EventScope: Amplifying Human Knowledge and Experience via Intelligent Robotic Systems and Information Interaction

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Abstract

The EventScope program develops publicly accessible "reality browsers" that display both archived and updating representations of remote environments derived from on-site robotic sensors. The interface encourages collaborative work within a community of users. Public exploration of real remote sites presents a variety of interface issues addressed by EventScope, including time delay, public exploration via a single robot and communication between geographically separate users from diverse backgrounds. Merging public interface with educational and contextual information extends the notion of "interface" to "remote reality library." EventScope is a NASA and private foundation-funded project based at Carnegie Mellon University.

1. Introduction

Publicly funded Earth and planetary exploration is conducted to increase knowledge of our universe. The public traditionally accesses this knowledge passively, through the media. However, the development of the Web and of robotic remote-sensing technology now make it possible for students and the public to actively participate in the scientific process. EventScope uses remote and autonomous robotics in conjunction with interface and technology design to create "reality browsers" that allow geographically decentralized users to engage in scientific processes via active exploration of telerobotic mission sites. EventScope builds on robotic interface work created for use by NASA scientists and engineers, such as visualization for the NASA Mars Pathfinder Mission [1] and the NASA Chernobyl Mapping Expedition [2].

1.1 Previous Projects

EventScope extends interface technology concepts to the public through educationally-oriented projects. Although these projects are designed as curriculum supplements for secondary education, they are presented on publicly-accessible Web sites. As such, any member of the public in any country has access to the current and archived NASA telerobotic missions upon which EventScope bases its projects. Previous projects include:

Big Signal Antarctica 1998 and 2000—A Web and technology portal [3] linking the public to the NASA/CMU robotic rover Nomad [4] on its field trials in Antarctica, this project combined live and archived robotic sensor data with daily updates from mission scientists, contextual information, and a "rock library" tool that enabled users to compare the rocks Nomad found with previously identified samples. This project reached 1000+ middle-school students in over 30 classrooms. It was profiled in the *New York Times* and Britain's *New Scientist*, on CNN.com, Yahoo.com and other Web sources [4]. It also is scheduled to appear in an upcoming issue of the ASME journal, *Mechanical Engineer*.

***EventScope: Mars*—**Designed to enable public access to NASA Mars data gathered by robotic rovers, probes and orbiters, *EventScope: Mars* will enable students and the public to explore 3-D virtual representations of the Martian surface derived from NASA data sets that are otherwise unavailable to the public. Data from future successful missions will be incorporated as the missions take place, potentially enabling live data to be used. Tools and technologies developed for *Big Signal Antarctica 2000* will be refined, and a curriculum is currently being developed to situate the Mars data within a scientific and historical context [5].

1.2 The EventScope Team and Process

The EventScope team embodies the principle of interdisciplinary collaboration within an iterative design process. The multidisciplinary EventScope team includes experts in robotics, human-computer interaction, programming, verbal and visual communications, education, cognitive psychology and design. Each project also incorporates contributions from experts in relevant fields: previous and current projects have included Earth and planetary geologists, astronomers and NASA engineers. The team anticipates completing one additional project per year. The current NASA mission to map the Eros asteroid is a strong candidate for inclusion in an EventScope project, as are upcoming Earth-based field trials for new NASA robotic rovers, including Fido.

An iterative design process is used to develop the major aspects of our work: technology, interface and content. When a project is in development, team members rapidly prototype each of these three aspects, presenting them to the team as a whole for comment. Comments are then integrated into a new prototype, which is presented to the team the following week. This process is repeated until all aspects of the project are sufficiently developed to conduct an external pilot test. We conduct full pilot tests in classrooms once per school semester, not including summer; this averages out to once every six months. In addition, workshops with teachers are held prior to pilot testing in order to further refine the interface and content prior to testing. This process instills great flexibility, enabling problems to be identified and corrected before they can impact the project as a whole.

2. The EventScope Interface

Public exploration of remote sites presents a range of interface challenges. The distance separating users from remote robots creates issues of time delay and non-continuous data streams. Interfacing many users through a single robotic vehicle while maintaining each user's sense of exploration and control is another challenge. Other major issues include determining the degree of control/real interaction to give users and the means of distributing that control, sorting data to streamline the interface, enabling collaboration between users and scientists, linking robotic-sensor data with archived data, creating coherent ways of allowing independent navigation of vast amounts of information, and representing remote sites both spatially and over time.

The interaction paradigms developed by EventScope resolve the above issues, enabling a range of possible interaction scenarios: many users/one robot, many users/multiple robots, users/users, and users/scientists. Each project is publicly accessible via the Web, but the associated curricula and educational outreach allow teachers to easily incorporate projects into their classrooms. Thus, "user" can designate any individual: a member of the public, a teacher, a student, a scientist or engineer, etc. The following sections will discuss interface issues and the interface features that enable intelligent robotic systems to act as amplifiers of human knowledge.

2.1 Public Control vs. Public Outreach

At this point in time, robots remain costly and rare enough that allowing individual users true control of a robot is not compatible with the goal of bringing robotics to large numbers of people. However, showing people robots they cannot control is something TV and other non-interactive media already do; it is not new. Fortunately, the rapid evolution of consumer-level computers, coupled with the capabilities of the Web, offer a third possibility. If a real-world environment and a robot are recreated digitally as 3D models, then each user can download a copy to use as they see fit. The user experiences control and autonomy, in that he or she can explore the remote site at will and direct the robot to do anything that is physically possible for it to do. This may include inadvertently damaging the robot or terminating the mission: if a given action would cause the robot to fall over at the real remote site, for example, the virtual robot will fall over. In *EventScope: Mars*, students who miscalculate the launch of a Mars probe will not reach Mars. Users can thus experience the whole range of possible outcomes of a telerobotic mission without harming a real robot or losing a real mission.

However, this paradigm is not the only one in which EventScope is interested. . Current investigation includes researching methods of allowing users a degree of control in a live mission. These methods might include a democratic model, in which the actions of each user within their 3D virtual world are monitored and uploaded to EventScope, with the most popular actions being forwarded to live-mission scientists for implementation. A competitive model is also possible, in which users or user teams are selected according to the success of their performance within the 3D world or the scientific merit of their suggestions. In either case, close cooperation of the live-mission team of scientists and engineers would be necessary. We are currently partnering with a range of robotics projects in development, with the intention of pilot testing some of these possible models of control.

2.2 Spatial/Chronological Maps

As data are gathered by the robot, we assemble them into a spatial map and associated timeline. These evolve throughout the mission, allowing users to view new information as it is gathered and examine earlier information for comparison. The remote site is always available for users to explore, and each "databurst" adds more exploration possibilities. The robot gathers data once, and EventScope converts the data into two-dimensional and three-dimensional spatial and chronological maps which are then assembled into a virtual environment: a spatial and chronological recreation of the robotic mission. This environment can be explored in the order in which the robot explored it, or out of order. Users can thus follow the mission in real time, join it at their convenience, or re-live the mission after it is completed. This resolves two issues: time lag and user scheduling.

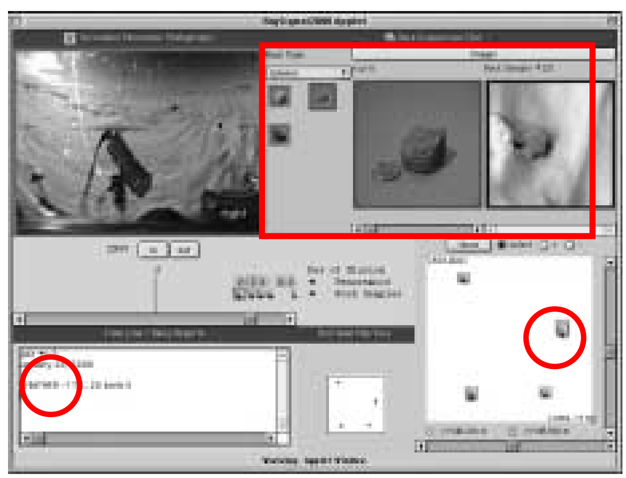

Fig. 1: BigSignal Antarctica 2000 Interface. Icons refer to time and spatial events [bottom]. Context libraries provide background information [top].

2.3 Context libraries

The rock library in *Big Signal Antarctica 2000* allowed users with little knowledge of geology to understand and participate in Nomad's work. The context library being developed for *EventScope: Mars* will build on users' knowledge of Earth features (volcanos, riverbeds, etc.) as a bridge toward assimilating knowledge of the Martian landscape. Each project's context library blends prior knowledge with an interface designed to let users make new discoveries for themselves. In addition to building the knowledge base of student users, this facilitates communication between users of different skill and knowledge levels. More knowledgeable users may use the context libraries as a reference when communicating with student or laymen users, while less-knowledgeable users may explore the context libraries in depth as part of an overall curriculum.

2.4 Flags

Users with comments or questions about a specific feature of the remote site, (e.g., a particular rock) can place a "flag" on that feature. Other users can see the flag, read the comment/question, and answer it or add their own. The interface allows each user to pre-set flag visibility to different levels: "view all," "view flags from my school," etc. This collaboration-enhancing feature is being developed for *EventScope: Mars*. Users who wish to plant a flag simply run their mouse across the screen and click on the object. Java 3D then shoots a "ray" into the onscreen 3D model, and whatever the "ray" intersects becomes the point where the flag appears. Comments, questions and other information inputted by users is in the form of a Java object.

Fig. 2: Flags link to users' comments and external or internal Web sites.

2.5 Linking EventScope's Navigation Tool with the Web

The interface's open-ended structure links real remote experience to Web-archived information. Users can click on features of the remote environment and trigger an associated Web page to open. This page may deliver contextual information, allow messaging or live chats between users, or show a more detailed view of the feature. Users may also change the display mode of the 3D viewer from an EventScope Web page. For example, users can alternate between geocentric (ancient, incorrect) and heliocentric (modern, correct) views of the Solar System to observe how the trajectories of planetary orbits differ between the two views.

To invoke the Web browser from within the 3D viewer, a Windows-native system call for resolving a URL and opening an application is used from within Java. To activate changes within the 3D viewer from a Web page, the browser calls a script which opens up a mini-3D viewer, which communicates with the main 3D viewer through Remote Method Invocation.

3. Conclusions

The current work of the EventScope Team involves using robotics and the Web to offer the public a new paradigm of human/ information and human/machine interaction. We create contextualized interfaces through which humans can project themselves into robots at remote locations, not only exploring locations they cannot physically explore, but also experiencing those locations as only the robot can: through robotic sensing devices. This paradigm is available to an elite group of scientists, but our goal is to extend it to the general public. We accomplish this in two ways: by creating software that mimics the functionality of high-end scientific software, but runs on standard consumer-level computers; and by contextualizing the remote sites in an educational, user-friendly way. The applications of this work are obvious: education and training, information dissemination, and potentially, even entertainment.

However, as robotic sensing devices and fully functional robots become more widespread, the potential applications will multiply. Our ultimate goal is to work with industry to define the standard for a "mediated reality browser," bringing real remote experience into classrooms, households and workplaces worldwide. The current model of human/information interaction will expand to include machine-mediated human/reality interaction: the boundary separating the "data space" of users and their computers and the "real world" will become seamless through robotic interaction with the physical environment. Robots will act as information explorers, experience gatherers, and agents of action in the physical world. This is the human/robot interaction paradigm we are now working toward.

4. References

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