Proceedings of the World Congress on Engineering and Computer Science 2010 Vol I
WCECS 2010, October 20-22, 2010, San Francisco, USA

New Approach of Telerobotic over Internet

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Abstract—**Telerobotics actually result from the merger of two originally separate areas that are teleoperation and robotics. Indeed, autonomous robotics are not yet fully developed, the robot must now be operated remotely by a human operator. We must therefore take into account the principles developed in teleoperation. However, as the robot can perform basic tasks independently, it is called telerobotics rather than teleoperation. Telerobotics has applications wherever man has difficulty working directly (hostile environment, too far or too small places) and the tasks are sufficiently complex or unpredictable to be an obstacle to full automation. The main condition for the development of telerobotics is the ability to compete with the direct intervention of humans or the use of an automated highly specialized. In the first case, the advantage of telerobotics is firstly the replacement of human labor painful or dangerous by another, more secure and more comfortable. In the second case, we must show the interest of a material more versatile than the automatic system dedicated to the proposed application.**

Index Terms—**, Telerobotics, Internet, Multi-agent System.**

I. Introduction

Teleoperation allows to human operators the reduction of risks associated with the work taking place in hostile environments. The first remote systems have been developed for handling radioactive materials, space exploration and underwater. Afterwards, and thanks to advances in technology and integration of advanced functions (including transportation) the scope of teleoperation has spread to several areas for instance: intervention contaminated sites, monitoring, disability support and service.

A teleoperation system can integrate a variety of technology components such as: sophisticated haptic interfaces (exoskeletons), with some robots capacity decision, advanced visualization techniques (virtual reality) and tools (shared control schemes, planning).

All this, and others inherited conditions of the first applications to which they were intended, are the construction of a teleoperation system is costly in resources and development time. For several years, the efforts have been made for teleoperation becomes more accessible. A lot of projects seek to reduce the cost and complexity of developing such systems.

In this chapter, we present the two main trends combining these efforts: teleoperation over the Internet and the definition of generic architectures for teleoperation systems.

Hence the interest to shed light on several parts spreaded in this order:

- Section II: State of the art
- Section III: Proposed Architecture based on Multi-agent system
- Section IV: Implementation of the teleoperation Platform
- Section V: conclusions and perspectives

To summarize, we will deal with a survey of the work done followed by a projection on the future world of teleoperation and MAS

II. State of the art

In many robotic systems operated through the World Wide Web have been developed in recent years. These systems require an infrastructure for easy deployment and are available worldwide. Moreover, since the interface is easy to understand and control, the user does not require training. More importantly, the teleoperation on Internet opens up very significant opportunities for collaboration and sharing of resources between different research teams scattered around the world.

The first device "distributed" on the Internet has been the Cambridge Coffee Pot. This system used a webcam to transmit images of a coffee maker placed in the computer lab at the University of Cambridge [1]. The Mercury project [2] has been put online in August 1994. It allowed users to grab and manipulate various objects using a robotic arm. In September 1994, another RMS has been online this time in the University of Western Australia [3]. In the first version of this system (Figure 1), users had to enter coordinates to specify the spatial movements of the manipulator. Several other interfaces were then used to simplify the robot control [4].

Manuscript received May 30, 2010.

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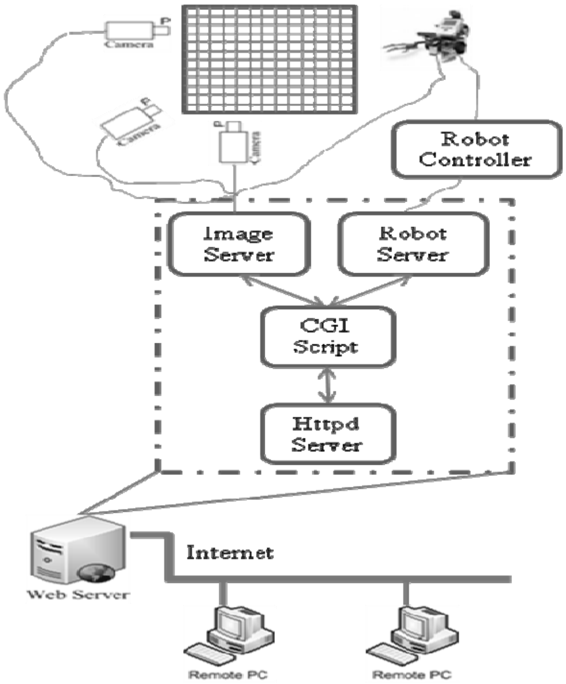

Fig. 1. Control architecture of a robot via the World Wide Web

The idea of making available a device using a web interface has been followed by many projects, including the robotic telescope Cox [5], the mobile robot "FortyTwo" in Manchester [6] DIGIMUSE system designed to visualization Interactive art [7] and the web interface for NASA's Pathfinder mission [8] that allowed researchers to collaborate and work in the mission without moving to the control center in California. Other projects are interested in remote control of mobile robots as systems KhepOnTheWeb [9], the proposed Museum Tour-Guide [10] and the proposed WebPioneer [11]. These systems allow the user to control a robot be in a static environment or in the exploration of dynamic environments.

Most control systems on the Internet were built using static HTML pages and CGI programs (Common Gateway Interface). The HTML page allows the user to know the state of the system and generate orders to execute. Orders are processed then executed by the CGI program that controls the robot, without supervision nor intervention of the user. Finally, when the order is completed or an error has occurred, a new HTML page is generated. The user interaction is limited because it is impossible to retrieve the user instructions and submit the information back together. To resolve this problem, the use of multiple CGI programs associated with different frames of an HTML page has been proposed. However, since a CGI program establishes a new connection each time it is invoked, their proliferation increased the response time of the system. The alternative adopted in the management interface has been the use of Java applets instead of HTML / CGI. With a Java applet, the connection between the Web interface and the robot controller is established once and the data can happen at any time in both directions. The system WebDrive [12] is an example of application of this technology. Being the successor system WebPioneer, WebDrive is designed for teleoperation of mobile robots operating in unknown dynamic environments. The user interface of WebDrive (Figure 2) is a Java applet that receives user commands and displays the sensor information the robot.

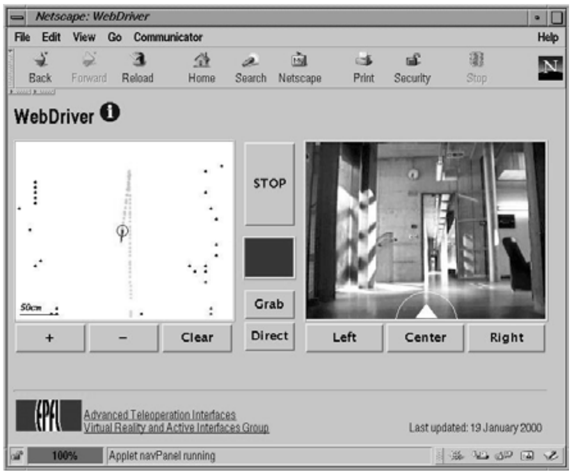

Fig. 2. WinDriver User Interface

Updates the images of the user interface when certain events (such as detection of an obstacle) occur. This pattern reduces the network traffic generated by a video server used for very easy to implement. However, by limiting the information to the work site only to video, the user has a limited perception of the environment. To improve the information back and manage the transmission deadlines, it is possible to achieve a graphical simulation (2D or 3D) of the desired action. The simulation is then overlaid on real images to help the user to perform its task. Another approach is to take into account the time to control the system remotely operated. This requires that a dynamic simulation of a predictor of the current state and future of the remote system. These ideas have been used in the construction of the system described by Leleve [13] for teleoperation of a vehicle with a manipulator. In this system, the association between the block depredation and the dynamic model can perform simulations and pre-show prediction of the state of the remote system before receiving it. The use of a 3D simulation allows control of a robot times when communications are important. Aditya et al. [14] have used Java3D to create and manipulate a robot. The simulation of the robot replaces the real images to reduce communication delays and network traffic. Hirukawa et al. [15] describe web interfaces that allow the operator to manipulate objects using a 3D graphical simulation contained in the browser. These interfaces follow either a tele-programming. Indeed, the tasks are first tested in the simulator and then the sequence of actions to achieve is transmitted to the real robot. In the system described by Finke [16], an autonomous mobile robot is connected to a virtual environment. The user can not only send instructions to the robot but also influence their behavior by placing virtual barriers. The sensor information the robot and the deductions made by the robot are displayed in the virtual environment, this allows the user to validate the decisions taken by the robot.

To facilitate the online devices, Ghias et al [17] proposed a reusable system, designed to allow the handling of devices via the World Wide Web. The system, built with Java and Python, seeks to reduce the number and level of skills required to deploy a remote controlled device. It provides mechanisms for interacting with the device, to build user interfaces and to make extensions and modifications to

ISBN: 978-988-17012-0-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

existing components. Other projects using technologies like Jini distribution allow the sharing and control of objects and devices in a multi-user virtual environment. In the system described by Inostroza [18] API access to scene graph is published as a Jini service, allowing participants to respond and other services (available online) to collaborate in the composition dynamic 3D environment. Other works currently show interest in the use of middleware technologies for the interconnection of various components of a robotic system. CORBA, for example, has been used in building a support system for disabled, the implementation of a distributed laboratory and the development of a mining system and Reconstruction of remote environments. The interconnection of heterogeneous systems can also be facilitated by the adoption of a standard language. This has been suggested by various studies using XML (Extensible Markup Language) for describing services offered by the devices and written instructions [19].

III. Proposed Architecture based on Multi-Agents system

A. *Utilization of MAS in teleoperation.*

The definition of a multi-agent system is more immediate: "a multi-agent system is an organized set of agents. We're just here to follow the usual definition of the term system, "an organized set of elements.

Collectively, we can also consider the idea of multi-agent system as an evolution of the concept of software component (object) for which the coupling between components is discussed in terms of knowledge and not in the types of data.

Many methods of agentification can distinguish three levels of abstraction in a multi-agent system: The level of individual agents, the level of interactions between agents and the level of the organization system and, the system is built from these three levels, in reifying the agents themselves and relying on the concept of role. An agent has three roles: functional, relational, and organizational.

The system distributes these three roles in the activity of agents who hold them by their actions and after negotiations with their connections, and thus define the groups to which agents have complementary roles, well structured and consistent.

B. *Proposed System architecture.*

The figure 3 is a general representation of the functioning of MAS in teleoperation. This diagram identifies all the connections between agents established namely: Bluetooth, Ethernet, Wifi, which aim controlling the robotic platform (NXT Mindstorm).

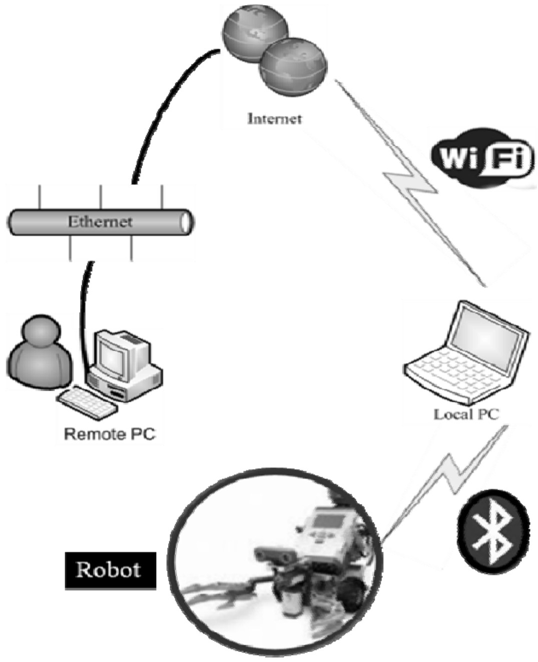

Fig. 3. Proposed system architecture

We use a hybrid control architecture developed in our laboratory (figure 4), which combines aspects of classic control and behavior-based control. This architecture called EAAS for EAS Architecture for Autonomous system [20].

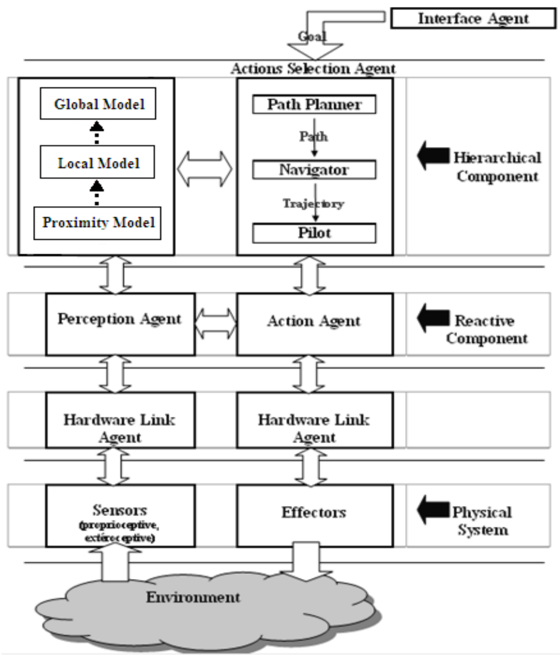

Fig. 4. EAAS Architecture

EAAS architecture consists in five agents: interface agent, actions selection agent, perception agent, action agent and hardware link agent.

This architecture allows to adapt the operation of the robot according to its environment and the organization of hardware and software resources of the robot to assign it intelligence and autonomy

The proposed control architecture affects two major components such as: hardware and software, this is what we will see with more details in the next section.

ISBN: 978-988-17012-0-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. Realization of the Teleoperation Platform

In this section we give an overview on the AUML.

AUML is an extension of UML to reflect the agent concepts. Agent UML inherits representations proposed by UML. It contains ten types of diagrams symbolizing many different views to represent specific concepts of information system.

In what follows we limit ourselves to present three diagrams: class diagram, behavior diagram and sequence diagram.

A. Static Aspect.

The figure 5, below, describes the structure of a system by showing the system's classes, their attributes, and the relationships between the classes

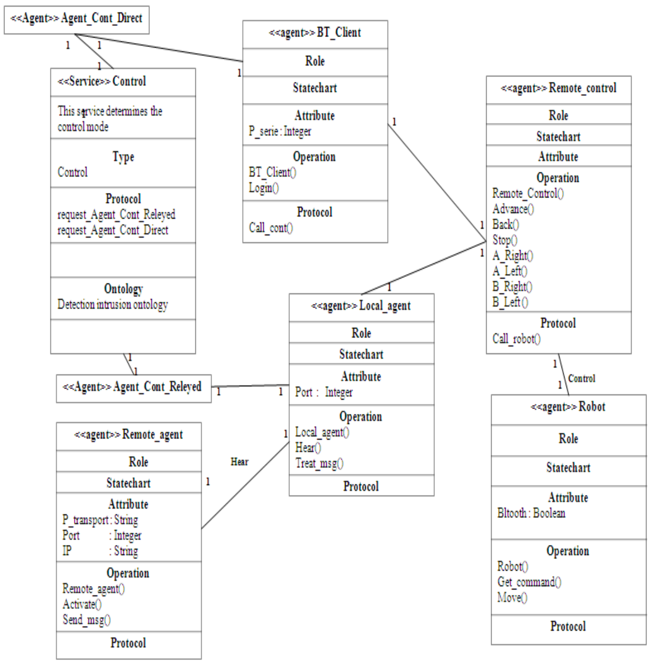

Fig. 5. Agent class diagram

B. Dynamic Aspect

Our system is composed of eight sequence diagrams for each mode; the figure 6 shows the sequence of movement forward and backward in direct mode, the figure 7 shows the sequence of movement forward and backward in the relayed mode.

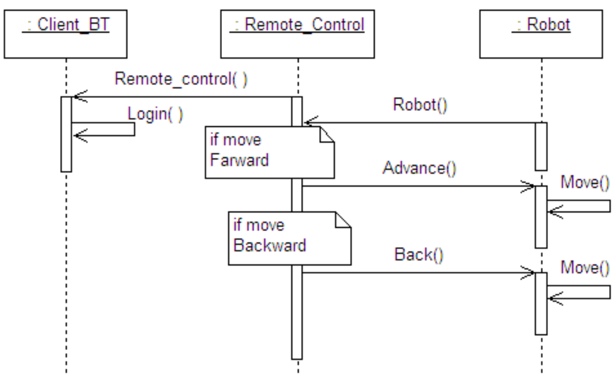

Fig. 6. Sequence diagram of direct mode

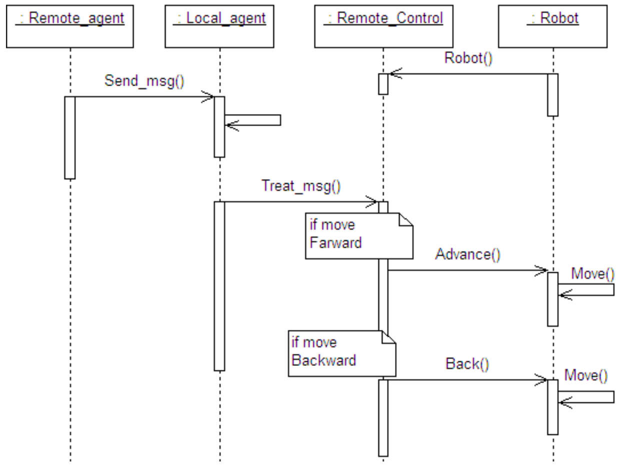

Fig. 7. Sequence diagram of relayed mode

The next diagram shows the functionality provided by the system in terms of actors, goals represented as use cases, and all the dependencies between use cases.

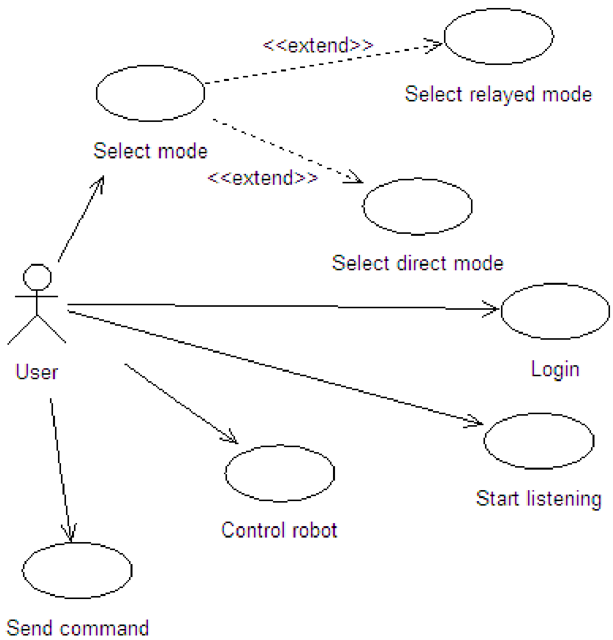

Fig. 8. Use case diagram

C. Software development

In the development of this application it was mandatory to use C#.Net which is intended to be general-purpose, agent oriented programming language.

This language is very used in developing software components Suitable for deployment especially in Distributed environments.

Besides, C# is very suitable to write applications for embedded systems and hosted both, ranging from the very large that use sophisticated operating systems, down to the very small having dedicated functions.

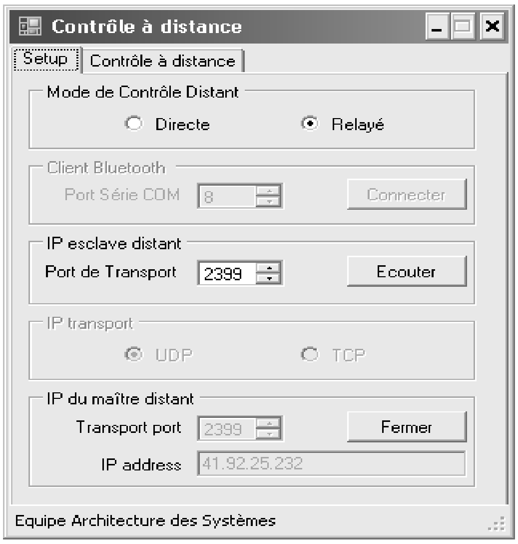

Fig. 9. Connection Interface

The embedded laptop runs a programme (written in C#.NET) able to receive orders from the Internet (e.g. over Wi-Fi) and to forward them to the NXT brick of the robot. The communication between the robot and the laptop is over Bluetooth: the laptop sends orders to the NXT brick that treats them

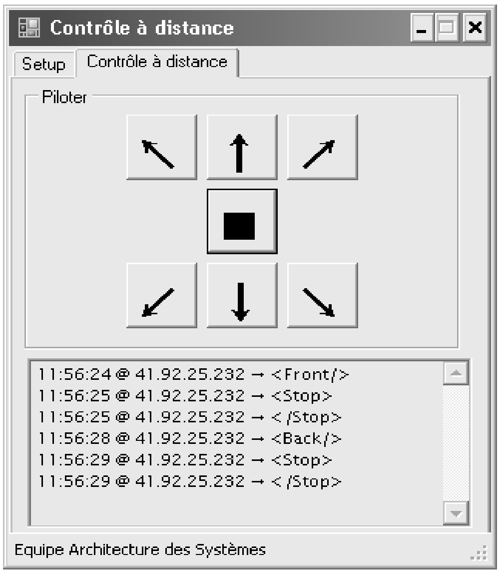

Fig. 10. Control Interface

The desktop computer runs a programme (written in C#.NET) able to send orders over the Internet to the laptop computer embedded on the robot. (It is the same programme as the one on the laptop computer, with different settings.) The sound coming from the embedded microphone and a real-time video from the embedded webcam are available, simply with videoconferencing software.

D. Hardware implementation

Our robotics platform (Lego Mindstorms NXT) is more than a simple toy. It allows the building of robots with advanced behavior, with several motors and various sensors. Nevertheless, embedded processing power, memory, and communication capabilities are far behind what is offered by PDA or laptop. Thus the idea of showing that a Lego Mindstorms NXT robot can carry a laptop computer when necessary, subsequently offering a new range of possibilities. A (old) laptop is indeed a common device and can sometimes be used, at least for prototyping, instead of buying more advance additional devices.
One of the many immediate interests is the possibility to communicate within a long range with Wi-Fi or by mobile telephony (e.g. GPRS, UMTS [3G] or better for videoconference), among other reasons to be remotely controlled and to send a video signal and data from sensors.

V. Conclusion

In this paper, we presented a new Architecture for remote control formed by an intelligent and distributed architecture based on the multi-agent aspect.

This architecture is validated by an application on Lego Mindstroms NXT Robot realized by the EAS team.

As a further work, we consider to improve our system to control multiple robots.

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ISBN: 978-988-17012-0-6
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