

Enhancing Museum Visitor Access Through Robotic Avatars Connected to the Web

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Abstract

Access to cultural exhibits is a central issue in museums and exhibition galleries that is recently

approached under a new, technological perspective. Although the cultural industries' practices in the cases of museums and cultural exhibits have remained practically unchanged for long, in recent years we are witnessing a gradual adoption of media-technologies in various aspects, such as collections archiving and digital document preservation, media- and Web-presentation, graphical animations, etc. The advent of such technologies contributes towards providing media-rich presentations of cultural exhibits and consequently offering better services to museum visitors. Lately, Internet and Web-based technologies have been employed for providing access, mostly to images of exhibited objects. With current technology such access is limited due to the non-interactive nature of pre-recorded images or videos and the difficulty in constant updating of the sites when there is change in the content. In few cases, the incorporation of higher-end technology, such as virtual reality, artificial intelligence, or robotics, is explored. Some science museums, large "edu-tainment" venues, and recreation parks have traditionally been the ones to embrace new media first, by employing fascinating and sophisticated interactive installations and presenting up-to-date results on the creative use of technology.

In this paper we present such an effort, the TOURBOT project, which emphasizes the development of alternative ways for interactive museum tele-presence, essentially through the use of robotic "avatars". TOURBOT, an acronym for TOUR-guide RoBOT, represents a collaboration between museums, technology providers, and brokers of technology to museums. The overall goal of TOURBOT is the development of an interactive tour-guide robot able to provide individual access to museums' exhibits and cultural heritage over the Internet. TOURBOT operates as the user's surrogate persona (avatar) in the museum by accepting commands over the web that direct it to move in its physical workspace and visit specific exhibits. In other words, the imaged scene of the museum and the exhibits is communicated over the Internet to the remote visitor. As a result the user enjoys a personalized tele-presence to the museum, being able to choose the exhibits to visit, as well as the preferred viewing conditions (point of view, distance to the exhibit, resolution, etc).

In addition to remote interaction with the robot, TOURBOT can also act as a flexible, on-site museum guide to visitors that are physically present. By interacting with the tour-guide robot, museum visitors have the ability to individually exploit the expertise stored in the robot, which can react flexibly to their requirements. It can, for example, offer dedicated tours of specific focus to exhibitions or alternatively give overview tours. As a side effect of this concept, museum visitors get acquainted with new, cutting-edge technology by easily interacting with a complex robotic system. Therefore, technological advances are seamlessly assimilated in everyday activities.

This approach to cultural heritage access presents a high degree of novelty as well as a number of technical and conceptual issues and challenges. This paper discusses these issues while analyzing the expected benefits and expectations from visitors, the community, and the museums.

1. Introduction

The goal of this project is the development of an interactive TOUR-guide RoBOT (TOURBOT) able to provide individual access to museums' exhibits and cultural heritage over the Internet (TOURBOT, <http://www.ics.forth.gr/tourbot>). TOURBOT operates as the user's avatar in a museum by accepting commands over the Web that direct it to move in its workspace and visit specific exhibits. The communication network is, thus, effectively extended by the introduction of interactive, mobile robotic platforms as terminal nodes. The imaged scene of the museum and the exhibits, is communicated over the Internet to a remote visitor. As a result the user enjoys a personalized tele-presence to the museum, being able to choose the exhibits to visit, as well as the preferred viewing conditions (point of view, distance to the exhibit, resolution, etc). At the same time, TOURBOT is able to guide on-site museum visitors providing either group or personalized tours.

In order to realize the TOURBOT system, a multimedia Web interface is created to allow people to interact with the tour-guide system over the Internet (Schulz et al., 1999). Furthermore, an on-board interface facilitates interaction with on-site visitors of the museum. Using the Web interface, people all over the world are able to tele-control the robot and to specify target positions for the TOURBOT system. Camera controls are used to choose the part of the

exhibition the user wants to inspect in more detail. The robotic tour-guide possesses a multimedia information base providing a variety of information about the exhibition at various levels of detail. Thus, the TOURBOT system essentially serves as an interactive and remotely controllable tour-guide that provides personalized access to exhibits with a large amount of additional information.

A tele-operated interactive tour-guide robot requires a high degree of autonomy since it operates in a populated environment in which humans are also present. Therefore, the project includes the development of a safe and reliable navigation system for TOURBOT (Trahanias et al., 1999; Fox et al., 1998; Argyros et al., 1999). The robotic avatar is equipped with a series of state-of-the-art sensors that allow it to acquire information about its environment. The navigation system uses this sensory information to adapt the robot's internal model of the environment and to plan the robot actions.

2. A New Paradigm in Access to Cultural Content

In the last couple of decades, museums have been evolving their concept and have been setting new priorities and objectives that follow a more global approach. Under this expanded approach, museums are expected to actively and energetically seek (and please) a broader audience (Ames, 1986). This signifies a change in the definition of the museum "public", now expanded to include school children, the working classes, minorities, individuals and groups with special needs. Changes of this kind were taking place as early as the end of the 19th century, when by opening the King's collections to the people, the primitive idea of the museum open to the public was substituted with the one of the museum belonging to the public (Poisson, 1950). With the advent of technology, museums begun to look at new ways for providing access to their collections and to their activities in general. Most museum technology applications involve the creation of archives, libraries, image galleries but also tools of virtual presentation of collections and 3D representations (Thomas and Mintz, 1998). We have many examples of successful projects presented on CD-ROMS, on-site kiosks, installations, and the Web, in a variety of forms, ranging from simple archives to innovative, experimental and interactive sites (Dietz, 1998).

Although significant progress has been realised in the past years, technical limitations still exist. In addition to the varying transmission speeds and copyright issues presented as problems for museum presentations on the Internet, keeping the pre-digitalized collections up to date and providing access to other more dynamic museum information, such as changing events and temporary exhibitions, is still quite difficult, time consuming and expensive. Furthermore, the resulting museum presentation may still be far from satisfying the need of the distant or remotely located visitor to experience the museum "environment". By museum environment, we mean not only the images and accompanying information of the digitised collections but also the "aura", the living and changing space where other humans are present.

In knowledge of these limitations, the TOURBOT project has attempted to introduce a new paradigm in providing access to cultural heritage exhibits (Konstantios, 1983). Through the introduction of museum visiting via a robotic avatar, it facilitates immersive tele-presence with advanced visualisation capabilities. Full access to cultural exhibits is granted to the user, in the sense that the latter is able to choose the exhibits to visit, as well as the preferred viewing specification (point of view, distance to the exhibit, resolution, etc).

There is no doubt that currently access to cultural heritage is limited, enjoyed mostly when physical presence in the exhibition premises can be possible. At the same time, it is common understanding that alternative ways should be developed in order to provide such services for remotely located exhibits. In the case of professionals who need to critically study realistic views of exhibits as part of their work, TOURBOT offers a viable alternative to the current model that requires on-site visits. Additionally, the robotic avatar operates on a twenty four-hour basis, seven days a week, permitting thus more people to exploit this service at their convenience.

The TOURBOT approach introduces a novel model of augmented environments, in that it allows human interaction with and workspace exploration of a remote site by means of a robotic avatar.

Technological advances in various fields have made it possible to envision such immersive, tele-presence applications; the current project exploits fully related technologies to provide an integrated solution for the particular case of exhibition places.

Compared to current approaches employed to provide services to people with special needs, TOURBOT presents a viable alternative, since it offers advanced, fully interactive access capabilities from a person's residence. In the current project, access to cultural exhibits in museums' premises is targeted; however, the concept introduced is quite general, offering a variety of options for new services for independent living, such as access to large trade fairs, technology exhibitions, etc.

As a unified service to remote users, TOURBOT extends current communication networks by allowing mobile robots to be part of the overall structure. Such a mobile agent acts as the user's avatar, operating in a physical environment that is perceived by the user through the robot's sensors; interaction with the (augmented) environment is achieved by using the robot's actuators. Therefore, TOURBOT results contribute towards the seamless integration of networks and mobile agents for providing full user access to exhibitions.

The next table summarizes the features of the proposed approach for cultural heritage access, contrasting them with the current possibilities offered by conventional Web presentation systems.

Evaluation Feature	Cultural Heritage Access	
	Conventional Web presentation	Robotic tour guide
Interaction	LOW The presentation is static and pre-programmed.	FAIR The visitor is virtually present in the museum through its robotic avatar.
Quality of information	LOW Storage and communication requirements trade off quality.	FAIR The visitor can choose the viewing parameters (viewpoint, resolution, etc).
Accessibility of information in short time	HIGH Distance is not a barrier.	HIGH Distance is not a barrier.
Dynamic adaptability to changes in content	LOW Reorganization of the material is required, which is a costly procedure, especially for exhibitions with often changes in content.	HIGH The visitor sees the current content of the museum. Revisiting the museum has zero or minimal additional cost.
Comfort for the typical visitor	HIGH The visitor can see the	HIGH The visitor can see the

	museum exhibits from a computer at the comfort of his residence, any time.	museum exhibits from a computer at the comfort of his residence, any time.
Accessibility to visitors with special needs	HIGH The only requirement is the ability to interact with a computer.	HIGH The only requirement is the ability to interact with a computer.
Savings in time for a typical visitor	HIGH Almost instantaneous access to any presentation.	HIGH Almost instantaneous access to a museum.
Financial savings for a typical visitor	HIGH Low cost, even for very distant museums.	HIGH Low cost, even for very distant museums.
Museum added value	FAIR The museum is advertised through the availability of such presentations.	HIGH The tour-guide robot becomes an exhibit by itself.

Table 1: Comparison of Web vs. Robot-enhanced presentation of museum content to visitors

3. Innovation

The very objective of the project, namely the development of a robotic avatar that allows virtual user presence in an exhibition, constitutes a contribution in a number of areas: interfaces for mobile agent tele-control; navigation technologies; multimedia presentation systems over the Web; virtual tele-presence and tele-visit. Such areas are deemed essential for the evolution of a new generation of remote access technologies, that built upon existing network infrastructure.

The Internet is a very fast evolving technology that electronically connects distant sites; however, up to now, electronic networks serve mainly to exchange and acquire information. In some cases this information is pictorial by means of images taken in “real time” with a stationary Web-camera. To take full advantage of a network such as the Internet, it would be desirable to get real physical interaction with the remote site being visited. Robots, and especially mobile platforms, can extend the Internet towards an interactive platform that allows actions to be carried out and dynamic information to be exchanged between distant sites.

The TOURBOT project implements exactly the above concept for the particular case of museums as remote sites. In other words, it augments current networks by substituting a terminal node with a mobile platform. The latter acts as the user’s avatar, by accepting commands over the Internet to rove in its workspace, communicating simultaneously the viewed scene and other information to the user. It therefore permits personalized tele-visiting of remote exhibition sites, physical interaction and dynamic selection and

acquisition of the information to be retrieved.

The current project capitalises on related, cutting-edge technologies to accomplish its goals. According to the interdisciplinary structure of the project, its major technical contributions lie in: (a) advanced Web-interfaces for mobile agent tele-control and remote visualization, and (b) improved navigation capabilities for complex indoor environments (museum premises). The user interface will allow visitors all over the world to control and interact with the robot. To safely navigate and reliably operate, the robot needs advanced navigation and error recovery capabilities that have not been fully demonstrated so far for autonomous robots operating in populated environments.

The field of mobile robotics has made serious progress in the recent years. The technology has reached a state that allows the development of mobile robot systems, able to operate autonomously in human environments over long periods of time, without human supervision. Until today, only laboratory experiments have been carried out, illustrating the capabilities of the developed control systems. These systems, for example, lack mechanisms for monitoring their progress and detecting execution failures. Long-term reliability, however, requires that mobile robots are able to detect and deal with sensor and execution failures and that they can recover from such situations, either by actively choosing the optimal sensor setup or by choosing necessary escape actions. Furthermore, current mobile robot control systems generally consider only the robot and try to maximize the robot's performance. In populated environments, however, robots must adapt themselves to the behaviour of the people surrounding them.

Based on the above, the scientific goals concerning the navigation aspects of a robotic tour-guide include advanced techniques for monitoring the execution and for detecting and escaping from execution failures. Furthermore, they include sophisticated sensor interpretation techniques allowing the robot to monitor its environment and to adapt itself according to the abilities of the people it is guiding.

The second aspect of scientific and technological objectives concerns the improved interaction abilities over the Web, as well as with people inside the museum. Current museum presentation systems provide only information at terminals, which are close to the specific exhibits. Visitors in the museum have to access these information terminals to obtain detailed information about the exhibits. Portable CD or MC players provide mobility, but only limited presentation and interaction capabilities. Users have to follow fixed tours and obtain only audio information. These presentation systems cannot in some cases flexibly react to the interests of the users. The goal of this project is to develop a flexible and mobile information agent, which provides individual access to the information stored in a multimedia information base. This information base will include graphics, images, spoken and written text as well as audio. The TOURBOT system will be able to adapt the presentation to the interests of the users, which will partially be derived from the interaction with them, e.g. by monitoring the kind of information required by the users.

A further contribution of TOURBOT lies in the aspect of technology integration. The TOURBOT system will use an integrated and inter-operable information base for representing all relevant aspects of the environment. This information base contains all multimedia information needed for the interaction with the users, as well as the layout information needed for navigation tasks. The problem of an integrated model of the environment serving different tasks of the robot, e.g. navigation tasks, scheduling tasks and interaction with users, is still an open issue.

In summary, the innovative aspects of TOURBOT include technological and conceptual novelties. TOURBOT capitalizes on relevant technologies to contribute to developments in remote access to cultural heritage. Moreover, it introduces a new model of remote information browsing over the Web. A few years ago, Web browsers were quite primitive; now they are becoming increasingly sophisticated and there are already versions of browsers that allow manipulation of three-dimensional worlds. The next step in this evolution chain seems to be the provision of facilities for active physical exploration of

distant sites. TOURBOT presents a real innovation in this aspect, by introducing this concept in museums and exhibition centers.

4. Community Added Value

Information society, in the dawn of the 3rd millennium, advances far beyond the mere use of technology in well-established application areas (i.e. banking, booking, office automation, etc), by incorporating novel models of information access and management. With a clear focus on user-friendliness, accessibility of technologies to the broader public, and integration and convergence across information processing, communication and media, research and development efforts are addressing conventional applications under a new perspective. Globalization and the ever-increasing demand for transparent and personalized access to various kinds of information are the driving forces for research in this area, paving the way towards services that are universally and seamlessly accessible to all.

Access to cultural heritage

Cultural heritage is currently being under-exploited, accessed mostly through conventional channels. In a few cases, attempts are developing towards Web-based systems, to provide access to specific views of related objects. Still, such systems support limited access, by either presenting static images or low resolution virtual reality representations of sub-sets of cultural exhibits. However, advanced and immersive access to such expositions is a prerequisite for a content-rich information society. TOURBOT assists the globalization of the access to cultural exhibits, by capitalizing on established technologies, to provide tele-presence in a distant museum's premises and personalized visit of the exhibits.

Tele-presence services

The mobility of the robot allows Web visitors to choose a wide variety of view-points and enjoy tele-presence in the museum. Therefore, it provides the means to overcome the barriers of distance, limited time and restricted mobility of potential users, offering them the possibility to visit the museum through a robotic avatar. Citizens and professionals can thus benefit from the increased services offered; moreover, this can be particularly advantageous for people with restricted mobility, since it provides customized, user-friendly and full access to cultural exhibits. Besides, increased interaction capabilities with the exhibits themselves are offered to the user, which may be useful when visiting a science or technology museum. In addition to this increased interactivity, the robotic avatar can deliver high-resolution images over the Web, being thus extremely beneficial to professionals and specialists.

There is no doubt that, currently, access to cultural heritage is limited, enjoyed mostly as a by-product of holidays or other recreational activities. At the same time, it is common understanding that alternative ways should be developed in order to provide such services for remotely located exhibits. In the case of professionals that need to critically study realistic views of exhibits as part of their work, TOURBOT offers a viable alternative to the current model that requires site-by-site visits. Additionally, the robotic avatar could operate on a twenty four-hour basis, seven days a week, permitting thus more people to exploit this service at their convenience. Since TOURBOT also operates as a tour guide in a museum's premises, certain advantages are offered to museum visitors. They have the ability to individually exploit the expertise stored in the tour-guide robot, which can react flexibly to their requirements. It can, for example, offer dedicated tours on temporary focuses of the exhibition or alternatively give overview tours. As a side effect of this concept, museum visitors get acquainted with new, cutting-edge technology by easily

interacting with a complex robotic system. Therefore, technological advances are seamlessly assimilated in everyday activities.

Successful completion of TOURBOT will trigger new vistas in other, related application areas, such as large trade fairs that need to be visited by remotely located persons. Besides the cultural aspects, TOURBOT has also a clear direction in education and entertainment. Imagine, for example, exploring the exhibits of a museum, all from the comfort of your home as a diversion on a cold winter evening. You are provided with your own, personalized telescope that aims at revealing the wonders of culture; certainly an entertainment and educational possibility.

Moreover, TOURBOT addresses the cultural industries' practices and strategies that, in the cases of museums and other cultural exhibitions, have remained practically static for the last decades. Such environments are usually organised in a way that a visitor will benefit from her physical presence to get an appreciation and other information regarding the exhibits. The recent introduction of fixed terminals and other audio-visual aids in museums (Roussou and Efraimoglou, 1999) has contributed towards providing better services to visitors, and thus helped increase their market penetration.

Museum Web-visitors are recently also experiencing Internet access to images of exhibits as well as virtual reality representations of a museum's environment. However, with current technology such access is limited due to the non-interactive nature of pre-recorded images or videos, or the inherent low resolution capabilities of virtual reality worlds. The TOURBOT concept facilitates active navigation in the real museum's workspace and observation of objects of interest through the robotic avatar. At the same time, the robotic platform serves as an on-site tour guide, providing advanced services to visitors. The above-described expansions to museums' practices and procedures are expected to contribute towards a corresponding increase in the market potential of such organisations and will constitute an asset for museums and other sites for cultural heritage promotion.

5. Economic Development and Prospects

The possibilities of new paradigms in providing access to cultural exhibits offered by the information society are developing fast. In recent years we are witnessing a gradual adoption of media-technologies in various aspects of the sector, such as digital document preservation, media- and Web-presentation, graphical animations, etc. The advent of such technologies contributes towards providing media-rich presentations of cultural exhibits and consequently offering better services to museum visitors. Lately, Internet and Web-based technologies are also employed, for providing access mostly to images of exhibited objects.

Worldwide, many museums and exhibition halls are currently exploiting such technologies, aiming at increasing their market shares. The potential offered by the introduction of media technologies is immense, provided that novel and attracting services will be offered as a result of such developments.

The TOURBOT concept is in-line with the above issues, facilitating tele-presence and effective access to cultural exhibits through robotic avatars. TOURBOT capitalizes on cutting-edge technologies providing increased interaction with the site being visited. Effectively, it augments existing communication networks that are nowadays used to transmit information that is viewed via a browser, with mobile platforms at particular nodes that allow for dynamic selection and acquisition of the information to be retrieved. An extrapolation of current trends reveals that its employment in the cultural industries' practices will have a positive impact.

Furthermore, new vistas open for TOURBOT results in other exhibition sectors, such as large trade fairs. In such exhibitions, and generally in exhibitions where the items presented (content being displayed) change often in short periods of time, TOURBOT technology may be extremely valuable for providing access to distant users. In such cases it is not realistic to provide even simple, static images of the exhibits on the Web, since the dynamic nature of the exhibition's content would turn the Web pages obsolete very fast. The situation is even worse with richer representations of the exhibits (videos, virtual reality representations), since the effort needed for their development may not pay off. Alternatively, robotic avatars can be introduced in these cases to seamlessly provide access to Web-visitors to the contemporary content of the exhibition.



Fig. 1.: The Robot RHINO in the Deutsches Museum Bonn.

Concluding Remarks

The TOURBOT project addresses the development of a robotic avatar, able to provide individual access to museums' exhibits over the Internet. Such mobile agents allow virtual tele-presence in physical environments, effectively supplementing existent network infrastructure by allowing mobile avatars to replace network terminal nodes. The project goals are pursued by a consortium comprised by technology providers, brokers of technology to museums and end-users (museums). Early experiments prior to TOURBOT have been conducted at the Deutsches Museum Bonn with RHINO (Burgard et al., 2000).

TOURBOT, as currently being pursued, aims at the development of interactive tour-guide robots able to provide access to museums' exhibits over the internet. The proposed approach introduces a novel model of augmented environments, in that it allows human interaction with and workspace exploration of a remote site by means of a robotic avatar. Therefore, it extends current communication networks by allowing mobile robots to be part of the overall structure and it contributes towards the seamless integration of networks and mobile agents, an application that will soon become an integral part of our everyday lives.

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