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**9**

# Universal Design with Robots Toward the Wide Use of Robots in Daily Life Environment

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## 1. Introduction

Robot technology has been cultivated by developing robots that work in special environments, such as industrial robots, robots for performing maintenance in nuclear power plants, and robots for use in space. On the other hand, the application fields of robots are expanding to include aspects of daily life, for example medical robots in hospitals, welfare robots in homes for the elderly, robots to perform cleaning in buildings and robots for use at home. Furthermore, the essentials of robot technology (RT) have been applied widely to endow mechatronics products with intelligence. Advanced examples include implementation of a robotic function in an automobile so that it automatically maintains a distance from the car in front, and an automatic parking function. In particular, various kinds of robots for home use, such as security robots, caretaking robots, information service robots, and communication robots, are now being developed (Japan Robot Association, 2003). A robot that provides support to people at home is generally called a "Daily Life Support Robot" or "Human Symbiosis Robot" in Japan (Japan Robot Association, 2005, 2006), (Matsuhira et al., 2005), (Hosoda et al., 2006). However, it is still difficult to realize a home robot capable of moving through doors and coping with differences in level, although the growing popularity of barrier-free designs are helpful in this regard. Here, we consider the concept of Universal Design (UD). UD, which is a design concept that aims to satisfy the needs of everybody in daily life, is also important for home robots or robots in daily life environment. Robots can move easily where wheelchairs can move easily. Robots can easily handle what a person who has trouble handling things can handle easily. Similarly, robots can easily find a sign that is easy for a person with impaired sight to find. A robot will be thought as one of users for UD. Thus the UD is important. Improvement of the environment by applying the UD concept is expected to lead to expansion of the sphere of robot activity and to spur practical use of robots. We propose Universal Design with Robots (UDRob™), a universal design concept encompassing both people and robots (Matsuhira et al., 2004), (Wada, 2004). A conceptual design of a robot-system based on UDRob™ has been developed and is presented here. So far, robot design has been mainly considered in terms of the figure or shape of robots themselves. We adopt the UD both for robots and the

environment as shown in Fig. 1. We believe that this new concept is important for facilitating the practical use of robots. A major problem concerns the performance of robots working in homes. Industrial robots perform predetermined tasks in predetermined environments. In society, many people need help in view of aging population especially in Japan. There are expectations that robots will help such people. The problem is that the environments and tasks for home robots are diverse. UDRob™ is a novel solution that originated from the collaboration between robotic engineers and designers. Toshiba Corporation and Tama Art University jointly conducted this research from 2004 to 2006.
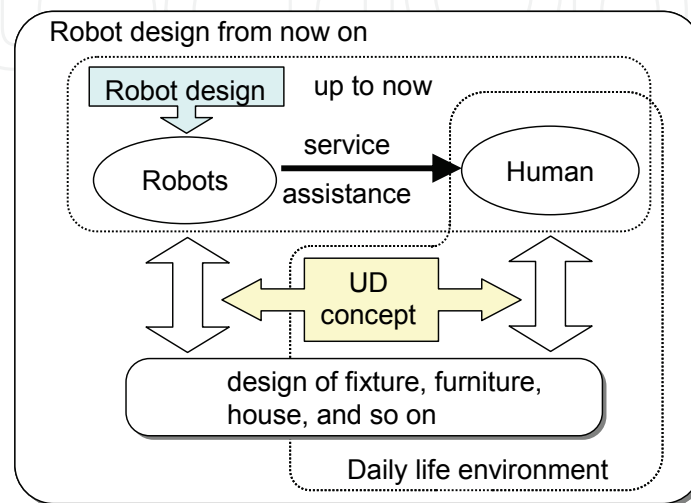


Fig. 1. New concept of robot design using UD

## 2. Universal design with robots

According to the Japan Robot Association (JARA), the Japanese market for service robots will be worth JPY 3,000 billion in 2010, increasing to JPY 8,000 billion in 2025 (Matsuhira & Ogawa, 2004). Main application field is the daily life support. Although a great deal of R&D on robotics is being done in Japan, there are few robots in practical use. There is a big gap between expectations and the actual performance of robots at present. One of the main reasons is that environments for the robots are diverse and the robot performance cannot catch up with the application requirements. In practice, it is very difficult to develop robots that have sufficient flexibility for the environments encountered in daily life such as *where is the object ?*, *what is it ?*, and *how to handle it ?* UD is one solution to this problem.

Hereafter, well-known definitions of UD are adapted for robots.

a)   Equitable Use: A robot can use the objects.
b)   Flexibility in Use: A robot handles the objects freely.
c)   Simple and Intuitive: A robot handles the objects easily.
d)   Perceptible Information: A robot easily recognises the objects.
e)   Tolerance for Error: A robot handles the objects safely.
f)   Low physical effort:  A robot handles the objects by simple motion, without fine positioning accuracy or dextrous motion being required.
g)   Size and space for approach and use: A robot approaches and handles the objects easily.

Essentially, these definitions mean that for robots and humans it is easy to recognise objects, access objects, and handle objects. If we solve the interface design, including mechanical and

audio-visual consideration, from the viewpoint of the UD concept, it will be possible to use robots more widely in daily life.

There have been few researches on UD that include robots. Based on a related concept, WABOT-HOUSE was built to coexist with robots (Sugano et al., 2006), and a practical experiment of robots was conducted on a public road in Fukuoka prefecture, Japan, with the aim of having robots play an active part in environments encountered in the course of daily life (Japan Robot Association, 2004). On the other hand, attempts have been made to combine networks and robots so that robots can acquire information, which includes self-localization data, map data, and what to do, from environmental sensors and knowledge such as "networked robot" (Hagita et al., 2005), (Chong et al., 2004). Recently information-structured environments have been actively developed as a common platform technology for next-generation robots (Tanie et al., 2007), (Kanda et al., 2007), (Hasegawa et al., 2006), (Ohba et al., 2007), (Sugawara et al., 2007). So far, information technology (IT) environment has been improved drastically in Japan as a common infrastructure. From now on, it is inevitable to arrange the physical interface as environmental contact point for robots to work in various applications as shown in Fig. 2. In a factory or a power plant, environments can easily be arranged for robots. However, a handle designed specially for a maintenance robot may be difficult for people to use. For a robot to work at home, an integrated design covering both the environment and the robot is required. In this paper, the design of a home robot was studied, considering the environment in which people live, and features of houses such as doors, steps, and stairs, based on UDRob™.
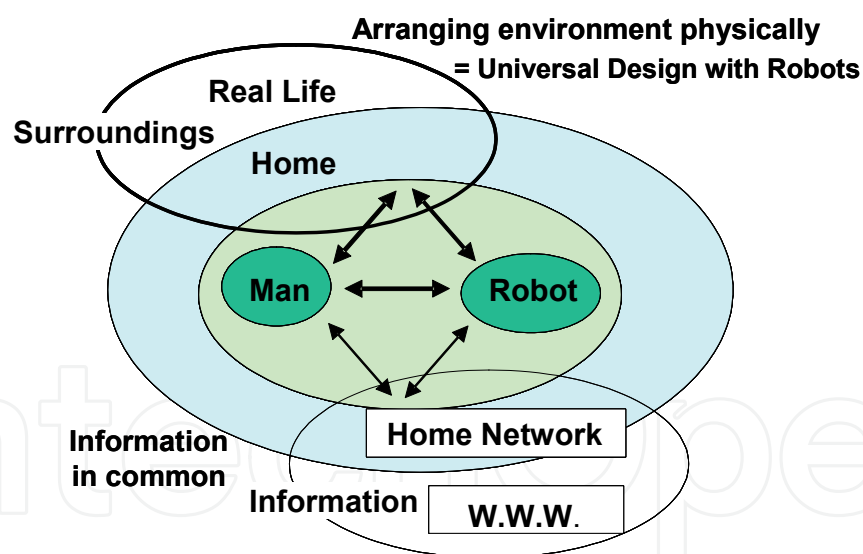


Fig. 2. Robot and infrastructure of the living and the networking environment

## 3. Adopting universal design with robots

We expect robots to move around freely and work with arms and hands, handling things in the home or elsewhere. There are many difficult issues to be solved in daily life environment such as motion control, localization, planning, recognition and perception. Here, UDRob™ can facilitate them. We focused on "to move", "to handle", "to look", and "to listen" and examined the arrangement of robot design from the perspective of design of the home.

### 3.1 To move

Regarding movement, robots are initially expected to move in a wide space such as public space or buildings, and then gradually be introduced into a more confined space such as a home. We have to secure aisles for robots, as well as stairs, steps, and doors. Obviously, it is advantageous to expand the robot's sphere of activity. For instance, an aisle where a wheelchair can pass easily is also suitable for a robot. Stairs and steps will be replaced by slopes. As for doors, power-assisted doors, automatic doors, and small doors for pets are already in use. We call this approach "Environmental interface design". It is not easy to facilitate movement of a robot and provide sufficient work space for it. But once the necessity of the robot is recognised, a suitable environment will be arranged. On the contrary, people will clean up their room for robots to work in the near future.

### 3.2 To handle

Handling comes after moving. Mechanical interface of handling targets should be as common as possible. Concretely, shapes of handling targets should facilitate easy handling by robots. So far, shapes of handling targets have been unified to facilitate handling by robots. For example, the handling part and coupling part of maintenance robots for power plants or space development are unified into several types as standard interfaces. We call this approach "Interface design of working target". These designs are helpful for simplifying tasks to reduce the cost of both hardware and software, and improve the reliability.

Consider a maintenance robot and maintenance work used in a nuclear power plant or in space development. A captive bolt is used avoiding falling out of hole. Picking up a fallen bolt and inserting it into the hole again is a very difficult task for robots and the fallen bolt may disturb the operation of the apparatus. To ease the positioning when the robot assembles components or fits together by insertion, compliance mechanisms to absorb misalignment are necessary. For example, a spring is used to release an overload, a tapered-shape is good to guide for fine positioning, a circular shape is also useful because parts can be inserted into a hole from any direction. There are many designs for maintenance robots or astronauts who cannot move dextrously because they are wearing the space suits with big gloves. Handles in there should be big enough to grasp when wearing gloves.

### 3.3 To look

There are many situations in which it is necessary for a robot to recognize the user's face and to measure what is where by using images. Accuracy of image processing is influenced greatly by a change of lighting or depends on the background. It is necessary to configure lighting condition, or to fix a place where more accurate results can be obtained. For recognizing places or positions or target objects, the heavy load for image processing can be reduced by using geometrical markers that show specific information of localization. Although image processing technology is advancing, robots don't have to rely on everything about environmental recognition to highly developed image processing in case there is another way to solve it. On the other hand, it is possible to acquire localization data from a specific protocol or networking device through a network by, for example, using radio-frequency identification tags (RFID tags) (Kim et al., 2005, 2006). We call this approach

"Environmental informative interface design". Furthermore, it is possible to have the shape of a target object serve as a landmark itself, such as a door, a doorknob, and a window frame. If it is possible to recognize from the shape of a handle that a door opens by pulling or pushing, or a window opens by sliding, this would simplify recognition and manipulation tasks not only for robots but also for humans. In the SLAM technology of mobile robots, a natural scene captured by a vision sensor is used to determine the location of the robot in the map (Thrun, 2001).

There are many geometric designs for interiors, floors, walls, etc. It's easy for a robot to use them to identify its position in the environment. IT is also important for the robot, and the robot is systemized with the network environment as an actual movable agent. But information from the actual shape of the object is more important as a UD, because signal information cannot be perceived by humans.

### 3.4 To listen

A robot is already able to recognise the human voice. But voice recognition is usually carried out through a microphone near to the user's mouth. In reality, however, the human is often distant from the robot. It is very difficult for the robot to understand what the user says because there is a lot of background noise in the daily life environment such as TV. Microphone array technology and noise cancelling technology have been developed to improve the performance of voice recognition (Amada et al., 2004), (Asano, 2004), (Brandstein, 1999), (Brandstein & Ward, 2001), (Nakadai et al., 2003). But it is expected to be a long time before robots can match the ability of humans to understand humans' voices in daily life environments. However if we talk to the robot using simple words, with a clear and loud voice as we do when we talk to the elderly, the robots are able to understand them easily. This is the concept of UDRob™.

## 4. Design of robot and environment

Tama Art University studied an environmental design suitable for a working home robot and human daily life. Storing things includes taking out and putting back, and delivering things so that it is realized by a robot in combination of environmental recognition with vision sensing, handling with arms and hands, and moving. The relationship among shelf as storage, tray as common interface, humans and robots are to be considered in the daily life.

a) Total image of the living room at the home

Fig. 3 shows a living room image with robots designed by UDRob™. The user assorts daily necessities to store in a tray divided by colour so that the robot recognizes the colour and marker in order to grasp a specific tray and deliver it to the user. Taking the example of daily medication, the user puts the medicine on the tray and sets the time schedule for taking it so that the robot delivers it to him/her as a regular basis, without running the danger of forgetting taking the medication, or overmedication. As mentioned above, the example of environmental design and practical use of the robot is shown as a concept of UDRob™.

Fig. 3. Image of a living room designed with UDRob™ concept



Fig. 4. Shared Shelf



(a) Variation of tray



(b) Tray as an interface
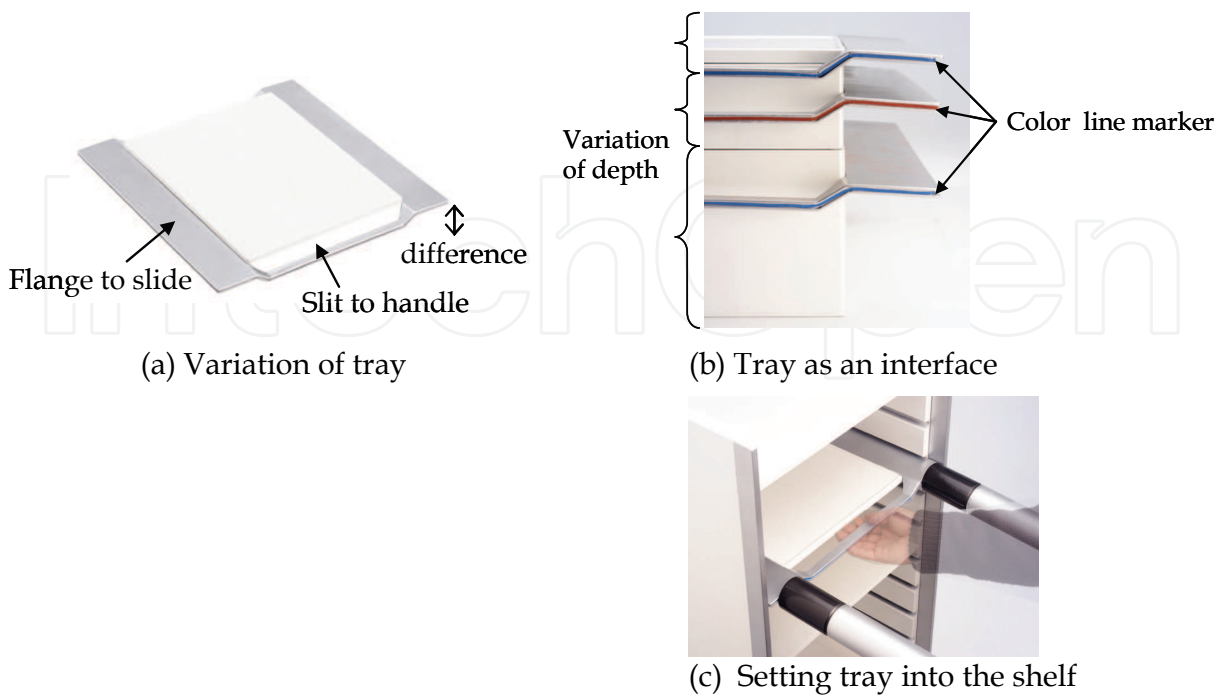


(c) Setting tray into the shelf

Fig. 5. Variation of tray

b) The shelf and the tray

The robot handles the tray unit that contains categorised objects. There are various kinds of daily necessities in our life. For the robot, handling each of them is not practical. It is equipped with the tray as a common interface and the user can put things on the tray. Fig.4 shows the studied design of the storage shelf that is shared by the robot and the user. This shelf consists of a frame and tray-shaped drawers as shown in Fig. 5. The user has only to set things on the tray and the robot delivers it to the shelf. There are various trays, some are flat, others have a profile, and the interface of the tray is designed to be suitable for both humans and robots. It is an interface design of working target. The shelf has no door so that robot can easily access it. The edge of the tray is painted or lighted in different colour to be distinguished easily by both the robot and the user. The task of carrying things at home is supported by sharing the shelf, easy to access and use by both.

c) The robot

Fig. 6. shows the mock-up of the designed robot that carries things from room to room at home. It moves with driving wheels, and two arms that can be folded in its body. The end of the arm is equipped with a gripper hand and a hand-eye camera that recognizes colour marker of the edge of the tray. The task is accomplished by moving with the tray set on the top of robot's body. Fig. 7. shows the sequence of the robot approaching the shelf and putting the tray on it. Fig. 8. shows the transportation scene with floor markers. The markers on the floor or wall are used as landmarks to show the robot a certain point or a direction of movement. Colour variations, geometric design patterns, and LED markers would also constitute a landmark. Combining landmarks and floor/wall designs can give advantages to the user. They can show the user the sequence of the robot's activity. Markers are helpful for both the robot and the user. It is an environmental interface design
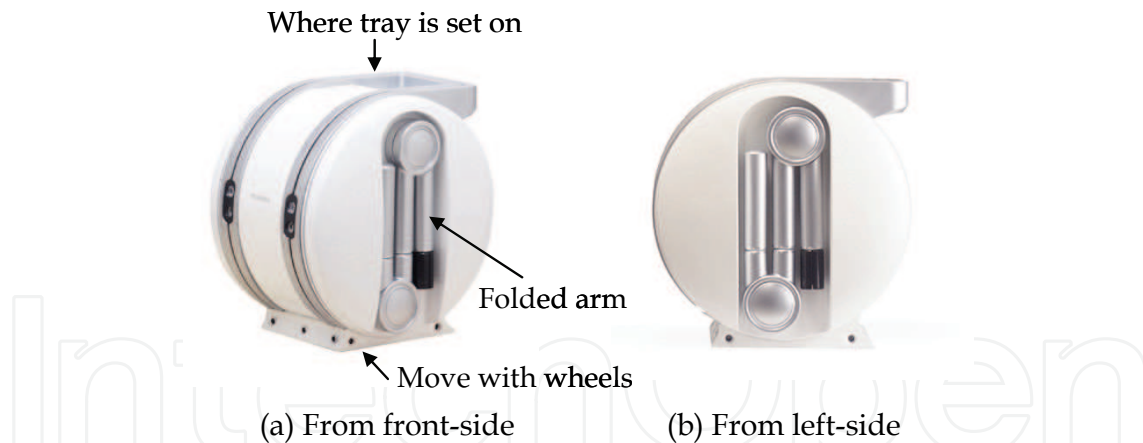


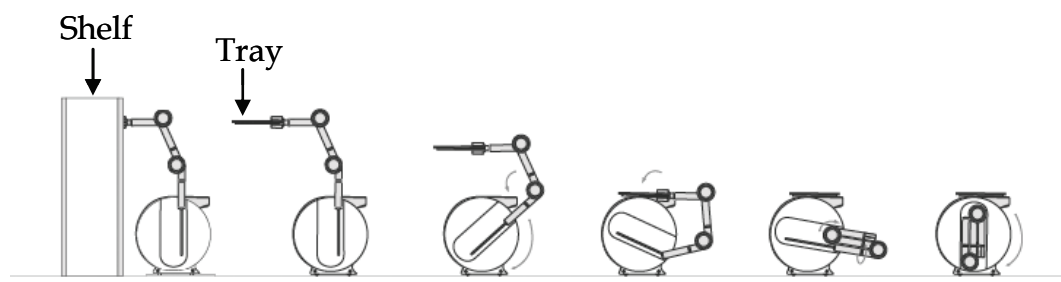Fig. 6. Mock-up of conceptually designed porter robot



Fig. 7. Sequence of setting a tray on robot with its extended arm

Fig. 8. Robot in movement, guided by line-marker

## 5. Introduction of UDRob™ to a real robot

Home robots are to be as small and light as possible considering the production costs and safety. If a robot is large, it becomes a big obstacle in a room at home. Fig. 9 shows the robotic interface home appliance ApriAlpha™ developed by Toshiba (Yoshimi et al., 2004), (Matsuhira et al., 2005). ApriAlpha™ controls networked home electric appliances such as TV, room lights, and air-conditioners by direction of its user's voice, and gets the information like weather forecast from the internet to tell it to the user. Table 1 shows the main specification of ApriAlpha™. It was originally developed as a robotic interface of information, and its size seems to be reasonable for this purpose. Although the robot is too small to carry our daily necessities, we can redesign it as a porter robot with the concept of UDRob™ as mentioned in the previous section. Among the shelf, the robot, and its user, the trays are the common interfaces designed for not only human but also robot and shelf, as shown in Fig. 10. Interface design is always to be considered in the environment, e.g., UDRob™.



Fig. 9. ApriAlpha™

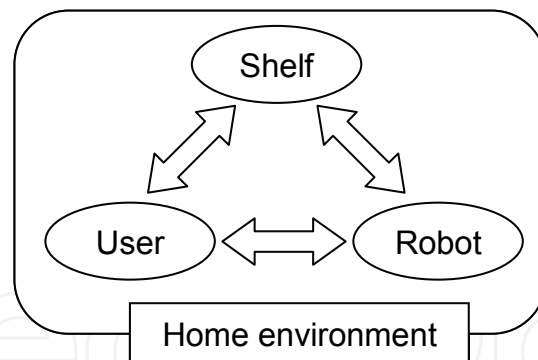| Height | 420 mm |
|---|---|
| Diameter | 380 mm |
| Weight | 9.5 kg |
| Velocity | 0.5 m/sec |
| Power source | Li+ Battery |
| Driving wheels | 2 |

Table 1. Specification of ApriAlpha™

Fig. 10. Relation of each element in home environment

a) Interaction between Tray and Robot

Where should be the interface placed between the tray and the robot? If you want the robot to carry things, they will be set on the carrier, and it can be pushed, tugged, or mounted by the robot. Among them, mounting things on the robot is selected so that the robot can move smoothly without controlling the carrier's motion. Fig. 11 shows the configuration of extendable arms. The arms are stored on both sides of the body. For making a delivery, extendable arms are designed to support the tray.

b) Interaction between Tray and Robot or User or Shelf

A self-positioning mechanism of the tray to the extended arm is developed to make it easier to place the tray on the robot. Fig. 11 (b) shows the sketch of it. Even if the tray is misplaced on the extended arms by humans or by the transfer mechanism of the shelf, the tray is automatically shifted to a stable position guided by a cam mechanism that consists of rollers and curved shape rails. The mechanism absorbs both the misalignment and the impact force during placement. The A4-size-tray is enough for carrying daily necessities such as wallet, pass, cellular phone and envelopes.
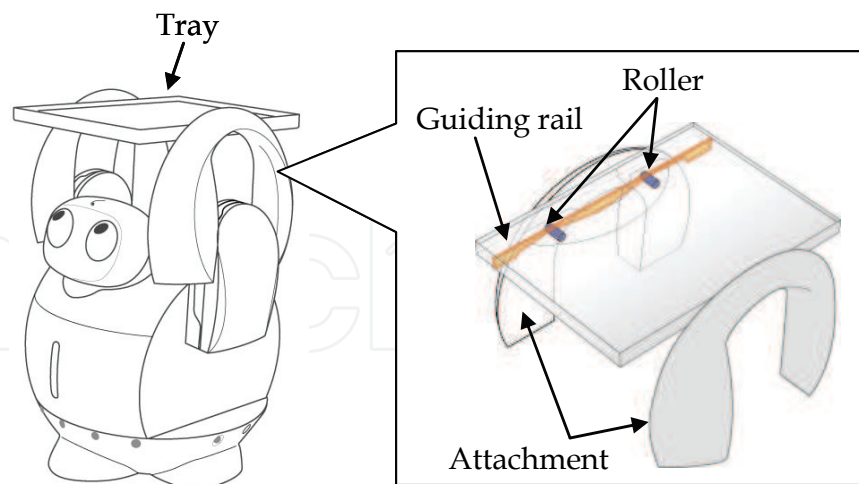


(a) Extendable arm to support tray    (b) Self-positioning mechanism

Fig. 11. Robot supporting the tray with extendable arm

c) Interaction between User and Robot

The extendable arms are designed not only for the support of the tray but also as the interface to the user. The robot is too short to serve the user. The arms can extend up to about 0.6 m in height to make it suitable for a user sitting on a chair to access the tray. Fig. 12

shows the relationship between the robot and the user. Fig. 13 shows the image of serving a light meal.
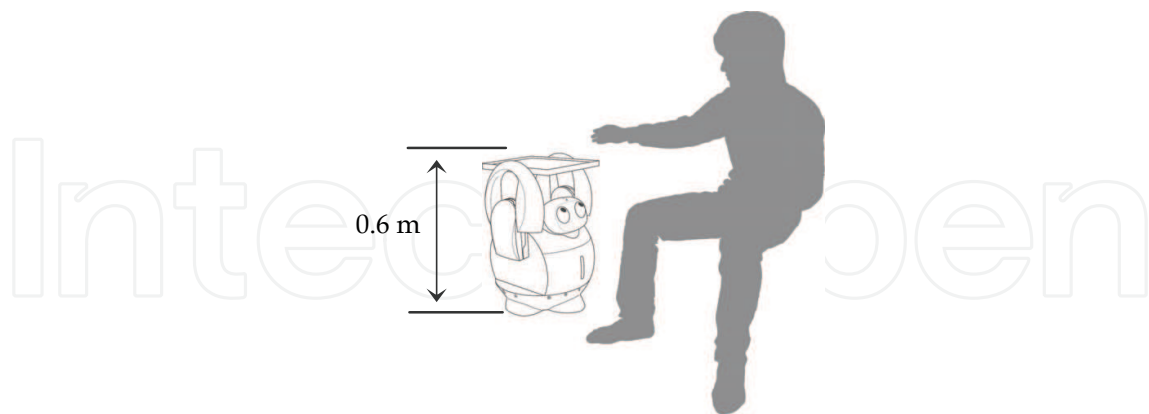


Fig. 12. Robot-User interaction



Fig. 13. Image of ApriAlpha™ serving a light meal

## 6. Conclusions

Robots are expected to provide help to those who need it in the aging society like Japan. Recently various kinds of home-use robots have been developed to support people in their daily life. However, robot's tasks are hindered in many different ways. Universal Design with Robots (UDRob™) has been proposed to cope with these problems. Interface designs for mobility, handling, and image processing are especially considered as a basic concept of UDRob™. Conceptual design of the robot system based on UDRob™ has been described here and it helps the realization of coexistence between robots and humans. Arrangement of environmental design has the potential of tremendously improving a robot's activities. However, that arrangement should be also useful to its user. The point of UDRob™ is not on requiring a special design for robots but on arranging a common design for humans and robots. As a result, it will improve the quality of our life. Collaboration between designers and robotics engineers are expected to be intensifying in the near future.

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**Advances in Service Robotics**

Edited by Ho Seok Ahn

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This book consists of 18 chapters about current research results of service robots. Topics covered include various kinds of service robots, development environments, architectures of service robots, Human-Robot Interaction, networks of service robots and basic researches such as SLAM, sensor network, etc. This book has some examples of the research activities on Service Robotics going on around the globe, but many chapters in this book concern advanced research on this area and cover interesting topics. Therefore I hope that all who read this book will find lots of helpful information and be interested in Service Robotics. I am really appreciative of all authors who have invested a great deal of time to write such interesting and high quality chapters.

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