Internet Based Crossover Robot Remote Control Competition in Asian Countries

-Development of practice based innovative education methodology-

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***Abstract*—Over the past decade, the internet has become more and more popular in human society which brings significant convenient to researchers and engineers in the joint development of highly complicated products such as robotic/mechatronic systems. Simultaneously, more and more opportunities are being given to students to attend robot competitions in universities. However, it is still very difficult for the students to collaborate with each other via the internet although the communication has become so advanced. This paper introduced an internet based crossover robot remote control competition project. We established a general platform for students to jointly develop robotic/mechatronic systems and hold competitions with the counterparts at oversea universities. The hardware and software of the systems are developed at two universities respectively during which the students of both universities negotiate with each other via the internet to exchange the design idea, unify the hardware/software interface, etc. The competition is implemented between the two systems whose hardware and software are cross-developed at the two universities. The demonstration of the preliminary competition between UEC and KMITL proves this project has unique benefits to students, such as the training of the internet based robot control technologies, the communication skills for collaboration with foreign member, and so on.**

***Keywords*—crossover, innovative education, internet-based robotics, remote control, robot competition**

I. Introduction

Over the past decade, network technologies have made rapid progress in which the internet has brought great impacts on every aspects of human society. Through the internet, human beings can order commodities, read online newspapers, manage personal financial accounts, etc, which brings significant convenience to their daily life. On the other side, multinational companies use the internet to connect and organize their numerous subsidiary companies in different sites into one strong and high efficiency system. The engineers and researchers working in these subsidiary companies can collaborate to design and develop the same product via the internet. All these revolutionary achievements rely on the internet and the people who hold the ability of using the internet.

To accommodate to the challenge resulting from the internet, many countries have drawn ambitious plans to develop internet based technologies, and promote their application in society to improve the living level of their national and the competitive strength of their corporations. Hence, university graduates with broad and firm internet application ability are welcomed very much and universities have devoted much resource to the internet based practical education program. Additionally, in Asia, manufacture factories, research and development (R&D) centers, and headquarters are distributed over different countries in the trend of global production. The internet is important to connect with each other among these elements.

On the other side, robotics and mechatronics are becoming two of the most attractive research fields. Many students, especially in Japan, have taken them as their major courses. Because robotics and mechatronics integrate the knowledge of mechanical engineering, electronic and electric engineering, automation, etc., multinational corporations have paid more attention on them and regarded them as their core technologies to develop. Which leads to the need for the project based style of practical training in the university education.

Due to the above-mentioned reasons, a trend, which combines the internet and robotics-mechatronics (RoboMech), has emerged. The earliest work which leads to today's internet based remote robot began with the development of a remotely controlled mechanical mechanism at Argonne and Oak Ridge National Laboratories for handing radioactive material. To the best of our knowledge, K. Goldberg *et al*. first developed an internet-based teleoperation system in their Mercury Project in 1994, which could be accessed through the WWW browser [1]. Lakehead University developed an internet-based teleoperation system for a robot manipulator-Thermo CRS A465, which applies the 3D virtual environment techniques to the control of the robotic manipulator remotely [2]. K. Goldberg *et al.* also proposed a Multi Operator Single Robot (MOSR) teleoperation system: Tele-Actor for distance learning that allows many students to simultaneously share control of a single mobile robot [3]. At Nankai University, a teleoperation/telegame robot platform (TTRP) has been built and a series of strong-interactive experiments have been conducted [4-5]. W. Chen *et al*. proposed an internet based robot soccer teleoperation

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system [6]. The Chinese Academy of Science (CAS) developed an internet based omni-directional mobile robots with a 5DOF manipulator [7]. The Chinese University of Hong Kong (CUHK) developed an internet based robot soccer system including two types of robots: IRIS1 and IRS2 [8]. Their system has a real time simulated screen as operation interface and a GUI programming interface which are very convenient for those students with limited knowledge on robotics. The Advanced Robotics and Teleoperation (ART) Lab at University of Alberta proposed an internet based tele-robot system [9]. The Advanced Robotics and Intelligent Systems (ARIS) Lab at University of Guelph also proposed an internet based wireless mobile robot (WiRobot) [10].

Except the educational and competitive systems, many scholars also investigated the internet based robotics from the point of view of academic concern, especially the technical problems resulting from the unpredictability of the internet communication, such as the random time delay, packet loss, and signal dropout, etc. The attempts to overcome the random time delay can be grouped into four general approaches: predictive control [11], bilateral control [12], teleprogramming [13], and event based scheme [14]. Combing event based planning with other control algorithms, many control approaches have been developed, such as [15-19]. In [20-21], the authors considered to use network quality of service (QoS) management to improve the efficiency of the teleoperation systems in the planning and control aspects. Kwee-Bo Sim *et al*. developed an optimal two-layer fuzzy controller and a color detection system to deal with the data transmission latency or data loss [22]. A. Goradia *et al.* discussed the applications, impacts and challenges and future directions of internet based robotics in detail and divided it into three types: teleprogrammed, telesimulated, and teleoperated [23].

Different from the aforementioned, our goal is to develop a practice based innovative education methodology and to bring up the next generation talents with the skill of project management, international communication, and global teamwork. Hence our project is not only a simple robot competition project but also requires students to fabricate the robot and make the competition rules, etc. by themselves and through cooperation with oversea teams. For the reason, the University of Electro-Communications (UEC) began to carry out the "Good Practice University Education Program" sponsored by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) about ten years ago, and started the project "Internet Based Crossover RoboMech Remote Control Competition and International Student Collaboration Training between UEC and α" three years ago, where α means an Asian university outside Japan.

In order to develop the first prototype of the competition platform for the project and get the first hands-on experience, and considering many Japanese companies have set up local divisions in China and Thailand to develop and manufacture productions for the global market, UEC has begun to cooperate with the University of Electric Science and Technology of China (UESTC) and the King Mongkut's Institute of Technology Ladkrabang (KMITL) in Thailand to push on this project. Thanks to the efforts of UEC, UESTC, and KMITL's students, the platform has been established in all the three universities respectively and a preliminary competition has been successfully implemented between UEC and KMITL.

This paper introduced this project and the rest part is organized as follows: The project overview is introduced in section II at first. Then the detailed competition platform including the hardware and software is discussed in section III. Section IV gives a successful demonstration of our developed platform. Summary is given in the final section.

II. Project Overview

This project named "I Internet Based Crossover RoboMech Remote Control Competition and International Student Collaboration Training between UEC and α" is a cooperation project between UEC and α, where, α means an Asian university outside Japan. The basic architecture of the project can be described by Fig. 1.

A. *Platform Overview*

According to Fig. 1, the physical robot remote control competition system provided by respective university consists of a host control computer, a LAN I/O control unit over TCP/IP and UDP protocol, a couple of wireless signal transmitter/receiver, a network camera, a robot, and a competition filed. The network camera on top of the competition field captures the real time dynamic competition scene and transfers it to the host computer at the partner university via the internet. The operator at the partner university then send control commands to the LAN I/O control unit via the internet according to his judgment based on the received competition scene and the competition rules. Consequently, the LAN I/O control unit forwards the control commands to the robot through the wireless signal transmitter/receiver to guide it to push colored cubes/balls to the specified target zones.

B. *Competition Equipment*

The basic competition equipments are described as follows:

1. Competition field: A2 sheet size platform as shown in Fig. 2.
2. Robot: The robot is equipped with the self-contained actuator, the rechargeable Lithium battery, the MCU and communication unit, etc. Its size is limited within a cube with 7 cm side length.

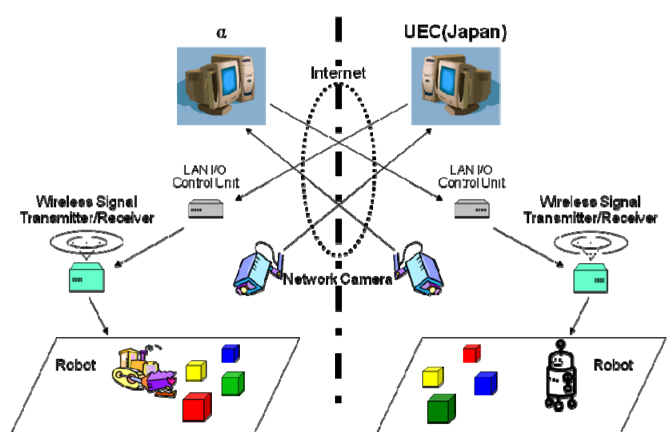


Fig. 1 Basic architecture of the competition platform

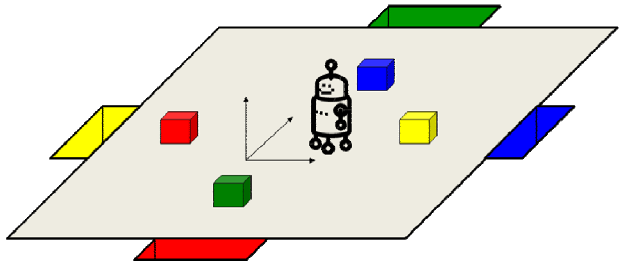


Fig. 2 Competition field

3. Target: 4 colored acrylic cubes with 1 inch side length or balls with 1 inch diameter (red, green, yellow, and blue).
4. Target zone: 4 colored target zone attached on each side of the competition filed as shown in Fig. 2.

C. *Crossover Team Organization*

As shown in the platform architecture (Fig.1), two groups should be organized in each university as shown in Fig. 3. One is IT group responsible for developing the software to control the robot at the partner university and the other is mechatronics group which is in charge of making the robot that can move to do the specified task. The general scopes are summarized as follows:

1. There are two groups (IT group and mechatronics group) to be assigned at both UEC (Japan) and α.
2. At UEC, mechatronics group is responsible for building the robotic/mechatronic system to be controlled by the partner university's IT group. IT group is responsible for developing software to control the robotic/mechatronic system built by the partner university's mechatronics group.
3. At the partner university, similar to the above-just switch the roles. The IT group is in charge of developing control software for the robotic/mechatronic system built at UEC and the mechatronics group takes charge of building the robotic/mechatronic system controlled by the software developed at UEC.

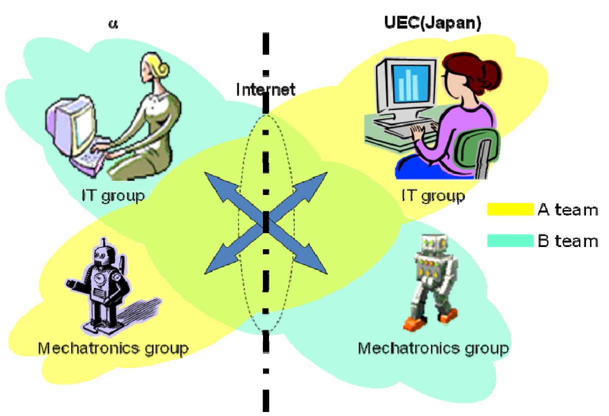


Fig. 3 Crossover team organization

4. The UEC's IT group and the partner university's mechatronics group are organized as one team; the UEC's mechatronics group and the partner university's IT group are organized as the other team. Two university's students belonging to the same team discuss technical issues, competition rules, etc. via the instant message (IM) tools or voice communication tools with real time video, such as SKYPE, MSN. Here the communication language is English! No Japanese or other country's native language.

D. *Competition Rule*

The competition task is pushing all four targets into the corresponding target zones (Fig. 2) with the same color in one hour. On the competition field, the network camera monitors overall the field and transfers the real time video scene to the host control computer at the partner university. The IT group in the partner university checks the position of both the robot and the targets, and then guides the robot close to the targets and to push them into the target zones as soon as possible. The total consumed time (second) is recorded and the score (one second=one point) is calculated according to the following equation:

$$Score = T1 + 3600 * N/M \quad (1)$$

Where,

1. T1 is the total consumed time, regardless of whether the target's color and the target zone's color are matching. If the task isn't finished in one hour, T1 will be 3600 (3600 seconds).
2. N is the sum of the number of the targets not pushed into the target zones and the number of the targets pushed into the target zones with different color in one hour.
3. M is the number of total targets, here M is 4.
4. Because all targets must be pushed into the target zones in 3600 seconds (one hour), we adopt a penalty function (3600*N/M) to punish the team pushing the target into a wrong target zone, or not finishing the task in one hour. Here, 3600/M is the average biggest acceptable time consumption of pushing one target into one target zone.

The team getting smaller score is the winner. Such competition will be held 5 rounds and the team winning 3 times will be the overall champion.

III. Crossover Remote Control Competition Platform

With the support by MEXT of Japan and UEC, some prototypes of the robot remote control competition platform have been successfully established, including both the robot body and the control software. The public internet based VPN communication system has also been set up between UEC and some Asian universities outside Japan.

All of the key modules of the platform are introduced in the following.

A. Hardware Architecture

This robot body consists of the following main parts:

- Drive unit
- Manipulator unit
- MCU board
- Wireless transmitter/receiver (T/R) unit

Where, the basic drive unit (Fig. 4) is a tracked mechanism powered by two small DC motors which are controlled by two TA7267BP chips; the basic manipulator part (Fig. 4) is made up of two arms and is driven by a motor to pick up/push the targets; herein both the drive unit and the manipulator unit can be assembled into different forms; the MCU board (Fig. 5) mainly consists of a TOSHIBA H8-3694 micro controller to realize all the required control functions; and the wireless T/R unit (Fig. 6) consists of a A01Drx receiving chip, a A01Dtx transmitting chip, and a LM324 comparator.

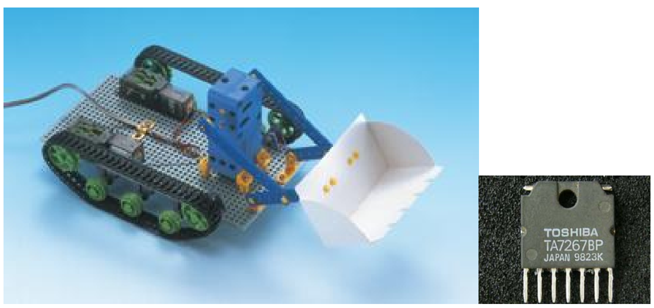


Fig. 4 Drive/manipulator unit and motor control chip

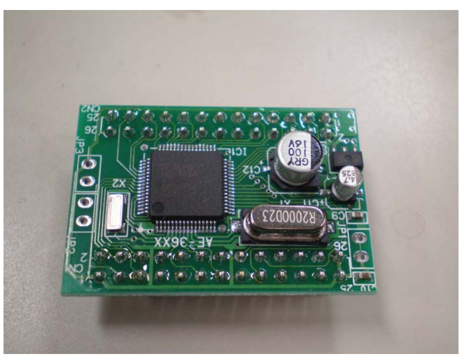


Fig. 5 MCU board

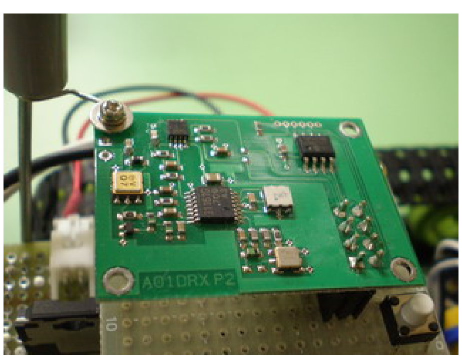


Fig. 6 Wireless T/R unit

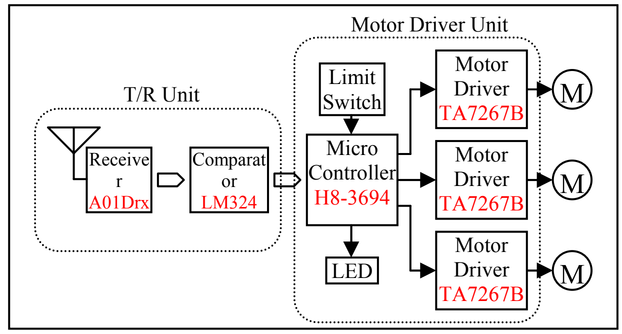


Fig. 7 Hardware block diagram

The whole hardware block diagram of the robot body is shown in Fig. 7. Besides the main parts, there are also some LEDs to indicate the received command and the robot's current action.

B. Software Architecture

The control software can be divided into two parts: one is the real time embedded software responsible for directly controlling the robot hardware; and the other part is the client program installed on the host computer to provide human-robot operation interface. The embedded software works following the process shown in Fig. 8. Currently, the robot actions include "forward," "backward," "turn left," "turn right," "stop," etc, and can be further extended. The human-robot operation interface of the client program is shown in Fig. 9.

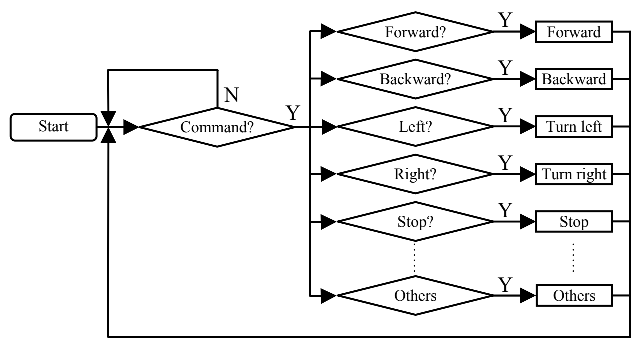


Fig. 8 Program flowchart

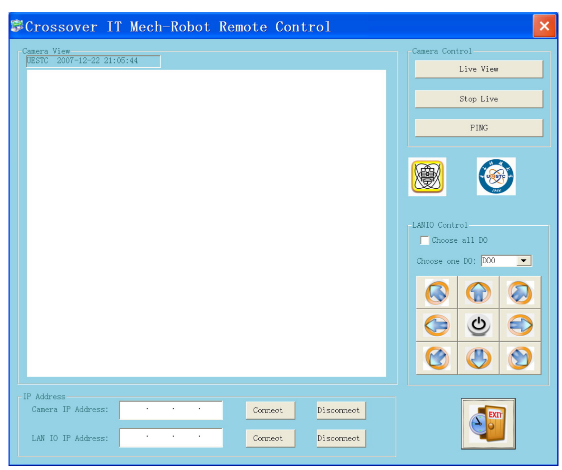


Fig. 9 Human-robot interface

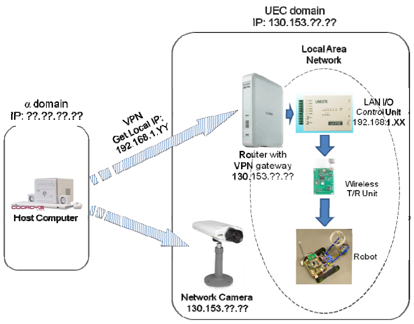


Fig. 10 Network architecture

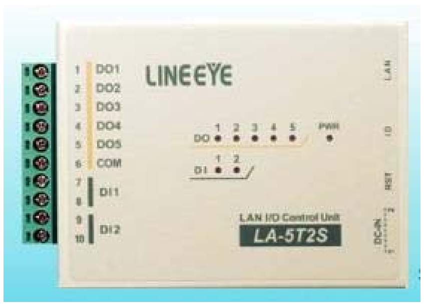


Fig. 11 LAN I/O control unit

TABLE I. COMMAND LIST

Robot Action	**Output of the LAN I/O Control Unit**				
	DO1	DO2	DO3	DO4	DO5
Forward	1	0	0	0	0
Backword	0	1	0	0	0
Turn Left	0	0	1	0	0
Turn Right	0	0	0	1	0
Stop	0	0	0	0	0

C. *Internet Communication System*

The architecture of the internet communication system is shown in Fig. 10. It contains three parts: the public internet, the Virtual Private Network (VPN) router, and the LAN I/O control unit (Fig. 11).

There are 5 output ports and 2 input ports in the LAN I/O control unit. The relations between the LAN I/O control unit output status and the robot's action are listed in Table 1.

At first, the host computer at the partner university remotely logs in the local area network (LAN) at UEC through the VPN router and becomes a virtual local member of the LAN; then the client program (Fig. 9) establishes connection with the LAN I/O control unit at UEC in the VPN; in the meantime, the network camera is accessed by the client program or the web browser through its global IP address to monitor the competition filed; finally the operator at the partner university can control the robot at UEC; vice verse.

IV. DEMONSTRATION

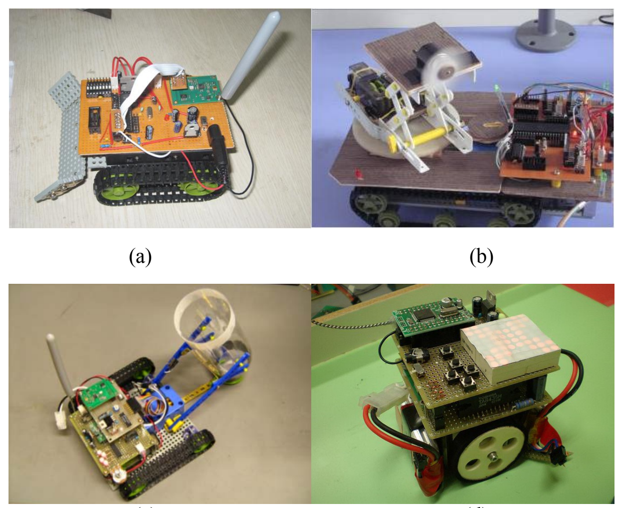
Based on the proposed infrastructure, we have successfully developed some internet robots and established some robot remote control competition platforms with some Asian universities, such as UESTC, KMITL, etc. This project has attracted many students and scholars; even Royal Highness Princess Maha Chakri Sirindhorn of Thailand has shown her interests in this project.

A. *Developed Robots*

Some robots have been developed through international collaboration between UEC and partner university's students. UESTC and UEC's students worked together and developed a robotic "bulldozer" (Fig. 12 (a)) and an advanced "fire fighting" robot (Fig. 12 (b)). KMITL and UEC's students cooperated and developed a robotic "carrier" (Fig. 12 (c)). A wheeled robot has also been developed (Fig. 12 (d)). Now, some more advanced robots are being in development.

B. *Competition between UEC and KMITL*

Based on the developed platform, preliminary robot remote control competition has been successfully carried out between UEC and KMITL. Fig. 13 shows the continuous robot actions of picking up a ball and putting it into a box remotely controlled by KMITL's students through the internet. This competition proved the success of the project.



(a) (b) (c) (d)

Fig. 12 Robots developed by students: (a) robotic bulldozer, (b) fire fighting robot, (c) robotic carrier, (d) wheeled robot

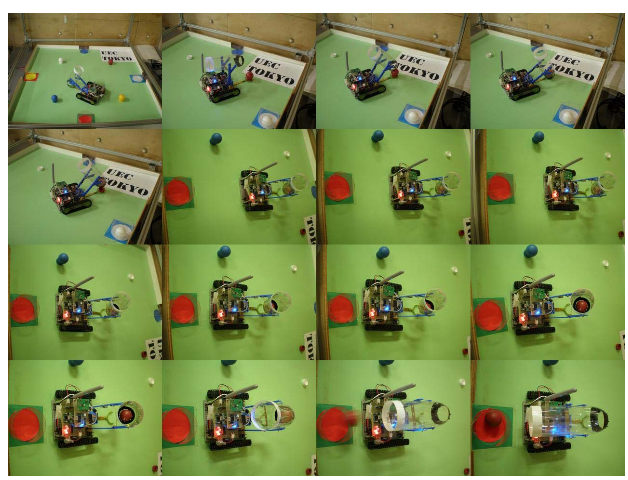


Fig. 13 Robot action controlled by KMITL's students

V. SUMMARY

In this paper, an international collaboration education project for training next-generation talents, "Internet Based Crossover RoboMech Remote Control Competition and International Student Collaboration Training between UEC and α" is introduced. To improve students' practical skills and communications skills in English, some internet robots have been jointly developed by the students of UEC and some partner universities in Asia countries outside Japan through collaboration. In addition, the client control software and the embedded control software of the robots have also been developed to realize the specified competition task. Based on the robots and control software, a general internet based robot remote control competition platform has been established and its practicability has been proved by the actual competition between UEC and KMITL.

Based on the current work, we will further push this project. Our next work includes, but not limited, developing more advanced internet robots, exploring new control strategy to deal with time delay in the internet, and developing new English E-learning texts and new education methodology.

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