Advanced Ubiquitous System Technologies for Symbiotic Evolution

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ABSTRACT This paper presents the concept of symbiotic evolution which aims to provide a better individual quality of life as well as an improved standard of work. Symbiotic evolution is a co-evolution process linking human activities and ubiquitous systems. We also discuss key technical challenges explaining three research projects. We continue to develop human-centered, environmentally-adaptive ubiquitous systems in order to enhance the applicability of symbiotic evolution.

KEYWORDS **Symbiotic computing, Symbiotic evolution, Ubiquitous computing, Technology forum, Ubiquitous workplace, Personal agent, Robust media understanding, Dependable network, Machine learning, Intelligent information integration framework**

1. INTRODUCTION

Recent progress in ubiquitous computing technologies makes it possible for anyone to access information, anytime and anywhere. Broadband convergence with mobile and broadcasting networks, for example, has been accelerating the process of the accessibility of such information. The emergence of RFID has enhanced the accessibility of real-world objects together with information on the Internet.

However, the target of the current ubiquitous technologies is too much focused on infrastructure, and little attention to the quality of human life and information utilization. As a result, the diversity of information literacy becomes even greater and of a more inferior quality. More serious security and privacy concerns are also arising as the ubiquitous information infrastructure matures.

In this paper, we propose the concept of symbiotic evolution to provide a better quality of life for individual persons as well as for work standards and specify the technical directions to realize such concepts. Symbiotic evolution is a co-evolution process involving human activities and ubiquitous systems. It was first introduced at the 2005 NEC Technology Forum, held on March 14-15 in Tokyo. We also explain the key technical challenges by describing three research projects that are being developed at the NEC Central Research Laboratories.

2. 2005 NEC TECHNOLOGY FORUM — SYMBIOTIC COMPUTING —

The NEC Technology Forum is an annual technical forum where discussions are held on emerging technical trends, which is jointly organized with industry, academia, and the government. The objective of the forum is to contribute to enhancing the corresponding IT technical domains and those of NEC's business domains. At the Forum held this year the theme was "Symbiotic Computing for Ubiquitous Information Society."

Professor Norio Shiratori, a keynote speaker from Tohoku University, addressed the concept of symbiotic computing, which is aiming at human-centered, environmentally-adaptive systems and is pursing the combined directions of creating new values as well as enhancing mobility (mobile computing) and information accessibility (connected computing). **Figure 1** shows a summary of the forum talks regarding symbiotic computing. Adaptations to humans, information aggregation and autonomic control, etc. were presented as key directions of the new value creation.

3. NEC'S APPROACH TOWARDS A MATURE UBIQUITOUS INFORMATION SOCIETY

We have also presented the approach regarding symbiotic computing and its marketing strategy at

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the NEC Technology Forum. In this paper, we summarize the objectives and the technical issues in more detail as follows:

3.1 Symbiotic Evolution

Through the discussion of the goal to apply symbiotic computing, we have introduced the term "symbiotic evolution." This is a co-evolution process linking human activities and ubiquitous systems, since we believe that new value creation emerges through such a process. We would like to provide a better quality of life for individual persons as well as improved work standards and also to specify the technical direction to realize these aims.

3.2 Ubiquitous Workplace

In order to realize these concepts let us first focus on the enterprise environment. By utilizing a convergence of mobile networking and office equipment as shown in **Fig. 2**, we are able to access various types of office information from outside the office, e.g., at home, on the way to the office and at customer sites, etc. This represents a physical extension of the office place and offers more opportunities to encounter new customers, new partners, new products, and new information to promote future business.

However, it is up to the employee's ability whether he or she can utilize such promising opportunities and realize actual business progress. Humans would be the weakest link in the entire process in such a situation. We need to support the capability of employee information processing and to improve the productivity of office work. Otherwise, the ubiquitous environment would just result in more difficulty for users to access the necessary information from the flood of unnecessary information.

In the Ubiquitous Workplace proposed here, we are aiming at the real-time processing of information acquisition, analysis, and action in a secure and reliable manner. These three processes form a cycle to create new information utilization values. In other words, we are focusing on the office worker's qualitative information processing rather than on just pursuing business volume development.

In the information acquisition process, real-time image capturing from the real world is important. We have developed a super-resolution image capturing technology. This is a real-time free-hand scanning system with mosaicing and super-resolving functions that aims to provide wide-field, high resolution image capturing. Through this process, we can apply object and character recognition technologies, and archive/sharing of such digitized information. Such a system will be achievable as an application for typical cellular phones with cameras in the near future. Such a technology is useful for real-time, real-world asset management as a complementary approach of RFID and sensor networks.

With regard to the information analysis process, real-time topic analysis is essential. This technology enables us to provide a topic that is fashionable in a community. The process would not be achievable if we were only to consider batch analysis. On the other hand, most advanced machine learning technologies regarding on-line processing provide significantly faster and more accurate information analysis using streaming data. This technology would be applicable for an information contact center, large scale news analysis, advanced customer relations management, etc.

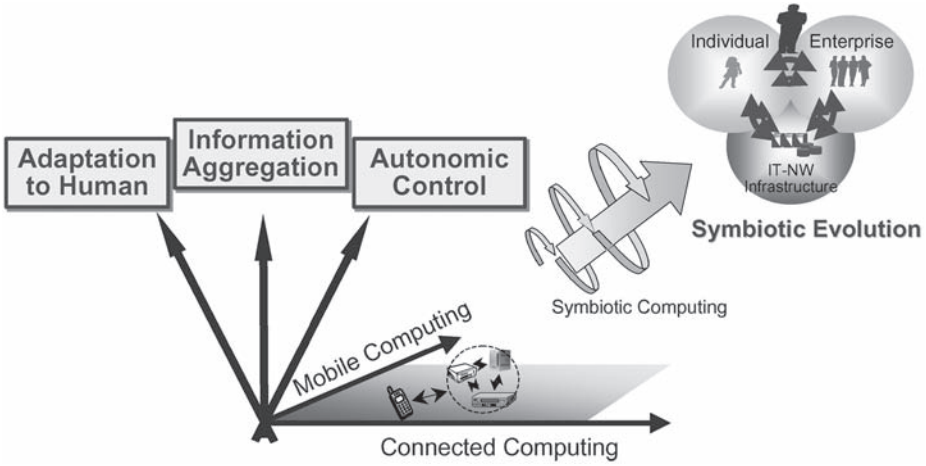

Fig. 1 Symbiotic evolution (2005 NEC Technology Forum).

Also, in the information action process, to support secure processing for the dynamic community is an important issue. The dynamic community refers to a virtual organization defined dynamically rather than an existing fixed organization. An inter-departmental project where members from different divisions, external consultants, partners, etc. work together, is an example. It is an inevitable situation in a typical ubiquitous environment. We need to provide secure information processing, even in such a dynamically defined environment. We have developed a secure document management technology in the unbounded organization. It is based on real-time document encryption and decryption processing with the combination of a public key and a content key. Within the dynamic secure community framework of the Web conference, collaborative editing system, etc. have been developed with ease of use.

As described above, real-time, smart information integration processing is necessary for the development of the Ubiquitous Workplace. NEC has conducted research and development on algorithm evolution as one of the most important issues.

3.3 Personal Agent

Personal Agent shown in **Fig. 3** is a project to

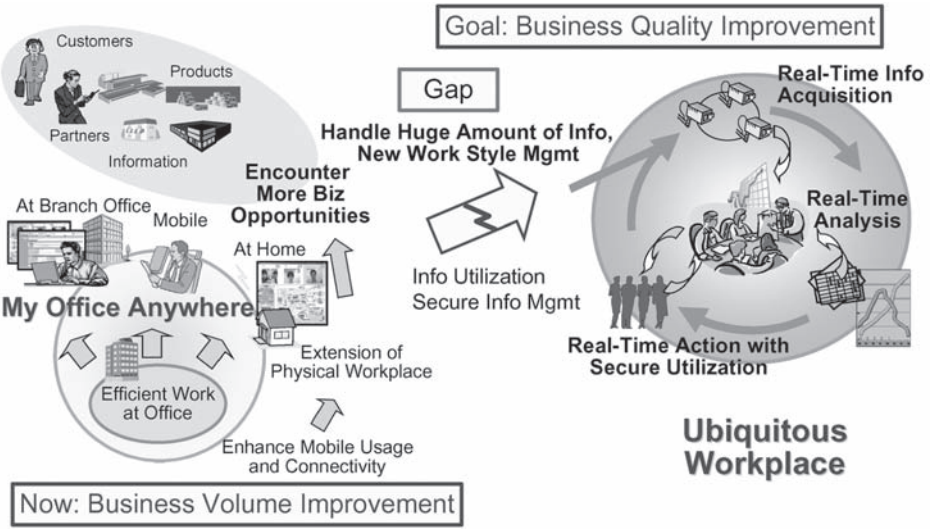

Fig. 2 Ubiquitous workplace.

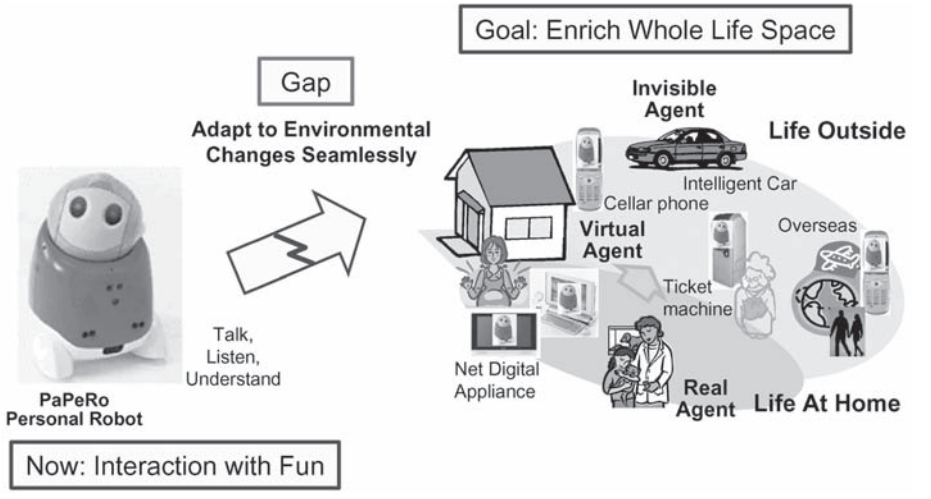

Fig. 3 Personal agent.

provide better personal life support to the human's five senses. PaPeRo, a personal robot developed by NEC, is the first step in achieving the goal. PaPeRo can listen, talk, and communicate with children as well as amusing them. PaPeRo can be considered as a real agent of the user.

As the next step, the virtual agent will support similar communications with an advanced CG (computer graphics) technology. In various information appliances such as audio-visual appliance, cellular phones, and vending machines, CG-based virtual agents are helpful to improve communication between the user and the system. This is useful if the user does not understand how to operate new appliances.

Additionally, an invisible agent will provide a seamless, invisible interface to maintain good interactions between the users and the system without any visible appearance of the agent. For example, if the driver is getting sleepy, the system can automatically detect the situation and sound an alarm or give some other warning action to the driver. This would be a concrete example of the calm computing that Mark Weiser explored after he introduced the concept of ubiquitous computing.

One of the essential technologies for the development of the Personal Agent is robust media understanding. The robust speech recognition that we have developed provides high quality recognition in various severe environments, e.g. noisy, hands-free, incapable of expression environments. Also, we have developed a series of robust image recognition technologies. Examples are a 3D face recognition technology adapting change of face orientation and change of lighting conditions, as shown in **Fig. 4**. An IMAP motion recognition processor enables to provide high quality object recognition even in bad weather conditions. These technologies would also be applicable for home security, intelligent transportation system, etc.

3.4 Dependable Network

The third domain towards the symbiotic evolution is the dependable network as an example of integrated IT and Network infrastructure as illustrated in **Fig. 5**. Client-server architecture is a basic framework for the current environment, and we adopt a policy-based network management system. The policy is basically predefined manually and later refined either autonomously or manually. The total number of clients currently connected to the network is at most a 100 millions. Otherwise, there would be a

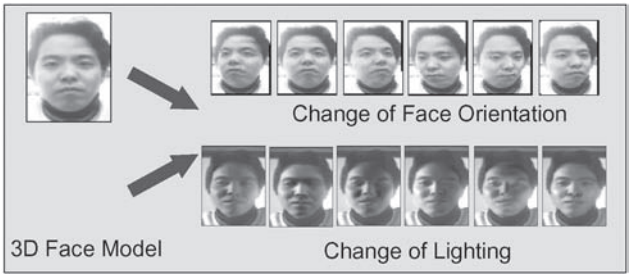

Fig. 4 Robust image recognition.

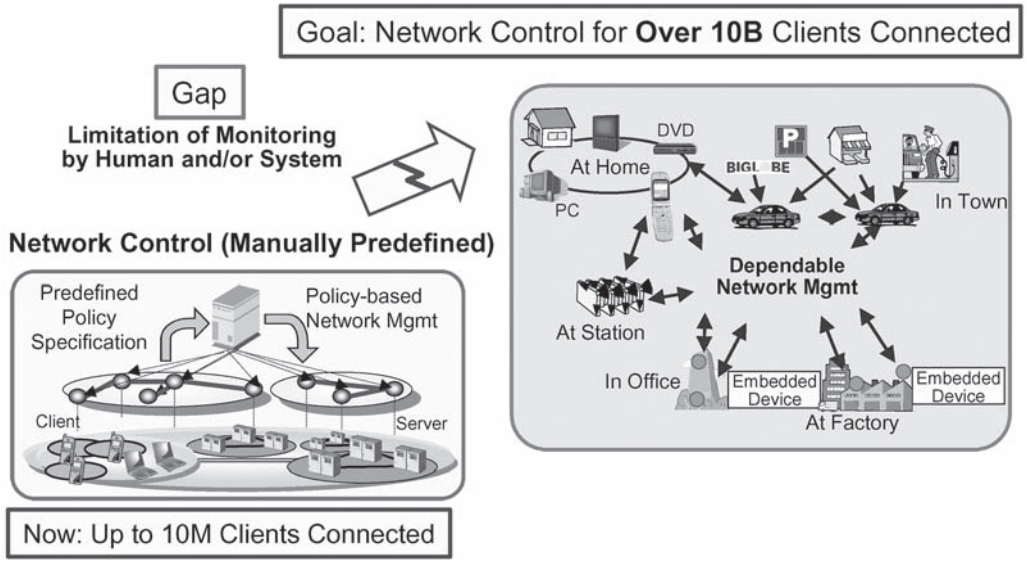

Fig. 5 Dependable network.

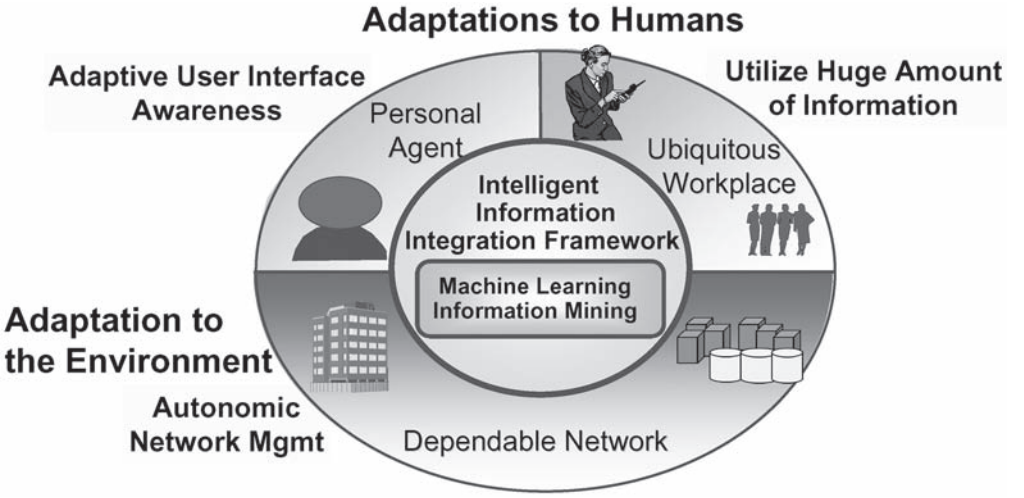

Fig. 6 Common technology — Machine learning —.

serious bottleneck of network monitoring. It would be difficult to manage it within an appropriate timeframe.

By 2010, the total number of nodes to be connected to the ubiquitous network will reach about 1 billion even in Japan. That is, in the matured ubiquitous information society, not only conventional PCs and cellular phones, but various types of appliances and embedded chips would be connected to the network. Therefore, it would be important to manage such a huge, non-persistent network. We call this the dependable network and need to provide a solution to monitor such a network efficiently.

3.5 Common Technology

As described above, we have introduced human-centered, environmentally-adaptive ubiquitous system technologies through the projects of the Ubiquitous Workplace, Personal Agent, and Dependable Network. The functional capabilities of the projects are the following:

- Adaptive user interface and awareness
- Information aggregation (utilize huge amount of information)
- Autonomic network management

The common technology used to realize the above functional capabilities is the Intelligent Information Integration Framework (I3F) where machine learning and information mining engines are the key components shown in **Fig. 6**. In association with I3F, we are able to provide real-time information acquisition, analysis, and action for systems such as the ubiquitous workplace. Users gain the benefits of the efficiency of systems development, and the accumulation of know-how. In other words, the origin of the new value creation comes from the engine. NEC has world-class groups researching into machine learning technologies in the global research organizations. We are able to refine the cycle of information acquisition, analysis, and action by using these key researchers and to apply it to the adaptive system in order to solve the real world issues.

4. CONCLUSION

In this paper, we have proposed the concept of symbiotic evolution to provide a better individual quality of life as well as an improved quality of work. Symbiotic evolution is a co-evolution process between human activity and ubiquitous systems. We have also presented key technical challenges explaining three research projects, e.g., Ubiquitous Workplace, Personal Agent, and Dependable Network, which are being developed at the NEC Central Research Laboratories. The common technology is Intelligent Information Integration Framework (I3F). We continue to develop human-centered, environmentally-adaptive ubiquitous systems to enhance the applicability of symbiotic evolution.

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Received April 19, 2005

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