EFFECTIVE TELEOPERATION OVER THE WORLD WIDE WEB

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Abstract

The Network-Centric Applied Research Team (N-CART) team has developed MAX the robot dog, a working prototype of a teleoperated device constructed from readily available components using a control metaphor derived from the way people a dog on a leash. MAX is wireless, highly mobile and may be easily controlled over vast distance via the World Wide Web (WWW) using a common Java-enabled browser.

Keywords: Teleoperation, Robotics, WWW

Introduction

The notion of physically affecting a distant site is beguiling and has lead to the deployment of a variety of demonstration projects on the Web. Each of these sites offers at least some ability for a remote user to physically affect the local environment of the site.

The N-CART team has developed and deployed a wireless microcontroller-based mobile robot prototype allowing teleoperated control via a web browser communicating over an IP network. The robot--MAX [1] 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 through an intuitive interface.

The following paper describes the goals of the MAX project, explains how these goals were addressed and discusses how successfully the implementation was.

Teleoperation on the WWW

The Web has fostered the creation of some fairly advanced teleoperated devices located at various sites. Probably the first notion of teleoperation was achieved by various sites that attempted to query and control non-computing devices that they had “wired” to the Internet.

The first of these devices were the innocuous “Coke” machines, where a remote user is able to interact with a remote Coke machine—checking its status or reserving a can [2].

One of the first truly teleoperated devices accessible over the Internet was the Australian Telerobot--a remotely operated 6 Degree of Freedom (DOF) manipulator located at the University of Western Australia [3] allowing users to manipulate various objects within its reach.

Various devices have become available on the Web, such as the Bradford Robotic Telescope [4]. The telescope allows remote users to request it to take pictures of remote celestial objects on a scheduled basis. The images are than made available for browsing at a later date. Recently, attempts have been made to connect devices that are more mobile to 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 [5].

In retrospect, the teleoperated devices that were the most successful, in our opinion, were those that shared some common characteristics. It was these characteristics which made the projects both durable and accessible. We have taken these characteristics and made them into our project's goals.

MAX on the Web

The School of Computer Science at Ryerson Polytechnic University offers a course in mobile robotics to senior undergraduates (CPS607). Several students expressed an interest in continuing the work they had started in the course and wished to extend it. Because of the nature of the project, various members of the N-CART team also provided input into the initial design of the robot. In the fall of 1997, the N-CART team undertook the task of constructing and placing a mobile robot on the Web. After a careful review of previous work, the goals of the MAX project became;

1. Fabricate from durable and commonly available components
2. Wireless operation
3. Inexpensive to construct
4. Intuitive user interface, and
5. Controllable from anywhere by anyone at any time

The next several sections discuss these goals in some detail.

Goal 1: Commonly Available Durable Components

We noted that several of the Internet sites with controllable devices experienced considerable down time due to the need to replace parts that were particularly difficult to find or required special fabrication. To avoid this problem MAX is fabricated from inexpensive and readily available components. Its body is constructed out of two pieces of salvaged aluminum from Ryerson Physics labs. MAX employs twin differentially driven wheels scavenged from several children's remote control cars. Control is provided by an on-board MC68HC11-based "miniboard" [6]. The B/W CCD camera was obtained from mail-order electronics. MAX is shown in the figure below.

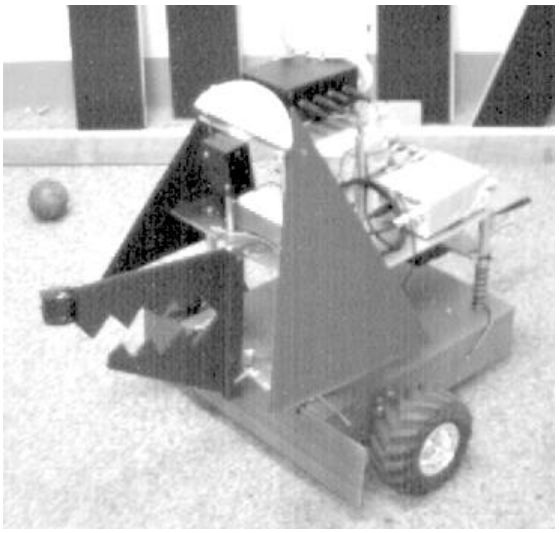

FIGURE 1 MAX THE TELEOPERATED DOG

Over time we have replace several of MAX's components. We have never had difficulty in finding replacement parts, and we have always been able to bring MAX back up in a timely fashion.

Goal 2: Wireless Operation

We discussed a common problem with several sites—that of entanglement. Because these devices are commonly available via the WWW, there is always the possibility that by accident or design the control and power cabling will become entangled in the robot mechanism thus, at the very least, bringing the device down.

The need for wireless operation became obvious to us almost immediately. We wished MAX to remain unconstrained by physical tethers, such as control harnesses. Like the other sites, it was realized through an early

prototype, that MAX would quickly become entangled in its own harness. The analog video signal produced by MAX is sent via a bi-directional radio transceiver over Television channel 52. The video signal is received by a remote transceiver and fed into the cable TV port of a VCR, which provides video-out to a capture board located on a PC server. Commands destined for MAX's on-board controller are sent on a very narrow back channel. The architecture for this is shown in the figure below.

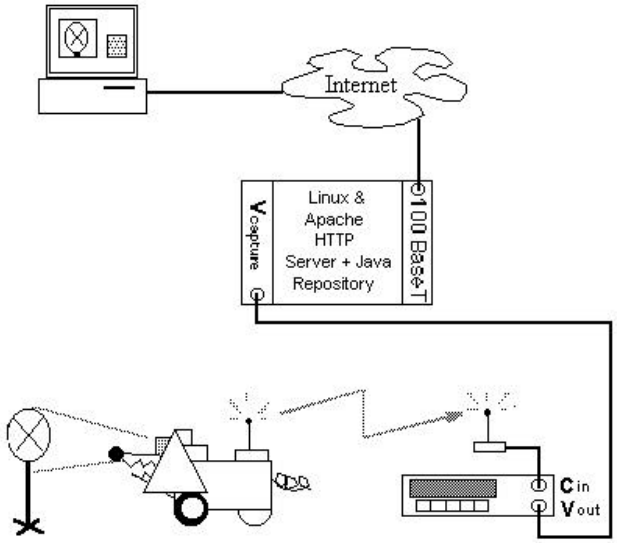

FIGURE 2 MAX'S SYSTEM CONFIGURATION

MAX Goal 3: Cheap

In order for teleoperation to become a commonly available means of interaction on the WWW, it is essential that devices be available at reasonable cost to both the provider and the end user. The total cost of all on-board components of MAX was less than (CDN) $1000. This was particularly advantageous for the project team as components could be severely stressed to the point of failure and replaced at minimal cost. For example, the first few interactions of MAX had severe power dissipation problems, literally causing MAX to catch fire on occasion. Because the components were readily available, this was of little concern—although it did lead to the purchase of an off-board fire extinguisher.

Another factor in overall cost is the bandwidth required to achieve an adequate video signal. While MAX is capable of utilizing high-bandwidth networks for improved picture quality, such a network is not essential for MAX's operation. We have tested MAX on dial-up connections as low as 14.4 KBS with adequate if not stellar results.

Goal 4: Intuitive User Interface and Adequate Video

Several teleoperated sites actually provided tutorials to learn how to use their interfaces. This requires a considerable investment of the user's time and effort to learn. Contrasting this, visitors to MAX's home page are presented a configurable "dog's eye view" of the environment presented through a Java applet. A second applet provides both gross and fine controls. Multiple users are accommodated through circular Queuing--allowing each user one minute of active control but unlimited passive viewing. MAX's control and video interfaces are depicted in the figures below.

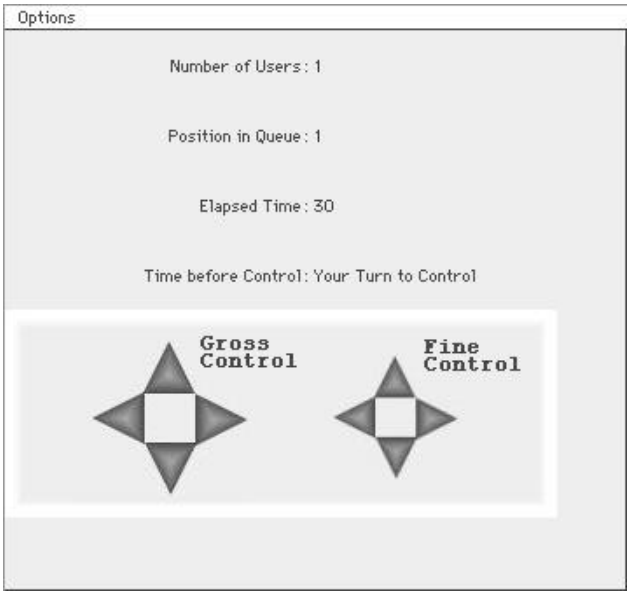

FIGURE 3 MAX'S CONTROL INTERFACE

Several video resolutions are available and can be changed dynamically at the users request.

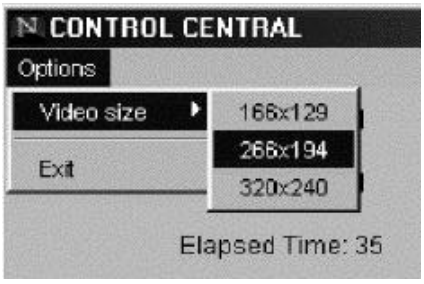

FIGURE 4 SELECTING VIDEO RESOLUTION

FIGURE 5 MAX'S LOWEST AND HIGHEST RESOLUTION AT 30 FPS

No instructions are supplied with the interface yet most people find it rather simple to use.


FIGURE 6 A THREE-YEAR OLD GIRL TAKES MAX FOR A "WALK"

At MAX's first public demonstration children as young as three years old could control MAX proficiently within seconds. This allowed the children in one room to make MAX follow their parents around in another room. 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 room.

Goal 5: Any Where, Any One, Any Time

Because of the global nature of the Web the development team has constructed a lighted enclosed arena to house MAX which allows anyone who can connect to the Web using a Netscape browser to control MAX at any time. We have compromised MAX's mobility by providing a power tether to a fixed power supply to avoid the problems of dead batteries. This has renewed our entanglement problem and we are working to resolve this issue.

Since both the video feed and control interface are Java applets, there is no special need for additional software or hardware components at the user's site. To date, we have had people control MAX from as far away as the University of Essex [7] in the United Kingdom.

Conclusion

Our intent is to allow the effective teleoperated control of various devices using

inexpensive and commonly available components allowing a simple means for the devices to be attached to networks like the WWW. In this way, we feel it will become possible to provide a measure of "situatedness" to remote users with a reasonable investment. Potential applications might include, roving surveillance, telepresence for the severely disabled, remote mine clearance and various other applications requiring a mobile remote device under local control.

Our short-term plans include providing MAX with streaming audio to accompany the video signal, which we hope, will provide additional information for the remote user. We also will provide on-board signaling mechanisms allowing MAX to communicate in its environment more effectively. MAX is currently configured with a mechanical wagging tail and will have the ability to bark to draw attention to messages shown on a LCD display.

In the longer term, we wish to provision MAX with on-board processing and telecommunications allowing the device to be connected to a wireless IP backbone. In this way MAX will be able to move around campus using the same access facilities provided for disabled members of the Ryerson community.

References

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[6] http://www.frc.ri.cmu.edu/robotics-faq/

[7] The 2nd International Workshop on Presence, April 6-7, 1999, University of Essex, Colchester, UK at http://privatewww.essex.ac.uk/~jfreem/Presence_Workshop.html