In Proc. of the 9th Int. WWW Conf., Culture Track, Amsterdam, Netherlands, May 15-19, 2000.

TOURBOT - Interactive Museum Tele-presence Through Robotic Avatars
Project Presentation and Prospects

By

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1. Summary

TOURBOT, the acronym of a project entitled “Interactive Museum Tele-presence Through Robotic Avatars”, represents an EU-IST funded activity aiming at developing alternative ways for interactive museum tele-presence [1]. In this paper we present the project framework, with emphasis on the project goals, approach and innovations, as well as the expected benefits and results.

The overal 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 avatar in the museum (i.e. as a remote “representative” of the

user, able to carry out actions and transmit information), by accepting commands over the Web that direct it to move in its workspace and visit specific exhibits; besides, TOURBOT can also act as a flexible, on-site museum guide.

More specifically, the TOURBOT objectives are: (1) to develop a robotic avatar with advanced navigation capabilities that will be able to move autonomously in the museum's premises, (2) to implement appropriate Web interfaces to the robotic avatar that will realize distant-user's telepresence, i.e. facilitate scene observation through the avatar's eyes, (3) to facilitate personalized and realistic observation of the museum exhibits, and (4) to enable on-site, interactive museum tour-guides.

2. Project Objectives

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 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 (World Wide Web) 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.

The TOURBOT system is based on a multimedia Web interface allowing people to interact with the tour-guide system over the Internet [2] and on an on-board interface allowing interaction of the on-site visitors of the museum with the system. Using the Web interface, people all over the world will be able to tele-control the robot and to specify target positions for the system. Camera controls will be used to choose the part of the exhibition the user wants to inspect in more detail. The robotic tour-guide will possess a multimedia information base providing a variety of information about the exhibition at various levels of detail. Thus, the system will serve as an interactive and remotely controllable tour-guide, which provides personalized access to exhibits with a large amount of additional information.

Such 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 implementation of a safe and reliable navigation system for TOURBOT [3,4,5,6]. The robotic avatar will be equipped with a series of state-of-the-art sensors allowing 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's actions.

3. A New Paradigm in Remote Access

The TOURBOT project introduces a new paradigm for access to cultural heritage exhibits [7]. Through the introduction of museum visiting via a robotic avatar, it facilitates immersive tele-presence with advanced visualization 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 specifications (point of view, distance to the exhibit, resolution, etc.).

The following table summarizes the features of the project, comparing them to those of the current state of the art, namely to on-site museum visits and to conventional Web-presentation systems.

Evaluation Feature	**Cultural Heritage Access**		
	On-site museum visit	Conventional Web presentation	The TOURBOT approach
Interaction	**HIGH** The visitor is present in the museum.	**LOW** The presentation is static and pre-programmed.	**FAIR** The visitor is virtually present in the museum through its robotic avatar.
Quality of information	**HIGH** The user sees the exhibits with his own eyes.	**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	**LOW** Due to the requirement for physical presence.	**HIGH** Distance is not a barrier.	**HIGH** Distance is not a barrier.
Dynamic adaptability to changes in content	**FAIR** The visitor sees the current content of the museum but he should revisit it to see any changes.	**LOW** Reorganization of the material is required, which is a costly procedure, especially for exhibitions with frequent changes in content.	**HIGH** The visitor sees the current content of the museum. Revisiting the museum has minimal additional cost.
Comfort for the typical visitor	**LOW** The visitor should travel to the museum premises and visit it in working days and hours.	**HIGH** The visitor can see the museum exhibits from a computer at the comfort of his residence, any time.	**HIGH** The visitor can see the museum exhibits from a computer at the comfort of his residence, any time.
Accessibility to visitors with special needs	**LOW** For many users, **FAIR** For some others.	**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	**LOW** A lot of time is needed for visiting a distant museum.	**HIGH** Almost instantaneous access to any presentation.	**HIGH** Almost instantaneous access to a museum.
Financial savings for a typical visitor	**LOW** Large costs for distant museums (travel, subsistence).	**HIGH** Low cost, even for very distant museums.	**HIGH** Low cost, even for very distant museums.
Museum added value	**LOW** This is the standard model of operation.	**FAIR** The museum is advertised through the availability of such presentations.	**HIGH** The tour-guide robot becomes an exhibit by itself.

There is no doubt that, currently, access to cultural heritage is limited, enjoyed mostly when physical presence in the exhibition premises is possible. At the same time, it is desirable to develop alternatives, in order to provide such access to remotely located exhibits. In the case of e.g. professionals, who need to critically study realistic views of exhibits as part of their work, TOURBOT offers a viable alternative to on-site visits. Additionally, the robotic avatar is able to operate on a twenty-four-hour basis, seven days a week, permitting thus more people to exploit this service at their convenience.

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 robot operates in a physical environment that is perceived by the user through the robot's sensors and interacts with it using the robot's actuators. Therefore, TOURBOT contributes towards the seamless integration of networks and mobile agents for providing full user access to exhibitions. This can be important in providing services to people with special needs, who are now able to access these exhibitions from their residences.

4. Innovation

The development of such robotic avatars constitutes a contribution in a number of technical areas, such as: interfaces for mobile agent tele-control; navigation technologies; multimedia presentation systems over the Web; virtual tele-presence and tele-visit. These areas are deemed essential for the evolution of a new generation of remote access technologies, that build upon existing network infrastructure.

The Internet is a 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. In order to take full advantage of a network such as the Internet, it would be desirable to be also able to physically interact with the remote site being visited. Robots, and especially mobile robotic platforms, can extend the Internet towards an interactive system that allows actions to be carried out and dynamic information to be exchanged between distant sites.

The TOURBOT project implements precisely this 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 robotic 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.

This interdisciplinary project capitalizes on and contributes to cutting-edge technologies needed to accomplish its goals: (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 over the Web. In order to safely navigate and reliably operate, the robot

needs advanced navigation and error recovery capabilities, which have not been fully demonstrated so far for autonomous robots operating in populated environments.

The field of mobile robotics has made serious progress in recent years and the related technologies have reached a state that allows the development of mobile robotic systems able to operate autonomously in human environments over long periods of time, without human supervision. Until today, it is mainly laboratory experiments that have been carried out, illustrating the capabilities of the control systems developed. 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 only attempt to optimize the performance of the robotic system. 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 TOURBOT 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 to the abilities of the people it is guiding.

The second aspect of the project's scientific and technological objectives concerns the improved interaction capabilities of the system over the Web, as well as with people inside the museum. Current museum presentation systems provide only information at terminals, which are located close to 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 can only obtain audio information. These presentation systems are not able, in most cases, to react flexibly 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 be partially inferred from the system's interaction with them, e.g. by monitoring the kind of information requested by the users.

Furthermore, the 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 building an integrated model of the environment which serves different tasks of the robot, such as navigation tasks, scheduling tasks and interaction with users, is still an open research issue, but will be addressed in the context of the project.

In summary, the innovative aspects of TOURBOT include both technological and conceptual advances. 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, by providing 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.

5. Community Added Value

The information society, in the dawn of the 3rd millennium, advances far beyond the mere use of technology in well-established application areas (e.g. 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 being made towards developing 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, in order 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 overcome the barriers of distance, limited time and restricted mobility, offering them the possibility to visit the museum through a robotic avatar. This can be particularly advantageous to people with restricted mobility, since it provides customized, user-friendly and full access to cultural exhibits. 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.

Access to cultural heritage is currently relatively 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 access to 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 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.

Moreover, TOURBOT addresses the cultural industry's practices and strategies that, in the cases of museums and other cultural exhibitions, have remained practically unchanged for the last decades. Such exhibitions are usually organized in a way that the visitor benefits and is able to appreciate maximally the exhibits, only when he is physically present. The recent introduction of

fixed terminals and other audio-visual aids in museums [8] 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 pictures of exhibits, as well as virtual reality representations of the museum's environment. However, with current technology such services are 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 organizations and will constitute an asset for museums and other sites for cultural heritage promotion.

6. Economic Development and Prospects

In recent years we are witnessing a gradual adoption of media-technologies in various aspects of accessing cultural exhibits, 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. Many museums and exhibition halls world-wide 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. It augments existing communication networks that are nowadays used to transmit information 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 make 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 allow Web-visitors to seamlessly access the current content of the exhibition.

7. Workplan

The TOURBOT project goals are pursued by a consortium composed of 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 the robot RHINO [9], as illustrated in Fig.1.

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

In order to achieve its goals in a tractable way, the project is divided into nine work-packages (WP), with specific (sub)goals. The systematic execution of WPs and accomplishment of individual goals will result in successful completion of TOURBOT.

1. Project Management	Coordinate the joint efforts of the consortium, ensure the smooth progress of the project according to the work plan, the fulfillment of the consortium's contractual obligations and the provision of the necessary liaisons between the consortium and EU.
2. Dissemination and Implementation	Support the preparation of two project documents: the Dissemination and Use Plan and the Technology Implementation Plan.
3. Application Specification	Specification of the operational requirements and design of the application.
4. Site Information	In this WP, the site maps of the validation sites, i.e. the robot's internal representation of the museums' environment and the related multimedia information base, will be constructed.
5. Hardware Configuration	This WP involves the setup of the hardware components of the system.
6. Avatar Navigation	The objectives of WP6 comprise the development of the software modules, which will control the navigation of the robotic avatar.
7. Interfaces	This WP focuses on the design and development of the Web and on-board interfaces.
8. Integration	WP8 includes the integration of all parts to a complete system, and lab tests. Their results will enable the final tuning of the complete system.
9. Assessment and Evaluation	The assessment and evaluation of the complete system on site, i.e. in the real museums' environment, will validate TOURBOT by testing the system reliability, safety and efficiency under real conditions.

A preliminary plan of the TOURBOT system architecture is illustrated in Fig. 2. It shows the various system modules and the communication links that interconnect them. As can be observed, there are two basic system components: (a) the mobile platform, including the sensors, navigation software (SW) and processing & control unit, and (b) the off-board workstation that has access to the information base and also administers the Internet connection to remote users.

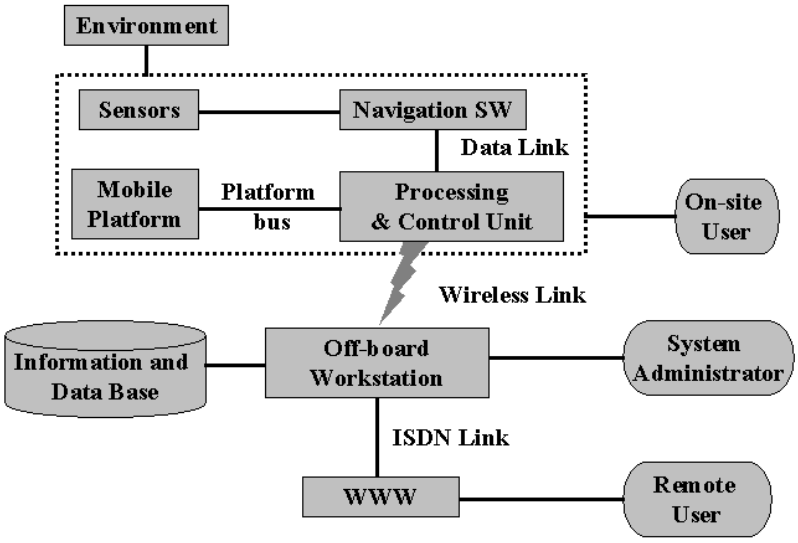

Fig. 2. TOURBOT system architecture.

8. Concluding Remarks

The TOURBOT project is aiming 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.

Acknowledgements

We would like to acknowledge the financial support of the EU-IST program to the TOURBOT project. The contribution of all participants in the TOURBOT consortium and, especially that of Lena Gaga, Pantelis Georgiadis, Elias Hatzis, Costas Constantinides, Mark Moors, Wasilios Ntallis, Esther Guderley, Andreas Lapourtas, Yiannis Stavrinos, Dimitris Ballas, Magda Syrrou and Heleni Grigoriou is greatly appreciated.

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