Cyber Assist project as service science

— A project that began ten years too early —

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[Translation from *Synthesiology*, Vol.3, No.2, p.96-111 (2010)]

The Cyber Assist project was launched in 2000, and its R&D was conducted at the Cyber Assist Research Center at AIST from 2001 to 2005. This project was a leading activity followed by ubiquitous computing and service science in Japan as well as one of foresighted projects in the world. It should be highly evaluated even in the present time. The project had its focus on human-centered information system that provides services in the physical world.This article rebuilds the goal and activities of the research center on the basis of documents produced then, and provides future research directions.

Keywords : Cyber Assist, service science, ambient intelligence, ubiquitous computing

1 Introduction

The Cyber Assist project was conceived in 2000, and its R&D was mainly led by the Cyber Assist Research Center from 2001 to 2005. The project was one of the leading edge activities of ubiquitous computing and service science in Japan, as well as one of the foresighted activities in the world. The main point of the project is the construction of human-centered information systems and putting them into service in the real world.

In general, it takes decades for a new technology to get high recognition by society. For example, object-oriented software development, which is currently in the main stream, was first introduced in late 1970's and began spreading to society around 1990. It took another 10 years for it to become the main methodology. Compared to this, the Cyber Assist Research Center existed very briefly and therefore left many unfinished issues.

However, the goal of Cyber Assist is getting wide recognition under different research and development themes. The purpose of this article is to point out those relationships and to re-evaluate the activities of Cyber Assist as a synthetic research that establishes a new framework of research and development. In particular, we want to relate the activity to practice of "service *kogaku*" Note 1) that is getting attention recently. In the rest of this article, we first review the goal and activities of the research center based on the documents produced by the center and then evaluate them.

2 Goal of research and development and its realization method

We first describe the goal of the Cyber Assist Research Center and the structure of the center to realize the goal.

2.1 Cyber Assist project

The plan of the Cyber Assist project was first published in 1999[1], whose background situation remains valid up to now:

The concept of Cybernetics was proposed by an American mathematician Wiener in "The Control and Communication in the Animal and the Machine"[2]*. He described the concept of control system with information feedback. We want to give such feedback systems (nervous systems) to cities, where central nervous systems process high-level information while peripheral nervous systems relay sensor information and communicate with human occupants.*

This movement has already begun. As information infrastructure such as the Internet became available, it became rather easy for ordinary people to get hold of worldwide information. The utility of the network will increase rapidly in the near future. It is also anticipated that people will carry their own personal information processors and communicate with social information systems through them.

The Internet provides us alternative means to activities we have been doing without it, for example, buying goods and making reservations to hotels and airplanes. But the power of information processing did not stop there and opened up new possibilities that had been impossible or difficult beforehand. At the same time, as the consequent, many problems such as information screening, security and privacy issues may elicit themselves. To cope with those problems, we need personalized information processing systems. Along the line, research on personal agents has already begun. We need technologies to select necessary information out of vast flood of data and to communicate safely. Law and social framework have to be readjusted in large of course.

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Original manuscript received September 15, 2009, Revisions received February 23, 2010, Accepted February 23, 2010

But at the same time, we engineers must prepare tools and technologies for such new design of society.

The above article was written prior to the establishment of the Cyber Assist Research Center (CARC, hereafter) and covers wider topics such as digital city [3]. It conceptually covers all human daily life (potentially) related to information processing, such as transportation infrastructure and systems, which is exemplified by ITS (Intelligent Transportation Systems), for ground (and possibly air and marine) transportation, urban information systems as well as systems for city design, systems for governments and public services, telemedicine, and information infrastructure for tourism. The concept also includes providing a nervous system to a city by implanting sensors like stress gauges into structural materials of buildings and bridges, and use it for real-time sensing of damages caused by earthquakes. Since the concept is too wide-spread and vast, we later focused our attention on personal information systems and the related technologies [4]:

The aim of the Cyber Assist project is to establish a society where all people can enjoy situated support of information technology in all situations of their lives. Traditional information technology was available only through computers sitting on the users' desks. Recent spread of mobile devices increased the opportunity to use them, but still only a small portion of the people use them only in limited scenes of their lives.

The society as a whole can be animated by providing an environment for live information usable "here and now", which is accessible by anyone anytime through mobile and/or ubiquitous information technology. We want to implement technical support for not only convenient but also rich (not limited to material) life with deep human to human relationship in the physical world by providing services such as automatically buying tickets according to the user's schedule, guiding through a shopping mall, or informing that the person next to you happens to be your old-time school mate.

The widely used key phrase at the time of CARC's activity was "anytime, anywhere and anyone" (we expressed this as WWW, i.e. "whenever, wherever and whoever"). This phrase refers to accessibility and usability of information communication devices in all situations. But we were foresighted and didn't stop there. We emphasized situated service and used the phrase "here and now". Both phrases are used currently to put value on context-aware services at all times and in all situations.

In the early stage of development, the application area of information technology (IT hereafter) was limited to the digital world accessible from computers. On the other hand, activities of our lives are carried out in the physical world. Therefore, extending the IT support to all living situations of all people involves *grounding digital information to the real world*. The real world, which is meaningful to human beings, is the integral of realities of goods, individuals, and society woven together. Grounding consists of sharing meanings and situations between the digital world and the real world. The goal of Cyber Assist is to enhance ties between humans and goods by implementing grounding through information communication infrastructures for measuring physical locations and semantic structuring of information content (Fig. 1) [4].

Without tight coupling of the digital and the real world, IT cannot be effectively used. As we saw in the crash of the "net bubble" in the USA, the digital world alone cannot produce any new value. A world closed under the Internet is analogous to a world closed under finance which excludes production of goods. Information has value only because there are human beings on both sides of the information communication channel. To produce many kinds of sound IT-based business models, and to increase values in many aspects of our daily life, it is essential to use IT to integrate the digital and the real worlds.

2.2 Concrete research goals and approach toward them

To carry out the Cyber Assist project, we have to consider various supports in a wide variety of situations of human daily life including transport, medical care and emergency situations. There is no doubt that a single research center cannot handle all of this. A proper set of sub-problems must be isolated. A research organization must be managed considering both the top-down requirements described above and the bottom-up constraints of research resources including research specialization of researchers, research facilities and funding. As a result, we set the following goals (quoted from the proposal document for the establishment of the center):

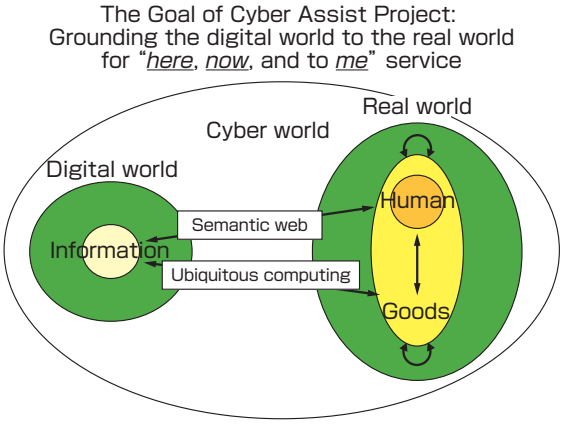

Fig. 1 The Goal of Cyber Assist Research Center

- *Goal: Personal Information Support (Technologies for information gathering, searching and presentation indexed by both location and ID)*
  1. *Situated personal agent*
  2. *Situated information search and presentation*
  3. *Structuring of content with tags*
  4. *Multimodal interface*
- *Approach: Situated communication software*
  1. *Location-based communication technology*
  2. *Gradual management of security and privacy*
  3. *Information services using physical information*
- *Media: Portable terminals and infrastructure using location-based communication*
  1. *Portable terminals*
  2. *Sensors and tags*

We held a meeting of all researchers once a week, and in the early stage of the center's activity, we concentrated on connecting each member's specialty and interest to the research goal of the center. The resulting diagram with concrete and detailed research themes is shown as Fig. 2. "Situated support" must be observed by all research themes. Everything placed under it are concrete research topics. Detailed descriptions of important research themes are given in chapter 3.

2.3 Structure and management of the research center

CARC used non-traditional organization and management to carry out research goals described in the previous section. In the current terms, it was organized to achieve Service Science, Management and Engineering.

Research and development of a system that implements a new service concept needs an organization for doing research from device to the application all together at the same place. Therefore, the research teams of CARC were organized in a ring shape as in Fig. 3, so that all the teams each of which corresponds to each technical layer can collaborate with each other toward the target of the situated support of users. The user interface team, responsible for the "interface" in Fig. 2, is given the top-level goal and collaborates with the device team, responsible for the "location-based communication" and the "devices" used for it in Fig. 2, the software team, responsible for the "communication software/infrastructure" in Fig. 2, the multiagent team, responsible for the "personal agent" in Fig. 2, and the intelligent content team, responsible for the "intelligent content", "GDA" and the "standardization" in Fig. 2. The basic concept is the same as the bazaar style of the consortium (appendix 9.3). All necessary technologies from basic to advanced levels are available in the house so that CARC can develop application systems on its own. This kind of configuration that gathers different technological areas in a single research unit is unique to AIST because of its mission to put technologies to social use. It more significantly holds for research centers that focus on the application side of research.

In the early stage of the center's activities, beside team-wise meetings, all researchers got together once every week to discuss services to be implemented so that all of them in different research areas can share the same target image. Furthermore, two or three days workshops were held annually to exchange their progress and to share application images.

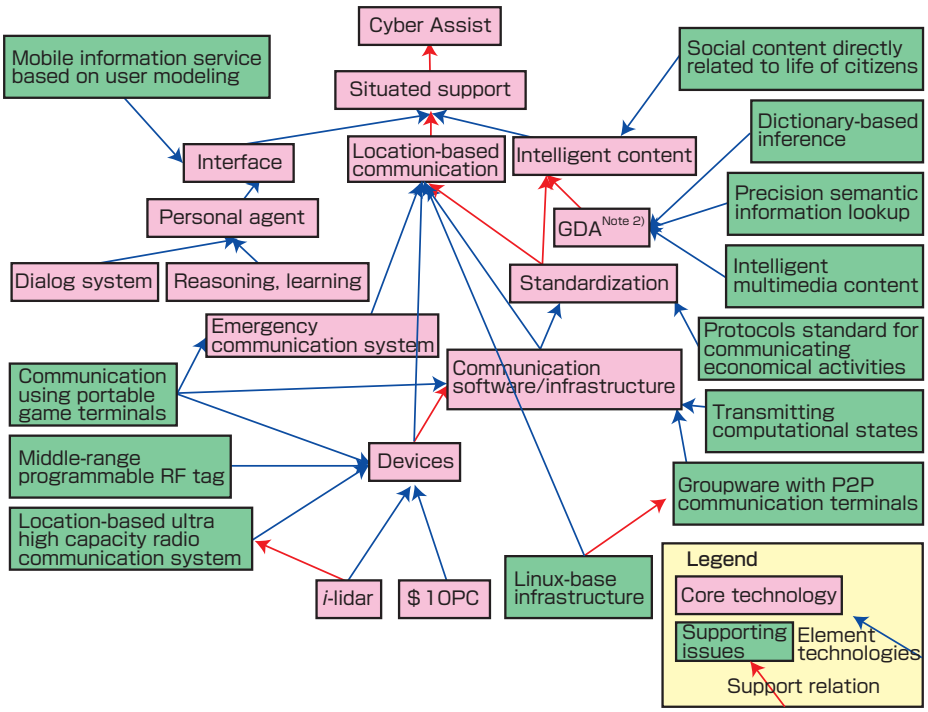

Fig. 2 Relationship among research themes of Cyber Assist (initial stage)

Since we put our stress on outcomes (applications to society), we adopted a coordinator[Note 3)] from the beginning. His activity was significant and resulted in hiring an industrial designer[Note 4)] and a head of a patent attorney office as our part-time advisor. A young patent agent attended every CARC meetings to assess patentability of our ideas. Proper management of intellectual properties is essential for joint research with private companies or establishment of venture companies. He also drafted rules for AIST consortiums because the Cyber Assist Consortium was the first one in AIST and there was no rule for it.

3 Research scenario

The Cyber Assist project has two characteristics as "ubiquitous computing" and "service science". Ubiquitous computing aims at establishing ubiquitous human assist by ubiquitous computers, and it is essential to have interfaces that do not make users aware of the existence of those computers. Vastness of the range of related basic technologies makes it difficult to focus on narrow research areas. The following research topics are therefore not consistently organized nor cover all areas of the Cyber Assist project. Moreover, the project's emphasis on practice as service science makes the list of technological issues detailed and long. It is difficult to write a traditional research paper with a clear story[Note 5)].

3.1 Location-based communication

The research area of CARC is "grounding information world to the real world". Many kinds of real-world information must be acquired and utilized to ground information content to the real world. Location is far more important and useful as information compared to others.

We proposed the concept of "location-based communication" in our early stage of research[5][6]. Location-based communication uses location of devices as the target address of communication, instead of uniquely identifiable addresses such as phone numbers or IP addresses. Use of location can hide the identity of the user for privacy protection at the same time enhancing situated (recently called "context-aware") support:

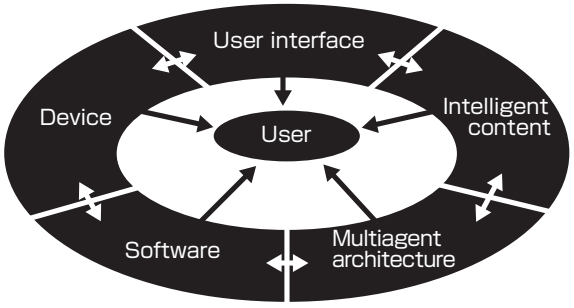

Fig. 3 Organization of Research Teams of CARC

Current information communication uses ID-based communication in the sense that communication is transmitted toward a uniquely identifiable ID of a user or a device, such as phone numbers, IP addresses, or MAC address of the hardware. To relay communication, there addresses are distributed world-wide. When the ID of an individual person is published as such, privacy cannot be protected. For example, when you pay by electrical means such as a credit card, your identity may be revealed. On the other hand, if you do not have the ID, you cannot even electronically communicate with a person in front of you and the system cannot support your every-day communication needs.

To implement useful communication systems for every-day life, while guaranteeing free societal life and economical activities, we need a communication technology that do not use personal or device ID for the target address. At the same time, we have to develop security enhancing technology to prevent malicious use of anonymity to support both privacy and security. (quoted from early CARC home page)

Location-based communication is also important for realizing situated user interface. For example, automatic gates at train stations are operated by the principle of location-based services. By physically restricting the space to allow only one person at a time, the system maps a user to payment. If a Suica[Note 6)] card is readable from 5 m distance, then the system cannot map the person to the payment, and the service breaks down. If the user's location cannot be used, then additional authentication is required and the interface of the system becomes more complicated. We claim that use of location information makes the interface simple. A similar idea is adopted in CoBIT system described later (section 4.1).

3.2 My-Button

CARC proposed a conceptual idea of an ultimate situated user interface "My-Button" [7]. It is a personal terminal with only one button (Fig. 4). This concept is rather a show model than a realistic design, to signify the target image of one-bit communication to provide "what I need, here and now", just like the communication of an old couple who is like a synchronized instrument each anticipating the other's wishes. The terminal understands and shares the situation with the user and functions properly without detailed instruction from the user. It is proposed as an ultimate image of a simple and natural interface. In practice, we need more than one button although it is still true that a small number of buttons is preferable. The concept at the same time claims that complete automation with no buttons is not good. The final authority must be left to the user.

We believe that we need this kind of idealized goal in constructive research that is neither needs-oriented nor seeds-oriented. The research scenario and the application

image are constructed based on this conceptual model. Research of service science maybe composed around a new idealized service model.

3.3 Intelligent content

Content services play a large part in recent service provision. Content such as movies, news, Web pages, music, etc. must go hand in hand with mechanisms to deliver them. CARC also focused on manipulation of content provided through devices such as CoBIT (section4.1). At CARC we developed technologies for compiling and delivering structured information content, called intelligent content, as well as proposing a standard format for those structured digital data [8]. Tags annotating digital documents, movies, and so on [9] allow computer programs to process semantic structures of such content. This makes possible semantic manipulation of content, in particular semantic matching and semantic restructuring. We further developed various application technologies of intelligent content based on natural language processing and multiagent technologies. We aimed at construction of a society for sharing and reusing semantic information of content. Since information content often concerns the real-world, we can semantically reconstruct the world by grounding intelligent content to the real physical world.

Location-based communication and semantic structuring of the world are two wheels of one cart for grounding digital information. They allow computers and people to share meaning of information, which should promote a conspicuous improvement over the whole society by making it possible to realize brand-new systems, because the application domains of these technologies encompass a very large realm concerning the entire communication technologies and intelligent information processing technologies. In particular, such technologies and technologies of cellular phones, etc. are complementary to each other, so that their natural integration will enable various ubiquitous intelligent information services.

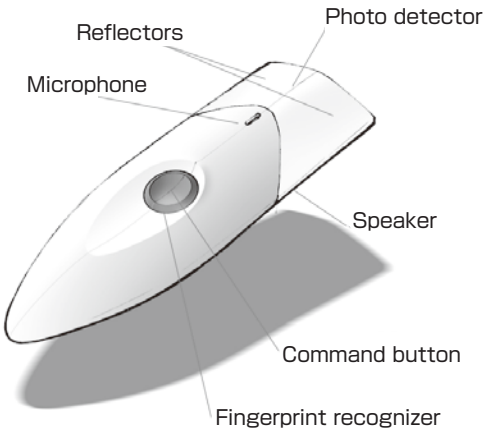

Fig. 4 Image of My-button (example)

CARC not only developed such fundamental technologies and promoted the standardization of related specifications, but also presented prototypes of representative application technologies involving major research issues, in order to provide common platforms for many applications and thereby to construct an infrastructure upon which private companies could develop various other application technologies. These research results are currently used for retrieval of movie scenes, collaborative authoring system for online comprehensive dictionary, and so forth.

CARC had also planned to use these technologies in event-space assistance system (section 5.2) and Expo 2005 Aichi Japan, to instantly reconstruct information required in the users' situations from huge annotated data and deliver it to the users' information terminals. Due to the large cost of content production and the lack of sensing equipments for extracting appropriate content, however, this plan materialized only partially.

4 Research and development projects

In this chapter, we describe research and development activities for each sub-theme at the final phase of the project. Since we covered diverse areas in our activities, the followings depict only significant results.

4.1 My-Button oriented terminals

In the early phase of the project, we were trying to implement "location-based communication" (section 3.1) using *i*-lidar-based locating and communication [11]. The *i*-lidar is a device for measuring the distance to the target by observing the resonance of frequency modulated laser beam with its reflection from the target. Combining this distance information with the direction of the laser-beam, we can measure the 3D position of the target. However, the device costs the magnitude of ten million yen for each set and it cannot be expected to become lower than one million yen even with mass-production. It is too expensive to be used in mass in the real-world applications. We therefore limited this issue for basic research only.

The concept of battery-less information terminal, CoBIT [12] was born as a deviation from *i*-lidar[Note 7] (Fig. 5). This terminal exemplifies location-based communication since it utilizes physical location to deliver information encoded as an infrared beam which also provides the power. It is the first product of CARC to realize the simple and natural interface requirement of the "My-Button" concept. By reducing the device implanted in the environment into simple LED systems, it became feasible to use the device in various applications. Many applications described in chapter 5 came up together with plans for popularization through an AIST venture company "Cyber Assist One, Inc." set up by some members of CARC.

CoBIT exemplifies location-based communication since it receives information only when it is located in front of the light source. Suica exemplifies another kind of location-based communication by its very-short range communication in the order of 10 cm while CoBIT's range is in the order of several meters. Suica must be short-ranged because it uses non-directional radio wave. CoBIT is directional, which is one of the advantages of light. Since CoBIT receives information only when it is directed toward the information source, it is possible to selectively receive one channel from multiple information sources even at the same location. As an example, consider a blind person trying to receive information of traffic light. One light is green while another light in 90 degrees difference is red. It is critical to choose information from the right direction to which the person wants to proceed.

4.2 Design and development of middleware

Traditional concept of OS that presupposes fixed configuration of devices cannot be used in ubiquitous computing where various devices are connected in an ad-hoc manner. A new layer, called middleware, must be constructed to interconnect the hardware and the software layers. The function of the middleware is to connect various devices and/or to set up a virtual hardware to be used by application programs.

The software team proposed and implemented the so called UBKit [13]. It is a set of software/hardware components to be used as modular building blocks for ubiquitous computing. They used it to implement intelligent home appliance systems.

At CARC, the device team was also developing its own middleware for CoBIT. We discussed to unify their designs in our meetings several times but did not succeed in merging them. The top priority of the center was to complete their application systems and those two middleware were based on different architecture and technologies to be merged in three years.

4.3 Applications of multiagent simulation

The multiagent team worked on various research themes including basic research on traffic simulation[14][15] and application of simulation technology for construction of standard simulators used in RoboCup [16], both in soccer and rescue, which provided the Japan originated international standard. Both soccer and rescue RoboCup's consist of real robot leagues and simulation leagues, and we participated only in simulation leagues. Our contribution to soccer leagues was initiated before CARC and carried over to CARC[Note 8], and contribution to rescue was newly added during CARC's activity. We also carried out simulation on rescue strategies and on information transfer using ad-hoc wireless connection in disaster scenes. Having a special communication system for disaster cases does not work. It is better to use the same terminal as in daily use. If we can use battery-less systems like a CoBIT, then our research themes complete a loop. Unfortunately though, we could not achieve it.

5 Abundant experiments and applications

At CARC, we emphasized not only designing a new service but also carrying out actual services and getting feedback from the applications– the practice of service engineering. The followings are typical examples.

5.1 After 5 years

When the New Marunouchi building was completed and opened for service, an exhibition named "After 5 Years" was held to present an information environment five years in the future. The original plan was to allow only silent exhibits because many booths were placed next to each other without enough separation to use any sound from speakers. We proposed to use CoBIT so that visitors can listen to the sound only when they stand in front of each exhibit, and it was successfully accepted (Fig. 6). This was our first application of location-based communication.

Using CoBIT in several exhibitions including "Doraemon" revealed the problem that LED used for the information

Fig. 5 CoBIT

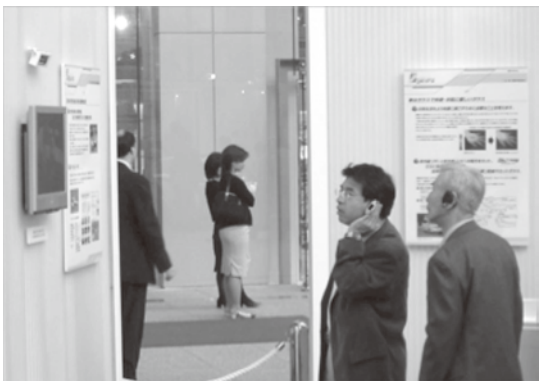

Fig. 6 Usage scenery in "After 5 Years" (The light source is located upper left)

source decays in much shorter period than their announced lifetime. We found that the cause was the periodical high voltage as the result of amplitude modulation of the source sound signal. Application of higher voltage than the design limit shortens the lifetime of LED significantly. We changed the design of the circuit to use the limiter. Laboratory tests cannot find this kind of problem.

Similar systems were used in several exhibits in many institutes including MeSci and AIST. The Aichi Exposition was the summit of them.

5.2 Event space support system

We designed a conference support system[17] and used it at the annual conference of the Japanese Society for Artificial Intelligence. As individual terminals, we used a modified version of name tags usually used for conference participants. We added an integrated system of infrared receptor, ear phone, reflector and LED light (visible at the center of the reflector) (Fig. 7 left). As information stations placed in various places of the conference site, we used a unit consisting of an infrared emitter, a camera and a display (Fig. 7 right is an experimental station using a plain PC). Besides the main function of listening to voice information from the station by the ear phone, we provided a function to keep record of the visitor who emits his/her ID using the LED, and a function to use the name tag as a mouse to give instructions to the station by tracking the movement of the reflector with the camera.

The content service of the system includes information retrieval based on the map of researcher relationships[18] automatically extracted from research papers lists on the Web [19]. This service makes use of the fact that the conferences are closed for research community only. The service also provides other contents based on conference programs. It is one of the rare applications of CARC that has intelligent contents.

This event space support system was used at consecutive annual conferences of the Japanese Society for Artificial Intelligence and also at an international conference on ubiquitous computing held in Tokyo (UbiComp 2005).

5.3 Intelligent home appliances

The software team conducted a field experiment in Yokohama to run an integrated system flexibly connecting several intelligent home appliances using UBKit[20] developed by the team. Users do not have to manipulate each appliance separately. By vocally announcing their intention, the intelligent system controlling the room accomplishes the task to fulfill their wish. For example, if you say "I want to watch NHK news", then the system takes series of actions including turning on the TV, setting the proper channel – note that the channel settings for NHK are different by regions, closing the curtain if the room is too bright, and so forth. It is also possible to preset the timer to automatically open the curtain and turn on the air conditioner at a certain time in the morning.

The experiment was conducted at the community center. We asked volunteers from the region to come to our meeting several months prior to the experiment, to answer our questionnaires and exchange opinions on intelligent home appliances. Through the meetings we gathered precious information on how people including elderly and weak-sighted person feel about computerized appliances and fed it back to our research plans[Note 9].

5.4 Expo 2005 Aichi Japan

The biggest application opportunity for CARC was at Expo 2005 Aichi Japan. It was an unprecedented challenge for AIST to provide a half-a-year long service in this worldwide event. CARC took part in two projects.

Global House: This was a pavilion directed by the Japanese government. It mainly featured collections supervised by Mr. ARAMATA Hiroshi, and CARC contributed technologies for audio commentaries about them. An advanced version of CoBIT equipped with ID tag was employed, named "A*i*mulet

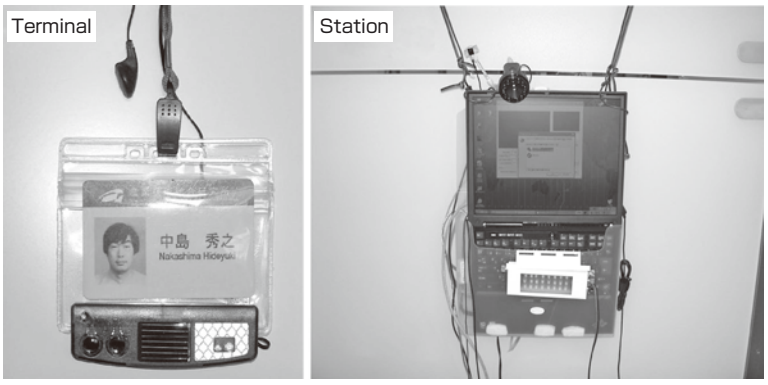

Fig. 7 The terminal (left) and the information station (right) for conference support system

Fig. 8 Field test of our intelligent home appliance system

(tm) GH" (Fig. 9). "A*i*mulet" is a neologism inserting "I" into "amulet" where "I" stands for both information and "ai" (love) in Japanese. "GH" stands for "Global House".

A*i*mulet GH aimed at multilingualism by multiple frequency bands of infrared rays like air broadcasting. In the early planning phase of the Expo we wanted to cover five languages including Asian ones. Later experiments revealed that a sufficient bandwidth was unavailable, however, so that the actual implementation was in Japanese and English only. It is a future task of service engineering to close such a gap between theoretical possibilities and practical applications.

Besides the audio explanation provided by A*i*mulet GH, sensors on the ceiling acquired visitors' traffic lines by detecting signals from tags embedded in A*i*mulet GH. This data will be important for later design of event sites.

Show & Walk: This was an event planned by performance artist Laurie Anderson, which provided artistic experiences to people visiting a Japanese garden installing sound sources and other artifacts (Fig. 10). Close to the principle of location-based communication, this suggested a new application field of CARC. We were responsible for the sound part only, and in the planning phase our researchers visited Laurie's office in New York to discuss various possibilities with her staff.

Fig. 9 A*i*mulet™ GH

We first aimed at spatial localization of stereoscopic sound, but it was unsuccessful and ended up with the same audio technology as CoBIT and A*i*mulet GH.

The terminal shown in Fig. 11, named A*i*mulet (tm) LA where "LA" is the initials of "Laurie Anderson," was manufactured inexpensively enough to distribute in place of entrance tickets. We considered that this low-price terminal should be a powerful tool, as museums and other facilities are generally having a hard time collecting without loss the rented out terminals to visitors, and the collection is even harder in an outdoor environment like a Japanese garden with many gateways. We also incorporated the notion of ecology, which was the theme of the Expo, into the frame design of A*i*mulet LA, by housing it in a bamboo sheath, which was resource-saving and inexpensive, so that the terminals needed not be collected and visitors could take them home.

Figure 11 is A*i*mulet LA viewed from the side of the photo receiver, which should face downwards when in use to avoid outdoor sunlight interference. The photo receiver uses spherical solar cells, which relax the directivity and provide a wide light-receiving area. In this connection, A*i*mulet LA was highly evaluated in terms of its usage of bamboo and solar cells, receiving a Good Design METI Minister Award for Ecology Design[Note 10)] in 2006.

A*i*mulet GH and LA are beneficial also because they need no battery replacement as solar cells supply their power. Since the replacement or charge of thousands of batteries is a huge burden, maintenance-free terminals without such need would be very useful in long-term events.

6 Service engineering and ambient intelligence

As the last issue of discussion, let us re-assess Cyber Assist research in the recent research map. CARC was performing "service engineering" research to realize "ambient intelligence" in the domain of "Cyber-physical system".

Fig. 10 A*i*mulet LA usage at Show & Walk (Left-hand side is Laulie herself)

6.1 Service engineering

Firstly, we have to clarify the meaning of "service engineering". The phrase "service kogaku (service engineering)" was first used at Research into Artifacts, Center for Engineering, the University of Tokyo ([21][22] p. 134). They define "service" as follows:

Activity of the provider to materialize the change requested by the receiver in exchange with some payment.

An English-Japanese Dictionary lists over 20 entries for "service"[Note 11] including work, religious ceremony, army, maintenance, serving a ball, and so on. This means that there is no corresponding word for "service" in Japanese.

However, it is possible to see the essence of the word: to provide something for use. The meaning differs depending on providing what. In the context of this article, service means to provide information systems for actual use. The target of service engineering is this "use" phase. Engineering in general is an academic discipline for constructing some system. Automobile engineering is for construction of automobiles, and information engineering is of information systems. In contrast to these engineering fields with vertical divisions, service engineering is a horizontal division of all of them in their "use" phase. It does not suffice to merely analyze the "use" phase objectively, as in science, but it is necessary to actually construct the phase, i.e., to provide service, and get new knowledge to feed it back to the system.

IBM is proposing a field called service science, management and engineering (SSME), and it is referred to as service science in Japanese. However, we believe that it should be called engineering rather than science if the discipline calls for actually constructing or designing a system [23]. Since service is what we should construct rather than analyze, it is proper to call it "service engineering". Japanese word "kogaku" fits much better because it has "gaku", meaning study, as in "kagaku". It is because the English word "engineering" does not fit well that the field must be called with such a long name.

Fig. 11 A*i*mulet™ LA

CARC's activity can be classified as achievement of service engineering in the sense that it is service oriented information engineering. Until the AIST research center was established, it was practically impossible to put research results into actual service unless they were turned into products of some manufacturer. This gap between research result and products is beyond the coverage of traditional public research and development funding. It was called, therefore, the "valley of death" or the "era of nightmare" [24] where neither researchers nor manufacturing companies could become involved. AIST made it possible to provide actual service by the following reasons.

1. By incorporation of AIST, it became possible to hire non-researchers with various specialties using research budget.
2. Venture assisting fund became available[Note 12].
3. In the case of Aichi Expo, running fund was given to AIST.
4. A new category of research unit, research centers, was created, whose activities were not limited to basic research.

In practice of service engineering, we believe it important to divide research units into two categories: those who primarily focus on basic research and those who primarily focus on providing services. The latter does not fit into traditional evaluation criteria of research activities.

6.2 Ambient intelligence

The research area to assist human activities through sensors and actuators located in the space of the activity is variously called as ubiquitous computing or pervasive computing. In Europe, it is often called ambient intelligence[Note 13].

Cyber Assist can be viewed as an application of artificial intelligence. In fact, many researchers at CARC including the director and deputy directors are from AI. Researchers in the US and Europe have to produce many research papers due to the strict evaluation of their research activities. They say it is difficult to aim at real application systems. Therefore, there the ambient intelligence research examples are limited to their lab and meeting room environments within their universities. CARC is unique in the activity outside the research labs, and it is why we were invited to give a talk at the International Joint Conference on AI 2007[25], whose main theme was application of AI to society.

6.3 Cyber physical system

NSF recently launched a research area called CPS (Cyber Physical System)[26]. The concept is very similar to Cyber Assist in the sense that they both deal with the feedback loop between physical and information systems where physical systems interact with information systems and information systems in turn control physical systems (although they call information systems cyber systems).

7 Self evaluation

Let us evaluate our activities.

7.1 As a research project

The Cyber Assist project was initially planned to achieve a part of "Intelligent Social Infrastructure Technology" set by the result of a pilot research program of Agency of Industrial Science and Technology, MITI. The detail is shown in the appendix. The pilot research program is conducted prior to launching a full scale national project such as the Fifth Generation Computer Program. Unfortunately, Intelligent Social Infrastructure program was never launched, partly because the plan involves many ministries and therefore it was too big to be managed by a single ministry of either MITI or METI. We were also expecting the Cyber Assist project to spread nation-wide through activities of CARC. It was a failure since we could not achieve this. We analyze the reason in the following sections.

7.2 As activity of service science

One of the roles of AIST is to go over the "valley of death" of R&D to fill the gap between the research and products. AIST has two kinds of research units: research institutes and research centers. We believe that the role of bridging the gap should be taken by research centers.

CARC tried to fulfill this role. In the IT area, the best way to fill the gap is to actually provide the service to show its effectiveness. In this sense, CARC's activity should be evaluated in the context of achievement of service science. At the same time, it can be the subject of service engineering research to establish proper research method of service engineering. This article is a review of the activity of CARC from the viewpoint of service engineering.

Services provided by CARC, e.g. event space support at conferences and exhibition guidance at Aichi Expo, can be assessed as successful when they are practically used in society. However, none of them were put into market independently. One of the reasons can be attributed to the short life span of CARC. New technologies need at least a decade before it is widely accepted by society. Three years was too short for this. If CARC remained in its form and continued on to the current Center for Service Research, some of CARC's results could have been sent out to the world.

7.3 On naming

Naming of projects, research papers, research themes and constructed systems plays a significant role in their success. Some of research themes became popular by its good naming (e.g., "Chaos") and many did not because of their bad naming. In this sense, our naming of Cyber Assist was a failure. We are proud that we have had a large influence on fellow researchers in close fields, but we could not reach further out toward manufacturing companies or planners of national projects as "ubiquitous" used by Ministry of General Affairs or "service engineering" used by Ministry of Economy, Trade and Industry.

Use of "cyber" was somewhat problematic. We used the term in the precise sense of Wiener's Cybernetics. But popular image was differently coined by the "Cyber world" of the movie "Matrix", where it is used to refer to the digitally rendered world to which people "jack in". "Cyber terrorism" is used for terrorism on the Internet. Therefore, our research may have been mistaken for activities on the Internet with no connection to the physical world. We had to repeat our definition:

$$\text{Cyber} = \text{Digital} + \text{Real}\ [27].$$

However, the very fact that we had to repeatedly explain it signifies our failure. What we aimed at is Cyber-physical system (section 6.3), which is recently getting attention in the US. We should have added some word that clearly designates the real world.

The second failure is that we did not use the phrase "ubiquitous". At the time of the establishment of the research center, the phrase "ubiquitous" existed but was not commonly accepted. It is reported that the prime minister at the time said it was incomprehensible and thus we could not project that it would become a common term as it is these days. It must be noted though that the current use of "ubiquitous" is along the line of Ministry of General Affairs which is in charge of communication infrastructure and hence has emphasized ubiquitous communication. It does not exactly reflect the original use by Marc Weiser. The use is limited to connectivity to the Internet "whenever, wherever and whoever". We agree that connectivity is a necessary condition but the most important part is services on top of it. It must also be noted that there are many other misuses such as "ubiquitous society".

We still think the inclusion of "assist" was a success, which puts emphasis on human support. It should be highly evaluated because it refers to the goal rather than the elemental technology or field.

If we can rename the project now, what would be the appropriate name then? Candidates are "ubiquitous assist", "cyber assist real" or "ambient intelligence".

7.4 On design issues

At CARC, we have been putting emphasis on design from the beginning, such as hiring an industrial designer Shunji Yamanaka as a research advisor. If we want our technology to be used in society, design is important. There are two kinds

of design: design of appearance and design of functions. The latter is somehow within the ability of researchers but the former is not.

According to Yamanaka, he used to be a designer of cars, but left the field to become independent because he thought that the shape design of cars has too much freedom to realize a desired function and therefore not very interesting. His philosophy that the function determines the shape is typically exemplified in his design of the Suica reader.

Yamanaka was present at our bi-weekly meetings as well as annual off-site workshops to propose ideas of shape design that implements functions we discuss. A*i*mulet LA, which received the Good Design Award, is the best successful example we have that turned desired function into a good shape. However, we regret that the infra red communication system exemplified by A*i*mulet LA did not make it to commercial use.

7.5 Unfinished goals

We had a "digital version of a tally method" on our research agenda from the early stage of the project, but it was never realized. Tally is a method to protect information content by physically dividing a paper or a plate on which information is written into two parts so that each piece alone is meaningless. Two pieces must be together to decode information. We wanted to have a similar system on digital data for privacy protection.

> *[Example] Information storage by the tally method*
> *Gathering personal information on a server is problematic in terms of privacy protection because it is vulnerable to malicious data usage or accidental leakage. We need a security or encryption method to divide information between the server and user terminal so that information is meaningless unless both of them are present.*

We understood that this is a next to impossible goal from the beginning. Simple encryption cannot be the solution because encrypted data becomes a plain data that can be copied when it is decrypted for use. For example, an encrypted personal medical record can be copied once a doctor displays it on his terminal and the doctor can keep the copy after the patient goes home. We need a method to guarantee that the data is accessible only while the patient is present. We thought this might be an unsolvable problem within the digital world alone. We thought some physical means, location-based communication for example, must be combined and searched for the solution without success so far.

7.6 Evaluation by the Advisory Board

The following is the executive summary of the final report by the advisory board of CARC given in 2004. It matches our own evaluation of CARC.

We find that the Cyber Assist Research Center (CARC) is a unique organization that is:

- *Pursuing a powerful new vision in a field of worldwide importance;*
- *Aggressively implementing research results as prototypes in real world settings;*
- *Gaining momentum as a laboratory of international standing.*

CARC's field is ambient intelligence, an approach to pervasive computing that emphasizes the thorough integration of information technology into devices, buildings, clothing, and other artifacts to dramatically increase their capability and utility. Within this field, CARC is focusing on using information technology to help human beings in all aspects of their daily lives. CARC's unique vision is that this assistance is best achieved by making maximum use of human and physical context, leveraging relatively simple information interaction to achieve the required capability.

CARC's commitment to deploy early prototypes of its research results provides immediate feedback from the public, and also establishes the benefits of the new technology in the mind of the public. External funding has been increasing, and is now poised for significant growth based on the success of CARC's prototypes.

CARC's vision and research methodology have created a growing reputation in the international research community. CARC is seen as one of the leading information technology innovation laboratories in Japan. It has a head start in the integration of three major worldwide information technology trends: ambient intelligence, semantic web services, and multi-agent technology. To realize the benefits of this competitive advantage, CARC needs to continue as a research center in energetic pursuit of its integrative vision.

8 Acknowledgments

CARC members contributed research described in this paper. Although we do not list names of researchers here, they can be seen in the references provided below.

CARC also had many non-research staff members. Without the industrial designer Shunji Yamanaka, we could not have enjoyed the success of CoBIT and A*i*mulet. Takahiro Koshibu from Nishizawa patent office attended our weekly research meetings to find patentable ideas and then took care of all document work from writing proposals to answering claims during the check phase. Cyber Souken Co. undertook management of the Cyber Assist consortium even though it was not profitable for them. Many others contributed to the project but the list of names is too long to be listed here.

Appendix

History and management of the CARC

1) History of establishment of CARC

Primary Study report on "Intelligent Social Infrastructure," conducted under the framework of Research and Development of Industrial Science and Technology of Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI), led by Yuichiro Anzai[28] proposed a new design of social infrastructure with IT. Proposed research area of intelligent social infrastructure technology was far beyond the coverage of MITI and did not make itself a national project. The Cyber Assist project described in this article corresponds to the software portion of the overall picture.

The name of "Cyber Assist" was coined in the committee for usability (1999)[29], which was formed as a successor of the primary research group and was also led by Yuichiro Anzai. The phrase "ubiquitous computing" was not used because it was not popular at the time.

When the Agency of Industrial Science and Technology of MITI was incorporated and reorganized as the National Institute of Advanced Industrial Science and Technology (AIST), the Cyber Assist Research Center was established as one of its research units, and literally became the center for Cyber Assist research. The following is the goal of CARC presented at its birth.

> *To realize a society in which anyone can receive sophisticated information support, we will develop and deliver the technology for information service that reflects the real world situations (situated intelligent information service) which solves information overflow, support information minority, and protects privacy. As the technological base, we will conduct research and development on the following technologies:*
>
> • *Technologies for situated communication software, location-based communication terminals and the communication infrastructure.*
> • *Technologies for semantic structuring of content and its usage.*
> • *Technologies for providing meaningful information adjusted to the user's situation.*

The following is a list of significant events during CARC's life span.

1998/3	Research report on the "Study of Intelligent Social Infrastructure technologies"
1999/3	Report of the Usability committee
2001/2	First Cyber Assist International Symposium
2001/4	Establishment of Cyber Assist Research Center (CARC) at AIST
2001/4	Establishment of Research Group on Intelligent City Information Infrastructure at Information Processing Society of Japan (till 2003/3)
2001/9	Establishment of Cyber Assist Consortium
2002/10	Second Cyber Assist International Symposium
2003/4	Establishment of Special Interest Group on Ubiquitous Computing System at Information Processing Society of Japan
2003/4	Establishment of AIST venture Cyber Assist One
2004/7	CARC joined other research institute to form Research Institute of Information Processing at AIST
2004/11	Third Cyber Assist International Symposium
2005/10	Fourth Cyber Assist (domestic) Symposium
2007/3	Termination of Cyber Assist Consortium

2) Advisory board with world top-class researchers

CARC formed its own advisory board and gathered world top-class researchers from related areas. The members are Shun'ichi Amari (Director, Riken Brain Science Institute), Yuichiro Anzai (President, Keio University), Rodney Brooks (Professor, MIT), William Mark (Vice President for AI, SRI International), Kokichi Futatsugi (Professor, Japan Advanced Institute of Science and Technology), Koji Oboshi (Advisor, NTT DoCoMo Inc.), Stanley Peters (Professor, Stanford University), Ikuo Takeuchi (Professor, The University of Electro-Communication), Yoshio Tanaka (Trustee, IBM Japan, Ltd.), Jun'ichi Tsujii (Professor, University of Tokyo), Wolfgang Wahlster (Director, DFKI GmbH – German Institute of AI), Steven Willmott (Universitat Politècnica de Catalunya), Akinori Yonezawa (Professor, The University of Tokyo) (affiliations in this list are at the time of CARC's operation).

3) Establishment of the first AIST consortium

We organized international and domestic symposiums even before CARC's establishment and held them alternatively each year since then. We used symposiums to invite companies to our consortium. The Cyber Assist Consortium was established just a half year after the launch of the center as the first consortium run by AIST – We had to draft all necessary rules for AIST.

We adopted a so called "bazaar method" where each participant brought different elements (either technology, market needs, or business plan). We allowed only one company for each particular area of specialty, and hoped that the combination of a device manufacturer and a service provider would help to bring our technology into the world.

4) Establishment of the first AIST venture company from zero

Although the director general of AIST advocated

establishment of venture companies, we initially did not have a plan to do so. However, once we included application to society within our target range[Note 14)], we found it necessary to have alliance with companies to manufacture devices of our design and set them up for use. No company met our specifications. We found it best to run a company by ourselves. We gathered the minimum requirement of ten million yen for a joint-stock company and established a venture company. Half of the members were and are CARC researchers.

Our intention regarding the management of the company nonetheless did not meet the blue print of AIST venture set by AIST. The most critical obstacle was the issue of "conflict of interest". AIST excluded the venture company even from bidding to undertake CARC missions, just because there was a *possibility* of conflict of interest because some of CARC members were stakeholders and board members of the venture company. It practically nullified our intention of setting up a venture company.

There was also a mismatch on the conception of the life span of AIST venture companies. As mentioned above, we set up the company because there was none to undertake our requirements. We researchers did not intend to run it for profit. Our intention was to sell the company when it became stable in its business. However AIST claimed to retrieve the right of industrial properties back to AIST after five years. We could not sell the company. As of the righting of this article (2009), we still run the company voluntarily, but there is no future plan.

5) Activities in academic societies

The Cyber Assist project had a plan to launch special interest groups at academic societies. We established a research group called Intelligent City Information Infrastructure at Information Processing Society of Japan in 2001. Its activity was centered on social application of IT. This research group, together with another research group of intelligent home appliances, became the core of the new SIG ubiquitous computing systems of IPSJ from 2003 to date.

There was another informal research group named Ubiquitous Joho (Ubiquitous Information) formed to which the director of CARC, Nakashima, contributed actively. This research group did not belong to any society. It rather functioned to bridge those academic societies. One of the major achievements of the group is a video presentation "Small Stories 2008"[Note 15)]. At the time, there were several research promotions, or future predictions, videos by Microsoft, Hewlett Packard, NTT DoCoMo and Nokia. We authored Small Stories 2008 as a near future vision of technologies realistically achievable by participating researchers. We featured scenes with information loupe reflecting the concept of CoBIT or My-button by CARC.

Notes

Note 1) We cannot translate *kagaku* as either "science" or "engineering" here, since it narrows the definition of the word. The definition of "service *kogaku*" is not settled yet. We regard it as a study of practice. We do not use the narrow definition as science or engineering for service enterprises.

Note 2) GDA or Global Document Annotation is a set of tags for intelligent contents.

Note 3) It was just before incorporation of Agency of Industrial Science and Technology that we persuaded them to employ a non-researcher formally and the proposal was accepted.

Note 4) We were lucky to have Shunji Yamanaka who is famous in designing Nissan Q45 and the Suica reader for JR.

Note 5) If the journal of *Synthesiology* were published at the time of CARC's activity, it would have been a good target. That is why we published this paper after CARC terminated.

Note 6) Suica was put into service in November, 2001. It is later than the establishment of CARC.

Note 7) CoBIT originated from the idea to use infrared beam of *i*-lidar for communication, instead of the original purpose of positioning.

Note 8) Research themes of individual researchers usually sustain beyond the period of a project or change of organizational structure of the research institute to which the researchers belong to. At CARC, we requested each member to distribute their effort one to one for group research themes and individual research themes. They of course may not contradict each other, and many themes satisfy interest of both. RoboCup is a good example where an individual theme was carried over as a group theme.

Note 9) Although we do not have enough space for details, let us exemplify one case. We learned that even a blind person enjoys TV programs. When he encounters a scene whose details cannot be figured out only from sound information, he places a phone call to his friends for explanation. In this case, synchronization of TV channels in distant locations is useful. We implemented the function.

Note 10) Ordinary Good Design award is given to about one thousand goods, but only twenty one of them are given the name of "METI Minister Award". Ecology design award has only two slots. We are very proud of receiving this.

Note 11) In fact, the situation is the same in English dictionaries.

Note 12) The use of venture assist fund was limited to research and development within AIST. It could not directly support activities of AIST registered venture companies. Our own venture company could not succeed due to this limitation, although it was good that the venture and CARC jointly developed service providing systems with the fund.

Note 13) The European Union report, Scenarios for Ambient Intelligence in 2010. (available at ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf)

Note 14) This was before the general director of AIST set the concept of full research.

Note 15) This video was sponsored by Ubila Project. http://www.akg.t.u-tokyo.ac.jp/ubila/video/

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Authors

Hideyuki Nakashima

Dr. Eng. from Graduate School of Information Engineering, the University of Tokyo in 1983. Research themes include artificial intelligence, especially on situatedness of intelligence. Also interested in multi-agent systems and its application to complex information processing. Currently, President of Future University Hakodate. Was president of Japanese Cognitive Science Society, board member of Japanese Society for Software Science and Technology, board member of the Japanese Society for Artificial Intelligence, vice president of Information Processing Society of Japan, and board member of International Foundation for Multi-Agent Systems.

Major publications: Handbook of Ambient Intelligence and Smart Environments (Springer), Chino no Nazo (Mystery of Intelligence) (Kodansha Bluebacks), Chiteki Ejento notameno Shugo to Ronri (Sets and Logics for (Construction of) Intelligent Agents) (Kyoritsu Pub.), Shiko (Thought) (Iwanami Lecture Series on Cognitive Science 8), Kigo no Sekai (World of Symbols) (Kyoritsu Pub.), Prolog (Sangyo Tosho Pub.). For the content of this paper, he was responsible for the design of the project and its achievement as the first director of the center.

Koiti Hasida

Dr. Sci. from Graduate School of Science, the University of Tokyo in 1986. Research topics concern natural language processing, cognitive science, artificial intelligence, and semantic computing. Researcher at Electrotechnical Laboratory from 1986 to 2001 and researcher at the Institute for New Generation Computing Technology from 1988 to 1992. Deputy director of CARC from 2001 to 2004 and its director in 2004. Presently, director of Social Intelligence Technology Research Laboratory, AIST, president of Japanese Cognitive Science Society, president of Association of Natural Language Processing, and a board member of Japan Society for Software Science and Technology.

Major publicatinos: Chi no Enjiniaringu: Fukuzatsusei no Chihei (Engineering of Intellect: Horizons of Complexity) (JustSystem), Gengo (Language) (Iwanami Lecture Series of Cognitive Science), Gengo no Suri (Mathematics of Language) (Iwanami Lecture Series of Linguistic Sciences), Topics in Constraint-Based Grammar of Japanese (Kluwer). For the content of this paper, he contributed to the design of the project and succeeded its execution, in particular EXPO 2005 Aichi Japan, as the second director of the center.

Discussions with Reviewers

1 Overall

Comment (Naoto Kobayashi: Center for Research Strategy, Waseda University)

I understand that this paper aims at reassessing the value of the Cyber Assist Research Center (CARC) set up at AIST in 2001 whose research strategy is still valid, or even more valid, in today's context, by looking back over its activities and comparing them with the current research trend. However, in the view that *Synthesiology* is an academic journal on *Type 2 Basic Research*, it does not suffice to merely reconstruct the research activities of CARC. To be accepted as a research paper of this journal, you should address the following issues which are essential elements of *Synthesiology*: (1) the research goal, (2) the scenario to the goal, (3) element technologies, (4) the method of synthesis of a new system by combining those elements, and (5) the conclusion.

Comment (Motoyuki Akamatsu: Human Technology Research Institute, AIST)

I understand that the theme of this paper is to describe how the Cyber Assist Research Center as a "synthesiological" research vehicle tackled the Cyber Assist project "synthesiologically", to assess the achievement and to analyze the whole process. I want you to narrow down the focus of the story, to "location-based communication" for example, and clarify the essence of your claim for the readers' easier understanding .

Answer (Hideyuki Nakashima)

I thank both of you for your objective comments. I found that issues we took for granted in designing CARC is not necessarily obvious for others. The internal structure of the center, for example, is an important one but we failed to convey the rationalization. We rewrote the overall paper to comply with your comments. However, since Cyber Assist is an activity of service engineering whose top-level goal is to support people, it is hard to focus on a narrow and coherent story. A service provider should not forget about trivial details. The whole combination of peripheral issues is meaningful more than the central device or function used for the service. This is one of the reasons that this kind of research and development was rare in the past. We also stressed the above points in our new manuscript.

2 Definition of "service engineering"

Question (Motoyuki Akamatsu)

The title of the paper claims that Cyber Assist is a kind of service engineering, and the latter is defined in your own way in the paper. In the initial manuscript, your definition of "service engineering" is unclear but there is a better description in section 6.1 of the final version. Should the definition of "service engineering" be understood as meaning, "to provide or to offer" services?

Answer (Hideyuki Nakashima)

Generally speaking, "a discipline of designing and/or constructing systems for practical use" contains as its part a phase of "providing the system for use". In this sense, "service engineering" should not be taken as its narrow meaning of engineering merely for the sake of service industries, but rather as service-providing portion of engineering, or a discipline of engineering reorganized around the phase of putting the system into practical use. We provided the description in section 6.1.

3 The subtitle

Comment (Motoyuki Akamatsu)

The subtitle states that the project is "ten years too early", but the reason is not clear in the first manuscript. If this is an important claim, you should elaborate more on the reason why it was difficult to perform at the time, or the reason why you expect that it would do better now.

Question (Naoto Kobayashi)

Does the subtitle "a project that began ten years too early" mean that the world was premature to understand the importance of "human-centered situated information service" that is the core concept of Cyber Assist, and that the three years of activity was too short to make the concept be recognized by the world? Or, can we understand that the world has now begun to understand its importance independent of CARC's activity?

Answer (Hideyuki Nakashima)

At the current moment, we can simply say that we are doing service engineering, for instance. However, we had to explain a lot at the time. We are proud that we were ten years ahead (our external advisory board said so). I don't want to claim that only CARC was the exception, however. There were others and we shared the same resistance of being at the leading edge. Our activity alone did not make the world as it is. But if our center went on for ten years rather than three years, its message would have better reached out to the world.

That having been said, the most significant aspect of being too early is that we failed to provide any commercially used "practical system" to the world.

4 Technology for Cyber Assist

Comment (Motoyuki Akamatsu)

A reader expects to understand technological aspects of Cyber Assist. To be more specific, more concrete description of the process in which you considered "both the top-down requirements and the bottom-up constraint of research resources" should be provided in section "2.2. Concrete research goals and approach toward them" to comply with the scope of *Synthesiology*.

Answer (Hideyuki Nakashima)

I agree that if we could analyze and clearly describe the process of considering "both the top-down requirements and the bottom-up constraint of research resources", it would be a very valuable document. However, our decision was made through weekly meetings, and it took very long to focus on our final shape. We cannot analyze it to make it describable. I am sorry but we could only write "We held a meeting of all researchers once a week, and in the early stage of the center's activity, we concentrated on connecting each member's specialty and interest to the research goal of the center. The resulting diagram with concrete and detailed research themes is shown as Fig. 2." and add the corresponding figure.

5 The resulting technology of research and development

Comment (Motoyuki Akamatsu)

It is written that Cyber Assist aims at grounding digital information into the real world, and that the center consists of location-based communication, My-Button, intelligent content and user interface. Those are in terms of technology, not sub-goals for Cyber Assist. If possible, please explain the relationships between chapter 2 and chapter 3 using a diagram, so that readers have a better understanding of the research scenario from the view point of technological elements.

Answer (Hideyuki Nakashima)

Yes, our description was not clear on that point. We added a description and a diagram (Fig. 2) in section 2.2. Moreover, since we tried to explain all research elements and made the main story obscure, we eliminated some of them.

Since we deleted the description on a "proposal of new transportation systems" from the paper, let me briefly explain about optimum route guidance using car navigation systems here. The current navigation system is known to have a problem that the system becomes less effective as the ratio of cars using the system increases. As the current system feeds back information on traffic congestion with some time delay, undesired oscillation of the feedback system takes place. We solved the problem completely by using future projection based on multi-agent simulation. The important point is that the solution is applicable using the current technologies only. We omitted this research issue because of the shortage of space and the whole story of CARC could be told without this. Let us note that we are currently preparing to apply this technology in Hakodate area by a team of Future University Hakodate and AIST plus some others. It is an exercise of service engineering for an actual city.

6 Role of demonstration for "synthesiology"

Comment (Motoyuki Akamatsu)

I suppose that the implementation and demonstration of a system lead to the discovery of new problems or important issues and then contribute to the next phase of research, as some of the previous papers of *Synthesiology* reported. Please describe the details of findings and feedbacks to new research issues discovered from your demonstrations.

Answer (Hideyuki Nakashima)

One of the problems is that the Cyber Assist Research Center dissolved in the middle of Aichi Expo, and I could not get hold of research details after then. We nevertheless tried to cover the issue as much as possible and included Note 8).

7 Assessment of the research outcomes

Comment (Motoyuki Akamatsu)

You mention the tally method of information storing as an unfinished research agenda. From the description in section 5.2, however, I suspect that you may have chosen a goal theoretically unattainable by digital technology. If this is the case, will you describe how the impossibility became clear in the course of the research?

Answer (Hideyuki Nakashima)

We believed from the initial stage that the "tally" problem should be solved by "digital + real". Even if the problem cannot be solved with only digital technology, it does not mean it is unsolvable. Although we could not find any effective methods, we still regard it as an interesting theme for information technology. We added some description to clarify this point.

8 Suica

Comment (Motoyuki Akamatsu)

At the end of section 2.2, there is a reference to Suica with respect to the fact that CoBIT is based on a similar concept. Suica is close to the idea of Cyber Assist in its location-based concept, user's initiative and privacy protection. It helps the understanding of users to have detailed discussion of the relationship between them because one side is already familiar to them.

Answer (Hideyuki Nakashima)

We added a comparison with Suica at the end of CoBIT section (4.1).

9 Research institutes and research centers of AIST

Comment (Naoto Kobayashi)

In the earlier version of the manuscript, there was a statement, "In service engineering, it is important to separate two kind of research units as in AIST: basic research oriented research institutes, and service oriented research centers" (section 6.1)

and "Basic and element technologies should be developed at research institutes and bridges to commercial products should be built by research centers" (section 7.2). Those are not official views of AIST. The current website of AIST (http://www.aist.go.jp/aist_j/field/index.html) states "Research Institute: Institutes continuously conduct research to achieve the missions and medium- and long-term strategies of AIST based on scenarios defined by research unit heads and research themes defined by the initiatives of researchers. Research Center: Originating from an institute or as a response to social needs, research centers intensively conduct research for a period of three to seven years under the strong leadership of research unit heads to swiftly produce technologies and knowledge to solve specific issues."

Answer (Hideyuki Nakashima)

In my personal understanding, the *Full Research* concept proposed by Yoshikawa, the president of AIST at the time, is divided into *Type 1* = "*kagaku*" (roughly but not exactly corresponding to "science"), and *Type 2* = "*kogaku*" (roughly but not exactly corresponding to "engineering"). His statement that the traditional research is *Type 1 Basic Research* matches the ordinary usage of basic research as a synonym of *kagaku* (the website mentioned above contrast them as basic and applied researches). However, since the word usage of "*kagaku*" and "*kogaku*" may differ from person to person, they must be defined here. "*Kagaku*" here refers to the analytic discipline to understand phenomena, and "*kogaku*" refers to the synthetic discipline to produce phenomena. Honestly, I do not understand the standpoint of "*Product Realization Research*", but I guess it refers to the final phase of *Type 2 Basic Research*.

According to my understanding described above, it is natural that research institutes mainly focus on *Type 1 Basic Research* and research centers on *Type 2*. Of course those two are not clearly separable. Some researchers may do both types of researches and a single research unit may have both types of researchers. However, the ideal design of units should clearly distinguish them. Defining units by time-scale as mentioned in the AIST website is subsidiary. Product realization period must necessarily be short, but not so by definition.

In any case, I managed CARC according to my understanding, and still believe it was the source of our strength that the center focused on *Type 2 Basic Research*.