Common Platform Technology for Next-generation Robots

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Abstract. The application-independent common technology for various robots, which can be used by most robot developers and engineers, is defined as "Common Platform Technology." In order to increase the efficiency of future robot research and development, the establishment of the common platform technology is a matter of urgency. The common platform technology is relevant to recent topics in robotics, including information-structured environments, network robotics, robot software framework, robot simulator, and so on. In this paper, we clarify the common platform technology and introduce the activities of the Coordination Program of Science and Technology Projects of the Council for Science and Technology Policy of Japan.

1 Introduction

Various research and development (R&D) projects for robots have been carried out by a large number of research groups. However, many research groups spend a lot of time and money to develop the basic robotic hardware and software before developing the advanced hardware and software specialized for each application field. The basic hardware and software might be used as common infrastructure.

The application-independent common technology for robots of any kind, which can be used by most robot developers and engineers, is defined as "Common Platform Technology (CPT)" [29]. In order to increase the efficiency of future robot R&D, the establishment of the common platform technology is necessary. In this paper, we clarify the common platform technology in Section 2.

In order to increase the efficiency of future robot R&D, the Council for Science and Technology Policy (CSTP) Coordination Program of Science and Technology Projects is promoting the CPT. The CSTP is one of the four councils for important policies of the Cabinet Office of Japan. We consider that the CPT consists of four kinds of platform technology. The classification of the CPT is described in Section 2. In regard to CPT, the CSTP Coordination Program of

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Science and Technology Projects is promoting Software Platform and Environmental Platform.

Although a huge amount of robot software is developed in the world, insufficient consideration is given to its reusability. In order to increase the reusability and the extendability of robot software, the establishment of a common software platform is indispensable. The software platform should consist of at least (a) Software Framework, (b) Software Library (a collection of basic software modules), and (c) Development Environment for robot software. The main component of the development environment is the robot simulator. The software framework should support the modular software development to increase the reusability and extendability of the robot software. The simulator would be able to simulate the performance of a robot using developed software modules. However, there are few simulators that guarantee the consistency of software modules. Therefore, there are few software platforms that have all the above three components. The development of the simulator is a matter of great urgency. The detail of the simulator, which we developed, is illustrated in Section 3.

In order to develop next-generation robots capable of working in complex and dynamic environments, and not just in factories, the ”information-structured environment” is a key technology. For example, the position information of the robots, objects and the humans in the working environment are required for any robotic application and might make the working environment closer to the structured environments, such as those in factories.The environmental platform is the standardized information-structured environment. Three prototype environmental platforms are described in Section 4.

2 Common Platform Technology for Next-generation Robots

Various R&D projects for robots have been carried out by a large number of research groups. However, many research groups spend a lot of time and money to develop the basic robotic hardware and software, which might be used as common infrastructure.

The application-independent common technology for various kinds of robots, which can be used by most robot developers and engineers, is defined as “Common Platform Technology (CPT)” [29]. In order to increase the efficiency of future robot R&D, the establishment of the CPT is a matter of urgency [31][32]. The CPT is relevant to recent topics in robotics, including hardware and software platforms, information-structured environments, network robotics, software modules, and dynamics simulators. The CPT consists of four kinds of platform technology, i.e., (1) Hardware Platform, (2) Software Platform, (3) Robot System Platform, and (4) Environmental Platform.

This classification is not fixed and includes overlap. The conceptual diagram of the four common platforms is illustrated in Fig. 1. The hardware platform consists of the standardized hardware for robots. We would be able to construct a robot by using the hardware platform. The software platform is the basic software infrastructure that enables robot researchers and engineers to share robot

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software. The detail of the software platform is described in Section 2.1. The robot system platform consists of robot systems, which conduct various robotic services by themselves and are expected to become popular in robot R&D. The environmental platform is a standardized environment in which robots work. The detail of the environmental platforms is described in Section 2.2.

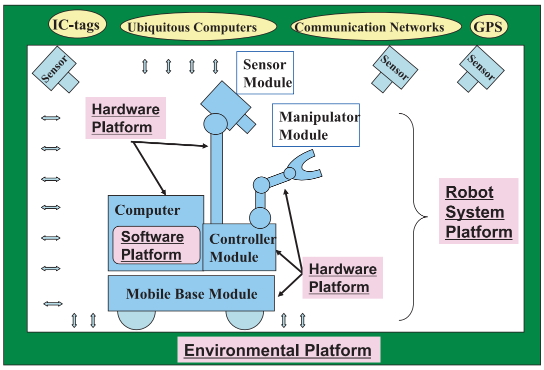

Fig. 1. Overview of Common Platform Technology (CPT)

Aimed at the “effective and efficient promotion of coordination programs for science and technology projects” supported by the special coordination fund for Promoting Science and Technology from the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), the four three-year projects described in Section 3 and Section 4 started from 2005-06 for further development of the CPT.

2.1 Software Platform

Since an effective mechanism enabling robot researchers and engineers to share such software has not been established, they have developed their own software independently in different research projects and research organizations. Similar software is often developed over multiple projects and a considerable amount of shared software exists. It is, therefore, essential to build social infrastructure that enables the provision of software for shared use [3, 4, 9, 1, 7]. A number of software development projects aiming at the establishment of the software platforms have been started. There are various software platforms, such as OROCOS[27], Orca[4, 26], Player/Stage[9, 28], ERSP[6], URBI[3, 33], MSRS[18], CLARAty[20], RT-Middleware[25], ARIA[2], Carmen[5], GearBox[8], YARP[16, 35], and Webots[17, 34]. However, the aptly named YARP, i.e., Yet Another Robot Platform, describes the situation of the software platforms well.

The robot software platform should consist of at least three programs, i.e., (a) Software Framework, (b) Library (software modules), and (c) Development Environment. Fig. 2 is a conceptual diagram of the software platforms. Since many and various software services are necessary for next-generation robots, the robot programs in robot computers should consist of software modules to increase the reusability and extendability of robot software as shown in Fig. 2.

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The software framework is the execution environment for the software modules. It should be based on distributed object technology to support the modular software development [3, 4, 1]. Since it is difficult to develop an OS specialized for robots, a middleware for robot software modules is virtually the software framework. The software library should extend from low-level software modules, which support basic robotic devices to relatively high-level software modules, which support manipulation, navigation, communication, planning, etc. The development environment would serve as a common management system for robot software to accelerate the development of software modules and to accumulate the modules.

The most important difference between the development environment for robot software and that for common software is that the robot simulator is the central component of the development environment to guarantee the consistency of the software modules. The simulator would be able to simulate the performance of a robot using developed software modules in comparison to that of other robots in the same virtual environment.

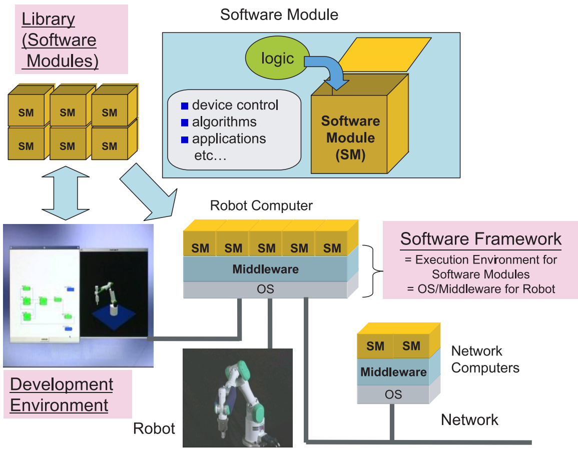

Fig. 2. Concept of Software Platform for Next-generation Robots

Although a number of software platforms have been proposed and developed, there are few software platforms that have all the above three components. In particular, the development of the simulator for promoting the sharable software modules is necessary. The simulator would be able to simulate the performance of a robot synthetically in terms of its hardware, sensors and sensing functions, control structure, and other functions, including work environment, environmental objects, etc.

2.2 Environmental Platform

The physical design of an environment, in which a robot works, is very important for various robot services. The future environments should be structured physically for robots. Furthermore, the informational design of the environment is important as well as the physical design. If position information can be acquired on the basis of a common structure, then R&D of robot systems for specific applications can be executed more efficiently. In the near future, robots themselves are not only expected to be equipped with intelligence and software, but also to utilize knowledge of their environment through integration with other technologies such as IT, ubiquitous computing, network communication technology, and use of GPS and RFID tags. These technologies have been developed as "networked robotics." The importance of "environmental information structuring technology" (that is, the embedding of programs, information, and knowledge for robots in the environments in which they operate as common infrastructure technology for developing various robots) is increasing. Therefore, it becomes necessary to develop a standard model of the information-structured environment.

"Environmental Platform" is defined as a standardized environment considering informational and physical structuring. The wall in Fig. 1 indicates the environmental platform.

3 Robot World Simulator: OpenHRP3

The National Institute of Advanced Industrial Science and Technology (AIST) et al. developed Robot World Simulator as a key component of the software platform. The objective of the project is to develop a robot simulator based on the distributed object technology [19, 24]. The name of the simulator is OpenHRP3 (Open architecture Human-centered Robotics Platform 3) [24].

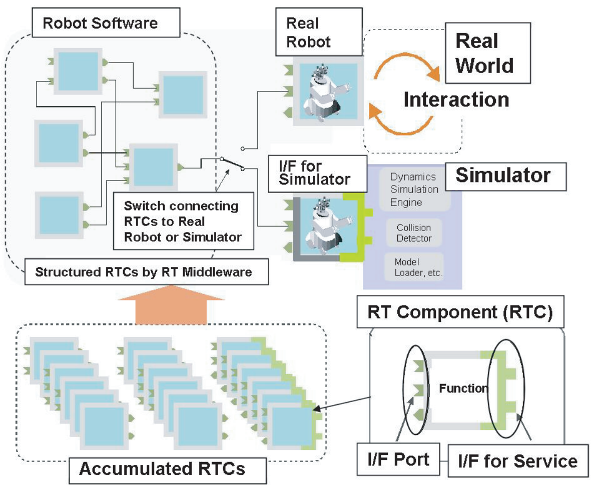

Fig. 3. Concept of Robot Simulator Based on Distributed Components

The distributed object modules are implemented by using RT-Middleware (RTM). RTM is a software framework developed by AIST to establish a common platform based on the distributed object technology. RTM supports the construction of various networked robotic systems by the integration of various network-enabled robotic elements called RT-Components (RTCs) [25]. RTM

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was adopted as a draft version of International Standard by the OMG (Object Management Group) in Oct. 2006. RTM framework guarantees the connectivity of the RTCs. Fig.3 shows the conceptual diagram of the simulator, the real robot and the RTCs. The simulator guarantees the consistency of the software modules by using the developed synchronization mechanism between the RTCs and the virtual environment of the simulator. Fig. 4 shows the user interface of OpenHRP3.

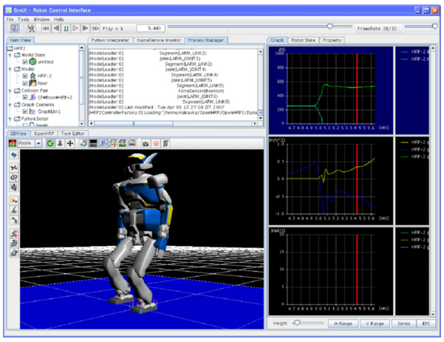


Fig. 4. GUI of OpenHRP3

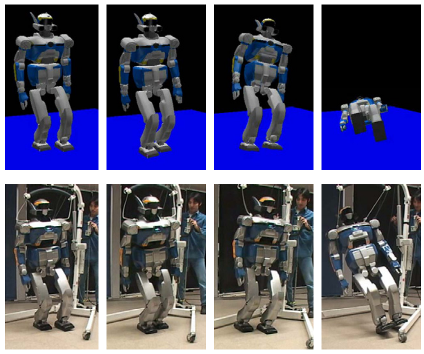
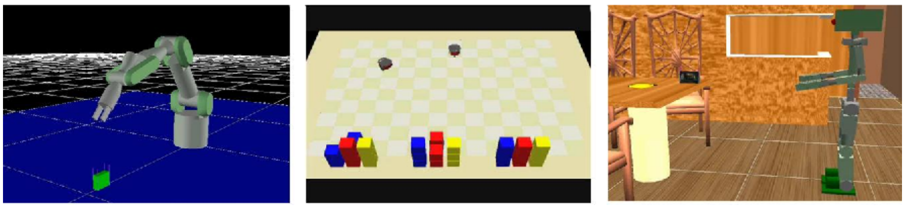


Fig. 5. Simulation Result and Experimental Result



(a) Industrial Robot (b) Multi-transporter Robots (c) Humanoid Robot

Fig. 6. Various Simulation Tasks

Fig. 5 shows the simulation result and the experimental result of the humanoid robot made by OpenHRP3. The tendency of the motion is almost the same. The simulation results were confirmed by a number of experiments using real robots. This is one of the advanced properties of OpenHRP3 as a robot dynamics simulator. Fig. 6 shows an industrial robot, multi-transporter robots, and a humanoid robot as samples of simulations. The simulator is available for unlimited users from June 2008.

4 Environmental Platforms

4.1 Robot Town Platform

Kyushu University et al. developed Robot Town. The objective of the Robot Town Project is to develop a common platform enabling robots to work in the ordinary environments encountered in everyday life. In the platform, sensors

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and RFID tags are embedded and connected with a network to support robotic activities [11, 12, 15]. Fig. 7 is a conceptual diagram of Robot Town.

To achieve autonomous robotic activities in such an environment, distributed sensors such as cameras and laser rangefinders (LRFs), and RFID tags connected with a network are distributed in the environment. Real-time data from the sensors and the robots are integrated by the Town Management System (TMS) together with GIS and other databases as shown in Fig. 8. Robots in the platform can obtain miscellaneous information required for their activities from the TMS. The information includes the positions and the motions of humans, cars, robots and obstacles in the platform. This platform was built in Fukuoka Island City and opened to robot researchers and developers in 2008.

Fig. 9 shows the experimental house and its surroundings. A number of open experiments have been conducted since January 2007. In the experiment in January 2008, when the wheelchair robot was called at the experimental bus stop, the robot went automatically to the person demanding the robot, using camera images from a distributed vision system and RFID tags on the road as shown in Fig.10.

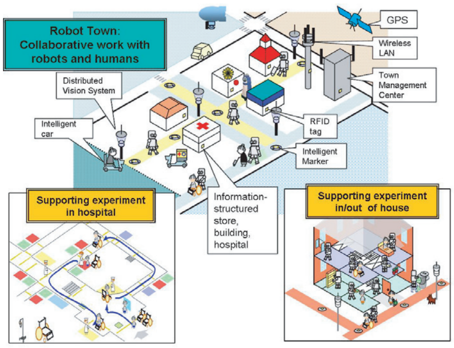

Fig. 7. Concept of Robot Town

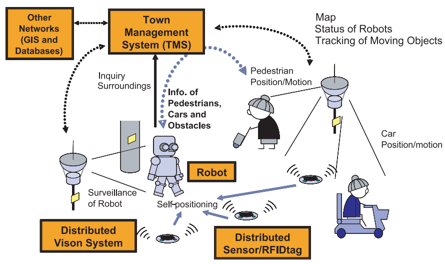

Fig. 8. Information Structuralization of Robot Town

Fig. 9. Experimental House and Its Surroundings

Fig. 10. Wheelchair Robot and Experimental Bus Stop

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4.2 Environmental Platform for Human Behavior Measurement

Advanced Telecommunications Research Institute International (ATR) developed an environmental platform providing human behavior information for various robot services. Structuralizing environmental information based on precise positions of humans who move in and out of buildings is one of the most important issues concerning realization of robots capable of providing various services [14, 22, 10].

For acquiring such information, the framework consists of three fundamental technologies: (a) Real-time robust measuring and recording of humans' positions, (b) Structuring environmental information based on the relationship between obtaining spatial information and the history of humans' positions, and (c) Constructing a common platform to provide the structured environmental information. The robotic service applications utilize the structured environmental information as shown in Fig.11.

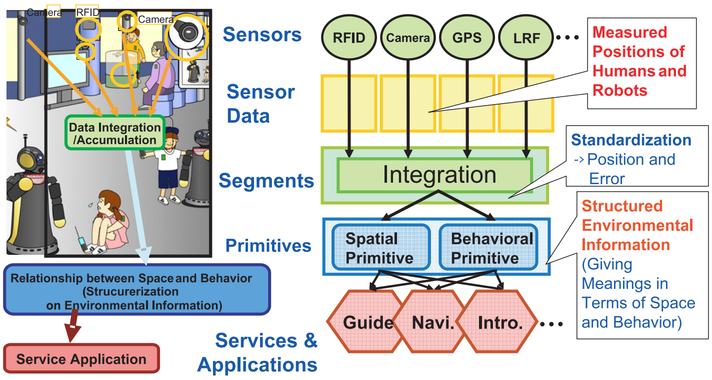

Fig. 11. Concept of 4-Layer Information Processing Model

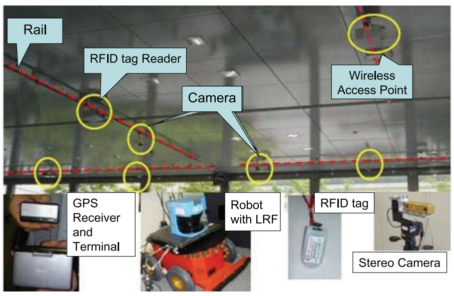

Fig. 12. Keihanna Environmental Platform

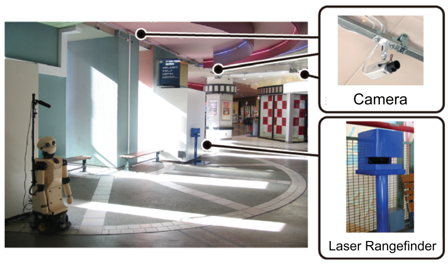

Fig. 13. UCW Environmental Platform

The information processing of the environmental platform is based on the four-layer model, consisting of sensor, segment, primitive and service-and-application

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layers, to give the meanings in terms of space and behavior for the robot services such as guidance, navigation and introduction.

These prototypes of the environmental platforms were built in Kansai. One is located at the lobby of the NICT (National Institute of Information and Communications Technology) Keihanna Building and another is at UCW (Universal City Walk, Osaka). The former is named the Keihanna platform. Fig. 12 shows the equipment of the platform. The latter is named the UCW platform. Since the UCW is located at the front of Universal Studios Japan (USJ), many people walk through there. Fig. 13 shows the equipment of the platform.

(a) Communication Robot Talking to a Person

(b) Display of Real-time Positions of Humans and Robots

Fig. 14. Experiment at UCW Environmental Platform

The sensing system composed of several cameras and LRFs was set around the open space, and more than ten people were detected simultaneously by the sensing system and their behavior was labeled as shown in the display. In an experiment in January 2008, the shop guidance by the robot was carried out at UCW as shown in Fig.14.

4.3 Universal Design of Environment and Task for Robots

AIST et al. researched and developed "Universal Design of Environment and Task" for robots. The goal of this project is to establish a common platform for robot infrastructure, i.e. universal design for next-generation robots, enabling various tasks in different environments by different robots [21, 13, 30]. Fig. 15 is a conceptual diagram of the universal design. To construct the robot platform, an environmental and robot manipulation framework is to be developed. The framework will be considered in terms of its physical level and informational level. The prototype of the platform is built at AIST, Tsukuba. The other platform is to be built in Kanagawa.

The prototype platform is equipped with RFID tags, cameras and laser rangefinders. Furthermore, Pseudolite ('pseudo' means 'imitated' and 'lite' means 'satellite'), i.e. indoor GPS, Starlite, i.e. infrared LED transmitter, and other sensors are integrated into the platform [21, 13, 30]. The interface of each sensor is standardized by RT (Robot Technology) middleware that has been proposed as a standard middleware for robotic technologies. The fine structure of a sensor is

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held as a profile. Each robot in the platform can obtain its position information in the same manner. It should be noted that the project is related to the standardization of the robotic localization service [23]. For robotic tasks, distributed RFID tags, which have links to the knowledge database for robotic tasks, and visual markers indicating the knowledge are developed.

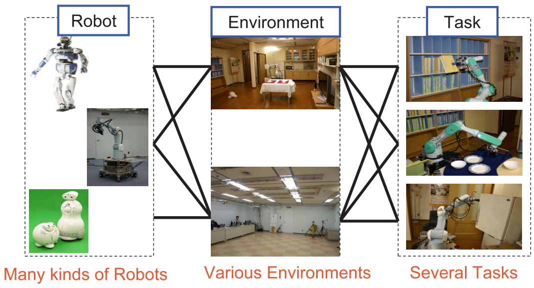

Fig. 15. Concept of Universal Design for Robots

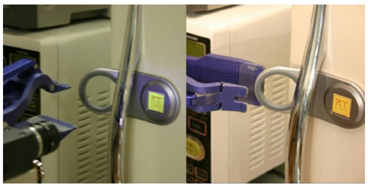

Fig. 16. CLUE on Universal Handle

Fig. 17. Some Experimental Tasks

Table.1 Specifications of Environmental Platforms

PJ	Robot Town by Kyushu University	Human behavior measurement by ATR	Universal design by AIST
Measurement accuracy	50 mm	50 mm	50 mm 5 mm (for manipulation)
Embedded devices	RFID Cameras LRF GPS	RFID Cameras LRF GPS	RFID Cameras iGPS (pseudolite) LRF
Middleware	RT-middleware	Cross ML	RT-middleware
Provided function	- Position; robot, moving object -ID information - API	- Position; robot, humans - API	- Position; robot, objects - API including RT-components
Demonstration	Convey baggage & clothes, Guidance	Human support, e.g., Guidance	Clear the table & return books to the shelf
Open site	Experimental house and roads in Fukuoka Island City	NICT lobby and UCW in Kansai	Experimental house in Kanagawa ROBOT park

To perform manipulation tasks, fine positioning within 5 mm and knowledge of the object to be handled are necessary. So, sensing strategy is changed depending on the distance and the knowledge is obtained through RFID tags and visual markers. A matrix code, also known as a 2D barcode, is utilized as the marker. The position and orientation of the matrix code is utilized for the visual servo of the robotic arm as shown in Fig. 16. The marker is named Coded Landmark for Ubiquitous Environment (CLUE). Since the matrix code of the CLUE is invisible under ordinary lighting, the CLUE has no effect on the design

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of the object, to which the CLUE is attached. The code emerges in ultraviolet lighting as shown in the right-hand image of Fig. 16. As a physical interface, the universal handle shown in Fig. 16 is developed so that a robot is able to handle miscellaneous doors easily. Furthermore, structuring of typical robotic tasks is conducted based on the pick-and-place task since most robotic tasks are divided into the pick-and-place tasks. The experiment was carried out in October 2007. The demonstration task was carried out in which the robot opens the door of the refrigerator, picks up the package and places it in the electric range, and finally places the package on the table. Fig. 17 shows some scenes of the robotic experiments.

As indicated above, these trials provide robot developers with a tool set which not only provides software usable solely for robot development, but also includes the environment in which a robot works. Table 1 shows the specification of the three environmental platforms.

5 Conclusions

In this paper, the concept of the Common Platform Technology for Next-generation Robots and the software platform and the environmental platforms developed in the CSTP coordination program of science and technology projects were introduced. Two projects, the Robot Town Project and the Robot World Simulator Project, were completed by the end of March 2008 and some projects will be utilized in the new robotic project on robot intelligence of the Ministry of Economy, Trade and Industry (METI). The standardization of the environmental platform, such as robot localization, has been started. We hope that robotics research will be accelerated by means of these core platforms.

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