
Ubiquitous Robot

Jong-Hwan Kim

Department of Electrical Engineering and Computer Science, Korea Advanced
Institute of Science and Technology

johkim@rit.kaist.ac.kr.

<http://rit.kaist.ac.kr>

Abstract. In the near future human beings will be living in a ubiquitous world where all objects such as electronic appliances are networked to each other and robots will provide us with services of every variety by any device through any network, at any place anytime. However, current robots have a number of constraints to become wholly ubiquitous. This research attempts to eliminate the spatial limitations by introducing virtual robots into the physical world. Ubiquitous robot, Ubibot, is introduced to integrate three forms of robots: software robot (Sobot), embedded robot (Embot) and mobile robot (Mobot). Sobot is a virtual robot, which has the ability to move to any place or connect to any device through a network, in order to overcome the spatial limitation. It has the capability to interpret the context and thus interact with the user. Embot is embedded within the environment or in the Mobot. An Embot can recognize the locations of and authenticate the user or robot, and synthesise sensing information. Mobot provides integrated mobile services. The services that will be provided by Ubibot will be seamless, calm and context-aware.

This talk will address the basic concepts of Ubibot. A Sobot, called Rity, will be introduced in order to investigate the usability of the proposed concepts. Rity is a 3D synthetic character which exists in the virtual world, has a unique IP address and interacts with human beings through an Embot implemented by a face recognition system using a USB camera.

1 Introduction

The term Ubiquitous Computing, UC, was first coined by Mark Weiser [1]. The basic concepts include the characteristics, such as every device should be networked; user interfaces should operate calmly and seamlessly; computers should be accessible at anytime and at any place; and ubiquitous devices should provide services suitable to the specific situation such as location, equipment, ID, time, temperature and weather. He also addressed the evolution of computer technology in terms of the relationship between the technology and humans [2, 3]:

- The first generation - the Mainframe Era, where a large elaborate computer system was shared by many terminals;
- The second generation (still current) - the Personal Computer era where a human uses a computer as a standalone or networked system, in a work or home environment; and
- The third generation - the ubiquitous computing era, where humans use various networked devices which pervade their environment unobtrusively.

Along with the ubiquitous revolution, robotics is also undergoing a paradigm shift. The first generation of robotics was dominated by industrial robots followed by the second generation in which personal robots became widespread. As a third generation, ubiquitous robot can be thought of. Figure 1 shows the comparison of the paradigm changes between the personal robot and ubiquitous robot eras. The personal robot era is based on individual robot systems. However, in the future multiple robot system will prevail.

	Personal robot era	Ubiquitous robot era
Platform	Single robot platform based on a Personal Computer: One person, One robot	Multi robot platform based on Ubiquitous Computing: One person, Many robots
Core	Application program	Software robot
Network	Wired network based on IPv4	Real time broadband wireless network based on IPv6
Service	Seaming and user-commanded service	Seamless and calmly context-aware service

Fig. 1. Comparison between the personal robot and ubiquitous robot eras

Within the ubiquitous environment, a number of robots, such as Embots, Sobots, and Mobots, will provide a human with various services. In the current level of second generation robotics, the application software controlling the robots occupies the core. However, in the future, software robots will form the core and control the hardware robots which will then take on the more practical roles.

The intelligence of personal robots still mainly relies on a user-directed service system, which means it functions at a very low level. Therefore, when a user gives a command, s/he must wait until the robot understands and

interprets the command, then acts on it. Third generation ubiquitous robots will be able to understand what the user needs, wants or prefers and supply continuous and seamless service. This technology will be made possible by the use of IPv6 format and broadband wireless network technology.

The Ubibot (Ubiquitous Robot) has been developed based on UC and robot technology [4]. For humans, the future will present a ubiquitous world where all objects and devices are networked. In ubiquitous space, u-space, a Ubibot will provide the user with various services anytime, at any place, by any device, through any network. As demonstrated in the general concept of UC, Ubibot will be seamless, calm, context-aware and networked. Ubibot could be classified as three integrated robot systems: Sobot, Embot and Mobot. Sobot, the Software Robot, can be transmitted and connect to any device, at any time and any place. It is context-aware, and will automatically and calmly provide continuous cooperation with the user. Embot, the Embedded Robot, is embedded within the environment of a Mobot. It detects the location of the robot or the user, recognizes and authenticates them, and collects and synthesises the various sensing information. Mobot, the Mobile robot, provides general users with integrated services.

In this talk, Rity, developed at KAIST's RIT laboratory will be introduced as an example of a Sobot. Rity is a 3D virtual pet [5]. It has its own unique IP address and communicates and interacts with the user in the real world through an Embot implemented by a physical device such as a USBconnected camera.

2 Ubiquitous Robot: Ubibot

Ubibot is created and exists within ubiquitous space (uspace) which will be developed as an essential component of Ubibot.

2.1 U-space and UbiBot

It is anticipated that, in the future, the world will consist of numerous u-spaces, where each u-space will be based on the IPv6 or similar system and be connected to each other through broadband, wired or wireless, networks in real-time, Figure 2 [6]. A robot working within the u-space is defined as a Ubibot, which, in other words, can be used for any service through any terminal and any network by anyone at anytime and anywhere in a u-space.

Ubibot exists within u-space, Fig.3, and consists of both software and hardware robots. Sobot is a type of a software system whereas Embot and Mobot belong to a hardware system. Embots are located within the environment, human or otherwise, and are embedded in many devices. Their role is to sense and communicate with other Ubibots. Mobots are mobile. They can move both independently and cooperatively, and provide practical services. Each ubibot has specific individual intelligence and roles, and communicates

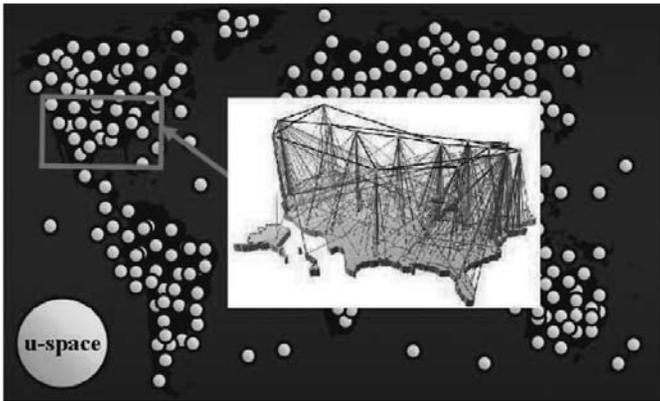


Fig. 2. Real world composed of billions of u-spaces

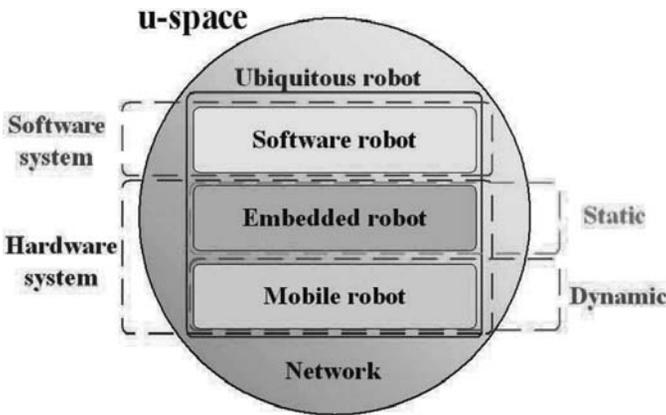


Fig. 3. Ubiquitous robot in u-space

information through networks. Sobot is capable of operating as an independent robot. However, it can also become the master system, which controls other Sobots, Embots and Mobots residing in other platforms as slave units.

2.2 Software Robot: SoBot

Because Sobot is software-based, it can move within the network and connect to other systems anytime and at any place. It can assess situations and interact with the user seamlessly. Sobot can be implanted into any environment and also other robots as a core system. It can control or, at an equal level, cooperate with Mobots. It can operate as an individual entity, without any help from other Ubibots. Figure 4 shows three main characteristics of Sobot: context-aware self-learning, context-aware intelligence and calm and seamless interaction [7, 8].



Fig. 4. Essential characteristics of SoBot

Context-aware self-learning

Sobot is autonomous and can determine and control its behaviour without external commands. Within the u-space, it can represent the user in behaviour and communication with others. Sobot also has the ability to “learn.” It can assimilate objects, motions and situations. This “learning” process can be continuously developed. When a new user is introduced, Sobot may need to adjust behaviours within the u-space.

Context-aware intelligence

Sobots are proactive software robots. They operate with clear goals and well-constructed plans. The plans are constantly reviewed. When new situations arise, Sobots can adjust and react to the situation rather than use a pre-determined reaction to a possible, or expected, situation. Sobots are able to demonstrate rational behaviour in the fact that they do not just “repeat” the same tasks, but can adjust to each task as necessary and produce a suitable outcome. Sobots remain context-aware at all times. They can modify and adapt themselves to the context, whenever needed. When they perceive a problem, they can locate and recognize the user automatically. By observing the user and user behaviour, they “learn” about the user and can easily adapt themselves to the user’s preferences and interests.

Calm and seamless interaction

All activities are implemented calmly and seamlessly. Each Sobot is distributed and independent. A Sobot can be embedded and work inside an Embot or a Mobot. However, its behaviour is often limited by the resources of the software or hardware in which it is embedded.

Sobots can communicate with the environment and other Ubibots. There will be a higher level communication language, which need not have a predefined message or set of rules for the communication. Ubibot is omni-present. It exists everywhere in the u-space and will provide us with seamless services, at any time and at any place. These continuous and seamless services are performed through the network connected to many other devices. Sobot has continuous interface between the physical world and the virtual world.

The interaction mode used for Sobots is multi-modal. This will allow for greater convenience and flexibility in user interactions and communications. Because of the complexity of such a system, it is demanded to have compatible application environment for Sobot. This will allow many different types of robots to communicate, to continuously develop new functions and to control the robots remotely and cooperatively.

2.3 Embedded Robot: EmBot

EmBot is implanted in the environment or Mobots. In cooperation with various sensors, Embot can detect the location of the user or a Mobot, authenticate them, integrate assorted sensor information and understand the environmental situation. An Embot may include all the objects which have network and sensing functions, and be equipped with microprocessors to control Sobots. Embots generally have three major characteristics: calm sensing, ucommunication and information processing, Figure 5 [9].

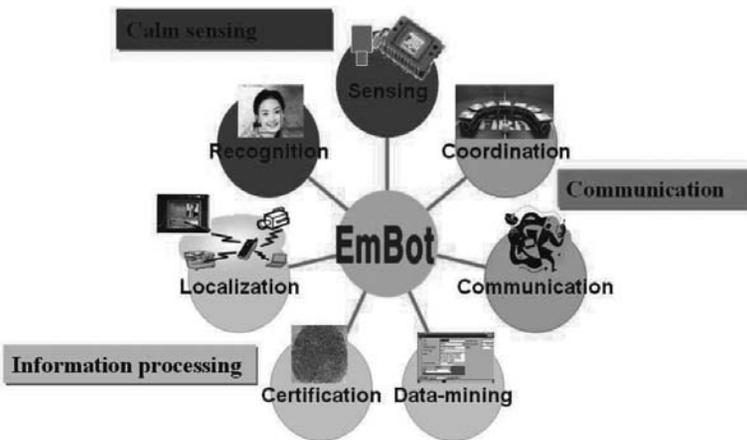


Fig. 5. Essential characteristics of EmBot

Calm sensing

Using various sensors, an Embot can detect and recognize objects even in crowded areas. This function works in cooperation with many other sensors embedded in humans, Mobots and other devices. Embots can calmly and unobtrusively sense human behaviour, status, preferences, relationships and neighbouring environments.

Embots recognize the patterns of human behaviour and status. Embots can also recognize environmental elements such as weather, time and climate which can impact on the daily behaviour and status of a human. They can also identify the different distances that exist between humans and may affect their behaviours. The distances are classified as contact distance, individual distance, social distance and public distance. Embots can identify human relationships, such as the social relationships between family members and visitors; friendship or personality. Embots can perceive the interactions between other humans and the main user. For example an Embot will know who is pointing, facing or gazing at the user.

Information processing

Embots can identify the location of Mobots, humans, objects and other environments. Embots can also assess and authorize a human to use a robot, authenticate various types of robots and robot users. Embots also possess data-mining abilities. They collect information about human behaviours, status and environment. Data created through the datamining process can be used to enhance the information search process.

Communication

Embots provide the user with assistance in various forms including: voice communication, behaviour, information transfer and motion guidance. This is done in accordance with the situation and through a network, in order to augment the communication with humans. Embots also facilitate and help multiple robots to cooperate, by using calm sensing and information processing. They can also provide services to hundreds of people through the sensor network.

Embots can recognize the location of humans and robots, behaviour of humans and the adjacent environment automatically. This is done using sensors embedded in the environment together with Embots' ability to certify, store and use previously gathered information. These features will allow easy communication between robot and humans and will be applied widely in homes, offices, and government buildings. This will also improve security and information searching systems, human research management and public resource management.

2.4 Mobile robot: Mobot

Mobot offers both essential services for general users and specific functions which are dedicated to the u-space. On the other hand, Embot is generally considered to have limited functions and resources. However, a Mobot will provide mobility and service; operates in the u-space; has Embot functions, Fig 6; and works together with Sobots neighbouring Embots.

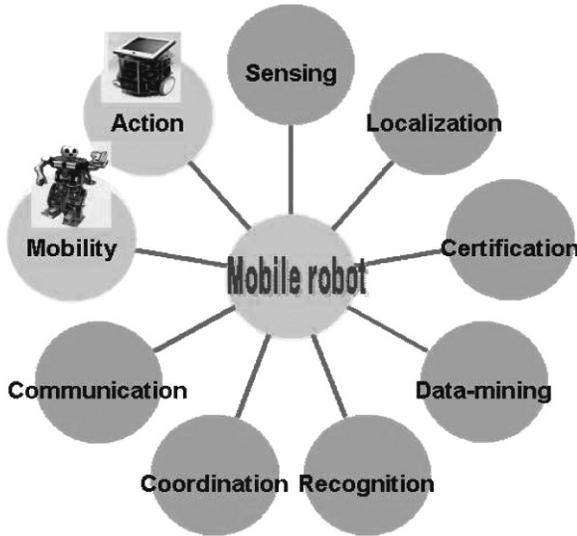


Fig. 6. Essential characteristics of mobile robot

Figure 6 shows the characteristics of Mobots, where mobility can be implemented in various types such as wheel and biped types, and action provides personal, public, and field services using manipulator and various devices.

Mobot communicates with Sobot in order to provide practical services based on information given by Embot. Mobot will be implemented as a multi-purpose service robot in the u-space such as home, work, public organization, amusement, traffic and public facilities.

3 Conclusion

In considering the Ubibots of the future, it is anticipated that, Sobots, Embots and Mobots will co-exist with humans and will provide us with seamless, calm and context-aware services anytime and at any place through the ubiquitous network. Based on their own functions and intelligences, each Sobot, Embot and Mobot will have an individual role, as well as working cooperatively with other Ubibots. In the new ubiquitous era, our future world will

be composed of millions of u-spaces, each of which will be closely connected through ubiquitous networks. The future of ubiquitous robotics has a lot to offer. However, in order to ensure efficient and effective communication and smooth integration of robot systems it is essential to provide a standardised language and a uniform set of protocols.

Acknowledgement

This work was supported by the ITRC-IRRC (Intelligent Robot Research Center) of the Korea Ministry of Information and Communication in 2003.

References

1. Weiser, M., "Some computer science Problems in ubiquitous computing," Communications of ACM, Vol. 36, No.7, pp. 75-84, Jul, 1993
2. Weiser, M., <http://www.ubiq.com/hypertext/weiser/UbiHome.html>
3. Weiser, M., "The computer for the 21st century," Scientific American, Vol. 265, No. 3, pp. 94-104, Sep., 1991.
4. Kim, J.-H., "IT-based UbiBot," (theme special lecture), The Korea Electronic Times, May 13, 2003.
5. Kim, Y.-D. and Kim, J.-H., "Implementation of Artificial Creature based on Interactive Learning," FIRA Robot World Congress, pp. 369-374, May 2002.
6. Ha, W.K., Kim, D.H., and Choi, N.H., "The Ubiquitous IT Revolution and the Third Space," The Korea Electronic Times, 2002.
7. Jennings, N. and Wooldridge, M., IEE Review, Volume: 42, Issue: 1, pp. 17-20, Jan. 1996.
8. Wooldridge, M., Software Engineering. IEE Proceedings, Volume: 144, Issue: 1, pp. 26- 37, Feb. 1997
9. ATR, <http://www.ktab.go.jp/new/16/0413.htm>