developed optical fiber amplifiers and planar lightwave circuits used in high-capacity optical transmission. In 2014, he joined NTT Access Network Service Systems Laboratories, where he has been researching optical fiber and its fabrication process. Dr. Aozasa is a member of IEICE and the Institute of Electrical and Electronics Engineers (IEEE).

Kyozo Tsujikawa
Senior Research Engineer, NTT Access Network Service Systems Laboratories.
He received a B.S. and M.S. in chemistry, and a Ph.D. in engineering from Tokyo Institute of Technology in 1990, 1992, and 2006. Since joining NTT, he has undertaken research on glass materials for low-loss optical fibers, measurement of optical fibers, and measurement of optical properties of fiber cables. Dr. Tsujikawa is a member of IEICE.

Kazuhide Nakajima
Senior Research Engineer, Supervisor (Distinguished Researcher) and Group Leader of NTT Access Network Service Systems Laboratories.
He received an M.S. and Ph.D. in electrical engineering from Nihon University, Chiba, in 1994 and 2005. In 1994, he joined NTT Access Network Service Systems Laboratories, where he engaged in research on optical fiber design and related measurement techniques. He is also acting as Rapporteur Q5/SG15 of ITU-T. Dr. Nakajima is a member of IEICE, IEEE, and the Optical Society of America.

Quality Estimation Technique for Video Streaming Services

Kazuhisa Yamagishi and Akira Takahashi

Abstract

The use of adaptive bitrate video streaming services over the network is increasing. The quality of these services is affected by video resolution, audio and video bitrates, bitrate adaptation, stalling due to the lack of playout buffer, and content length. Therefore, service providers need to monitor quality in real time in order to verify that their services are functioning normally. A model that can be used to estimate quality is necessary in order to accurately monitor quality. This article introduces a quality estimation technique that assesses user quality of experience of audiovisual content in adaptive bitrate streaming services.

Keywords: adaptive bitrate streaming, quality of experience, quality estimation

1. Introduction

The use of adaptive bitrate streaming over the network has recently been increasing. HTTP (Hypertext Transfer Protocol)-based adaptive bitrate streaming provides users with the best possible quality of experience for various network conditions because the client application can adaptively select a media file with a suitable bitrate.

Streaming quality degrades due to compression and network conditions (e.g., packet loss, insufficient bandwidth, delay, and jitter). When a reduction in throughput occurs, the quality level that is best suited under current network conditions can be selected (known as *adaptation*) because there are several files (i.e., chunks/segments) corresponding to representations of different bitrates on the server. The throughput is reduced, and packet delay and jitter are introduced due to network congestion. As a result, the playout buffer slowly fills or depletes. When the buffer is empty, the playback of the audiovisual content is interrupted until sufficient data for playback are received (**Fig. 1**). Therefore, it is important to monitor the normality of streaming services.

2. ITU-T SG12

The quality of adaptive bitrate video streaming is affected by compression degradation, adaptation, and stalling events. Therefore, it is important to monitor quality at the client application as well as the quality of servers and networks.

In-service quality monitoring is an important application for quality estimation. An example of this is to detect the locations where quality has degraded by gathering a large amount of quality data through cloudsourcing. Also, even when users do not notice degradation due to compression or network congestion, the quality estimation technique can detect small amounts of degradation. Therefore, service providers can quickly improve their services by using the detected information.

The International Telecommunication Union - Telecommunication Standardization Sector Study Group 12 (ITU-T SG12) has been studying a quality estimation model for adaptive bitrate video streaming and will standardize it in 2017. This model is called the parametric non-intrusive assessment of TCP-based multimedia streaming quality (P.NATS) (**Fig. 2**).

The P.NATS model consists of four modules:

1) Parameter extraction module

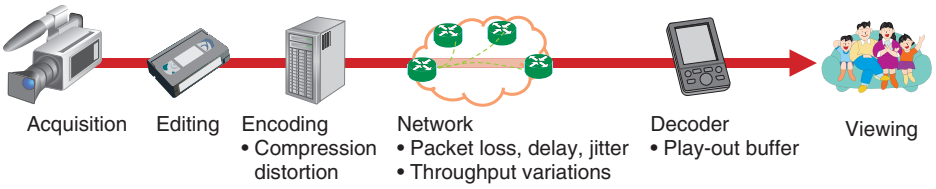

Fig. 1. Quality degradation factors.

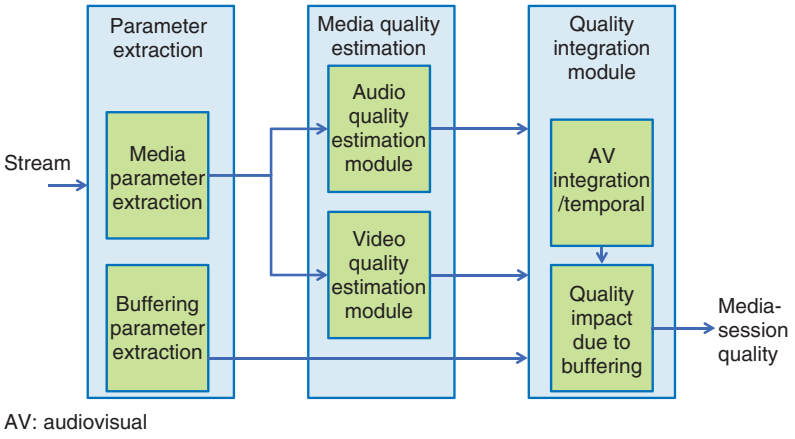

Fig. 2. Recommendation P.NATS model proposed by ITU-T.

This module receives and acquires information about the audio and video bitrates, resolution, and framerate per chunk, measures the rebuffering timing and duration, and calculates stall-related parameters using rebuffering information.

2) Audio quality estimation module

This module estimates audio quality per 1-second sampling interval using the audio bitrate.

3) Video quality estimation module

This module estimates video quality per 1-second sampling interval using the video resolution, framerate, and bitrate.

4) Quality integration module

This module takes audio and video quality and stalling parameters as input and estimates final media-session quality.

Accurate estimation of the quality of adaptive bitrate video streaming requires accurate estimation of audio and video quality. Moreover, quality adaptation due to throughput variation and stalling events due to the lack of a playout buffer need to be taken into account.

To verify the accuracy of the quality estimation models, ITU-T SG12 analyzed the results of 30 subjective quality assessment tests submitted by seven organizations from seven countries. In the subjective tests, audiovisual content was encoded using Advanced Audio Coding - Low Complexity (AAC-LC) [1] (bitrate: 24–196 kbit/s) and H.264/Advanced Video Coding (AVC) [2] (bitrate: 75 kbit/s–12.5 Mbit/s; pixel resolution: 426 × 240–1920 × 1080; framerate: 7.5–30 fps), and various types of stalling events were added. The models proposed by DT/T-Labs, Ericsson, Huawei, NetScout, NTT, Opticom, and SwissQual were equal in the statistical analysis, and ITU-T SG12 therefore agreed to develop a single model by merging these models.

3. Outlook

This article described the P.NATS model that can be used to estimate the quality of adaptive bitrate video streaming services and that will be standardized in 2017. In the next step, ITU-T SG12 will standardize a P.NATS Phase 2 model that can be used for estimating the quality of 4K-ultrahigh definition content

encoded by H.264/AVC, H.265/High Efficiency Video Coding (HEVC), and VP9.

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Kazuhisa Yamagishi

Senior Research Engineer, NTT Network Technology Laboratories.

He received a B.E. in electrical engineering from Tokyo University of Science in 2001 and an M.E. and Ph.D. in electronics, information, and communication engineering from Waseda University, Tokyo, in 2003 and 2013. He joined NTT in 2003. He has been engaged in the development of objective quality estimation models for multimedia telecommunications. He has been contributing to ITU-T SG12 since 2006.

Akira Takahashi

General Manager, Planning Department; Project Manager, Telecommunication Traffic & Quality Project, NTT Network Technology Laboratories.

He received a B.S. in mathematics from Hokkaido University in 1988, an M.S. in electrical engineering from California Institute of Technology, USA, in 1993, and a Ph.D. in engineering from University of Tsukuba, Ibaraki, in 2007. He joined NTT in 1988. He has been contributing to ITU-T SG12 on performance, quality of service, and quality of experience since 1994. He was a Vice-Chairman of ITU-T SG12, a Vice-Chairman of Working Party 3 in SG12, and a Co-Rapporteur of Question 13/12 for the 2009–2012 and 2013–2016 study periods.

Fax Transmission Failure Analysis Method Requiring Multi-signal Analysis

Abstract

This article describes a problem a customer had involving facsimile transmission failure and how it was resolved through analysis of multiple signals. This is the thirty-eighth article in a series on telecommunication technologies. This contribution is from the Network Interface Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: facsimile, IP network service, echo

1. Introduction

The Network Interface Engineering Group provides technical support in relation to Internet protocol (IP) network services such as FLET'S HIKARI NEXT. This includes analyzing the Ethernet interface between terminal equipment and telecommunications equipment as well as analog line and ISDN (Integrated Services Digital Network) interfaces comprising gateways and private branch exchange (PBX) equipment.

We introduce here a case study in which we applied our analysis methods to determine why a Group 3 (G3) facsimile (fax) machine accommodated by PBX equipment would sometimes fail to transmit fax data to a specific party.

2. Case study overview and investigation method

The customer was using a G3 fax machine connected to PBX equipment. The customer found that the transmission of fax data from this machine to a specific party would occasionally fail.

The approach taken by maintenance personnel in past cases of fax machine transmission problems was to replace the outer-line package for Hikari Denwa use or the extension package for fax use housed within the PBX equipment, or to change the transmission level of the fax signal. This time, however, the problem could not be solved with that approach, and the Technical Assistance and Support Center was asked to investigate the cause of the problem.

To collect data at the time of failure occurrence, we installed packet capture equipment in the Ethernet interval and a G3 facsimile tester in the analog line interface and proceeded to collect and analyze IP packets and fax signals (**Fig. 1**).

3. Analysis of collected data

(1) Ethernet

No anomalies were found in the Session Initiation Protocol (SIP) communication sequence for Hikari Denwa call control. In addition, no packet losses or abnormal packet arrival intervals that could cause the failure could be found in the Real-time Transport Protocol (RTP) packets carrying the fax signal.

(2) Analog line interface

The sender fax communication sequence of the

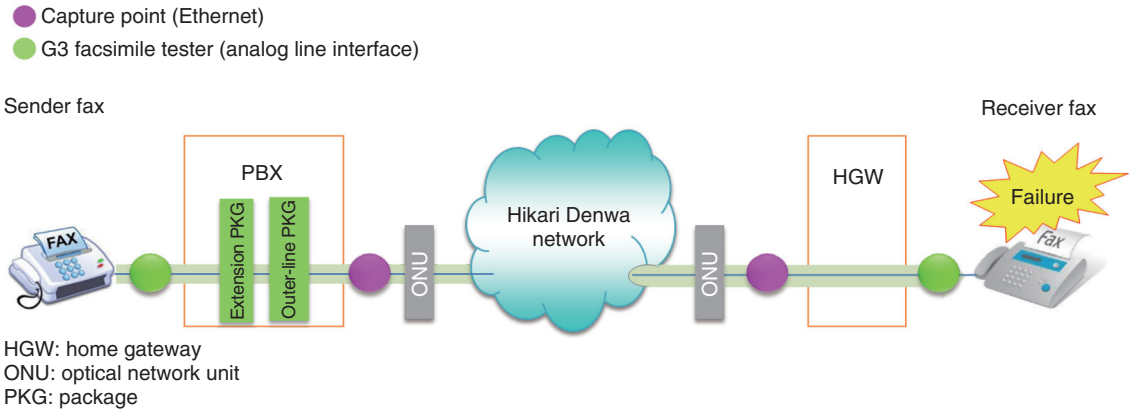

Fig. 1. Connection configuration and data-collection points.

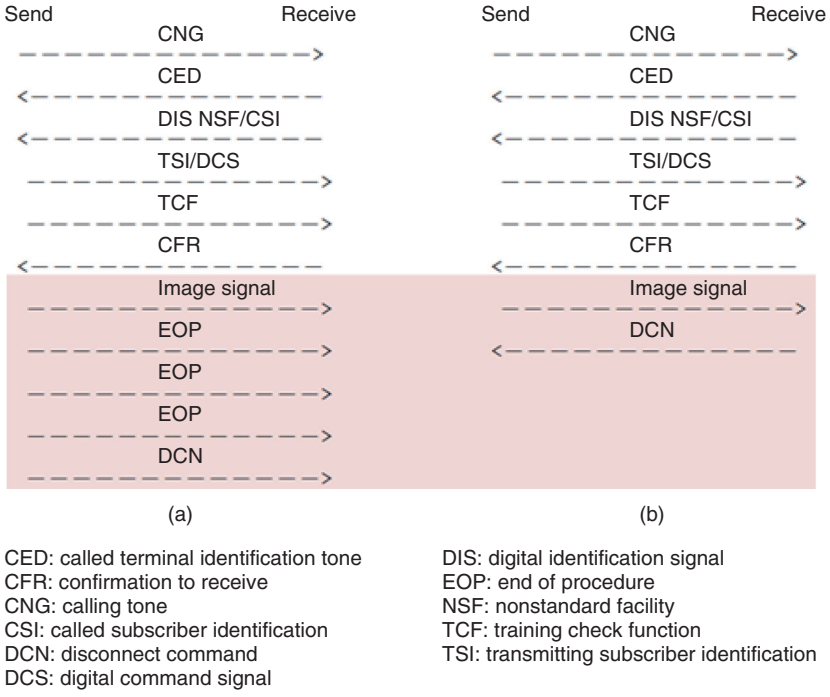

Fig. 2. (a) Sender fax communication sequence; (b) receiver fax communication sequence.

reporting customer and the receiver fax communication sequence of the other party as collected by the G3 facsimile testers are shown in **Fig. 2**.

(3) Sender fax communication sequence

The sender fax sends an EOP (end of procedure) signal after sending the image signal. However, as no MCF (message confirmation) signal is received from the receiver fax, the sender fax sends a DCN (disconnect command) signal and disconnects the communication (Fig. 2(a)).

(4) Receiver fax communication sequence

After receiving the image signal, the receiver fax sends a DCN signal before receiving an EOP signal from the sender side and disconnects the communication (Fig. 2(b)).

Therefore, we conducted a detailed analysis to find out why the receiver fax was disconnecting in this manner.

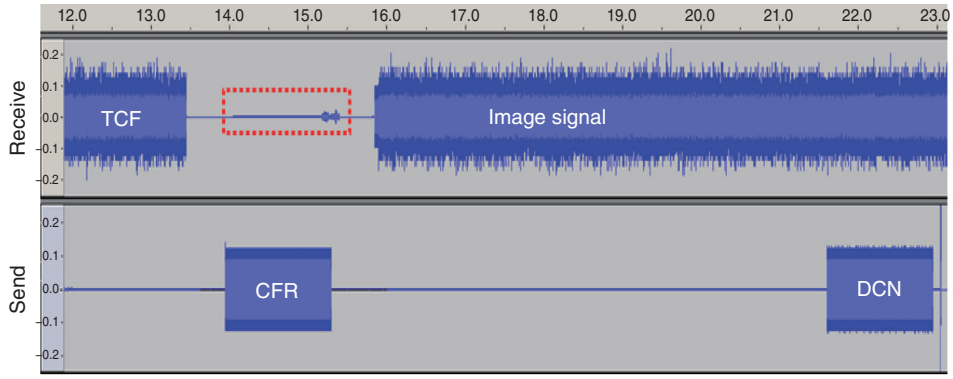

Fig. 3. Results of analyzing audio file using Audacity.

Table 1. Results of signal analysis.

	CFR	Detected signal
Signal transmit time	Approx. 1350 ms	Approx. 1350 ms
Signal frequency	Approx. 1650 Hz	Approx. 1650 Hz
Signal level	Approx. –18 dBm	Approx. –45 dBm

4. Analysis of audio data using Audacity

We extracted RTP packets from captured Ethernet data on the receive side at the time of failure and analyzed the audio files saved for each call made and received using Audacity[*1] software. In our analysis, we found a particular signal that could not be recognized by the G3 facsimile tester (**Fig. 3**, red-framed box).

This signal differed from the TCF (training check function) signal and image signal transmitted by the sender fax, while it had the same signal transmit time and signal frequency as the CFR (confirmation to receive) signal transmitted by the receiver fax (**Table 1**, red-framed box).

The above results suggest that this signal was an echo[*2] of the CFR signal transmitted by the receiver fax and that it originated in the extension package of the PBX equipment on the sender side (2-line/4-line converter), as shown in **Fig. 4**.

5. Cause of failure

It was thought that a CFR echo of approximately –45 dBm or greater generated in the extension package of the PBX equipment (2-line/4-line converter) would exceed the receive-level threshold of the receiver fax. This echo would consequently be erroneously recognized as a signal from the sender fax, causing this failure to occur. The signal level of the CFR echo during normal operation was approximately –70 dBm (**Fig. 5**).

6. Countermeasures

We considered that the receive-level threshold of the receiver fax could be raised so that the echo would not exceed that threshold, or that the transmit level of the receiver fax could be lowered so as to reduce the echo and prevent it from being recognized as a valid

*1 Audacity: Audio editing software that allows for data editing while viewing graphs (waveforms/spectra) that visually represent the content of the audio file. http://www.audacityteam.org/

*2 Echo: G3 facsimiles (V.17 and beyond) operate on half-duplex communications, which means that the transmit-control section uses the same frequency band for both send and receive signals. Consequently, if the echo is large, the echo of the transmit signal when transmit control switches between send and receive may be mistaken for a signal transmitted by the other party, giving rise to an anomaly in transmit control.
(Excerpted from CIAJ (Communications and Information Network Association of Japan) standard CES-Q006-1: Guidelines on VoIP-TA/Facsimile Terminals When Accommodating Facsimile Terminals via VoIP-TA in IP-PBX, 3.1.1.3 Effects of Echo, Oct. 2007 (in Japanese).)
http://www.ciaj.or.jp/gazou/guideline/guide_uns.pdf

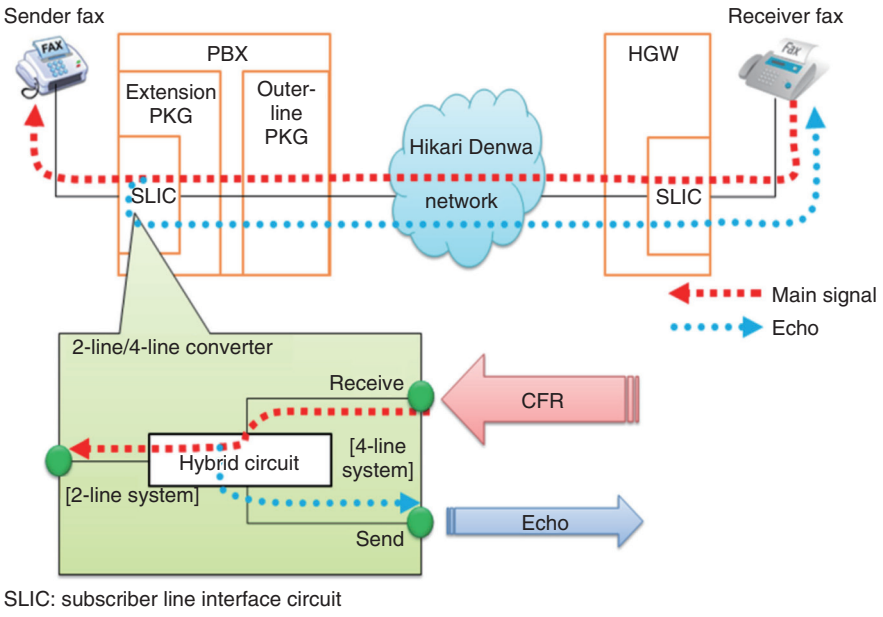

Fig. 4. Echo generation at 2-line/4-line converter.

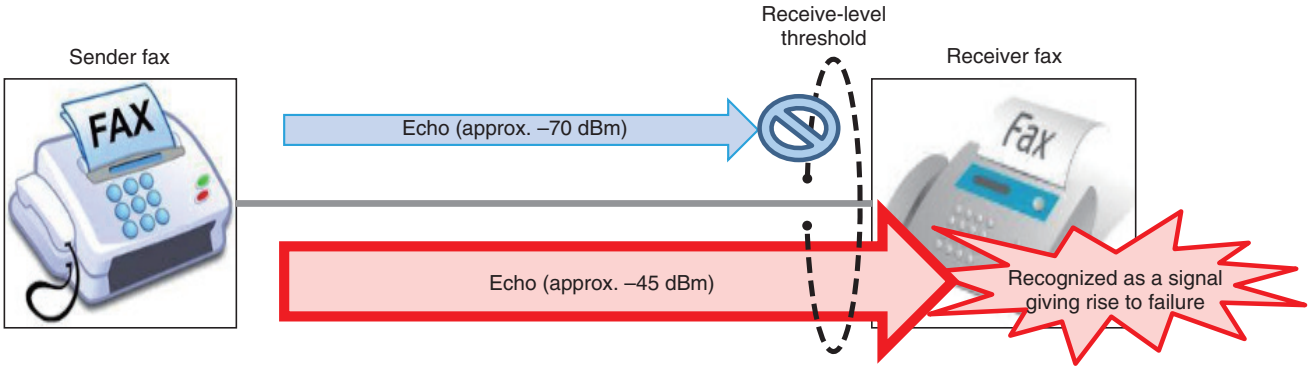

Fig. 5. Threshold of receive level.

signal.

However, because the receiver fax was a model for which the receive-level threshold could not be changed, we lowered the transmit level in 1-dB increments and found that lowering it by 2 dB was enough to prevent the reoccurrence of this event. We considered that this was because the echo would no longer exceed the receive-level threshold of the receiver fax at that transmit level, thereby preventing the echo from being mistakenly recognized as a signal from the sender fax.

7. Conclusion

In IP network services, devices with analog line or ISDN interfaces may be used in configurations consisting of gateways and PBX equipment. Solving problems in such configurations requires a combination of measurement equipment and analysis methods for each type of interface.

The case study presented here showed how analyzing analog line interface signals and Ethernet data made it possible to solve a puzzling problem. Going forward, the Technical Assistance and Support Center aims to continue its work in solving difficult

problems through the use of diverse tools and the analysis of signals and data for a variety of interfaces.

Experimental Test of Macroscopic Realism Problem Using a Superconducting Flux Qubit

1. Introduction

NTT and the University of Illinois have conducted an experimental test on the *breaking* of macroscopic realism[*1] in a superconducting circuit using a flux qubit[*2].

The idea that an observed object exists even before it is observed is called realism. This is commonly accepted in the macroscopic world in which we live. In contrast, in the microscopic world described by quantum mechanics[*3], realism is *broken*[*4]. This means that a state cannot be determined before it is observed and is in fact determined by the observation. If the macroscopic world is also described by quantum mechanics, realism must be broken there. The question is, can realism be broken in the macroscopic world, or is there a limitation to the application of quantum mechanics in the macroscopic world? This is one of the biggest unsolved problems since the discovery of quantum mechanics.

We tested this using a superconducting flux qubit that had 10^{12} electrons flowing around it per second and found that realism was broken in this supercurrent. We demonstrated that quantum mechanics is applicable on a macroscopic scale in this supercurrent. This contributes significantly to the field of fundamental physics and shows that a superconducting flux qubit works as a real quantum device.

This work was published in the online version of *Nature Communications* on the 4th of November, 2016 (GMT) [1].

2. Background

Even a single electron passing through a double slit exhibits interference fringes[*5]. Interference fringes do not appear if the electron passes through only one slit. This means that superposition is realized between the left slit passed state and the right slit passed state. These interference fringes disappear when we obtain information (by observation) revealing the slit that the electron passed through. This means that realism, as it is commonly accepted in the macroscopic world, does not hold in the microscopic world described by quantum mechanics. We can expect realism to be broken in the macroscopic world if this world also obeys quantum mechanics. The purpose of our work is to demonstrate the breaking of macroscopic realism, and thus imply that our commonly held belief is wrong (**Fig. 1**).

3. Experiment

NTT Basic Research Laboratories carried out a test experiment on breaking macroscopic realism using a superconducting flux qubit made of aluminum and demonstrated breaking of the realism of a superconducting flux qubit current state by 84 times the standard deviation. This work demonstrated that quantum mechanics can be applied on a macroscopic scale with a large supercurrent and is not simply limited to

*1 Realism: The idea that an object exists independent of its observation, for example, "The moon exists even when no one looks at it."

*2 Superconducting flux qubit: A superconducting circuit constructed from a superconducting loop including Josephson junctions. By applying a magnetic field with an optimal bias, we can consider this circuit to be a quantum two-level system, with clockwise and anti-clockwise current states.

*3 Quantum mechanics: A set of physical laws that can govern the behavior of particles and waves at the microscopic level (for example in electrons and atoms). It allows strange behavior such as quantum superposition and entanglement.

*4 Realism breaking: The idea that the state is determined at (not before) the time of the observation. For example, with a quantum superposition of two states, the state is not determined before its observation. The observation collapses one of the two states that make up the superposition.

*5 Interference fringes: A stripe pattern appearing when a system composed of several superposed waves is measured.

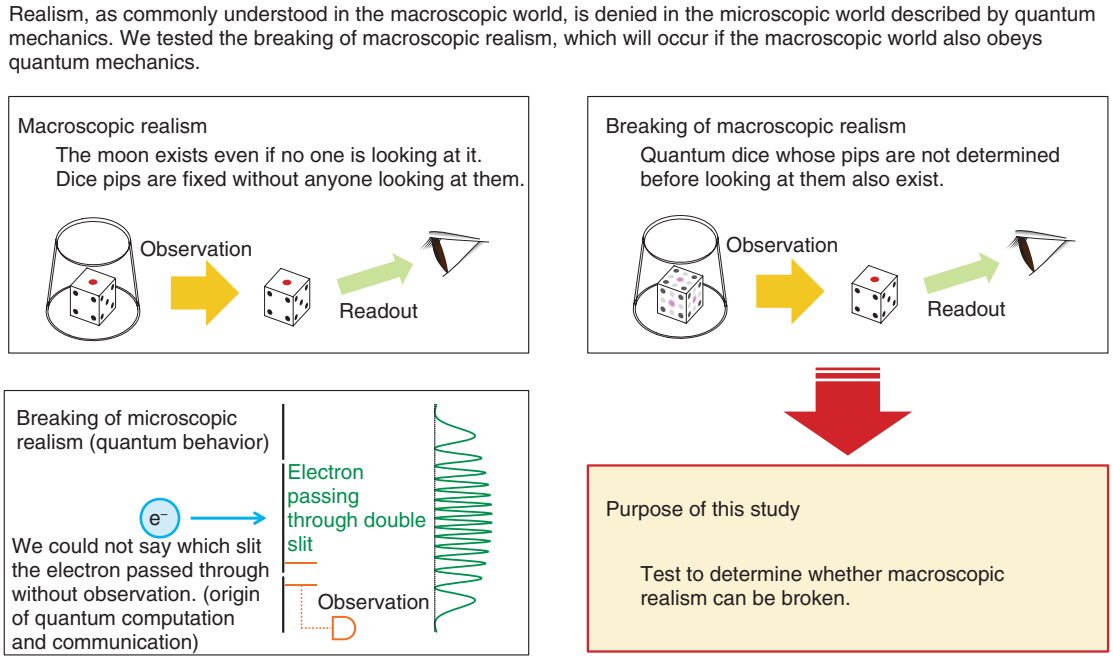

Fig. 1. Breaking of macroscopic realism.

a microscopic scale.

The experiment was performed by cooling a superconducting qubit to 10 mK. This enables us to prepare qubits in the lowest energy state (ground state: –1) because there is no thermal excitation in this temperature region. We then read out the qubit state after performing two operations (qubit state rotations) on the superconducting flux qubit. We compared the results obtained with and without observation during these two qubit operations.

We prepared the flux qubit in a coherent superposition of its ground (–1) and excited (+1) states with a first state operation and measured the difference between the results with and without observation (main experiment[*6]). If realism is true, we can expect the readout result to be independent of the observation because the state is determined before the observation. On the other hand, if realism is broken by quantum superposition, the qubit state will become +1 or –1 as a result of the observation. In our case, differences appeared in the readout results because of the observation.

Next, we carried out control experiments to confirm that the observation did not disturb the qubit state (control experiment[*7]). We prepared +1 or –1 states by using the first state operation and measured the difference between the results caused by the existence of the observation. By confirming that this difference is small, we can confirm the non-invasiveness of the observation, which means that our (+1, –1) control state was not changed by the observation. The difference from the result of our main experiment was well beyond that of the control experiments, meaning that we successfully demonstrated realism breaking on macroscopic objects such as a current state.

4. Technical features

(1) Measurement method mathematically equivalent to Leggett-Garg inequality[*8]

To confirm the breaking of realism on a physical

*6 Main experiment: This is an experiment designed to confirm that the generated superposition state changes into one of +1 or –1 states by observation. It is expected that the results obtained with and without observation show different values, respectively, if a quantum superposition state is realized.

*7 Control experiments: These are experiments undertaken to confirm that the state is not changed by observation when we prepare a pure +1 or –1 state. We expect to see sufficient small observation induced changes in these experiments to distinguish changes in the superposition state.

*8 Leggett-Garg inequality: An inequality obtained by correlating values measured at several different times. This inequality is satisfied in a system in which realism appears; however, this is sometimes broken in the quantum world.

system, we first need to demonstrate the breaking of the condition called the Leggett-Garg inequality. This inequality is always satisfied if realism is correct; however, it can be broken in systems that do not obey realism, for instance, quantum mechanics. It is difficult to show the breaking of the Leggett-Garg inequality directly because we have to measure the qubit state at least three times using high fidelity detection while the qubit maintains its quantum characteristics. These are hard conditions to achieve experimentally. We used an alternative method that is mathematically equivalent to the Leggett-Garg inequality and that avoids this detection difficulty.

(2) Superconducting flux qubit and state observation

To show the breaking of macroscopic realism, we need to detect small disturbances caused by observing a macroscopic system. A superconducting flux qubit has two states corresponding to +1 and –1. In each state, a few hundred nanoamperes of superconducting circulating current flow clockwise and anticlockwise, respectively. These currents correspond to 10^{12} electrons flowing around the loop per second, and this is a sufficiently macroscopic value to be detected with a current meter. It is necessary to observe the qubit current state without disturbing it. However, quantum non-demolition measurement[*9], which can achieve this, has proved difficult to realize. We achieved fast and highly accurate quantum non-demolition measurement of a superconducting flux qubit current state using a Josephson bifurcation amplifier[*10].

5. Future plans

We aim to demonstrate measurements with much less observation disturbance and to increase the macroscopic nature of the system by using a large supercurrent qubit or an ensemble of superconducting flux qubits.

Reference

[1] G. C. Knee, K. Kakuyanagi, M.-C. Yeh, Y. Matsuzaki, H. Toida, H. Yamaguchi, S. Saito, A. J. Leggett, and W. J. Munro, "A Strict Experimental Test of Macroscopic Realism in a Superconducting Flux Qubit," Nat. Commun., Vol. 7, 13253, 2016.

For Inquiries
Public Relations,
NTT Science and Core Technology Laboratory Group
Email: a-info@lab.ntt.co.jp

*9 Quantum non-demolition measurement: A measurement that keeps the state after measurement unchanged when we prepare an eigenstate such as an excited state or a ground state.

*10 Josephson bifurcation amplifier: A device for detecting small displacements. We can generate a bistable state in a nonlinear resonator including a Josephson junction by driving it with an optimal microwave. The nonlinear resonator converges to a different stable state depending on the displacement of the coupled object, so we can obtain information about displacement. We can read out a superconducting flux qubit state quantum non-destructively.

External Awards

IEEE Fellow
Winner: Shinji Matsuo, NTT Device Technology Laboratories
Date: January 1, 2016
Organization: The Institute of Electrical and Electronics Engineers (IEEE)

For his contributions to heterogeneous integration of semiconductor lasers.

Best Paper
Winner: Tatsuaki Kimura and Hiroshi Saito, NTT Network Technology Laboratories
Date: November 15, 2016
Organization: The 19th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM '16)

For "Theoretical Interference Analysis of Intervehicular Communication at Intersection with Power Control."
Published as: T. Kimura and H. Saito, "Theoretical Interference Analysis of Intervehicular Communication at Intersection with Power Control," Proc. of MSWiM '16, pp. 3–9, Malta, Nov. 2016.

ITU Kaleidoscope 2016 Best Paper Award
Winner: Kazuhide Nakajima, Takashi Matsui, Kotaro Saito, Taiji Sakamoto, and Noriyuki Araki, NTT Access Network Service Systems Laboratories
Date: November 16, 2016
Organization: International Telecommunication Union (ITU)

For "Space Division Multiplexing Technology: Next Generation Optical Communication Strategy."
Published as: K. Nakajima, T. Matsui, K. Saito, T. Sakamoto, and N. Araki, "Space Division Multiplexing Technology: Next Generation Optical Communication Strategy," ITU Kaleidoscope 2016, Bangkok, Thailand, Nov. 2016.

Electrical Science and Engineering Promotion Award
Winner: Yuichi Higucihi, NTT Device Innovation Center; Masaru Kobayashi and Toru Miura, NTT Advanced Technology Corporation
Date: November 16, 2016
Organization: The Promotion Foundation for Electrical Science and Engineering

For development of a cleaning technique for an optical fiber connector and for diffusion of the optical connector cleaner.

Best Young Presentation Award
Winner: Daisuke Kitayama, NTT Device Technology Laboratories
Date: November 25, 2016
Organization: Symposium on Frontier of Terahertz Science III

For "Metamaterial-based Flat Lens toward Dynamic Control of Transmissive Waves."
Published as: D. Kitayama, "Metamaterial-based Flat Lens toward Dynamic Control of Transmissive Waves," Symposium on Frontier of Terahertz Science III, Fukui, Japan, Nov. 2016.

Papers Published in Technical Journals and Conference Proceedings

Quantum Algorithms for Finding Constant-sized Subhypergraphs
F. L. Gall, H. Nishimura, and S. Tani

Theoretical Computer Science, Vol. 609, No. 3, pp. 569–582, January 2016.

We develop a general framework to construct quantum algorithms that detect if a 3-uniform hypergraph given as input contains a subhypergraph isomorphic to a prespecified constant-sized hypergraph. This framework is based on the concept of nested quantum walks recently proposed by Jeffery, Kothari and Magniez (2013) and extends the methodology designed by Lee, Magniez and Santha (2013) for similar problems over graphs. As applications, we obtain a quantum algorithm for finding a 4-clique in a 3-uniform hypergraph on n vertices with query complexity $O(n^{1.883})$ and a quantum algorithm for determining if a ternary operator over a set of size n is associative with query complexity $O(n^{2.113})$.

Power of Quantum Computation with Few Clean Qubits
K. Fujii, H. Kobayashi, T. Morimae, H. Nishimura, S. Tamate, and S. Tani

Proc. of 43rd International Colloquium on Automata, Languages, and Programming (ICALP 2016), pp. 13:1–13:14, Rome, Italy, July 2016, arXiv:1509.07276 [quant-ph].

This paper investigates the power of polynomial-time quantum

computation in which only a very limited number of qubits are initially clean in the |0> state, and all the remaining qubits are initially in the totally mixed state. No initializations of qubits are allowed during the computation, nor intermediate measurements. The main results of this paper are unexpectedly strong error-reducible properties of such quantum computations. It is proved that any problem solvable by a polynomial-time quantum computation with one-sided bounded error that uses logarithmically many clean qubits can also be solvable with exponentially small one-sided error using just two clean qubits, and with polynomially small one-sided error using just one clean qubit. A similar result is proved in the case of two-sided bounded error.

Optomechanics: Single-photon Frequency Shifting

E. Kuramochi and M. Notomi

Nature Photon, Vol. 10, No. 12, pp. 752–753, December 2016.

A fingertip-sized on-chip optomechanical device offers a controllable way to shift the frequency of single photons in the telecom band while preserving their quantum information.

Quantum Query Complexity of Almost All Functions with Fixed On-set Size

A. Ambainis, K. Iwama, M. Nakanishi, H. Nishimura, R. Raymond, S. Tani, and S. Yamashita

Computational Complexity, Vol. 25, No. 4, pp. 723–735, December 2016.

This paper considers the quantum query complexity of almost all functions in the set $F_{N,M}$ of N-variable Boolean functions with on-set size $M(1 \le M \le 2^N/2)$, where the on-set size is the number of inputs on which the function is true. The main result is that, for all functions in $F_{N,M}$ except its polynomially small fraction, the quantum query complexity is $\Theta\left(\frac{log\ M}{c+\log N-\log\log M}+\sqrt{N}\right)$ for a constant $c>0$. This is quite different from the quantum query complexity of the hardest function in $F_{N,M}$: $\Theta\left(\sqrt{N\frac{log\ M}{c+\log N-\log\log M}}+\sqrt{N}\right)$. In contrast, almost all functions in $F_{N,M}$ have the same randomized query complexity $\Theta(N)$ as the hardest one, up to a constant factor.

A Fast Exact Quantum Algorithm for Solitude Verification

S. Tani

arXiv:1612.05317 [quant-ph], December 2016.

Solitude verification is arguably one of the simplest fundamental problems in distributed computing, where the goal is to verify that there is a unique contender in a network. This paper devises a quantum algorithm that exactly solves the problem on an anonymous network, which is known as a network model with minimal assumptions [Angluin, STOC'80]. The algorithm runs in $O(N)$ rounds if every party initially has the common knowledge of an upper bound N on the number of parties. This implies that all solvable problems can be solved in $O(N)$ rounds on average without error (i.e., with zero-sided error) on the network. As a generalization, a quantum algorithm that works in $O(N \log 2\ (\max\{k, 2\}))$ rounds is obtained for the problem of exactly computing any symmetric Boolean function, over n distributed input bits, which is constant over all the n bits whose sum is larger than k for $k \in \{0, 1,\ldots,N-1\}$. All these algorithms work with the bit complexities bounded by a polynomial in N.

Active Manual Movement Improves Directional Perception of Illusory Force

T. Amemiya and H. Gomi

IEEE Transactions on Haptics, Vol. 9, No. 4, pp. 465–473, December 2016.

Active touch sensing is known to facilitate the discrimination or recognition of the spatial properties of an object from the movement of tactile sensors on the skin and by integrating proprioceptive feedback about hand positions or motor commands related to ongoing hand movements. On the other hand, several studies have reported that tactile processing is suppressed by hand movement.

Thus, it is unclear whether or not the active exploration of force direction by using hand or arm movement improves the perception of the force direction. Here, we show that active manual movement in both the rotational and translational directions enhances the precise perception of the force direction. To make it possible to move a hand in space without any physical constraints, we have adopted a method of inducing the sensation of illusory force by asymmetric vibration. We found that the precision of the perceived force direction was significantly better when the shoulder is rotated medially and laterally. We also found that directional errors supplied by the motor response of the perceived force were smaller than those resulting from perceptual judgments between visual and haptic directional stimuli. These results demonstrate that active manual movement boosts the precision of the perceived direction of an illusory force.

Tactile Apparent Motion on the Torso Modulates Perceived Forward Self-motion Velocity

T. Amemiya, K. Hirota, and Y. Ikei

IEEE Transactions on Haptics, Vol. 9, No. 4, pp. 474–482, December 2016.

The present study investigated whether a tactile flow created by a matrix of vibrators in a seat pan simultaneously presented with an optical flow in peripheral vision enhances the perceived forward velocity of self-motion. A brief tactile motion stimulus consisted of four successive rows of vibration, and the interstimulus onset between the tactile rows was varied to change the velocity of the tactile motion. The results show that the forward velocity of self-motion is significantly overestimated for rapid tactile flows and underestimated for slow ones, compared with optical flow alone or non-motion vibrotactile stimulation conditions. In addition, the effect with a temporal tactile rhythm without changing the stimulus location was smaller than that with spatiotemporal tactile motion, with the interstimulus onset interval to elicit a clear sensation of tactile apparent motion. These findings suggest that spatiotemporal tactile motion is effective in inducing a change in the perceived forward velocity of self-motion.

Sanshool on the Fingertip Interferes with Vibration Detection in a Rapidly-adapting (RA) Tactile Channel

S. Kuroki, N. Hagura, S. Nishida, P. Haggard, and J. Watanabe

PLOS ONE, Vol. 11, No. 12, e0165842, December 2016.

An Asian spice, Szechuan pepper (sanshool), is well known for the tingling sensation it induces on the mouth and on the lips. Electrophysiological studies have revealed that its active ingredient can induce firing of mechanoreceptor fibres that typically respond to mechanical vibration. Moreover, a human behavioral study has reported that the perceived frequency of sanshool-induced tingling matches with the preferred frequency range of the tactile rapidly

adapting (RA) channel, suggesting the contribution of sanshool-induced RA channel firing to its unique perceptual experience. However, since the RA channel may not be the only channel activated by sanshool, there could be a possibility that the sanshool tingling percept may be caused in whole or in part by other sensory channels. Here, by using a perceptual interference paradigm, we show that the sanshool-induced RA input indeed contributes to the human tactile processing. The absolute detection thresholds for vibrotactile input were measured with and without sanshool application on the fingertip. Sanshool significantly impaired detection of vibrations at 30 Hz (RA channel dominant frequency), but did not impair detection of higher frequency vibrations at 240 Hz (Pacinian-corpuscle (PC) channel dominant frequency) or lower frequency vibrations at 1 Hz (slowly adapting 1 (SA1) channel dominant frequency). These results show that the sanshool induces a peripheral RA channel activation that is relevant for tactile perception. This anomalous activation of RA channels may contribute to the unique tingling experience of sanshool.

Mobile Silk Fibroin Electrode for Manipulation and Electrical Stimulation of Adherent Cells

T. Teshima, H. Nakashima, N. Kasai, S. Sasaki, A. Tanaka, S. Tsukada, and K. Sumitomo

Advanced Functional Materials, Vol. 26, No. 45, pp. 8185–8193, December 2016.

Microfabricated mobile electrodes, nanopallets, designed to provide adherent cells with electrical stimulation are reported. Nanopallets composed of a cross-linked silk fibroin hydrogel matrix incorporated with poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS) are used. The silk fibroin composite is characterized not only by mechanical and electrical conductive properties, but also by its optical transparency in both the visible and ultraviolet regions, and by its biocompatibility with adherent cells. It is demonstrated that the adherent cells, including normal cell-lined cells and primary neuronal cells, loaded on the nanopallets can be manipulated while faithfully retaining their adhesive properties. By applying voltages via the nanopallets, the voltage-dependent calcium channels expressed in the cells are selectively stimulated, and this is confirmed by using confocal fluorescent microscopy during manipulation and performing multiangle observations. These features are attributed to both the mobile operation of the transparent nanopallets, and the ability to simultaneously measure electrical signals and perform fluorescent observations.

Manipulating and Trapping Light with Photonic Crystals from Fundamental Studies to Applications

E. Kuramochi

Journal of Materials Chemistry C, Vol. 4, No. 47, pp. 11032–11049, December 2016.

Photonic crystal technology, which was initially proposed as a way to realize nanoscale nanocavities and nanowaveguides, is now finding applications as a surface interface layer technology for light-emitting diodes with high brightness and solar cells with high conversion efficiency. On the other hand, nanocavities, which can efficiently confine light in an ultrasmall footprint with significantly enhanced photon lifetime, have greatly contributed to cavity quantum electrodynamics studies. Such nanocavities have also realized prototypes of ultralow-power functional devices and high-density integrated photonic circuits. In this review article, I focus on planar and two-dimensional slab photonic crystal and related structures, which have played major roles in both fundamental studies and device applications.

MSF: Architecture to Leverage Commodity Switches into Carrier-grade Networking

H. Yoshioka

Carrier Network Virtualization 2016, Palo Alto, CA, USA, December 2016.

The vision, development status, and innovation roadmap of NTT's NetroSphere concept and MSF (Multi-Service Fabric) architecture were explained.

Collective First-person Vision for Automatic Gaze Analysis in Multiparty Conversations

S. Kumano, K. Otsuka, R. Ishii, and J. Yamato

IEEE Transactions on Multimedia, Vol. 19, No. 1, pp. 107–122, January 2017.

This paper targets small- to medium-sized-group face-to-face conversations where each person wears a dual-view camera, consisting of inward- and outward-looking cameras, and presents an almost fully automatic but accurate off-line gaze analysis framework that does not require users to perform any calibration steps. Our collective first-person vision framework, where captured audio-visual signals are gathered and processed in a centralized system, jointly undertakes the fundamental functions required for group gaze analysis, including speaker detection, face tracking, and gaze tracking. Of particular note is our self-calibration of gaze trackers by exploiting a general conversation rule, namely that listeners are likely to look at the speaker. From the rough conversational prior knowledge, our system visualizes fine-grained participants' gaze behavior as a gaze-centered heat map. An experiment achieves a mean absolute error of 2.8 degrees in gaze tracking.
