Experiences from the Use of a Robotic Avatar in a Museum Setting

Maria Roussou[1], Panos Trahanias[2], George Giannoulis[1], George Kamarinos[1], Antonis Argyros[2], Dimitris Tsakiris[2], Pantelis Georgiadis[2], Wolfram Burgard[3], Dirk Haehnel[3], Armin Cremers[4], Dirk Schulz[4], Mark Moors[4], Elias Spirtounias[1], Mika Marianthi[1], Vassilis Savvaides[5], Alexandra Reitelman[6], Dimitrios Konstantios[7], Andromachi Katselaki[7]

[1]Foundation of the Hellenic World
Poulopoulou 38, 11851 Athens, Greece

[2]Institute of Computer Science
Foundation for Research and Technology – Hellas
71110 Heraklion, Crete, Greece

[3]Dept. of Computer Science, University of Freiburg
79085 Freiburg, Germany

[4]Dept. of Computer Science III, University of Bonn
53113 Bonn, Germany

[5]THEON Mobile Platforms S.A.
Kanari 5, 15344 Glyka Nera, Greece

[6]Deutsches Museum Bonn
Ahrstrasse 45, 53175 Bonn, Germany

[7]Byzantine and Christian Museum of Athens
Vas. Sophias 22, 16344 Athens, Greece

{mr@fhw.gr, trahania@ics.forth.gr, ggg@fhw.gr, kamari@fhw.gr, argyros@ics.forth.gr, tsakiris@ics.forth.gr, georgiad@ics.forth.gr, burgard@informatik.uni-freiburg.de, haehnel@informatik.uni-freiburg.de, abc@informatik.uni-bonn.de, schulz@informatik.uni-bonn.de, moors@informatik.uni-bonn.de, ejs@fhw.gr, mathi@fhw.gr, vsavvaides@efagroup.gr, eule.dmb08@real-net.de, protocol@bma.culture.gr}

1. 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. Lately, Internet and Web-based technologies have been employed for providing access, mostly to images of exhibited objects. In few cases, the incorporation of higher-end technology, such as virtual reality, artificial intelligence, or robotics, is explored. In this paper we present such an effort, the TOURBOT project (an acronym for TOUr-guide RoBOT), which emphasizes the development of alternative ways for interactive museum tele-presence, essentially through the use of robotic "avatars", and comment on the experience gained from its use in a museum setting.

Keywords

Access to cultural content, autonomous mobile robots, museum tele-visiting.

2. INTRODUCTION

Mobile robotic technology and its application in various sectors is currently an area of high interest and research in this field promises advanced developments and novelties in many aspects. Recent events, such as the mission of a mobile robot on Mars, provide spectacular examples of mobile robot applications that fascinate and attract public attention. On a more "earth-bound" level, applications of mobile robotic technology in public spaces can be found in a field that we can informally term "museum robotics".

A few museums in Europe have already been involved in projects that use robots in their spaces, as for example, the *Museum für Kommunikation* in Berlin (Germany), the *Technorama* in Winterthur (Switzerland), the *City of Kids* in Genoa (Italy) or even experimental art installations in museums such as the *Ars Electronica Center* in Linz, Austria. This indicates that there is both interest and perhaps a need in obtaining and using robots in museums. Presently, the approach of some of these museums is characterized by attempts to assess and evaluate the use of museum robots, which are expected to clearly affect the future deployment of robots in museum environments.

The TOURBOT project, presented in this paper, explores this new direction through its attempt to incorporate robotic "avatars" in a museum environment. TOURBOT, an acronym for TOUr-guide RoBOT, is essentially a collaboration between museums, technology providers, and brokers of technology to museums, that emphasizes the development of alternative ways for interactive museum tele-presence [10,13,14]. 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.

3. DESCRIPTION OF TOURBOT

The TOURBOT project, a research and development activity entitled "Interactive Museum Tele-presence Through Robotic Avatars", introduces a new approach to tele-presence and the distance observation of exhibits.

The original objectives of the project included the following:

- To develop a robotic avatar with advanced navigation capabilities that will be able to move (semi)autonomously in a museum's premises,
- To develop appropriate web interfaces to the robotic avatar that will realize distant-user's telepresence, i.e. facilitate scene observation through the avatar's eyes,
- To facilitate personalized and choice-driven access to information about museum exhibits, and enable on-site, interactive museum tour-guides.

The above were realized through combined research and development on many levels. The outcome of the research has resulted in the development of a mobile autonomous robot that serves as a personal guide, with a number of capabilities and a great deal of knowledge (Fig. 1).

Through the Internet the autonomous mobile robot lends its eyes to the users, scanning for the works exhibited and providing audio, textual, and even photographic information about them. Each user is also able to tele-control the robot and direct it to visit exhibits of interest, deliver a complete guided tour, or perform other actions of interest.

Figure 1: 'Lefkos', the TOURBOT project's robot, in the museum exhibition space.

If the users are physically present at the exhibition, the TOURBOT robot acts as an on-site guide. Using advanced robotic systems, it is possible, wherever we happen to be, to enjoy tele-presence in a Museum that is equipped with such a robot. In other words, we can visit and closely examine, by means of our

representative, the actual exhibition site, and not just a virtual representation of it.

By remote controlling the robot, we can direct it to specific exhibits or any other point in its workspace, and see through its eyes (by means of its cameras) the exhibits that interest us, examine them as closely as we wish, obtain information about them and photograph them, without this requiring our physical presence there.

In order to realize the TOURBOT system, a multimedia Web interface has been developed to allow people to interact with the tour-guide robot over the Internet [8]. 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. Furthermore, in a similar fashion, an on-board interface facilitates interaction with on-site visitors of the museum. 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 [2,5,11]. The robotic avatar is equipped with a number 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.

From all the above, it becomes evident that a mixture of hardware and software technologies and platforms realizes the TOURBOT system. The integration of these components into one, smoothly operational system has been a challenging task. It has been achieved by adopting a procedure, generally known as continuous or incremental system integration. According to that, components are first integrated into subsystems, subsystems are then combined into functional units and then functional units are integrated into the overall system. Careful consideration of what the TOURBOT system consists of, gave rise to a concrete incremental plan, which was subsequently implemented to result in the final, TOURBOT system. During all phases of the integration procedure, extensive laboratory tests were performed in order to fully verify the functional components at this level. The complete system was also thoroughly tested in laboratory conditions, before its introduction and operation in the museum setting.

4. WHY ROBOTS IN THE MUSEUM?

In the last couple of decades, museums have been evolving their modes of operation 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 [1]. 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 [12].

Under this revised perspective, access to cultural exhibits is viewed as a central issue in museums and exhibition galleries. 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. Consequently, as the advancements of technology start reaching museum professionals, museums begin to look at new ways for providing access to their collections and to their activities in general, with a technological point of view.

Most museum technology applications involve the creation of archives, libraries, image galleries but also tools of virtual presentation of collections and 3D representations [9]. Internet and web-based technologies have been employed for providing access, mostly to images of exhibited objects, while there are 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 [4]. In a few cases, the incorporation of higher-end technology, such as virtual reality, artificial intelligence, or robotics, is explored [7].

However, although significant progress in these directions has been realized 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-digitized 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", that is, the environment provided not only by the static pre-constructed images and accompanying information of the digitised collections but also the "aura", the living and changing space where other humans are present.

Being aware of these limitations, the TOURBOT project, through the introduction of museum visiting via a robotic avatar, has attempted to introduce a new paradigm in providing access to cultural heritage exhibits [6]. This paradigm aims at facilitating 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).

A robotic avatar in a museum can introduce a novel model of augmented environments, in that it allows human interaction with and workspace exploration of a remote site. 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 public places.

In the case of professionals who need to critically study realistic views of exhibits as part of their work, the use of robots in such a

way may offer a viable alternative to the current model that requires on-site visits. Additionally, a robotic avatar can operate on a twenty four-hour basis, seven days a week, permitting thus more people to exploit its services at their convenience.

Compared to current approaches employed to provide services to people with special needs, the use of specialised robots could present a viable alternative, offering 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.

If perceived as an interface to remote access, a robotic solution extends current communication networks by allowing mobile robots to be part of the overall network infrastructure. 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, robots used as interfaces can contribute towards the seamless integration of networks and mobile agents for providing full user access to exhibitions and at the same time act as an international means of promoting cultural treasures on display.

5. THE PILOT APPLICATION: TOURBOT IN THE MUSEUM

The TOURBOT project was recently presented to the public at a special event held by the project consortium at the Foundation of the Hellenic World (FHW). This was the first major public event for TOURBOT and it took place at the Foundation's *Hellenic Cosmos* Cultural Center in Athens in May 2001.

The robot, named 'Lefkos' after the son of Talos, mythical "robot" of antiquity, became the resident tour-guide for one week in an exhibition site of 2,000 square metres where the exhibit on 4000 Years of Hellenic Costume is currently presented (Fig. 2, 3, 4). The FHW's costume exhibition is an example of a rich media environment, where the latest audiovisual technology is employed in order to present historical content. The exhibition is set-up in a theatrical fashion, due to its atmospheric lighting, the combination of real objects, costumes, video, multimedia projections, and the ambient music and sound. It was exactly this environment and atmosphere that the TOURBOT project wished to convey to remote visitors through the robot's journey within the space.

During the trial week, Lefkos was assigned with the task to take museum guests on guided tours of the exhibition or present them specific exhibits upon request. In parallel, Lefkos gave web visitors the opportunity to be tele-present at the exhibition site, to take part in its guided tours and, to direct it to the exhibits that they wished to view.

The robot operated at the exhibition site non-stop for one week, as a pilot application of the TOURBOT project. During this pilot application, the total operation time of Lefkos was approximately 50 hours, covering a distance of more than 15 kilometers.

A large number of on-site visitors of all ages interacted with the robot while following it around on the tours. Lefkos served on-site visitors in 39 different sessions. During these sessions, Lefkos, often had to conduct a tour among crowds of people, who blocked its sensors, while the random position of the visitors affected the robot's perception of the workspace, blocking passageways and drawing the robot to un-prescribed areas. Lefkos quickly detected such situations and made its way towards the exhibits, providing safe and reliable navigation, through crowds of people, for many hours. Of particular significance is the fact that the robot, when unhindered, moved at approximately walking speed.

Figure 2: Visitors tour the FHW costume exhibition with the help of the robot during TOURBOT's first trial and event in May 2001.

In this same period, approximately 1200 web users observed the exhibition through the eyes of Lefkos and more than half of these web visitors got to control the robot.

The informal observations gathered during this trial period were significant both on a technical level (to correct technological shortcomings) and as indicators of the acceptance of the robot by museum visitors and staff.

Robots are for the most part new to museum visitors who will either become curious and wish to explore them or treat them with fear and consequently reject them. Thus, issues such as the outer appearance and design of the robot as well as its way of addressing visitors (inclusion of emotional factors, such as the formal/informal tone of the robot's voice, etc) showed to play an important role in the acceptance of the robot as a museum guide. Older visitors, who are not used to encounter advanced technology in a museum context may feel uncomfortable at the appearance of a robot while, on the contrary, younger visitors experience the appearance of a museum robot with enthusiasm.

Museum staff seemed positive toward the inclusion of the robot in their everyday mode of operation. However, for a permanent installation, the inclusion of the robot must be planned and constructed as a supplement and assistance to the museum staff/guards with respect to guided tours and answering of questions within the museum. If not, the robot could be considered as a potential threat and would face little chances to be accepted by the staff. The museum management may have great difficulties to consent to include a robot on a day-to-day basis under these circumstances.

The trial succeeded to attract wide media coverage both on major television broadcast stations, newspapers, but also specialised journals and magazines in the fields of culture and informatics (Fig. 5). An important outcome of this first public showing of TOURBOT is that individuals of various disciplines, educational institutions, museums, technology companies, and policy makers were present at the event, participated in the trial and expressed a very strong interest in the possibilities that an endeavour such as TOURBOT entails and the possibility of permanent introduction of similar robots in cultural and educational organizations.

Early experiments prior to this first TOURBOT trial event were conducted at the Deutsches Museum Bonn with RHINO [3]. Before the end of 2001, the project will perform two more pilot studies at the other two museum sites participating in the consortium, the Deutsches Museum Bonn and the Byzantine and Christian Museum of Athens.

6. ADVANCING ROBOTIC TECHNOLOGY FOR USE IN PUBLIC SETTINGS

The very objective of a project that seeks to develop and incorporate a robotic avatar that allows virtual user presence in an exhibition, constitutes a technological advancement 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 [13].

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 robotic navigation capabilities for complex indoor environments (museum premises). The user interface allows 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 been developed in the course of the project.

The field of mobile robotics has made serious progress in 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.

Figure 3: 'Lefkos' guides FHW visitors through the exhibition during the first trial week in May 2001.

A second aspect of scientific and technological advancement 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 has been to develop a flexible and mobile information agent, which provides individual access to the information stored in a multimedia

information base. This information base includes graphics, images, spoken and written text as well as audio. The TOURBOT system communicates the information to the user, in conjunction to the current exhibit that is presented.

In terms of technology integration, the TOURBOT system uses 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 advancements proposed through the TOURBOT project's approach 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 introduces this concept in museums and public venues.

Figure 4: The TOURBOT robot leading the tour through FHW's "4000 years of Hellenic Costume" exhibition.

7. SOCIAL AND ECONOMIC IMPLICATIONS

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.

The mobility of the robot allows Web visitors to choose a wide variety of viewpoints 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.

It is expected that 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. You are provided with your own, personalized telescope that aims at revealing the wonders of culture; certainly an entertainment and educational possibility.

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.

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.

Figure 5: Front page of "Metrorama" newspaper showing young visitors touring the FHW exhibition with "Lefkos" during the 1-week trial period.

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.

8. CONCLUSIONS

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.

In summary, the TOURBOT project, as currently pursued and described in this paper, aims at the development of interactive tour-guide robots able to provide this kind of 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. In this sense, 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.

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.

However, as every innovative application just being introduced and tested, many issues and challenges remain to be seen. Some of these open issues that call for further examination can be summarized in the following questions:

- How to adapt this technology in order to fit the long-term operational needs of a museum.
- How to achieve the maximum level of compatibility and adaptability of the new robotic technology in different museum cases and diversified exhibition spaces, thus providing a flexible technological standard that will facilitate the wider adoption of the use of this novel technology among other museums and similar organizations.
- How to adapt the administrative structure and the operational methods of the museum in order to smoothly and quickly integrate the new technology with a low cost.
- How to evaluate the system in terms of its impact to the main function and objectives of the participating museum (financial impact, accessibility, marketing and promotion, impact on visitor demographic, etc.)
- How to evaluate the content and educational added value of the specific interface and technology to museum visitors, and generate a feedback to the technology developers in order to

improve in the future the robotic avatars and adapt further to the needs of the users.

ACKNOWLEDGMENTS

The TOURBOT project is being carried out by a consortium of seven partners, representing technology providers, brokers of technology to museums and end-users/museums. Specifically, the members of the TOURBOT consortium are: the Foundation for Research and Technology - Hellas, the University of Freiburg, the Foundation of the Hellenic World, the University of Bonn, THEON Mobile Platforms S.A., the Deutsches Museum Bonn and the Byzantine and Christian Museum of Athens. The project has been partially funded by the "Information Society Technologies" Programme of the European Commission. In addition to the contribution of all participants in the TOURBOT consortium, we wish to greatly acknowledge the contribution of Mandy Koliou, Lena Gaga, Elias Hatzis, Costas Constantinides, Wasilios Ntallis, Esther Guderley, Andreas Lapourtas, Yiannis Stavrinos, Dimitris Ballas, Magda Syrrou, and Heleni Grigoriou.

REFERENCES

[1] M.M. Ames. *Museums, the Public and Anthropology*. L.P. Vidayathi (Ed). Vancouver: University of British Columbia Press, 1986.

[2] A.A. Argyros and F. Bergholm. Combining Central and Peripheral Vision for Reactive Robot Navigation. In Proceedings *of Computer Vision Pattern Recognition Conference (CVPR'99)*. Fort Collins, 1999.

[3] W. Burgard, A.B. Cremers, D. Fox, D. Haehnel, G. Lakemeyer, D. Schulz, W. Steiner, and S. Thrun. Experiences with an Interactive Museum Tour-guide Robot. *Artificial Intelligence (AI)*, *114 (1-2) 2000.*

[4] S. Dietz. Curating (on) the Web. In D. Bearman & J. Trant (Eds.) *Museums and the Web98 Proceedings*. CD ROM. Archives & Museum Informatics, 1998.

[5] D. Fox, W. Burgard, S. Thrun, and A.B. Cremers. Position Estimation for Mobile Robots in Dynamic Environments. In Proc. of the *National Conference on Artificial Intelligence (AAAI)*, 1998.

[6] D. Konstantios. Cultural Heritage-Modern Methods of Confrontation. In Proceedings of *A΄ Cultural Congress of Ioannina,* 1993.

[7] M. Roussou and Dimitris Efraimoglou. High-end Interactive Media in the Museum. In *Computer Graphics*, New York: SIGGRAPH 99.

[8] D. Schulz, W. Burgard, A.B. Cremers, D. Fox and S. Thrun. Web Interfaces for Mobile Robots in Public Places. *IEEE Magazine on Robotics and Automation*, 1999.

[9] S. Thomas and A. Mintz. *The Virtual and the Real: Media in the Museum*, American Association of Museums, 1998.

[10] TOURBOT website, http://www.ics.forth.gr/tourbot. Last update: Jan. 31, 2000, consulted on September 15, 2001.

[11] P.E. Trahanias, S. Velissaris and S.C. Orphanoudakis. Visual Recognition of Workspace Landmarks for Topological Navigation. *Autonomous Robots Journal*, 1999.

[12] G. Poisson. *Les Musées de France*. Presses Universitaires de France, 1950.

[13] P. Trahanias et al, "TOURBOT: Interactive Museum Telepresence through Robotic Avatars," In 9th Intl. World Wide Web Conf. Culture Track, Session A-2: Museums on the Web - Case Study, Organizer: A.M. Ronchi, Amsterdam, May 15-19, 2000.

[14] G. Giannoulis et al, "Enhancing Museum Visitor Access Through Robotic Avatars Connected to the Web," in Proc. Museums and the Web 2001, Seattle, USA, March 14-17, 2001.