

# *Mercator Atlas Robot: Bridging the Gap* between Ancient Maps and Modern Travelers with Gestural Mixed Reality

Gustavo Marfia, Marco Rocchetti, Marco Zanichelli  
Department of Computer Science and Engineering  
University of Bologna, Italy  
Mura A. Zamboni 7, 40127 Bologna  
{roccetti, marfia, zanichelli}@cs.unibo.it

Angelo Varni  
Department of History, Geography and Anthropology  
University of Bologna, Italy  
P.za San Giovanni in Monte 2, 40124 Bologna  
angelo.varni@unibo.it

**Abstract**—The advances made in both Human Computer Interfaces (HCIs) and in Mixed Reality (MR) systems during the past decade have opened the gates to countless new applications in fields ranging from applied science to fine arts. In fact, computers have evolved from boxes with which it was possible to interact solely using mice, keyboards and monitors, to become devices that permeate and intersect with the space where human beings live and move, being now capable of interpreting their gestures as long as mixing with and contain the objects that surround them. Such richness has been widely employed within new and engaging computer games, where it is now possible to play while moving and connecting to the virtual characters that compose mixed worlds, directly from home. However, such potential is far from being fully exploited everywhere. In public spaces such as museums and exhibitions, for example, new means of interaction and mixed worlds could contemporarily reach two goals: (a) augment the user experience, and, (b) increase visitors' accessibility to all artifacts. In this work we show how both goals have been achieved with the devise and implementation of *Mercator Atlas Robot*, an application that supports the exploration of *Mercator's World Atlas*, the book that first has wholly described the world through a collection of maps. In particular, we here describe how the combination of a gestural interface and mixed reality paradigms has let visitors travel through *Mercator's* volume in a simple and intuitive way. All this has been possible with only low cost, off-the-shelf, hardware, where all the *intelligence* is entirely based on software components.

**Keywords** – *Mixed Reality; Gesture Recognition; Human Computer Interfaces; Gerardus Mercator; Poggi Palace Museum Bologna.*

## I. INTRODUCTION

Since their first birth, interactions with computers have been commonly regarded as a privilege reserved to trained users, as the correct utilization of output and input hardware devices (e.g., keyboards, monitors, etc.) required a literacy that was not readily available to all. In fact, understanding how it could be possible to input the desired information to a computer and interpret its output has for long been a burden that weighed on the sole shoulders of human beings. Aware of such important impediment, computer designers have constantly researched for technological advancements that could simplify the flow of information in both directions.

In the output direction, important breakthroughs (usually associated to significant processing power increments) have been achieved with the development and refining of Graphical User Interfaces (GUIs). Input ones, instead, have typically been correlated with innovations made in sensor and communication technologies, and have resulted from the devise of novel hardware control devices (e.g., mice, joysticks, etc.), capable of easing and speeding up the procedures required to enter information.

Now, after long decades where the semantics of human computer interactions could be classified as computer-centric, as human beings were required to learn how to interact with the objects that were represented by digital systems, we entered a new era where interactions are progressively becoming human-centric, as computers can now adapt to: (a) recognize human languages at large, and, (b) process and display real objects. In fact, computers, with the aid of advanced sensor technologies and software systems, can now *understand* humans and create representations of the world environments as a composition of digital and real objects. Sounds, taps, gestures and movements are now part of the vocabulary understood by many digital systems, including smartphones and gaming consoles, which are also now capable, in the majority of cases, of displaying accurate representations of reality.

The idea that digital systems could serve the role of mediators between users and real environments has been present for long. Already in 1994 Milgram and Kishino coined the term Mixed Reality (MR) to indicate those systems whose displays fitted *anywhere between the extrema of the virtuality continuum, where the virtuality continuum extends from the completely real through to the completely virtual environment* [1]. Technological advancements, however, have gone further away than probably expected in 1994, as today computers have also broken social barriers and are not anymore seen as machines that can be solely understood and controlled by *geeks*, but as tools that can be found and controlled by anyone, even computer illiterates, and speak anyone's language, in any type of environment [2], [3].

In such type of scenario, digital systems can be proficiently put to good use to serve as tools that, in transparent and natural ways, support the accessibility and the exploration of those objects and places that, otherwise, could not be reached.

Computers, hence, can be thought of as the proxies of any communication and interaction that occurs between any user and any object, in any place.

All this becomes even truer in the specific, but important, case of places like museums and exhibitions, where often precious artifacts are preserved that cannot be exposed to the public for some reason due to the fact that those objects could not be readily or easily available, observable or even touchable [4]. With reference to this specific context, we will here describe how the digital technologies available in the 21st century can aid the exploration process of a volume that served the same purpose four centuries ago. In fact, the volume, a printed copy of Mercator's World Atlas, which dates back to 1630, aided both geographers and travelers in bringing light on areas of the earth that were poorly known, during its almost four hundred years of history. Now, the scope of our work has been that of using advanced gestural and mixed reality technologies to bring visitors close to this precious artifact as: (a) it represents a unique piece of historical and geographical knowledge, and, (b) due to its fragility, the volume cannot be left freely accessible to all, with the result that its pages and beautiful illustrations cannot be appreciated as a curious and fascinated visitor would instead desire. To accomplish both of the listed goals, we devised a novel application, named *Mercator Atlas Robot*, that: (i) brings the pages of Mercator's volume to the sight of all interested visitors, and, (ii) provides an intuitive and tangible way of browsing through the pages of the volume; (the term Robot is here simply evocative of the fact that through automatic means the Atlas pages are brought to the attention of visitors).

All this was performed with the devise and implementation of a system that comprises a gestural interface and a mixed reality display. In particular, the gestural interface served the purpose of letting users navigate through the volume's pages, which could be chosen and turned with simple and intuitive gestures, thus requiring no training at all. The mixed reality display, instead, provided the means by which users entered to be part of a fantastic world that also included their personal video representation while virtually holding Mercator's ancient maps, thus revitalizing, through their interactions and their experience, the metaphor of Atlas holding the world. Now, anticipating here what are the main contributions of this work:

(a) To the best of our knowledge, differently from any previous work pursuing similar purposes, our system is solely based on low cost, off-the-shelf devices, thus not requiring any complex, expensive or even specific hardware, whereas all the intelligence is pushed onto the software side;

(b) We devised and implemented a system that creates a direct and transparent *interface* between a museum exhibit and its visitor, thanks to its simple and intuitive gestural interface capable of recognizing the sensible areas that are activated by visitors through waving arms in the air;

(c) We declined a novel mixed reality paradigm where past information (Mercator's Atlas) and contemporary means of exploration (i.e., gestures and virtual graphical elements) merge all together.



Figure 1. Atlas on the frontispiece of Mercator's volume (Courtesy of University of Bologna).

The remainder of the paper is organized as follows. In Section II we sketch the historical background and the rationale behind the chosen combination of gestural and mixed reality technologies. We then provide an overview of the system in Section III. Specific technical issues and their solutions are discussed in Section IV. We finally conclude with Section V.

## II. BACKGROUND AND VISUALIZATION CHOICES

The importance of Mercator's work for both cartography and exploration is simply witnessed by one fact and one anecdote, which we will shortly describe. The fact is that Mercator's contribution to cartography, performed in the Flanders of the 16th century, has been of such relevance that the map projection, that takes his name, is still commonly in use in the maps that are printed in the 21st century. The anecdote, instead, is that the World Atlas naming of any complete collection of world maps after the Greek mythological Titan Atlas can be ascribed, from the publishing of the first 1595 edition thereafter, to Mercator. More in detail, Mercator dedicated the last 20 years of his life to the project of publishing a comprehensive collection of World maps, to be named World Atlas. The first edition of his work was printed in 1595 and was never seen by its author, as he passed away in 1594. However, the notice of the high quality, the completeness and the cartographic novelty of this volume, which comprised 111 exceptional maps for that time, spread through Europe and led to the printing of many successive editions during the years that followed. All maps were realized utilizing the famous Mercator projection technique, which consisted in a *cylindrical map projection in which the meridians and parallels of latitude appeared as lines crossing at right angles and in which areas appeared greater,*



Figure 2. *Susanna* hall (Courtesy of University of Bologna).

*farther from the equator*. This technique was already known at the time when the first edition was printed, as its author first employed it in his *ad usum navigantium*, a volume composed of 18 maps, published in 1569. However, it was only in his last piece of work that Mercator decided to engrave the figure of Atlas observing, and not holding, as it is usually represented in mythology, the world (Figure 1). While different explanations regarding this choice are available in literature, the most widely accepted one approaches it to a metaphor where the rehabilitated Titan represents the mankind that now, through Mercator's work, can control and explore the world [5].

After this jump in the past, that let us put our work into context, the opportunity of working with Mercator's masterpiece came from the discovery of one of the tenth edition reprints, dated 1630, at the library of the Department of Physics of the University of Bologna. While this discovery was at large greeted for its importance, it also immediately posed the problem of how such masterpiece could be made available to the whole community, as its preservation prevented from planning any regular consultation of the volume. The idea that took shape, hence, was that of displaying the volume utilizing advanced information and communication technologies, in an appropriate environment. The right environment was found in the *Susanna* hall of the Poggi Palace Museum of Bologna (Figure 2), institution that collects the most remarkable of the eighteenth century Bolognese scientific and medical laboratories, and whose scientific vocation is also witnessed by the opening in its premises of the Institute of Sciences founded by Luigi Ferdinando Marsigli in 1711. Now, within the introduced context, the aim was that of finding a way of letting visitors to explore Mercator's maps that exceeded those offered by the publication of their digital copies on a website or a book. Respecting his pioneering cartographic work that contributed to let mankind dominate the world through exploration and discovery, we wished to provide an experience that would keep intact such spirit. In particular, we thought that, in the suggestive context provided by the Poggi Palace Museum,



Figure 3. Browsing Mercator's maps.

visitors should be put in the condition of exercising the same curiosity and feel the same fascination that navigators and explorers felt centuries ago when staring at Mercator's maps.

After a thorough analysis, that involved the teamwork of different professional figures, which included a historian, an art director, a museum curator and two computer scientists, we narrowed down the technological means that could help us meet such requirements to gestural interfaces and mixed reality systems.

In fact, inspired by the metaphor thought by Mercator, with his representation of a thoughtful Atlas that holds the planet earth and looks at its different parts, we wanted to put visitors in the condition of living such metaphor, thus holding the world, while exploring its maps. However, just as it happens to true explorers that are equally attracted by the experience of an adventurous trip and by the final arrival to destination, we wished to propose a system that would raise a feeling of fascination for the beauty of the exposed maps as long as for the means provided to browse them. This led us to the creation of a gestural interface that required users to raise and wave their arms, while discovering and reaching the descriptions of new terrains (Figure 3).

Similarly, we regarded the use of mixed reality technologies as the means that most correctly could present the artifact to visitors. Once again, inspired by Mercator's new interpretation of Atlas's (i.e., mankind) role, and somewhat reinventing in contemporary terms the spirit of the Renaissance, which finally posed after many centuries man at the center of historical happenings, we wanted to let visitors observe an interface where they appeared and blended together with the precious maps. Hence, visitor's figures, and particularly their hands, became an integral and visible part of the system at work, thus once more rejuvenating the original spirit that we carefully attempted to respect in our design choices.

### III. THE EXHIBIT AND ITS ARCHITECTURE

Before getting into the details of the architecture that was implemented and utilized in the system that was displayed at

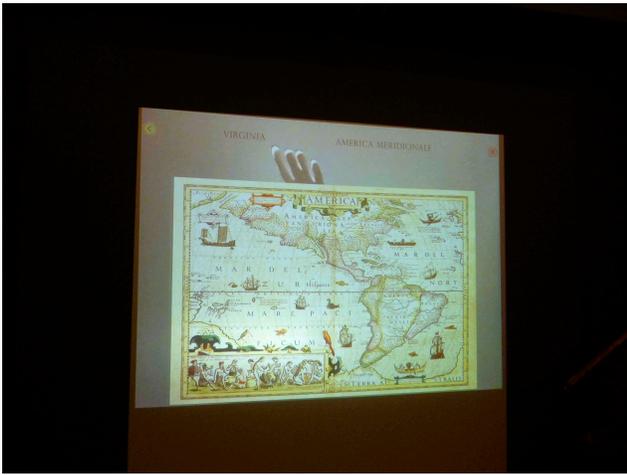


Figure 4. The Exhibit (Courtesy of University of Bologna).

the Poggi Palace Museum, we wish to anticipate here what was the underlying technical choice that has driven all the exhibit's implementation decisions. The system, which we named *Mercator Atlas Robot*, was, in fact, based on very non-specific hardware components, that comprised a simple \$20 off-the-shelf webcam and a MS Windows OS-based notebook. This choice was dictated by two principles. The first is that we aimed at pushing the complexity of our implementation as much as possible on the software side, as this made the application more easily portable and simpler to install in future new sites, renewing the compliance to a principle that we already pursued before [6], [7]. The second is that we wished to obey the original design principle that computers should keep as transparent as possible, leaving space to interactions and explorations that resulted as natural as possible. A representation of a running example of the exhibit is depicted in Figure 4, where we can identify three main components. The first component is one of Mercator's maps that occupy two pages of an open volume, just as in reality. The second is a visitor's hand, while moving in the space above the map. Finally, the third, are the *sensible areas* that lie above the map and that are represented by: (a) the regions that can be reached from that page (e.g., Virginia and South America, in this particular case), and, (b) two buttons, a *back* and *home* button (at the top leftmost and rightmost corners, respectively), that recall the mode of interaction users are accustomed to with web browsers. Depending on the sensible area that is reached and "virtually touched" by a visitor's hand, two possible animations can occur. In particular, if the hand selects a map (e.g., Virginia or South America in Figure 4): (a) the map's name turns blue, (b) a Google-maps-like pin falls from above on the selected region, and, (c) an animation flips the volume from the current to the next page, returning the chosen map. If, instead, the hand selects the *back* or *home* button, the animation turns the Atlas to the previous page, returning the preceding map (e.g., the planisphere if the current page was that depicting a single continent) or the frontispiece, respectively. This said, we delineate the software architecture of *Mercator Atlas Robot* in Figure 5, where we also reiterate that only a simple webcam and a notebook are needed. We employed three different modules/libraries: a first that provides support for graphical

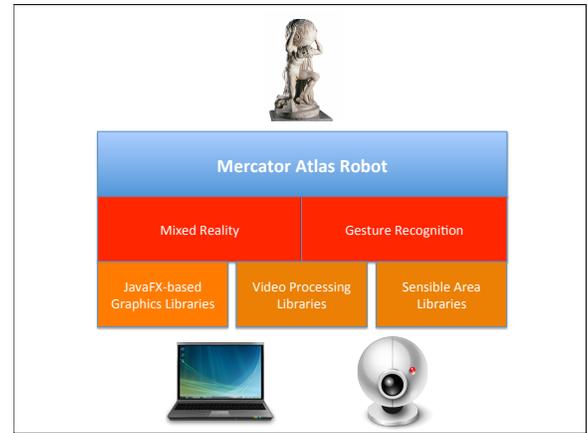


Figure 5. System architecture.

animations and is based on the use of JavaFX [8]. Two additional libraries were also exploited that have been developed as original software modules implemented in our lab [6], [7]. The first one processes the incoming video stream capturing visitors' bodies in real-time, while the second one deals with the precise recognition of gestures when sensible areas are activated by visitor's hands waving in the air. In particular, as shown in Figure 5, the JavaFX graphics libraries are the main ingredients used to build the mixed reality portions of our system and all its visual effects, while the video-processing module manages the display of the video stream (originated from the webcam) that captures the visitor's waving hands. Finally, precise gesture recognitions are achieved based on the use of original algorithms that exploit sensible areas as described in [6]. In the following, we provide additional details regarding how the communication of these different software components was managed.

#### IV. TECHNICAL ISSUES WITH SOLUTIONS

As anticipated, the experience that we wished to offer to visitors provided us with application design guidelines that led us to merge two different technologies, gesture recognition and mixed reality, specifically. In practice, for each action that was performed correctly (e.g., touching a virtual object/button), the displayed visualization changed, showing a new graphical element (e.g., a new map) corresponding to the selected item. However, this was not performed simply transitioning from one image to another, but was provided implementing a trail of animations that first comprised the fall of a Google-maps-like pin on the map and then a realistic flip of a book's page. This type of approach posed two problems. The first one amounts to devise an adequate strategy to manage the graphical rendering of animations, whereas the second one is a more general problem concerned with the smooth running of our system. In the following we will sketch the solutions that we provided to such problems and conclude describing the application logic that supported an easy navigation of the maps.

As already mentioned, the first technical problem we dealt with has been that of choosing the software platform that best could support an easy integration of graphical animations effects with the gesture recognition APIs we developed in Java

[6]. To this aim, we opted for the JavaFX libraries, which also provide guarantees of stability and portability, as they have been first released at the end of 2008 and are compiled in Java bytecode. The rationale for our choice is as follows. The starting point for almost all JavaFX applications is based on the idea of defining *nodes* (i.e., graphical objects) and placing them on the graphical scene. After this task is accomplished, it is possible to apply transformations to the graphical objects, as well as more sophisticated visual effects, like clipping or animations. In particular, transformations are based on graphical object translations where the coordinates change according to specific rules. Basically, JavaFX support the following type of transformations: translation, rotation, scaling and shearing. The animations that were hence included in Mercator Atlas Robot are based on translations, rotations and shearing. For example, the fall of a Google-map-like pin, upon selection of a given map, is simply implemented with a translation. Flipping pages, instead, is implemented as a complex combination of a translation, a rotation and a shearing and has been obtained modifying the libraries provided in [9]. A second major problem was that of defending our system against deadlocks. In fact, although JavaFX animations are easily integrated in Java-based applications, a not adequate implementation of the interoperability between JavaFX and other software components could lead to deadlocks. Basically, JavaFX is not thread safe and hence all its animations are thought as of running on the JavaFX processing thread, thus preventing a JavaFX application to interact with a thread other than its main processing one. We overcame this problem implementing the application logic on the Java side, but managing any interaction between Java and JavaFX by means of an Observer design pattern, where, every time a series of JavaFX methods is to be invoked with a given timing, the parent Java thread waits until a notification of the completion of the current graphical operation comes, before moving on to the subsequent invocation (this is for example the case when a Google-map-like pin falls and after three seconds the page flips). As might be guessed from the description made so far, the transitions that are made possible to flip from one page to the next one are based on the principle of moving towards more detailed maps, within a given geographic region. Hence, for example, from the general planisphere it is possible to reach the Amsterdam map via a navigation that runs through the Europe map first, and then through the map of the Flanders (a specific Dutch region). A similar pattern is required to reach Morocco, through Africa, to cite just another example. The issue here is that of devising an application logic that favors a smooth running and a good overall performance of the system. We then structured the navigation through maps as based on a tree rooted at the frontispiece, whose leaves are given by the maps with a higher zoom. We implemented such tree utilizing a Java-based hash table data structure, which allowed us to limit the complexity (i.e., constant time bound) given by finding and loading all the graphical objects required at each step. While this was not a particularly critical issue in the current implementation, as the number of graphical objects included in the Mercator Atlas Robot has been limited (e.g., 20 maps plus the frontispiece), such choice will reveal its importance when extending our application to additional maps.

## V. CONCLUSIONS

We have described the design principles and the implementation of Mercator Atlas Robot, a software application publicly displayed at the Poggi Palace Museum of Bologna, March 8th to April 9th, 2012 that supports an interactive navigation of Mercator's 16th century Atlas. We solved two types of challenges. The first was that of devising an interaction design that well suits the particular context of the exhibition. We have achieved this permeating our software application with the themes of navigation and exploration as well as with the rejuvenation of the Atlas's myth. The second challenge was that of providing a catchy interface [10]. We did so blending two technologies, namely gesture recognition and mixed reality, in a unique user experience. All this was possible with no substantial investment on the hardware the composed the system, but pushing all the *intelligence* onto the software side.

## ACKNOWLEDGMENTS

Our acknowledgements go to the ALTER-NET (PRIN) project for the financial support. We thank the Poggi Palace Museum and the University of Bologna for their hospitality. This work would not have been possible without the museum assistance of Anna Addis, Massimo Donattini and Giovanna Residori.

## REFERENCES

- [1] P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," *IEICE Transactions on Information Systems*, E-77D(12), pp. 1-15, 1994.
- [2] J. Wither, R. Allen, V. Samanta, J. Hemanus, Y.-T. Tsai, R. Azuma, W. Carter, R. Hinman and T. Korah, "The Westwood experience: connecting story to locations via mixed reality," in *Proc. of the IEEE International Symposium on Mixed and Augmented Reality - Arts, Media and Humanities*, 2010, pp. 39-46.
- [3] A. Hamidian, C.E. Palazzi, T.Y. Chong, M. Gerla and U. Körner, "Exploring Wireless Mech Networks for Collaborative Augmented Reality Environments," *The International Journal of Virtual Reality*, 9(2), pp. 21-30, 2010.
- [4] T. Naemura, Y. Kakehi, T. Hashida, Y.-a. Seong, D. Akatsuka, T. Wada, T. Nariya, T. Nakashima, R. Oshima, and T. Kuno, "Mixed reality technologies for museum experience," in *Proc. of the 9th ACM SIGGRAPH Conference on Virtual-Reality Continuum and its Applications in Industry*, 2010, pp. 17-20.
- [5] M. Donattini, "Vincenzo Coronelli e l'immagine del mondo fra isolari e atlanti," *Mostra Vincenzo Coronelli e l'imgo mundi*, Longo Editore Ravenna.
- [6] M. Rocchetti, G. Marfia, A. Semeraro, "Playing into the Wild: A Gesture-based Interface for Gaming in Public Spaces," *Journal of Visual Communication and Image Representation*, Elsevier, vol. 23, n. 3, 2012, pp. 426-440.
- [7] M. Rocchetti, A. Semeraro, G. Marfia, "On the Design and Player Satisfaction Evaluation of an Immersive Gestural Game: the Case of Tortellino X-Perience at the Shanghai World Expo," in *Proc. of 29th ACM Conference on Design of Communication*, 2011, pp. 1-6.
- [8] Online: <http://javafx.com/>, last visited on March 4th 2012.
- [9] Online: <http://www.javafx.com/samples/BookPanel/index.html>, last visited on March 4th 2012.
- [10] M. Rocchetti, P. Salomoni, "A Web-based Synchronized Multimedia System for Distance education," in *Proc. of 2001 ACM Symposium on Applied Computing*, 2001, 94-98.