Low Bandwidth Video and Control of a Mobile Robot on a Wireless Personal Digital Assistant

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ABSTRACT

Given the seemingly insatiable desire for low-cost and highly capable mobile computing devices in the form of personal digital assistants (PDAs), and the increasing popularity and deployment of wireless networks it was inevitable that video services would be a target for network deployment. Unfortunately wireless networks currently available rarely support data rates approaching those necessary for full motion video. At The Network-Centric Applied Research Team (N-CART), we are attempting to introduce workable service architectures dealing with this reality. We have developed a prototype service delivery model allowing both low-bandwidth video to be generated for and displayed on a PDA as well as allowing real-time control of the video source--in our case a robot. We have applied this model to our MAX teleoperation project.

1. INTRODUCTION

Various individuals and groups have recognized the promise of PDAs for use as robot controllers[1]. Proposals have been made for extending video services onto wireless PDAs and allowing those same PDAs to act as controllers [2][3]. Unfortunately, currently deployed networks rarely provide sufficient bandwidth to allow full motion video on such devices and the inevitable latency in frame delivery is a significant problem for end users attempting to determine what activity is going on at the video's source.

At N-CART we have developed a network-centric model for the deployment of low-bandwidth video and control services. This model takes into account existing network interfaces and allows them to be extended into the wireless domain without substantial alteration.

2. MAX: WEB-BASED SERVICE ARCHITECTURE

N-CART's MAX Project was initiated in 1997 [4][5]. The goal of the project was to develop and deploy a wireless robot allowing teleoperated control via a web browser communicating over an IP network. The robot--MAX [6] streams JPEG images continuously via an analog radio link from an on-board camera to a web server. Anyone having made a connection via a Java-enabled web browser can control Max and receive the video stream.

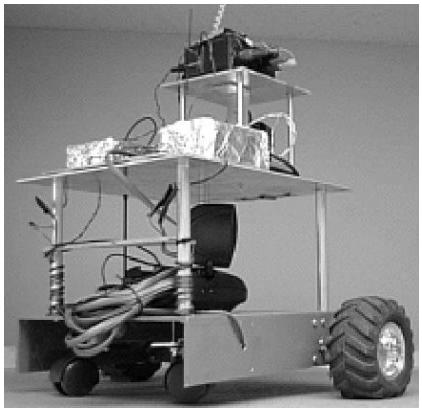

Figure 1 MAX the robot

The video server provides a stream of JPEG images to a client Java Applet at a relatively high resolution. The client is also provided with a Java control Applet allowing gross and fine control of the robot's motion.

The web browser supplies the client side of the interaction having been loaded from the MAX web server. Two other logically independent server components provide control and video support. This is shown in the figure below.

Figure 2 MAX Logical Architecture

3. MAX: WIRELESS-CLIENT SERVICE ARCHITECTURE

MAX's service architecture has proven to be both flexible and extensible allowing control services to be extended to a PDA through relatively minor application

programming interface (API) modification. A Palm Pilot PDA was arbitrarily selected as the target controlling device and the MAX controller written as a Java applet to run under KVM environment on the PDA.

In order to provide an effective low-latency video stream to the PDA client it was necessary to make certain pragmatic decision concerning how MAX's architecture should be extended to support extremely low-bandwidth video. We restricted our efforts to providing video and control services over a maximum of 14.4 KBS network link--typically the maximum bandwidth available for such devices. While high-bandwidth wireless application will undoubtedly become available in the near future [7][8] we believe there will always be a requirement for service over low bandwidth links.

We carefully crafted the system and the communication protocol to derive optimal performance from this connection speed for the video experience of the user. This is a marked departure from other interesting work such as [9][10] that seek to provide alternative interfaces to the remote scene.

The wireless video server acts an intermediary between the PDA client and the MAX video server. It listens for connection requests from the PDA client and is subsequently responsible for retrieving the video stream from the MAX video server. It converts and processes the video to a reduced size and compatible format for the PDA. This relationship is shown in the diagram below.

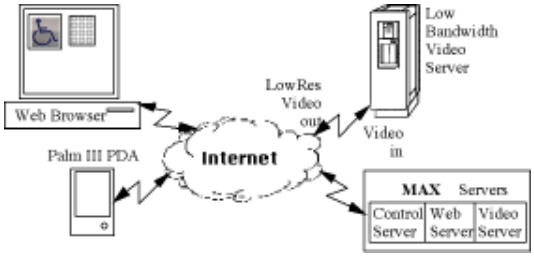

Figure 3 MAX Wireless Service Architecture

4. VIDEO CONVERSION

With the goal of reduced latency over a low bandwidth link, the JPEG images streamed by the MAX video server go through a conversion process on the PC-based wireless video server. The images are scaled to a 48x48-pixel frame and converted to monochrome. While there is significant loss in quality, the resultant images are still quite useable, providing enough clarity to allow the PDA user to distinguish between objects in the images displayed.

Figure 4 Image Conversion Steps

5. EXPERIMENTAL RESULTS

Using this conversion technique we are able to achieve two or three frames per second with relatively good synchronization with the MAX video server. This provides the end user with the ability to detect motion within the displayed image, thus adding to their comprehension of the displayed scene. Because the effective bandwidth is so low, conversion of images can easily occur before transmission of the 288 bytes plus overhead per frame happens.

The figure below is that of a single frame captured from the wireless video server stream as displayed on a PDA simulator. The camera is currently facing a window onto an internal hallway. Because of the reduced quality of the image, it is not possible to identify a blob in the center left of the image as a person. However, because of the relatively fast frame rate, motion can easily be detected and used to enhance the user's interpretation of the scene.

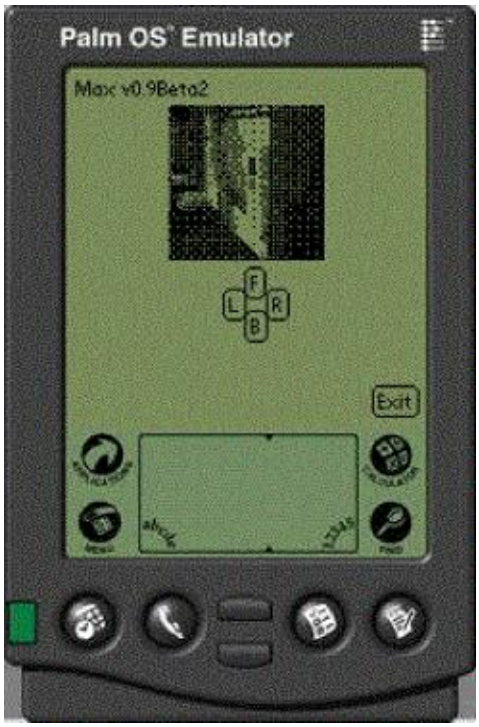

Figure 5 Video on the Palm Pilot

6. APPLICATIONS AND FUTURE WORK

We envision that this work may find application where low bandwidth and resolution are acceptable. Typically this would be the case in certain area surveillance applications. In addition we believe there are potential applications for these techniques where intermittent connections are sufficient. For example, in the monitoring of equipment vaults or even day care facilities. In the future we hope to apply the techniques we have developed to extremely low-resolution displays typically available on devices like mobile phones.

7. REFERENCES

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