Using Augmented Reality Virtual Assistants to Teach the Traditional Leather Tanning Process

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Abstract— **The leather tanning process carries a high cultural value in Guimarães city. In some areas of Portugal, most of the society and its history are somehow interlaced with the history of the leather and all the associated processes of its production. There is a great lack of a "vivid" memory about the leather tanning process and its social implications. References to it in Guimarães city can be reduced to text and poor quality pictures. On the other hand, it is important to transmit to future generations the valuable role of the leather tanning in the local culture. At this point, the use of augmented reality techniques can help to illustrate interactively, expressively and with a compelling degree of immersion how this process used to be done, and help to preserve its memory. This project consisted in the development and implementation of an augmented reality application to young audiences that illustrates the ancient leather tanning process step-by-step. The resulting visualizations offer an impressive education experience that help to transfer a significant culture value of the Guimarães city.**

Keywords: Augmented reality, multimedia learning, cultural heritage.

I. INTRODUCTION

In the past, the leather tanning process used to be a very rough procedure. It was mostly a handicraft process that polluted heavily the surrounding environment, but also affected drastically the way and kind of life that workers had to have. Most of all, the traditional leather tanning process had a significant impact that transcends its economic effect, but also in terms of cultural and social values in the Guimarães city, in Portugal, from the 19th century. This means that the history of the leather tanning process is somehow interlaced with the cultural heritage values of the Guimarães city and Portugal. This cultural value must be preserved for future generations, before its memory is faded absolutely away. This preservation has been done most through pictures (old snapshots) and text, lacking a more interactive or dynamic aspect in the memory transference to people. These aspects are very important, because they can increase significantly the information apprehension by the end-user and thus the memory preservation of the leather tanning process.

Through the telling of a story that explains how the leather tanning process used to be done, the end-user might easily understand how it was. If this story is not only told but graphically illustrated step-by-step, so that the user can see it happing before them, this understanding could be enhanced. At this point, the use of computer graphics technology is fundamental in order to recreate visually what is not there anymore. If this story is narrated in loco (inside an ancient tanning processing unit) with the use of an augmented reality approach, where the end-user visualizes it through special glasses, it would help to catch his attention and thus memorize it easier, because a great level of immersion into historic facts is achieved.

This paper presents an augmented reality solution that was developed inside the scope of a project which main goals are:

- To illustrate to children how the leather used to be processed in the ancient time;
- To illustrate it according to an educational, interactive and immersive approach;
- To preserve the cultural value of the leather tanning in the Guimarães history;
- To make children have contact with new technologies.

This paper consists of seven sections. Section 2 describes the scientific background behind it, while in section 3, the scenario used in the application, and the rationale behind it, were explained. Then, section 4 describes its conceptual design. Section 5 presents the description of the technical implementation, section 6 lists the main conclusions and section 7 sheds some light on the possible directions for future work.

II. SCIENTIFIC BACKGROUND

Augmented Reality (AR) [3] is a field of computer graphics that combines the real world with synthetic, computer-generated elements. This combination [4] is performed normally through the use of fiduciary tags, which identify target zones in the real world where the virtual object is over-layered in run-time. Many uses and applications have been developed so far, with different goals [2] and target audiences: medicine, entertainment, education [11] [12], advertising, ambient-assisted living, etc. Future applications of augmented reality include the creation of virtual devices of all kinds, enhanced media applications, virtual gadgetry or even the creation of virtual decorations, plants or illuminations. Figure 1 illustrates augmented reality visualization.

Figure 1. Augmented reality visualization with fiduciary tags [13]

Numerous application domains make augmented reality [5] a highly multidisciplinary field of research involving signal processing, computer vision, graphics, user interfaces, human factors, wearable computing, mobile computing, computer networks, distributed computing information access, information visualization, and hardware design for new displays. Although AR has been around for a while, it still faces many challenges [1]. Because it is usually supposed to run in real time, it often introduces some processing demand to the applications that use AR. Depending of the complexity of the visualization to be represented, this might be a challenge. The performance of such applications is especially critical in fields such as medicine or industrial processing. Other limitations are imposed by the fiduciary tag itself. Its spatial position defines where the virtual element is going to be placed on the real scene. This direct dependency limits the degrees of freedom that the objects attached to tags can have on the final scene. On the other hand, occlusion or collision between tags is still not well resolved. Finally, natural interaction with the augmented elements is still an open issue. In order for AR to become a daily tool with tangible value to the end user it must be accessible everywhere. This implies that it must be available beyond the traditional computer monitor or LCD screen and become mostly “wearable” and “portable” – as in goggles, or mobile phones. Costs and hardware limitations remain a drawback.

Visual markers (or fiduciary tags) [13] are widely used in existing AR applications (figure 2). Marker-based AR systems [25] commonly use live video as input. As a result, the performance of a marker-based AR system strongly depends on the tracking system used for marker detection and pose estimation. Another way less used to create AR visualizations is with a markless tracking approach.

Throughout the last few years, there has been an increase in the interest and the results reached in the technologies of AR on desktop PC environments. Because of this, several platforms have been developed with different architectures; including AMIRE[14], ARVIKA[15], StudierStube[16], DWARF[17], DART[18], etc., and software tools for development are also available: NyARToolkit [19], ARToolkitPlus [20], SLARToolkit[21], ATOMIC[22], IrrAR[23], OSGART[24], etc.

III. USAGE SCENARIO AND RATIONALE

The goal of the project was to develop a solution to an interactive space in the Guimarães city which aims to spread knowledge of science and technology within the public of all ages. In this space, science is considered to be "alive" and can be experienced by everyone in an interactive fashion.

Our project, called Virtual Assistants, is primarily aimed to allow young people interact with an augmented reality (AR) environment, gaining a better insight of the AR technology while also learning about the Guimarães history itself. Because the space where the project was deployed had been a leather tanning factory in the past, and since one of the scientific themes covered is the textile engineering, we chose to develop a solution that could teach the visitors how the leather was processed at the end of the 19th century.

In order to create an interactive experience to the end user, an environment was created that actually narrates and illustrates the different stages of the leather processing pipeline at that time. Some research was also made [6] in order to be able to describe properly this process according to the late 19th century. Figure 2 illustrates one of the pictures that were gathered at this research phase. The overall goal was to produce vivid animations, with good visual quality and satisfactory degree of immersion to the user. The main underlying goal was to preserve the ancient leather tanning process memory and allow the end-user to have an augmented reality interaction experience.

Figure 2. Leather tanning process [7]

A. *Interaction and learning environment*

The leather process pipeline is fully animated, and the character moves between different process stages and some ambient background sounds can be heard. The end-user can stop or restart the visualization just by hiding or showing the tag.

The interaction scenario occurs in a room where 3 computers are available for the end-users. Each of the computers has a high resolution USB camera, in order to properly capture the tag, and 50" LCD monitors. AR goggles could be also used. At the entrance of the room, the user should pick a printed tag and use it to interact with each computer. The room is inside an ancient leather tanning facility and is decorated accordingly.

The user is asked to approach and read the situated basic instructions of "how to play". To start "playing" the story, the user should show his tag on the palm of his hand, before the camera. The camera is calibrated to catch the user's image, so that when he starts seeing the virtual assistant, he is positioned just before the user, on his hand. The user is asked to move the tag and to visit for a while each of the other computer stations.

On the first station, he can customize his character (virtual assistant), while the other two are used to actually illustrate and show the different steps of the leather processing pipeline to the visitor. The customization allows the change of the virtual assistant's clothes, hair and skin color. The customization process helps to increase the level of interaction and involvement between the end-user and the application [27].

B. *Visualizating the Leather Processing Stages*

The ancient leather process treatment used to be composed of nine basic stages. Each one of them was essentially used to design and create an animation. Below, a short description of what each action animation does is provided:

- Unhairing and fleshing: the character peels off all the fur and grease from the skin using a curved blade;
- Soaking: it's the cleaning of the leather performed in big sinks and with the help of long hooks;
- Tanning: the leather was colored in large rolling wood tanks;
- Drying: in between some stages the leather had to be dried before being handled again;
- Smoothing: depending on the goal of its usage, the leather had to be smoothened using normally a wood baton;
- Pressing: made to stretch the leather using a roller;
- Sanding: an abrasive tool is used to soften the skin and remove bumps and other imperfections;
- Cutting: it's the cutting of the leather into handy pieces on a table with a knife;
- Polish: Again, depending on productions goals, the leather should be polished using a special brush.

IV. CONCEPTUAL MODEL

The Virtual Assistant solution model (UML package diagram in figure 3) is composed of 3 minor packages, plus the classes Error and VirtualAssistantsRoom and their respective instances. These two classes are responsible for the error handling and the configuration of the computer station where the solution is going to run, respectively. This configuration is especially important because the solution should be able to run according to 3 different profiles. In each profile a specific augmented reality assistance and interaction with the end-user is available.

The DataRepository package holds the list of tags, the 3D models and their animations, and also other tables that are fundamental to the functioning of the solution. This package works much as a data server to the solution because the assistant might be customized by the user. The relationship between tags and 3D models and their behaviors are changed in real time (according the station and the interaction performed).

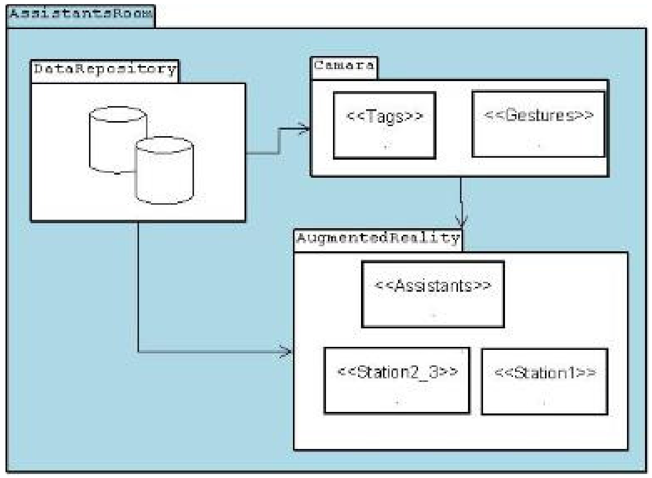

Figure 3. UML package diagram of the solution

The Camera package contains the Tags and Gestures classes and their respective instances. These classes are directly related to the capture and processing of the AR fiducial markers. This package does not only perform the recognition and tracking of the markers, but also controls some interaction aspects that the user does before the camera – customization of the assistant. This last one is done though a sequence of covering and revealing of the tag before the camera at the first interaction station. It receives data from the DataRepository package besides processing data captured in real time by the existing camera at the interaction station.

Finally, the package AugmentedReality holds the classes Assistants, Station2_3 and Station1 and their respective instances. It receives data both from packages Camera and DataRepository. It is responsible for actually creating the proper visualization of the 3D models and playing their animations according to the tag, the station and the stage of interaction. The character customization, described above, is performed by both the Assistants and the Station1 classes.

Because the goal of this project was to illustrate to the visitor the ancient handicraft leather processing pipeline used at the end of the 19th century (figure 4 illustrates one stage of the handicraft leather process), the AugmentedReality package tells an interactive story that is split into in 8 different stages. The sequence of these stages narrates and illustrates the leather processing pipeline to the visitor in a logical order and in two parts. The first part, played at computer station 2, includes the unhairing, fleshing, soaking, tanning and drying of the leather while the second part, played at computer station 3, includes its softening, pressing, sanding, cutting and polishing. The classes Station2_3 and Assistants are responsible for the implementation of this setup.

Figure 4. Sanding the leather

V. VIRTUAL ASSISTANT DETACHED BEHAVIOR AND INTERACTION

In order to develop the "user experience", the rules that are normally used and considered in visualization in computer assisted learning were taken into account. This was especially important because the visualization should cause a vivid and high interactive experience to the visitor. This is one of the main goals of the Science museum.

The following pedagogical [9] goals which support the designing of an interactive environment of visualization for computer assisted learning were considered:

- Understanding of the target domain of the student (in this case, the visitor);
- Support for different learning skills, learning styles and levels of knowledge;
- Motivation and increasing the interest for the teaching topic;
- Promotion of an active engagement in using interaction tools;

We also took into account the supporting of different learning scenarios, including demonstrations in classroom, homework and exploration (in this case, it was not a classroom, but a science museum). These pedagogical goals had to be adapted because the Virtual Assistants solution was not supposed to be running in a school, but in a museum. On the other hand, studies have suggested that Virtual Environment (VE) learning does not yield the same quality of information as real world learning [8, 26]. However, unlike VE, AR mixes real and virtual images and information. The AR can potentially combine the best of each situation: the virtual and the real [28, 29].

Due to these reasons, the solution tries to combine both strengths in terms of user's perception – the virtual representation of the story and the use of markers, taking advantage, as much as possible, of the mixed reality approach and taking into account a computer assisted learning environment. For instance, when the leather processing pipeline narration happens, the assistant "detaches" himself for a while from the physical location of the fiduciary marker. This means when the narration starts, the assistant walks away from the physical location of the marker and starts interacting with different 3D objects and accessories along a certain path. Thanks to that, the visitor has his attention fully captured while the interaction via his tag occurs and consequently, can learn better how the leather processing pipeline used to be executed. Because the assistant is a humanoid who resembles a typical leather factory worker from 19th century and "teaches" an art craft lesson to the visitor, the user is fully engaged in the learning process. To achieve a more realistic presentation, the use of textures and ambient lights are also employed in the AR visualization.

The conceptual model also considered that some issues should be avoided in order to achieve an acceptable level of usability, such as [10]:

- If the real world is augmented with large amounts of virtual information, the display may become cluttered and unreadable;
- User adaptation to AR equipment can negatively impact performance;
- Delay causes more registration errors than all other sources combined;
- AR displays that are uncomfortable may not be suitable for long-term use.
- In resume, our Virtual Assistant should attend the following requirements:
- Easy to use by children;
- Able to engage them in the experience and thus memorize what was presented to them;
- The story should be easy to understand and illustrate accurately what used to be the leather tanning process, helping children to learn it;
- Help children to understand better what augmented reality is and how it can help them.

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VI. TECHNICAL DESCRIPTION

The Virtual Assistant project was developed using Virtools 5.0, C++, Maya 6.0 and Virtoolkit as the AR plugin for Virtools. Because it was important to create an augmented reality environment that mets the reality of the leather craft from the late 19th century, a 3D reconstruction of a leather processing factory was built using the Maya modeling software, based on photos of the real factory that existed previously on the installation site, as mentioned in Section III. Then, in order to assist the user, a character to represent the typical factory worker from those days was also prepared and texturized. The texture was hand-made using Photoshop to warp and combine pictures of real workers in dressed in production attire for different stages of the taning process. These pictures, obtained in the research stage, were thus mapped into the texture space of the 3D model, based on its original texture. This character accompanies visitors as they go through each of the stages in the augmented reality application. Finally, and because this character should tell a story that illustrates the leather manufacturing process, 3D models for several different tools were produced, also in Maya, and textured according to photos of real leather tanning tools, and the corresponding animations were created for both the tools and the character. Since these were very specific movements, no predefined animations existed, nor motion capture data for them. The animations were thus produced in Maya using key frame animation. These animations were then exported from Maya to the Virtools format, and imported into the scene. Figure 5 illustrates the soaking of the leather animation.

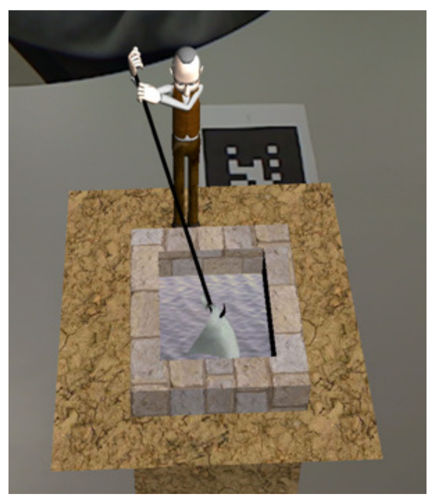

Figure 5. Soaking the leather

The work performed in Virtools consisted in animating to the scene by creating real-time interaction scripts based on Virtools' predefined building blocks (BBs), as well as in external BBs from the Virtoolkit plugin (based on the wellknown ARToolKit framework). A custom BB was also developed in C++ using the Virtools SDK, in order to provide the ability to synchronize the customizations of the characters across the three stages of the application. Finally, several scripts using Virtools' scripting language (VSL) were created in order to provide a more fine-grained control over the behavior of the character and the objects.

With these tools, the final scene became a fully interactive story-telling environment, supporting multiple characters at the same time (up to 50, theoretically, even though the camera's field of view and resolution does not allow the testing of this limit), each one with its own timeline, featuring separate pause events for each, transparency fading transitions to reduce cluttering, memory management algorithms, and customization based on synchronization within the three stages.

A. *Making Characters Stroll Around*

Another interesting issue and goal of this project was to create the notion of detachment of the character regarding its tag. Usually, the augmented reality representations fix the position of the character (or any other object attached to the tag) to the same actual position where the tag is. This happens due to technical constrains normally imposed by AR libraries. In this project the character can in fact stroll around the tag while illustrating the leather processing stages. This is done through the definition of a path, which is itself attributed to the tag. At any time, it is possible to move the character between the nodes of the path, showing and hiding objects (like tools for instance). Since the path is still attached to the tag, the user can still move it to observe the character from various angles and distances. Also, ways to implement playing control, such as pause or restart, were implemented in what we considered to be an intuitive manner, based on simply hiding the tag; this prevents the user from losing track of the story and effectively provides every user with a single, unique experience.

VII. TECHNICAL DESCRIPTION

In order to validate the work, the Virtual Assistant project was tested with 30 teenagers. We mounted the 3 computer interaction stations (as described in section 2), and gave to them tags. We only explained to the end-user what the experience was in its overall aspects, because we wanted to replicate, as much as possible, the real scenario that is going to really happen in the museum facilities. We used both an observation and a questionnaire approach to evaluate user's reaction. To assist the visitor with the use of the application, we put a small poster with some basic instructions at the first stopping station. Then, we asked them to go through the three stations and answer a questionnaire. The questions tried to evaluate these aspects of the user-experience:

- Usability - how easy to use and to interact?
- Learning – how easy was to understand the leather tanning original process?
- Amusement – how entertaining was to play with the tags?

We also observed the user's reaction, especially in terms of dealing with the tag and interacting with the application using it. The overall scores of the application pointed out a very positive evaluation: 90% of the users were satisfied in terms of usability, while 75% were able to fully perceive how the leather used to be processed in the 19th century. Finally, all of them answered that it was a very interesting and amusing experience, although at the beginning they found a little bit boring (because they had to "learn" how to use the tag properly). This final conclusion was according to what we observed. The charts in the figure 6 and 7 illustrate the overall score that was reached in terms of usability and learning.

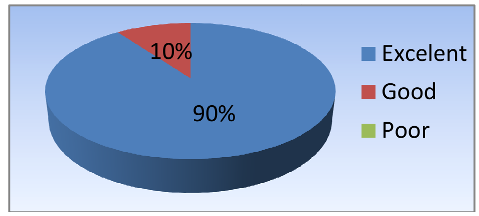

Figure 6. Usability evaluation chart

Although our application could be used by several persons at the same time, its usage showed that the final visual effect might become unsatisfactory, because more than 3 tags can easily introduce some occlusion in terms of the augmented reality visualization (the animations start to appear in front of the others, for instance). On the other hand, we did not use sound (characters spoken narrative) exactly because the multiple users simultaneously scenario was considered. We were not able to evaluate if the sound would be a plus in terms of the learning process.

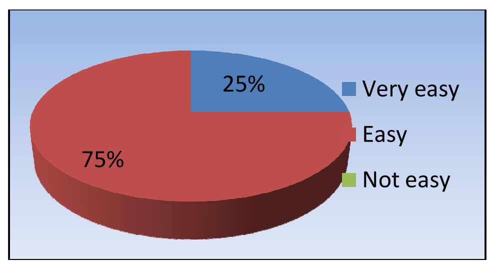

Figure 7. Learning evaluation chart

VIII. CONCLUSIONS

Based on our evaluation we were able to conclude that:

- The use of an augmented reality approach in our application helped to catch children's attention and thus, engage them in the learning experience;
- The users found the experience funny and were able to memorize the information presented and tell it to other children;
- They interact very intuitively with the tags and the use of animation;
- The use of the sound increased their engagement;
- The use of a detached approach of the character to the tag, made them loose the focus on the tag and thus increases the attention on the story that was being told;

- No more than two users should be simultaneously interacting at the same computer station due to the occlusion effect, and, to a certain degree, the loss of engagement – the user tends focus the other user's virtual assistant instead of their own.

IX. Future Work

In terms of future work, we would include the sound but not as a narrative attached to a character, but to the interaction station itself. It could be a good support to the user to play from time to time an explanation about what is showed in general terms. It also would be nice to use some background sounds typical from an old leather processing factory. Finally, the adding of some descriptive text to the visualizations in general terms, would also help to achieve a better usability.

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