INTERFACING A ROBOT CONTROL APPLICATION WITH A REMOTE USER*

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Abstract

Mechatronics is an important field of science and technology providing a large spectrum of applications, being also an important educational discipline for engineers. Engineering education has special requirements, and the development of remote laboratories will be efficient not only considering costs of educational resources, but also offering simultaneously access to advanced technology.

This paper describes recent developments in web-based tele-operation of robots. Different architectures offering remote interactivity were identified and a comparison is presented. Details on interfacing a Mitsubishi industrial robot with a remote user are presented in the framework of remote collaborative research and distance education in robotics.

Key-words: *remote robotics, client-server, remote laboratories, engineering distance education, Mitsubishi industrial robot control and programming.*

Computing Reviews classification: I.2.9, C.2.4, C.2.5, H.5.2, I.3.7

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* A preliminary version of this paper was presented at the Conference on *Applied Mathematics and Informatics*, 14 December 2007, Faculty of Mathematics and Informatics, *Spiru Haret* University, Bucharest, Romania

** During the study on virtual environments based on mechatronics tools, the author was supported by the UNESCO Chair in Information Technologies at the University of Oradea. When the paper was extended for publication in this journal, the author was affiliated to *Spiru Haret* University, Bucharest, Romania.

*** The investigation on e-laboratories for distance education was realized during the author's PhD program, and the results will be part of the PhD Thesis.

1. **Introduction**

Both devices teleoperation and distance education for remote students are hot topics nowadays due to the progress of technologies and knowledge. Engineering education has special requirements, and the development of remote laboratories will be efficient not only considering costs of educational resources, but also offering simultaneously access to advanced technology.

Mechatronics is an important field of science and technology providing a large spectrum of applications, being also an important educational discipline for engineers. For a computer scientist, the mechatronics field imposes challenging tasks in software modeling and programming techniques.

Based on recently developments in Information and Communication Technologies (ICT field), research organizations, universities and industrial sectors had reported advances in mechatronics and its applications. The list of included references represents only a selection of recent references used for this study. Fundamentals topics in robotics and mechatronics are covered by Bishop [3], Edwards [6], Pires [20], and Selig [25], to mention only a few monographers.

The networking technologies made possible the Internet integration into industrial, educational, and home applications. Robotics, telematics (telecommunications + informatics), virtual reality, and web – interfacing gave life to new approaches in real-time remote robotics and telexistence, as shown in [19].

According to the mentioned references, some early systems like Mercury project (1994), Australia's Tele-robot on the web (1995), Tele-Garden project (1995), Puma Paint project (1997), Digimuse (1998), and many others, using TCP/IP, web technologies and Java or other client-server gateway interfacing methodologies, were developed, not only for experimental point of view, but also for real life applications.

The most challenging applications deal with operation into hostile environments like mining, nuclear waste disposal, and surveillance, according to Vale et. al [29]. Other internet applications of telerobotics are oriented to entertainment, tele-manufacturing, and tele-medicine, as Bambang says in [2].

Our interest is oriented toward research and educational tasks for engineering fields. Some remote laboratories were built for teaching robotics or engineering sciences: Robolab System [14], the control and robotics remote laboratory of the University of Maribor [23], the 4 projects for laboratory based distance learning [26], the R-lab architecture [15], Robot programming language using Codelab [12], the Mentor-MVTSI system [10], etc.

Of course, according to the progress in ICT and software engineering, there are many generations of projects. The recent trend is to consider Java technologies [21, 33], modern modelling paradigms [14, 20, 22, 27, 32], intelligent control [11, 13, 31], and virtual reality advancements, including mobile robots [1, 4, 10, 14, 24, 27].

Considering the experience on developing a wide spectrum of applications, already reported by the Mechatronics team at University of Oradea, the next step is to upgrade the projects to support distance control.

This paper describes recent developments in web-based teleoperation of robots. An overview of such developments will be described in the second section.

Details on interfacing a Mitsubishi industrial robot with a remote user are presented in the framework of remote collaborative research and distance education in robotics, in the third section. The last section will provide concluding remarks and future research themes.

2. **Recent advances in telerobotics**

The mechatronics is “a vibrant area of study”, “a youthful subject” even the term was coined in 1970s, as Bishop [3] remarks. As an evolutionary process, the mechatronics refers to “the synergetic integration of mechanical, electrical, and computer system” [3].

When developing real-life software applications, the scientists have to manage topics like physical systems modeling, sensor and actuators, signals and systems, computers and logic systems, and software and data acquisition. Any complex software system for mechatronics applications integrates knowledge about these topics, algorithms, software design techniques, human-computer interface design, and communication protocols.

A particular mechatronic system is the robot. In most cases the robotics systems are composed by a sensing unit, a controller and an actuating unit. The controller uses the information coming from sensors, uses one or more control algorithms (in mono or multitasking manner), and sends commands to actuators.

In order to support robot modeling and visualization, computer graphics fundamentals, and geometric modelling methods have to be considered when someone design interfaces for remote controlling of robots using web environment and support virtual environments [19, 25, 27].

Also, image acquisition, processing and understanding are required for applications supporting robots vision [1, 5, 22, 32], and speech synthesis and recognition for human language interfacing [21].

In the following, the most important architectures, technologies and tools for controlling robots will be described.

One can identify four generations of telerobotics systems based on ICT advancements. The first generation has the following characteristics [2]: the communication is based on HTTP service on port 80, three subsystems will interact in some way: the robot, the robot server PC (supporting robot actuating and feedback, Common Gateway Interface (CGI), HTTP server), and the remote client terminal. Single video cam is supported. The second generation uses the robot server and Web server on the same PC, and support multi-user interaction based on queue data structure. The third generation integrates many video cameras, remote programming, and intelligent control. The fourth generation offers real-time tele-operation as requested by recent virtual reality applications.

The HTTP server will accept HTTP request from one or many users surfing the Web, or interacting with a mechatronics laboratory. The content of the page received by the remote user is generated dynamically, and provides an interface to support the interaction with the robot (sending simple commands, uploading programs and activate them).

The robot server receives commands/programs from the user, analyses them and if running such command/program keep the robot safe, the command/program is accepted, otherwise is rejected. The robot server is not only a lexical/syntax analyzer, but it is a virtual interpreter of the robot command/program. Only valid commands/programs are sent to the robot.

Real-time remote robotics, asks for fast reaction, and the Internet has limitations. According to Tachi [27], virtual reality interfaces (HMD, CAVE) and new languages and protocols (like RCML/RCTP) are required to support data interchange over network and geometric visualization. RCML is an extension of VRML and describes information about robot and its environment (geometry of the robot and its configuration, the sensory information, and the remote environment geometry and its specifications).

3. The RV-2AJ teleoperation

The Mitsubishi RV-2AJ robots are 5/6 axis robot arms featuring 64-bit RISC/DSP controller technology, and load capacities of 1.5 and 2.0 kg respectively. The robot system is composed by the Mitsubishi RV-2AJ robot arm, the robot controller, a TeachBox and the PC as robot server.

In order to extend already existing robot programs and to develop new software, some alternatives have to be compared. From the programming languages point of view the extension can use the following paradigms: structured programming, specialized packages, object oriented programming, web programming, and artificial intelligence methodologies. Not only the programming language is important, but also the development methodology and the user interface design.

In order to develop a fourth generation telerobotic system a Java3D approach is useful. Not only Java offers an object oriented environment, but the Java3D offers a high-level application programming interface (API) for 3D scene description and graphical control based on VRML/X3D technologies. Offering multi-threading programming, a powerful model for event processing, Java3D, and the capability of creating complex interfaces, Java3D meet all requirements to be selected for developing an Internet-based teleoperation environment for the Mitsubishi RV-2AJ robot. Java3D applets can be integrated in web pages in order to create teaching material for remote learners.

Our project uses HTML/Java3D approach for the content of web-pages, and PHP/MySQL for managing the user access (password authentication) to the remote laboratory. A multicast protocol (like IGMP/PIM) is used to manage delivery of multicast streams to the groups of recipients on a LAN, in order to support remote classrooms in mechatronics teaching. The client interface offers information about the robot sensors, support for sending commands (a text window, and specialized buttons), and starting already existing programs, and a window receiving images of robot while executing the commands.

4. Summary and further research

The Mitsubishi RV-2AJ robot is an industrial one, being designed as a flexible and adaptable system to many tasks in manufacturing industry, research laboratories, and medical facilities.

The increasing interest in distance education for engineering sciences motivates us to consider interfacing the mechatronics laboratory to remote users.

The next step is to develop a strategy for collaborative laboratories, and to use collaborative research in Internet telerobotic systems.

REFERENCES

1. Agis, R., Carillo, R., Moran, V., Gonzalez, A., Morillas, C., Pelayo, F., and Bernier, J.L, *Monitoring a Mobile Robot Using a Web Interface*, 2005.
2. Bambang, R., *Development of Architectures for Internet Telerobotics Systems,* ICIUS 2007, Bali, Indonesia, 137-142, 2007.
3. Bishop, R.H. (ed), *The Mechatronic Handbook*, CRC Press, 2002.
4. Carusi, F., Casini, M., Prattichizzo, D., and Vicino, A., *Distance Learning in Robotics and Automation by Remote Control of Lego Mobile Robots*, Proceedings of the 2004 IEEE International Conference on Robotics & Automation, New Orleans, 1820-1825, 2004.
5. Duff, E., Usher, K., Taylor, K., and Caris, C., *Web-based Tele-robotics Revisited,* The Australasian Conference on Robotics and Automation, ACRA'07, http://www.araa.asn.au/acra/acra2007/papers/paper53final.pdf, 2007.
6. Edwards L.A.R.W., *Open-source Robotics and Process Control Cookbook,* Elsevier, 2005.
7. Ferworn, A., Lu, W. Coleshill (J)E, and Shiu, W, *WAX – Next Generation Robot on the Web*, International Conference for Upcoming Engineers (I-CUE'02), Ryerson University, Toronto, Canada, 2002.
8. Foit, K., The Web-based Programming Interface for the Mitsubishi Movemaster Robot, JAMME, 27(2), 183-186, 2008.
9. Foit, K., Remote Programming of the Mitsubishi Movemaster Robot by Using the Web-based Interface, JAMME, 31(2): 639-645, 2008.
10. Kaddour-El Boudadi, L., and Berrached, N., *Multiusers Internet Based Teleoperation Station with Augmented Reality,* Acta Electrotechnica et Informatica, 7(2): 1-6, 2007.
11. Khamis, A., Rodriguez, F., and Salichs, M., *Multiact Approach for Building Web-based Education Environments: Mobile Robotics Course as a Case Study*, The 11th Mediterranean Conference on Control and Automation, MED'03, Greece, 2003.
12. Harris, W., and Arnow, D., *Remote Shared Access to a Classroom Robotics Lab,* Robots and Robot Venues: Resources for AI Education, AAAI, 2007.
13. Hazry, D., Sugisaka, M., and Yuji, T., *Human-Robot Interface over the Web-based Intelligent System,* American Journal of Applied Sciences 3(1): 1634-1639, 2006.
14. Herias, Candelas F.A., Bravo, Jara C.A., and Medina, Tores F., *Flexible Virtual and Remote Laboratory for Teaching Robotics,* Current Developments in Technology-Assisted Education, 1959-1963, 2006.
15. Hua, J., and Ganz, A. *Web Enabled Remote Laboratory (R-Lab) Framework*, The 33rd ASEE/IEEE Frontiers in Education Conference, T2C: 8-13, 2003.
16. Marjanovic, T., Zorc, D. and Essret, M., RobotOnLine – Web Robot Control, 13th DAAAM International Symposium, 2002.

17. Mitsubishi Electric, MELFA. Industrial Robots. Instruction Manual, BFP-A5992, 2005.
18. Ngai, L., Newman, W.S., and Liberatore, V., *An Experiment in Internet-based, Human-assisted Robotics*, The IEEE International Conference on Robotics and Automation, ICRA, 2002.
19. Paşc, Ildiko Margit, Ţarcă, R C., Popenţiu-Vlădicescu, F., and Albeanu, G., *On Designing Virtual Environments Based on Intelligent Mechatronic Systems.* In Hoang Pham (ed.), ISSAT International Conference on Modeling of Complex Systems and Environments (July 16-18, 2007; HO CHI MINH CITY, VIETNAM), pp. 126-130. International Society of Science and Applied Technologies, 2007.
20. Pires, J.N., *Industrial Robots Programming: Building Applications for the Factories of the Future,* Springer, 2007.
21. Preston, S., *The Definitive Guide to Build Java Robots,* Apress, 2006.
22. Ritter, G.X., and Wilson, J.N., *Handbook of Computer Vision Algorithms in Image Algebra,* CRC Press, 1996.
23. Safaric, R., Truntic, M., Hercog, D., and Pacnik, G., *Control and Robotics Remote Laboratory for Engineering Education*, iJOE International Journal on Online Engineering – www.i-joe.org, 2005.
24. Schultz, D., Burgard, W., Fox, D. Thrun, S., and Cremers, A.B., *Web Interfaces for Mobile Robots in Public Places,* IEEE Robotics and Automation Magazine, 7(1), 48-56, 2000.
25. Selig, J.M., *Introductory Robotics,* Prentice Hall, 1992.
26. Sobh, T. Mihali, R., Ghimire, B., Vovk, K., Gosine, G., and Batra, P., *Laboratory Based Distance Learning: Case Studies in Web-controled Devices and Remote Manipulation,* in the International Journal of Robotics & Automation, special issue on Web-based Automation, 17(3): 120-127, 2002.
27. Tachi, S., *Real-time Remote Robotics – Toward Networked Telexistence,* IEEE Computer graphics and applications, 6-9, 1998.
28. Thamma, R., Huang, L.H., Lou, S-J., and Diez, C.R., *Controlling Robot Through Internet Using Java,* Journal of industrial technology, 20(3): 1-5, 2004.
29. Vale, A., Inácio, P. Antunes, N., Sequeira, J., Ribeiro M.I., *Robot Concurrent Remote Operation Through Internet*, 4th Portuguese Conference on Automatic Control, Guimarães, Portugal, 447-452, 2000.
30. Wronka C.M., and Dunnigan, M.W., *Internet Remote Control Interface for a Multipurpose Robotic Arm,* International Journal of Advanced Robotic Systems, 3(1), 179-183, 2006.
31. Xia, H., Liu, Y., Song, T., and Tan, B., *Research on the Industrial Robot Control System Based on Ontology and Web Service*, ISKE-2007 Proceedings: Advances in Intelligent Systems Research, doi:10.2991/iske.2007.122, 2007.
32. Zuech, N., *Understanding and Applying Machine Vision*, 2nd ed., Marcel Dekker, Inc., 2000.
33. ***, Developer Resources for Java Technology, http://java.sun.com/