Expo 2005 Robotics Project

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Abstract. This paper overviews a robotics project at the Expo 2005. The project consists of long term experimental evaluation of practical robots at the Expo site simulating the society in the future and short term demonstration of prototype robots. The long term evaluation can let robots advance from the demonstration level to the practical use one, and the short term demonstration from the single shot experiment level to the demonstration one.

1 Introduction

The 2005 World Exposition (Expo 2005) has taken place at Aichi, Japan from Mar. 2005 for half a year. Though "Nature's wisdom" is the message of Expo 2005, Expo 2005 has shown many kinds of advanced technologies as Human's wisdom. Robots are one of major display at many pavilions. For example, music playing robots at Toyota pavilion is one of most popular attractions at Expo 2005.

New Energy and Industrial Technology Development Organization (NEDO for short), a funding agency of the Japanese Government, runs a robotics project at Expo 2005. The project consists of long term experimental evaluation of practical robots and short term demonstration of prototype robots, where the practical robots are expected to be used in the society before 2010 and the prototype ones before 2020.

The applications of the practical robots are the cleaning and security of the Expo site, autonomous wheelchairs, clerks at the information desks, and children sitters. The practical robots are used every day for the whole period of Expo 2005, i.e. 185 days. The Expo site is supposed to be a simulated society in the near future. The long term evaluation could let the robots advance from the demonstration level to the practical use one.

Sixty-five kinds of prototype robots have been developed, whose applications diverge widely. The demonstrations of the prototype robots had been shown for two weeks in a simulated town of 2020 at the Expo cite, where people and robots live together. Most of the prototype robots were developed by universities and the demonstration of two weeks let the robots advance from the single shot experiment level to the demonstration level, where the single shot experiment level means the level of a robot which can work properly only once for taking a champion video segment.

This paper overviews Expo 2005 Robotics Project of NEDO. Section 2 presents the details of the practical robots, and section 3 those of the prototype robots. Section 4 concludes the paper.

2 Long term evaluation of the practical robots

2.1 Mobile robots

The first category of the practical robots include mobile robots that consist of cleaning robots, security robots and an autonomous wheelchair. The key technology of the robots is autonomous navigation in the open air. The navigation is implemented by combinations of dead reckoning, laser measurement sensor, RTK-GPS and RF-ID. More details of the robots are described in the following.

Cleaning robots

The missions of the cleaning robots include the cleaning of the main pedestrian loop of the Expo site, called Global Loop, whose diameter is about 1 km. The Global Loop has many curves and slopes as well as many obstacles like benches and bending machines, and the robots can not see enough number of the GPS satellites at some places. Though the cleaning is done at night to avoid a crowd of visitors, a small number of employees may walk on the Global Loop. A map of the Global Loop is shown in Fig.1 and a photograph of the Global Loop in the daytime in Fig.2.

The cleaning robots consist of Subaru Robohiter RS1 developed by Fuji Heavy Industries Ltd. and SuiPPi by Matsushita Electric Works Ltd., whose picture are shown in Fig.3. The size of RS1 is $1,080mmW \times 1,600mmD \times 1,160mmH$ and the weight is about 360 kg. RS1 can clean about $3,600m^2$ per an hour when it travels at $3km/h$, and continue to work more than 3 hours. The size of SuiPPi is a bit larger than that of RS1, that is, $1,200mmW \times 1,513mmD \times 1,233mmH$ and the weight is about 500 kg. SuiPPi does not use GPS, and its localization is calibrated by a laser measurement sensor. The required infrastructure for the navigation of the robots are two RTK-GPS stations at the Expo site and reflectors for the laser along the Global Loop. The reflector is mounted every 20 meters on the loop, which is shown at the lower-left corner of Fig.4.

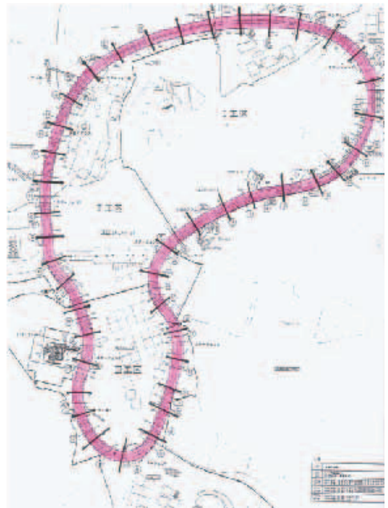

Fig. 1. Map of the Global Loop

Fig. 2. A photograph of the Global Loop

RS1 and SuiPPi had been successfully applied to the cleaning of the Global Loop for half a year. Though the robots are designed safe enough to be operated at the Expo site, it was not possible for the robots to meet all the related regulations for the safety. Therefore the robots had been operated under the supervision of a human. A photograph of RS1 working at night is shown in Fig.5. Fuji Heavy Industries Ltd. also developed Subaru Robohiter T1 that can exchange garbage cans.

Fig. 3. Cleaning robots RS1[Fuji Heavy Industries] and SuiPPi[Matsushita Electric Works] ©NEDO

Fig. 4. Reflector for the laser on the Global Loop

Security robots

Though security robots are expected to watch the Expo site, report suspicious events and remove them if possible, the current abilities of security robots are still limited. For example, it is very difficult to judge if a person is suspicious and if an object is unattended. Instead, ALSOK GuardRobo i, 190kg weight, developed by Sohgo Security Services Co.Ltd. can go around and send live pictures to a security center, find a human around the robot when nobody should be there, and report an object exists where nothing should be there. Mujiro/Ligurio, about 300 kg weight, developed by tmsuk Co.Ltd. can pick up an object by two manipulators via teleoperation. Photographs of the security robots are shown in Fig.6.

Autonomous wheelchair

An autonomous wheelchair is an enhanced electronic wheelchair with navigation ability. TAO Aicle, 40 kg weight, developed by Aisin Seiki Co.Ltd.,

Fig. 5. RS1 working on the Global Loop in the night

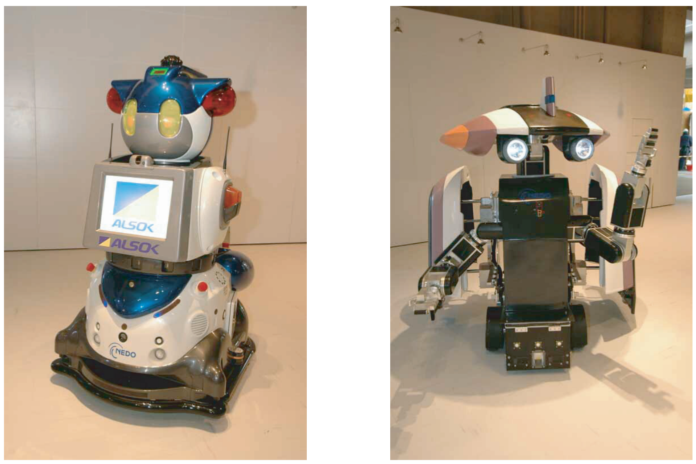

Fig. 6. ALSOK GuardRobo i[Sohgo Security Services] and Mujiro·Ligurio[tmsuk] ©NEDO

Fujitsu Ltd. and AIST can travel autonomously while avoiding obstacles[4]. The maximum speed of TAO Aicle is 2 km/hour and the maximum operating time is 3 hours. Each wheel is driven by a DC motor of 90 W, and the maximum weight of the passenger is 100 kg. The navigation of TAO Aicle depends on RTK-GPS and RF-ID embedded in the working environment. The wheelchair can know its position from the RF-IDs which are embedded in the floor. The RF-IDs are put with the interval of 15cm in a belt, and the belts are arranged every four meters. The visitors to the Expo could try to use TAO Aicle in the experimental environment. A photograph of TAO Aicle in the environment is shown in Fig.7. TAO Aicle can communicate with a traffic

Fig. 7. Autonomous wheelchair TAO Aicle[Aisin, Fujitsu, AIST] ©NEDO

signal via a wireless LAN, and stops when a traffic signal is red. Though the navigation of TAO Aicle should depend on the infrastructure significantly, the requirements for it can be considered realistic in the near future and the long term experiments at the Expo have proved that it can be operated reliably when it is available.

The user interface of TAO Aicle is implemented by a PDA and is designed to be friendly even to senior people. For example, the user can specify the destination by touching its panel.

2.2 Interactive robots

The second category of the practical robots includes interactive robots that consist of clerk robots at the information desks in the Expo site, receptionist robots, and children sitter robots. The key technology of the robots is the understanding of spoken languages. The clerk robots can understand spoken Chinese, English, Japanese and Korean in a specific domain. The four languages were chosen since the Expo expects most visitors from the countries in which the languages are spoken.

Clerk robot at an information desk

The mission of the clerk robots is to answer questions about the Expo. The information desks are located near three gates of the Expo site, and the robots can understand spoken Chinese, English, Japanese and Korean in a noisy environment. Usually the information desks are surrounded by several tens of people and a cloud of people may walk around them.

Actroid developed by Kokoro Co.Ltd. and Advanced Media, Inc. has served as the clerk robot. Actroid is a concatenation of an actor and an andoroid, and is supposed to stand for a robot actor whose picture is shown in Fig.8. As you can see from the picture, Actroid has a realistic appearance of a

Fig. 8. Clerk robot Actroid [Kokoro and Advanced Media] ©NEDO

human female. The behavior of Actroid are also designed to emulate those of a human. The appearance and behavior can make the visitors feel to interact with a real human. In fact, most visitors seem to be very happy when they asked questions to Actroid. The hardware and the behavior of Actroid were developed by Kokoro.

It is very difficult to understand the questions when Actroid does not know which language is spoken. So we ask the user of Actroid to start from hello or the equivalent in four languages. Then Actroid can be ready for the selected language. The noise and echo in the working environment of Actroid are reduced by a cancellation technique to realize the understanding. More than twenty responses are prepared to single question to realize a natural discourse. The speech recognition software was developed by Advanced Media. Actroid has been operated for the whole period of the Expo, and a huge number of people have enjoyed it.

Receptionist robot

The missions of the receptionist robot are to call a person specified by a visitor at a reception and to answer questions about a daily life like today's weather or hot topics. The receptionist robot can also understand spoken Chinese, English, Japanese and Korean in a specific domain. The receptionist robot is wakamaru developed by Mitsubishi Heavy Industries Ltd., whose picture is shown in Fig.9. wakamaru has 1 meter height, 30 kg weight and 13 d.o.f. The

Fig. 9. Receptionist robot wakamaru [Mitsubishi Heavy Industries] ©NEDO

robot can be operated for 2 hours by battery, and can go to a charge station autonomously.

wakamaru can also find how many human faces are around it and where they are. Then wakamaru can look at the speaking person and interact with the person more friendly.

wakamaru may hit a nearby user because it has two arms to express his feeling. So the tips of its arms are covered by soft material. A hand of a user may be caught by one arm and the body too. The related joints of wakamaru has mechanical stoppers to avoid the accident. Such safety design is very important to run wakamaru for 185 days in a cloud of people.

Childcare robot

The missions of the childcare robot is to interact with a child and make him/her enjoy. The childcare robot is PaPeRo developed by NEC Corporation[1, 2], whose picture is shown in Fig.10. PaPeRo has three kinds of ability to sit children. PaPeRo can recognize a human face when it is registered in advance. Ten faces can be registered at most. PaPeRo can understand Japanese spoken by children, which had been considered more difficult than that by Adults. PaPeRo is equipped with noise canceller software so that it can recognize voice even in very noisy environment like exhibition rooms. When PaPeRo fails to understand some words, PaPeRo analyzes why the understanding failed and suggests the user to speak in a better way. For example, PaPeRo may say

Fig. 10. Childcare robot PaPeRo [NEC] ©NEDO

"Please speak in a smaller voice". The last ability of PaPeRo is to provide entertainment. PaPePo can dance when requested, and react when touched. The robot can provide quiz to a kid and teach him/her how to give greetings.

PaPeRo has been used to play with children, and the performance of the robot has been evaluated from various viewpoints. A photograph of PaPeRo playing with a child is shown in Fig.11.

Fig. 11. PaPeRo playing with a child

2.3 Biped robot

The last category of the practical robots is a biped robot. The biped robot is not a humanoid but a biped dinosaur robot, developed by AIST and NEDO. Two types of the dinosaur robot were developed, one is Tyrannosaurus Rex and another Parasaurolophus, whose pictures are shown in Fig.12 and Fig.13 respectively. The length of the robots is about 3.5 meters and the weight

Fig. 12. Tyrannosaurus Rex [AIST and NEDO] ©AIST and NEDO

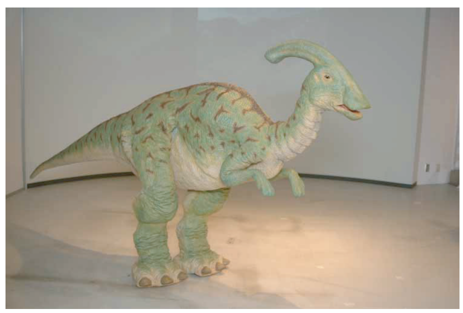

Fig. 13. Parasaurolophus [AIST and NEDO] ©AIST and NEDO

is about 86 kg. The structure of the dinosaur robot is an endoskeleton type, which is covered by soft material. The soft cover can reduce the impact when the robot fall down, and realize a realistic appearance as well.

The biped walking is implemented by the software used for humanoid robot HRP-2. The dinosaur robot has shown its demonstration of fifteen minutes more than 1,500 times and fell down four times so far. The long term operation of the robot is also a very nice evaluation of biped robot technologies.

3 Short term demonstration of the prototype robots

Sixty-five kinds of prototype robots were developed and embedded in a simulated town in 2020. The message of the demonstration is “We live together with robots in 2020”. A perspective picture of the simulated town is shown in Fig.14 and a snapshot of the real counterpart is in Fig.15.

Fig. 14. Simulated town in 2020

Fig. 15. Snapshot of the simulated town in 2020

The prototype robots can be categorized into service robots, medical and welfare robots, outdoor robots, robots for special environments, partner robots, and humanoid robots. The list of the selected prototype robots is shown in Table 1.

Table 1. Selected List of the Prototype Robots for Expo 2005

Service robots

Life Pod (Fuji Electric Sys.)	a smart vending machine for security services
COOPER (Yoshikawa Kikai et al.)	a robot caricaturist
Picture Robot (Gifu Ceramics RI et al.)	a ceramics painting robot
TELEsarPHONE (U of Tokyo et al.)	a robot making people feel in a remote place
EMIEW (Hitachi)	a robot that acts as a work mate
Momochi (Kyushu U. et al.)	a contents-driven companion robot
SmartPal (Yaskawa Electric)	an autonomous mobile robot with dual arms
Cyber Assist Meister Robot (Saitama U.)	an interactive robot
Power Effector (Ritsumeikan U.)	a power effector directly operated by a human
ApriAlpha (Toshiba)	a robot that recognizes spoken language

Medical and Welfare Robots

MM-1 (NHK Eng. Services et al.)	a microsurgery robotic system
Surgery Robot (Nagoya U. et al.)	a surgical robot for remote micro surgery
EVE (Nagoya U.)	a high-precision patient robot
HAL (U. of Tsukuba)	a robotic power suit
Optical-tongue Robot (NEC Sys. Tech. et al.)	a robot that analyses taste of foods

Outdoor Robots

WallWalker (Miraikikai et al.)	a wall cleaning robot
MOIRA2 (Kobe U.)	a mobile inspection robot for rescue activity
IMR-Type 1 (IHI)	a leg-wheeled mobile robot
Dr.Impact (Gifu U. et al.)	a pipe inspection robot
Batting Robot (Hiroshima U.)	a high-speed batting robot
WOODY-1 (Waseda U.)	a robot woodcutter

Robots for Special Environments

ACM-R5 (TITech et al.)	an amphibious snake-like robot
Kinshachi Robot (Ryomei Eng.)	a real fish robot
UMRS-NBCT (Int. Rescue Sys.)	a mobile robot for NBC pollution

Partner Robots

DAGANE (Business Design Lab. et al.)	a verbal and nonverbal communication robot
Repliee Q1expo (Osaka U. et al.)	an android that looks like a human
InterAnimal (Okayama U. et al.)	an interactive animal-like robot
Robovie & wakamaru (Yoshimoto et al.)	comedian robot-duo
Dress-up Robot (Future U. Hakodate et al.)	an authoring robot
PBDR (Tohoku U. et al.)	a parner ballroom dance robot

Humanoid Robots

HRP-2 with Human Supervision (AIST)	a humanoid robot that can investigate objects
HRP-2 that interacts people (NAIST)	a humanoid robot that uses spoken dialog
WIND Robot System (Chiba IT et al.)	a small humanoid robot driven by a SIP
UT-μ2: magnum (U of Tokyo)	an animatronic humanoid robot
WABIAN-2 (Waseda U.)	a biped humanoid robot

One of the service robots is SmartPal developed by Yaskawa Electric Corporation, which can serve drinks at a cafe, and one of outdoor robots is WOODY-1 developed by WABOT-HOUSE which can cut branches of a wood while climbing it. Pictures of SmartPal and WOODY-1 are shown Fig.16.

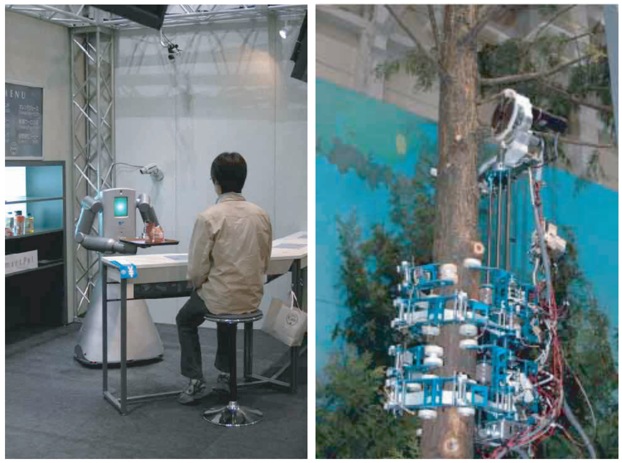

Fig. 16. SmartPal [Yaskawa Electric] and WOODY-1 [WABOT-HOUSE] ©NEDO

Figure 17 shows dance parter robot PBDR [Tohoku University], HRP-2 [AIST], Nagara [Gifu], Robovie and Wakaramu [ATR].

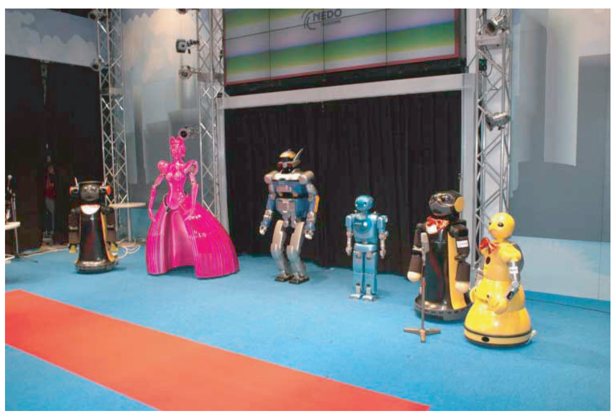

Fig. 17. PBDR, HRP-2, Nagara, Robovie and wakamaru ©NEDO

The demonstrations of the prototype robots had been shown for two weeks, and attracted more than 100,000 visitors during the exhibition. It was amazing that the robots developed by laboratories of universities can show the demonstrations for two weeks without serious problems, and the exhibition offered a nice opportunity to train the robots.

4 Conclusions

The Expo site was a simulated society in 2010 to evaluate the practical robots for 185 days, and could let the robots advance from the demonstration level to the practical use one.

The exhibition site of the prototype robots was a simulated town in 2020 in which we live together with robots. The demonstration of two weeks let the robots advance from the single shot experiment level to the demonstration level.

From the results, Expo 2005 could train the robotics in Japan significantly, and we believe it can promote more applications of the robots to the society.

Acknowledgments

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