Fusion of IT and RT: URC (Ubiquitous Robotic Companion) Program

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1. Introduction
As the industrial robot market tends to stagnate, robot industry is facing requests to open new market opportunities beyond industrial robots. In 1990s, several efforts to commercialize new types of robots which provide human with useful services have been realized such as a hospital courier robot Helpmate [1][2], an entertainment robot Sony’s AIBO [3], a security robot Alsok’s GuardRobo [4], etc. Also, recent technological advances in the area of artificial intelligence, sensor-based control, human computer interface, or wireless networking enable service robots to be recognized as the market leader in the 21st century next to the conventional industrial robots.

Especially, social and economical needs for intelligent service robots to support daily life of human are recently increasing with the advance of aging society. Aiming at the potential service robot market in the era of ‘one robot in every house’ to be prevalent in the next decade, advanced countries have tried to enter the market with the competence in advanced robotics technologies. However, a small scale of initial market has been created with cleaning robots or toy/pet robots. In order for service robots to be introduced in our daily life as if they were digital appliances, they should provide satisfactory services to us with reasonable costs. However, current service robots seem to cost too much yet provide just simple services. This problem arises from the fact that customer’s expectation level of robot services is relatively high rather than the technology level to implement those services. An alternative to resolve this problem is to fuse advanced information technology (IT) and conventional robot technology (RT), i.e., to appropriately utilize advantages of information technology such as network-based service benefits and cost-down effects of networking.

Recently, Korea Ministry of Information and Communication has strategically promoted a R&D program to develop IT-based intelligent service robots, called URC (Ubiquitous Robotic Companion), and the goal of the program is to improve service benefits as well as reduce robot costs by introducing IT into RT and to ultimately enable the service robot industry to be a major driving force of Korean economic growth.

2. IT-based Intelligent Service Robot — URC
URC is defined as “a robot which provides various required services whenever and wherever.” From the conventional viewpoint, a robot is considered as a physical entity that is composed of sensing, processing and actuating elements. The main approach of URC is to distribute these three functional elements through high-speed network, and moreover, to fully utilize external sensors and external processing servers, leaving minimal functions of sensing and processing elements into physical robot for main action (Fig. 1). Generally speaking, it may be more efficient to utilize external sensors embedded in environments rather than to expand the sensing functions of robot itself. Also, it may be more effective to utilize a shared high-performance computing server in a remote site rather than to increase computing power of the physical robot itself. By adopting these kinds of concept, we believe that the sensing and processing power can be enhanced with the aid of external devices as well as the cost of the physical robot itself can be quite reduced due to the shared computation of processing and sensing.

Fig. 2 shows how URC provides services to users in...
human-symbiotic environments. In ubiquitous network environments, users can be provided with seamless information services by conventional hardware robots at home/office as well as software robots appearing in terminal devices in office buildings or outdoors. That is, by adding the networking functions to the conventional robot, URC is capable of possessing high mobility and enhanced service availability. The enhanced mobility is applied not merely to the hardware robot, but also to the software robot that is mobile through communication networks and appearing in terminal devices. Service availability can be also enhanced by the shared service configuration in the server-client framework.

### 3. URC Enabling Technologies

We classified the URC enabling technologies into four categories: URC infra system, URC client robot platform, URC embedded component technology, and network-based humanoid. The URC program plans to develop these four classes of technologies, which we believe to enable the service robot industry to be activated and grow up in the next decade.

#### 3.1 URC Infra System

The URC requires not only the hardware infrastructure, such as ubiquitous broadband/sensor networks and high-performance computing servers, for providing dependable real-time services but also the software infrastructure residing on the hardware infrastructure which provides context-aware proactive services whenever and wherever. In order to support various kinds of robot platforms or URC client terminal devices, the following three technologies has to be developed: URC network technology, URC server technology and software robot technology. The URC network supports real-time performance and connectivity in wired/wireless network by use of network protocols for server/client control and security. The URC server provides highly available clustering service to hundreds of simultaneous users and also supports QoS for voice/vision processing. Software robot is defined as “an intelligent software system which proactively provides appropriate services in ubiquitous network environment.” Software robot technology includes remote control/monitoring functions, context-aware networked robot engine (CAMUS) [5], and software agent user interface. **Table 1** shows the essential technologies to be developed in the URC infra system.

#### 3.2 URC Client Robot Platform

URC client robot platform is required to have ba-
sic functions of mobility and user interface, but minimal functions of sensing and processing in the hardware robot platform. For example, since the voice recognition/synthesis functions are to reside in the server side on the basis of the URC concept, the client robot platform needs to merely have voice signal pre-processing function. In cooperation with the URC server, the client robot platform is required to provide elementary services such as proactive information provision, automatic speech recognition, text-to-speech, remote home monitoring, user identification, etc. Additionally, the URC server-client system has potential capability to provide enhanced network-based services such as visual security, health-care, entertainment, robotic IP telephony, emotional communication, etc.

3.3 URC Embedded Component

The URC server-client system is composed of various hardware and software components, which maximize the commercial value of service robots, such as embedded processing modules, operating system, efficient middleware, modular network interface, navigation, manipulation, visual recognition, voice recognition, knowledge management, inference engine, etc. We classified the URC embedded components into the following five categories: (1) intelligent task control technology which includes software components for navigation/manipulation tasks; (2) human robot interaction technology which includes software components for natural human-robot interaction based on vision and voice; (3) robot software architecture which implies software framework simplifying the URC application programming; (4) robot hardware components which includes core electronic hardware modules and SoC IP for networked robot hardware platforms; (5) intelligent service framework technology which implies proactive robot service framework based on knowledge processing and semantic web service. Table 2 shows the detailed essential technologies to be developed as URC embedded components.

### Table 2 Essential technologies in URC embedded components

<table>
<thead>
<tr>
<th>Essential Technologies</th>
<th>Details</th>
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<tbody>
<tr>
<td>Intelligent Task Control</td>
<td>Localization and mapping, Autonomous navigation, Collision avoidance, Visual SLAM, Sensor-based manipulation, External/internal sensor fusion, USN(Ubiquitous Sensor Network)-based navigation/manipulation</td>
</tr>
<tr>
<td>Robot Software Architecture</td>
<td>RTOS, Middleware for server/client integration, Robot software communication architecture(RSCA), Common robot interface framework(CRIF), Behavioral control, Behavior/Task coordination</td>
</tr>
<tr>
<td>Robot Hardware Components</td>
<td>Main control processor module, Sound pre-processing module, Vision interface module, Multi-modal sensor interface SoC IP, Real-time network for motion control, Low cost sensor system(for inertia/range sensing or localization)</td>
</tr>
<tr>
<td>Intelligent Service Framework</td>
<td>Semantic web service configuration, Knowledge base management, Inference engine for context-awareness or user-preference identification, Proactive service planning/execution</td>
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3.4 Network-based Humanoid

Intelligent service robots to be commercially available in daily life in a few years are almost expected to have wheeled mobility. However, in the far future, legged-type humanoid will be prevalent since it can maximize mobility. Moreover, two-arm coordinated motion may be required for natural task execution of robot in human-symbiotic environments. In order to prepare for the future lifestyle with humanoid, we plan to develop some essential technologies for network-based humanoid with more complex hardware/software structure than for simple wheeled mobile robots. The following technologies are to be developed in the integrated system with the networked server and the client humanoid: two legged walking algorithm, dynamic motion simulation, two-arm coordination, multi-DOF hand control, 3-dimensional environment recognition, visual servoing, remote monitoring/control, etc.

4. Conclusion

In the conventional robot systems, sensing, processing and action elements are included in a single independent robot platform, and thus functions and services of the robot were restricted to the on-board computing/sensing power. Recently, as the IT technology has developed, the network connectivity has become a basic feature for computing systems including robot. In
order to fully utilize the advantages of network connection to robots, we proposed a new concept of IT-based intelligent service robots, called URC, where the processing/sensing elements are distributed over network. We expect that this distribution concept may increase the benefits of robot users as well as decrease the front-end robot costs. This means that the service robot market becomes easy to grow up by introducing the URC concept.

In the URC program, we plan to apply five types of robot platforms and networked server systems to real houses and post offices as test-beds from 4Q of 2005, in order to prepare for entering the new service robot market and get feedback from real users. IT-based intelligent service robots are just located at the starting point of new market. Therefore, the URC program is expected to contribute to make a firm base for growing the new service robot market as well as for maintaining our international competitiveness in the IT fields.

References


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Young-Jo Cho received the B.S. degree in instrument and control engineering from Seoul National University, Seoul, Korea, in 1983, and the M.S. and Ph.D. degrees in electrical and electronic engineering from the Korea Advanced Institute of Science and Technology (KAIST), Seoul, Korea, in 1985 and 1989, respectively. In 1989, he joined the Korea Institute of Science and Technology (KIST), and had worked as a Principal Researcher at the Intelligent System Control Research Center (ISRC), KIST, by February 2002. He was a Visiting Researcher the Mechanical Engineering Laboratory, Tsukuba, Japan, from 1993 to 1994, conducting event-driven tele-operation research for a force-reflected robot system. He also worked as a Visiting Scientist at University of Massachusetts at Amherst, for three months in 1997, investigating the area of mobile robot control architecture. From March 2002 to January 2004, he had worked as the director of R&D Center in iControls, Inc, for investigating intelligent home networking products. Since February 2004, he is working as a Vice President at Electronics and Telecommunications Research Institute (ETRI), the head of Intelligent Robot Research Division. His research interests include control architecture of intelligent robots and system integration of network-based intelligent service robots. Dr. Cho is a member of IEEE, the Korea Institute of Electrical Engineering, the Korea Robotics Society, and the Institute of Control, Automation, and System Engineering, Korea.

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