MAX: Wireless Teleoperation via the World Wide Web

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Abstract

The N-CART team has developed a working prototype of a teleoperated device based on a control metaphor derived from the way people control dogs on leashes. MAX the robot dog is wireless, highly mobile and may be controlled over vast distance via the Internet using a common Java-enabled browser.

1. Introduction

The Internet made convenient and cost-effective communication between individuals and groups possible. The World Wide Web (WWW) removed the complex, and often esoteric, nature of the communication through an interface which allows even the most novice user to communicate in ever more complex ways. With communication comes the promise of true interaction. By this, we do not mean interaction through the exchange of information, but the richer interaction, which comes through the ability to physically manipulate elements of a remote environment.

We believe it should be possible to extend the breadth of communication over the WWW by providing a physical manifestation of the local communicator at the remote site. We have been working toward this goal.

The N-CART team at Ryerson Polytechnic University has developed and deployed a wireless microcontroller-based robot. The robot can be controlled via a web browser communicating over an IP network. Our robot streams video images continuously via analog radio link from an on-board camera to a web server. Anyone having made a connection via a Java-enabled Netscape web browser can control Max.

2. The History of Teleoperation on the Web

The first teleoperated device accessible over the Internet was probably the Australian Telerobot--a remotely operated 6 Degree of Freedom (DOF) manipulator located at the University of Western Australia [1] allowing users to pickup and manipulate various objects within its reach. The Tele-Robotic Garden on the World Wide Web [2] extended the notion of purposeful control by allowing users to tend a garden situated around an Adept 6 DOF arm at the University of California at Berkley.

Various other devices have become available over time, such as the Bradford Robotic Telescope [3] which allows remote users to request the telescope to take pictures of remote celestial objects on a scheduled basis and makes the images available for browsing at a later date.

Recently, attempts have been made to connect more mobile devices to be controlled via the web. One such system--Khep on the Web provides streamed video, sent from a tethered Khepera robot in Switzerland to any web-connected browser in the world. A more complete listing of teleoperated devices on the web can be found at [4].

3. The Max Project

The Max project was initiated as an undergraduate thesis project in Ryerson’s School of Computer Science in 1997 and has been evolving since that time. The goal of the project is to put a mobile robot on the web--Max. It quickly became apparent that by the nature of the WWW and TCP/IP it would be very difficult to accomplish the level of control and feedback necessary to achieve that of a classic teleoperated system. Given this fact we began musing about why it was necessary to have this level of control at all.

4. Tight vs. Loose Control

The traditional model for teleoperation [6] is illustrated in the figure below.

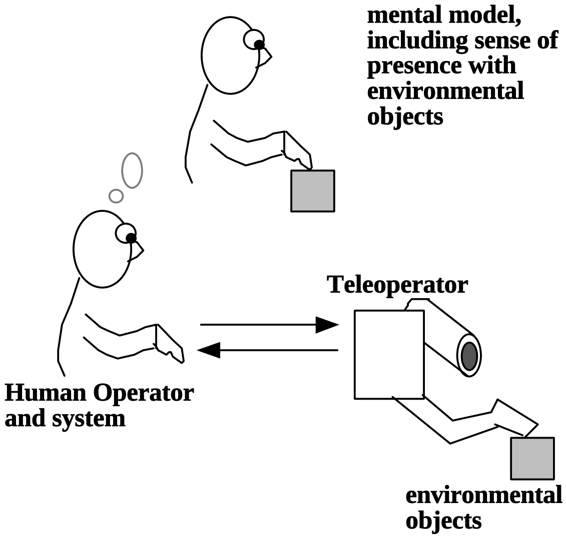

Figure 1. Classic Teleoperation

This form of control implies a tight linking between what the operator sees and what they expect to happen at the remote end. Tight control is generally desirable where the outcome of a particular action must be assured. Tele-surgery, for example, is an application where momentary loss of control, or loss of information coming from the remote site, is highly undesirable and could easily lead to disastrous results.

There is however another class of application where the “tightness” of control is not the critical measure of success. For example, remote security cameras typically provide very noisy images and allow only intermittent or “loose” control (if any), yet still provide sufficient information for a human operator to feel confident in their function and make use of their information.

4.1 The Dog Leash Metaphor

We selected a dog's leash as a metaphor for loose control of a remote device much in the same way that one maintains loose control of a dog while it is being walked. The dog is controlled through tugs on its leash which is usually adequate to make it move in the desired direction, yet the dog is free to do what it wishes within the restrictions imposed by its tether.

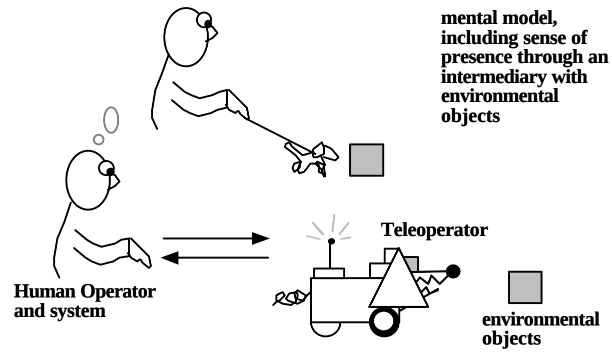

Figure 2. Dog Leash Teleoperation

We adopted this metaphor because of the way a communication channel such as the WWW works. Our device would be controlled through a somewhat noisy analog signal. The signal would eventually be sent over the inherently unreliable Internet. Occasional network delays or even randomly generated "noise" could degrade the video feed, or interfere with the movements of the dog, making it seem as if it had a will of its own.

5. The Fabrication of Max

Max is fabricated from inexpensive and readily available components. Its aluminum body employs twin differential drive wheels salvaged from an old toy car. Control is provided by an on-board MC68HC11micro-controller responsible for interpreting received commands into motor control signals. An early prototype of Max is shown in the figure below.

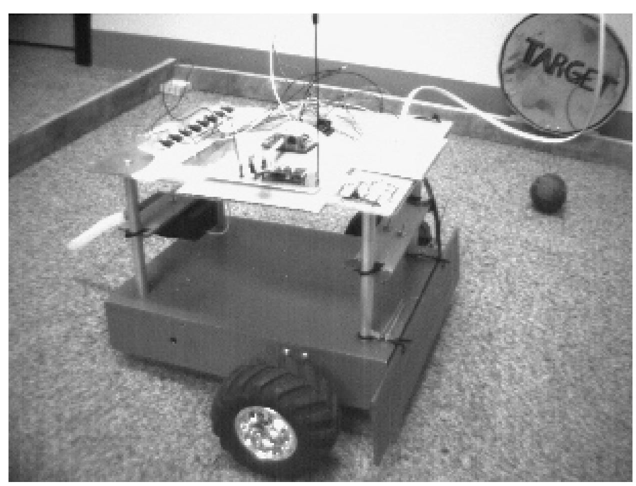

Figure 3. Early Prototype (Camera Not Mounted)

Max is equipped with a B/W CCD camera which is used to provide video images. The video stream is sent via a bi-directional radio transceiver that also receives commands for the controller. The range of the transceiver is several meters, thus allowing Max to rove about its base-station without physical encumbrance.

The video signal is received by a remote transceiver and fed into the cable TV port of a salvaged broken VCR, which provides output to a video capture board located on a Pentium-based PC server. This PC is running the Linux operating system and an Appache HTTP server. It is connected to the Internet via 100 Mbit Ethernet.

The streaming video software is provided through a custom Java application in conjunction with a Java applet downloaded to the user's browser. The figure below illustrates this configuration.

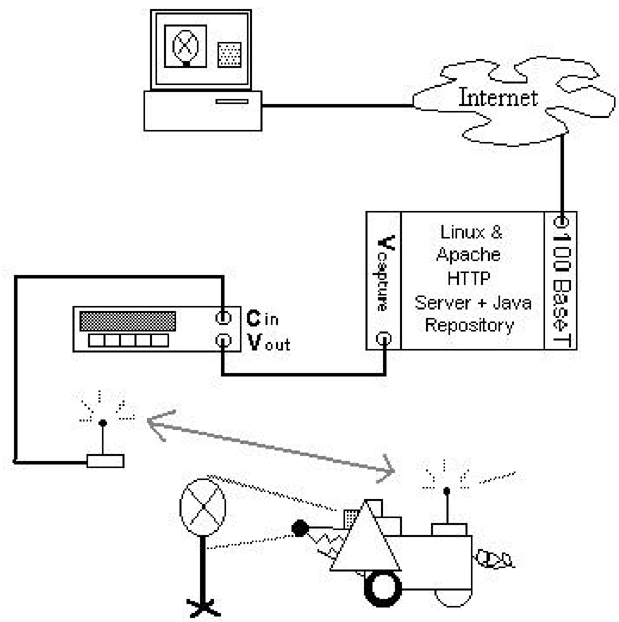

Figure 4 Schematic of Max's Configuration

Visitors to Max's home page are presented a configurable "dog's eye view" of the environment and an applet providing both gross and fine controls of Max. The Java video application on the server and the Java applet on the user's browser negotiate the quality and speed of the video that will be sent. This is shown in the next two illustrations.

Multiple users are accommodated through circular Queuing--allowing each user to have one minute of uninterrupted, active control but unlimited passive viewing until their turn comes up again.

Figure 5 Video applet displayed at 14.4 KBPS

Figure 6 Raw video feed at 100 MBPS

The control interface is shown in the figure below and presents the user both gross and fine controls for controlling Max's movements.

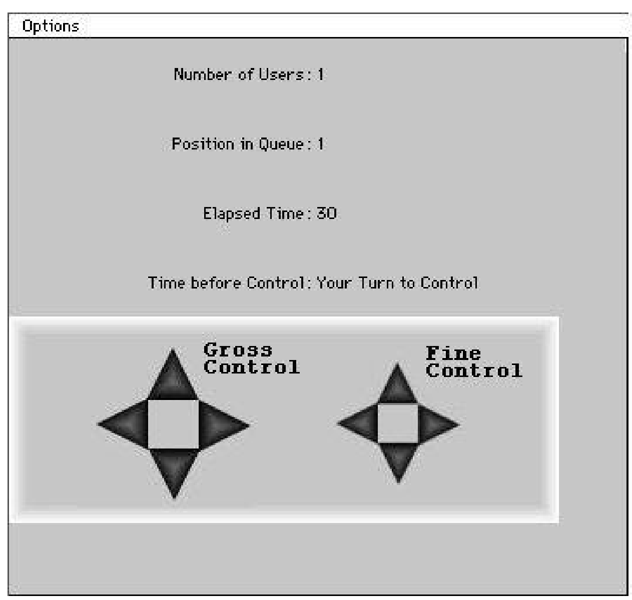

Figure 7 Max's control applet

6. Early Results

Max became operational and was first publicly demonstrated at the Ryerson Polytechnic University Open House on October 24, 1998. Since that time literally hundreds of remote users have taken Max for a walk.

Figure 8 Max as a Stylized Dog

6.1 Children Love a Dog

During our initial trials our target audience consisted of young children. We believed that they would be more accepting of the role playing necessary in order to justify the kwerky nature of Max. To facilitate this understanding we dressed Max to appear as a stylized dog and built an enclosed arena which allowed an operator to see Max before they attempted to control him. The enclosure was built around a bench outside a public elevator. This location allowed Max to interact in a limited way with people who were not involved with our trial but just happen to be there.

Dozens of children were attracted throughout the day. Inevitably each child caught on to the metaphor and within seconds was skillfully urging Max around the enclosure. In several cases the child controlling Max was able to make him follow individuals in the enclosure for some time with little difficulty. To date, children as young as three years old have successfully taken Max for a walk.

Max can currently be found under the projects link at [5]. Server logs indicate that Max has been controlled by several hundred users located throughout Southern Ontario with transmission rates at low as 14.4 KBPS, and continues to function adequately.

8. Future Plans

Our intent is twofold:

1) facilitate the effective teleoperated control of various devices using the dog leash metaphor, and
2) Suggest simple means for devices allowing interaction to be attached to networks like the WWW.

We feel that with a modest investment, it will become possible to provide a measure of true interaction with an environment to remote users.

Potential applications might include, roving surveillance, farming, mining, remote mine clearance and various other applications requiring a mobile remote device yet with a tolerance for a certain amount of signal and control loss.

Our short-term plans include providing Max with streaming audio to accompany the video signal. We hope this will provide additional information for users. We also will provide on-board signaling mechanisms, allowing Max to more effectively communicate to humans in his environment.

Max is currently mute but is configured with a mechanical wagging tail and will have the ability to bark to draw attention to messages shown on his LCD display.

In the longer term, we wish to provision Max with sufficient processing and telecommunications capability to allow the device to be connected to a wireless IP network. We hope that Max will be able to move around the Ryerson campus using the network as a kind of extended “spine” to communicate with its remote server.

We will be using the access facilities provided for disabled members of the Ryerson community in order to allow Max to move between buildings. To accomplish this goal we are adding additional components to Max that will allow him to prod various “handicap access” buttons to open doors automatically.

8.1. Conclusion

Using the dog leash metaphor, we have demonstrated a working, mobile wireless robot which can loosely be controlled over vast distances while providing sufficient feedback to a user to allow intelligent decision making to take place.

By discounting tight control through our metaphor we have gained a measure of independence from the need for it. In short, if you aren't controlling a device which is pretending to be a human at the remote end you don't expect human reactions--after all, it’s just a dog!

12. References

[1] Australian teleoperated arm on the web located at http://telerobot.mech.uwa.edu.au/

[2] Teleoperated garden on the web located at http://telegarden.aec.at/html/spie.html

[3] Teleoperated telescope on the web located at http://www.eia.brad.ac.uk/rti/index.html

[4] Additional teleoperated resources on the web located at http://ranier.oact.hq.nasa.gov/telerobotics_page/plans.html

[5] Max’s home (under “projects” link) at http://max.scs.ryerson.ca

[6] Zhai, S., Milgram, P., "A Telerobotic Virtual Control System", SPIE Vol. 1612, Cooperative Intelligent Robotics in Space II, 311-320, Boston, Nov 1992.