Building a 3D Interactive Walkthrough in a Digital Storytelling Classroom Experience

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This paper presents a real time 3D walkthrough application based on interactive VR technologies, designed and realized with and for secondary school students in order to raise their awareness about their local heritage, in particular the Medieval Walls of Grosseto, Tuscany, one of the rare examples in Italy of defensive walls remained nearly intact to this date. After detailing the learning methodology used in the classroom experiences, the paper thoroughly presents the strategy used to realize the resources needed to build the 3D model of the old town and the final application, built with an interactive digital storytelling approach.

Povzetek: Opisan je 3D sistem virtualne realnosti za Medieval Walls of Grosseto, Toskana, Italija.

1 Introduction

Several recent educational approaches are successfully exploiting technologies (such as tablets, smart phones, videogames, etc.) which kids use routinely. In this respect, Interactive Digital Storytelling (IDS) [1] represents an interesting opportunity taking advantage of multimedia technologies to develop learning mechanisms [2] , with the added values of providing a tool able to convey even complex concepts in an intuitive and playful way, and easily customized to meet different needs, personalities, capabilities [3] .

Following these principles, we have in the past [4] [5] setup a learning methodology and experimented a number of educational programs focused on the following objectives: conveying a content, identified together with teachers, by telling a story; providing knowledge about technology, by means of a learning-by-doing approach enabling kids to create a multimedia product suitable to tell the chosen story; enhancing team skills in kids.

We have applied such a methodology to the case of the Grosseto, a town in Tuscany whose city walls have remained almost completely intact since their foundations in the XVI century, following a development approach already experimented with success in previous occasions related to the towns of Pisa [6] and Lucca [7] . The result is an interactive application that will be disseminated on the web, exploiting HTML5 3D features, and as a kiosk in local museums using touch interaction.

2 Related work

In general, when dealing with Digital Storytelling teachers have usually to keep into account previous experiences of children, their wish to participate, interact and collaborate, their attention span, the perceptual modes of their personal style of learning. Interactive Digital Storytelling is undoubtedly and firmly bound to interactive multimedia, by means of which it conveys content and knowledge [8] . Computers and multimedia let children create virtual environments, new worlds that interact with the real world. This interaction between real and digital allows to setup innovative educational methods and tools that exploit a novel concept of "tangibility": toys, workbooks, drawings assume new embodiments and turn into virtual worlds, hypertexts, bytes.

Using Interactive Digital Storytelling for educational purposes has a number of positive impacts. When using technological tools together with a good and aimed pedagogy, children are stimulated and their enthusiasm is awoken. Moreover, technological means are themselves very appealing for children, who feel strongly encouraged to make use of them to communicate their experiences [9] . There is a large number of projects which use computer-based tools to tell stories; a

thorough selection is hosted on the "The Educational Uses of Digital Storytelling" website of the University of Houston. In [10] it is explained how Digital Storytelling may literally hook children into writing, offering, at the same time, useful insight on the teacher's role. In [10] the involvement of the family in developing multimedia tools (in this case, e-portfolios) in early childhood education is explored. An important side effect is the development of individual creativity. Similarly, in [12] Digital Storytelling is introduced as a way to exhort children to tell about themselves and their personal story.

Previous relevant investigations on digital storytelling as a learning tool for the specific case of humanities cultural heritage are found in [13] , where it is seen as a means to build "a safe and empowering space for cross-cultural collaboration and learning", and in [14] , where narrative is seen, together with digital technologies, as a support for lifelong learning in cultural settings, being it central to collaboration and to the building of community identity. In latest years new digital technologies, such as VR and AR, are providing powerful means to support IDS due to the better involvement achieved thanks to immersion. Interesting discussions on the use of VR as the digital means for storytelling are found in [15] and [16] .

3   The learning methodology

The learning methodology we commonly use in our classroom experiences engages kids in the creation of a multimedia product, such as a movie or a game, in order to stimulate their curiosity and motivation through the use of technology to create, tell and share a story.

The protocol we follow is commonly based on the following steps:

1. definition of the learning objective and of the time schedule, together with the teachers;
2. identification of the story object of the narration;
3. definition of the multimedia product;
4. identification of the technological layer;
5. realization of the storyboard;
6. production of the resources (text, images, etc.);
7. development of the product;
8. test and evaluation feedback.

All these steps see the participation of teachers and students, but especially the first steps deeply involve the teachers as they require to define the topic (usually integrated in the existing school programs), the learning aim and the calendar of meetings (Fig. 1), that has to be defined in accordance with the normal school activities. Subject to the availability of tools and equipment in schools, and depending on the multimedia product to be realized, the technological resources to be used in the process are identified. If needed special equipment, such as Virtual Reality devices, is made available by our institution. A storyboard is then created. Starting from a first draft of the story, the narration becomes structured and broken into elements. At this stage, we also identify all the "fancy" elements meant to improve the involvement, the level of the desired interaction, and

other detail features such as non-linearity, immersion, participation and navigation.

Depending on the storyboard, we identify the needed resources (text, audio, drawings, images etc.) that are collected, if already existing, or otherwise created from scratch. This also requires to translate the story into the visual language, using traditional means such as technical drawing, art expressions and creativity, to be later associated with other digital means, such as scanners and graphics tablets. Drawing is one of the aspects we mainly focus on, as it is an important way for developing creativity and permitting kids to mature. Especially in primary schools drawings often offer a better way than language does for understanding children, as they commonly represent objects not as they actually appear, but rather through a schematic reduction to the essential.

Once all the material needed to tell the story has been identified and/or collected, it is processed using digital techniques, such as 3D scanning, image editing, digital recording. Voice, sound, and artistic expression are channels enabling students to communicate their thoughts and their creativity in a spontaneous and entertaining way. In order to accomplish the needed operations, the basics of computer science and digital imaging are introduced to the students. In the case of more complex projects involving also 3D environments, students are also introduced to the basics of 3D geometry and shape modelling.

All the processed material is then gathered and used for the production stage according to the defined outcome. At this stage the work is commonly divided into tasks, some of which are collectively performed while others are distributed depending on the different abilities and preferences. When the product is particularly demanding in terms of the needed technological expertise (for instance programming), we typically continuously assist the development or, in some cases, we completely take over the activity.

When the product is ready, all the people involved (kids, teachers and we, as tutors) deeply test it, sharing the outcome also with other classrooms, in order to assess the level of clearness of content, to gather suggestions useful to improve the result and to fix errors and inaccuracies. Sometimes, in addition to observation, questionnaires are also provided to all the participants in order to better evaluate the overall experience.

4   The classroom experience

The MuraVagando project was developed in order to introduce high school students to their own cultural heritage in a way that differed from the usual in-class activity. The project has been organized by Scuola Superiore Sant'Anna of Pisa and Mnemosyne Digital Culture, supported by the History Institute of the Contemporary Age (ISGREC) of Grosseto, and developed together with the V classes of the Polo Bianciardi Arts High School of Grosseto. The students have undertaken an innovative educational path aimed at acquiring scientific and technological competencies

applied to the communication of cultural heritage. This experimentation dealing with the Town Walls of Grosseto has built on a knowledge base previously formed in other experiences of the same high school students and integrated with a VR-based technological approach. To enrich their daily learning experience, students were made part of the creation pipeline of a Virtual Application, also named MuraVagando, which enables users to visit a 3D reconstruction of their home town, Grosseto. A series of meetings in the classroom has leaded to get the students familiar with the concepts of storyboard making, 3D modelling, video shooting/editing and 3D programming.

Being "Arts and Drawings" their area of expertise, students were asked to use their artistic skills in order to design a nice-looking interface as well as producing several assets to be used in the final application. After visiting the most relevant historical sites of the city to familiarize with the local artistic style, students were guided to design every element of the final application and its features under our technical supervision. They were first asked to draft a draft of the main User Interface, comprehensive of buttons, background images, menus and icons. After that, every student was asked to select a unique spot of the city, draw it on paper, write a description to be used as label, draw a stylized icon, and draw a cardboard cut-out of what a local citizen would have looked like when that opera was created. Once all the assets were completed and digitalized, our task was to find the best fit for all those elements, creating a digital scene that users could explore and share.

5   The interactive walkthrough

The final product is a large 3D interactive reconstruction of Grosseto's Old Town and of its walls that can be accessed both as a web-page and as a stand-alone applications running on touch-screens, also providing portability to immersive setups such as Oculus Rift. Particular focus was put on reconstructing all those elements that students have focused on throughout the entire project, such as churches, statues, protective walls and ramparts, as well as other elements they have chosen for their drawings. The application consists of a single centred canvas rendering the 3D scene; a contextual menu is positioned to the left side of the canvas containing four items named "Bastioni" (ramparts), "Chiese ed edifice" (churches and buildings), "Monumenti" (monuments) and "Video" (Figure 1, top). A slightly different layout with the same functionalities is presented in the Web version of the MuraVagando application (Fig. 1, bottom). While pressing on any of these buttons, a second menu appears to the right side of the canvas, showing a list of specific elements belonging to the selected category. A single button representing the city map is positioned right below the canvas, and it is used to access the corresponding view mode**.**

5.1   The scene

The main focus of the scene is always on the external walls, cardinal element of the entire project and main architectural element of the town.
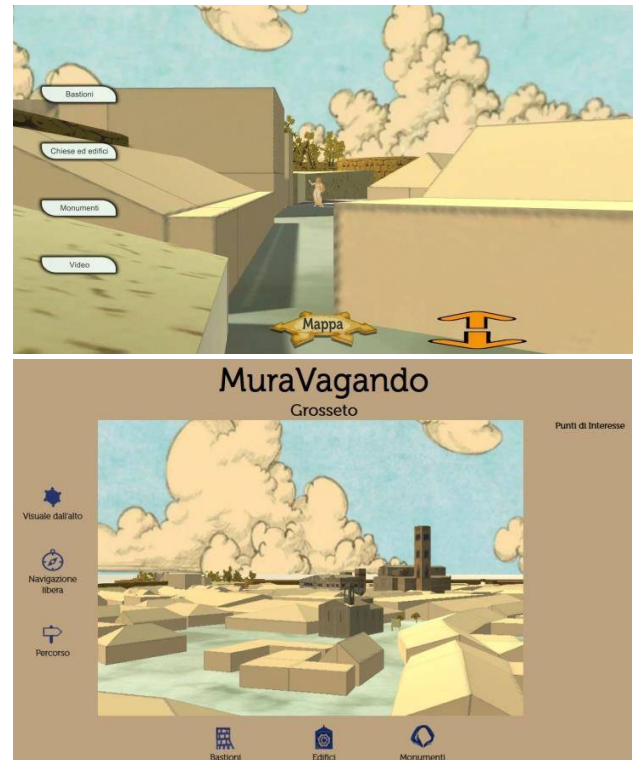

Figure 1: The main page of the Kiosk application (top) and of the Web application (bottom).

The walls have been reconstructed in 3D in accordance with the real structure and with the students' drawings. Transparency was applied on the floor edges to create a turntable effects: the walls and the city are standing on a drawing that fades out to merge with the surrounding environment. It is important to notice that the final model is not a precise scale reconstruction of the actual town: each point of interest chosen by the students was highlighted by scaling up the corresponding mesh to make it stand out from the context, and brighter materials were applied for the same purpose. Each of these spots comes with a descriptive panel written by the same student, presented in the model as a big wooden board (see Figure 2). Panels locations are also used as landing point for state transitions activated by the already described menus.
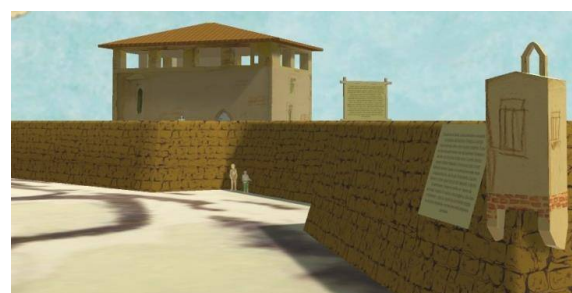

Figure 2: Descriptive panels.

5.2   Navigation

Users can navigate the scene in three different modes:

- Free Mode: on Free Mode, users can freely move inside the scene with no limitations. In the Kiosk version, a combination of touch gestures and GUI buttons is used to move/rotate/pan the view. In the Web version, mouse and keyboard are used for the same purpose.

- City Tour: on City Tour mode, the camera follows a predefined path that starts from just outside the city walls, and moves around the entire scene, like a modern drone. The camera visits all the interesting spots in the scene in a continuous seamless loop, however users can still "look around" by rotating the view while moving on the predefined path. This mode is used as default when the application does not receive any input for more than 30 seconds in Free Mode.

- Map Mode: on Map Mode (see Figure 3), the camera floats above the scene, continuously rotating on the vertical axis. Hotspots corresponding to the most relevant locations can be selected either by touching (kiosk version) or by clicking (web version) the circular elements representing them. Selecting a hotspot triggers a change in the view bringing the virtual camera just in front of the location corresponding to the hotspot.

Each navigation mode can be activated in any moment by using the GUI. Smooth transitions are implemented during the location changes to avoid spatial disorientation, both when switching navigation mode and after a hotspot or a menu item selection.

Figure 3: The map mode.

6   Technical implementation

Both versions of the application have been developed using the Unity engine, so as to allow a fast portability to various platforms, including web versions.

6.1   3D models

The main challenge of modelling a web-based scene including dozens of different monuments and buildings is to keep the number of vertices low. While buildings, such as churches or palaces, can be effectively approximated to boxes, other elements such as statues, fountains and walls require a more complex geometry to be described without too much data loss. Different modelling pipelines had therefore to be used in order to create the meshes:

1) the old Medieval walls have been reconstructed by repeating a mesh sample on a NURBS path. A high-poly version was first created; subsequently a low-poly version was modelled, following the high-poly version topology and transferring the UV coordinates from the first model to the other;

2) the most important buildings, such as churches or fountains (see Figure 4), have been manually modelled, following the proportions given by the students' drawings. Such models were also scaled up in order to stand out from the overall view. Minor structures such as modern houses were also recreated, based on their real position;

Figure 4: A manually modeled element.

3) statues have been modelled loosely according to their shape. However, since students provided only one perspective drawing for each statue in the project, it was decided to use a billboard mesh resembling the statues front shape, to map the drawing as a texture, and extrude some vertices in order to create a 3D effect (see Fig. 5);

Figure 5: Sculpture billboards.

4) minor elements have been procedurally generated by using Unity: trees were added to the scene with the Unity Tree Editor, and the sky was created by using the Unity standard skybox material. (Fig. 6).

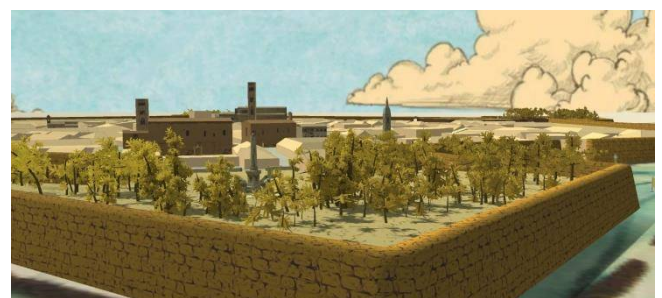All the manually built models have been realized by using the free modelling tool Blender.

Figure 6: The 3D model of Grosseto:

6.2 Textures and materials

One of the biggest challenge of the project was to achieve a homogeneous look. The students were encouraged to use their own style to realize the drawings, and this brought inconsistency among the produced material. The papers we received came in different colours and styles, using different backgrounds; some students drew different parts of the same object while some others drew just the main view, and most importantly for a 3D model, most of them drew in perspective mode, rather than using an orthogonal view.

The only shared feature we could identify amongst the drawings was a certain similarity with cartoons. Besides that, all the drawings differed from each other in terms of style, proportion, colours and techniques used. Being purpose of the project to preserve students artworks, the chosen approach was to create a game-alike "cartoony" environment, applying the drawings as textures on the meshes, reducing the reflectivity and increasing saturation (see Figure 7). Minor buildings were rendered using CEL shading materials for the same purpose.

To avoid inconsistency in the scene, we pre-processed each single drawing we received with an image processing tool, increasing the yellow balance where needed, and adjusting proportions. Once the images had a homogeneous appearance, they were imported into Blender and applied as textures to the UV unwrapped models we previously created. No normal mapping was applied, to keep the scene as "toony" as possible.

Figure 7: Modeling town elements.

A special case is represented by videos. During the first meetings with the students, it was agreed all together that the application should speak the language of young people, avoiding as much as possible a formal approach. Therefore, the entire experience was conceived as a gathering where some of the students of the school invite people of the same age to wander around the ancient walls (MuraVagando recalls the Italian term for "wandering") and discover a place in their town rich of stories and cultural elements, yet often disregarded by young people. Therefore in the beginning, and occasionally in specific points of the town, cut-scene videos appear that have been shot by students playing as actors. In order to keep consistency in the visual environment, videos do not substitute the 3D scene as often happens; instead they are mapped onto virtual signboards (see Figure 8, top) placed close to the locations referred by the videos. The overall consistency is also kept using the same type of virtual signboard to

display text descriptions related to the architectural elements and placed close to them (see Figure 8, centre).

Finally, we decide to insert an easter-egg represented by a room in the interior of a building onto whose walls the names of the teachers and of the students involved in the project appears as carved into stone (see Figure 8, bottom).
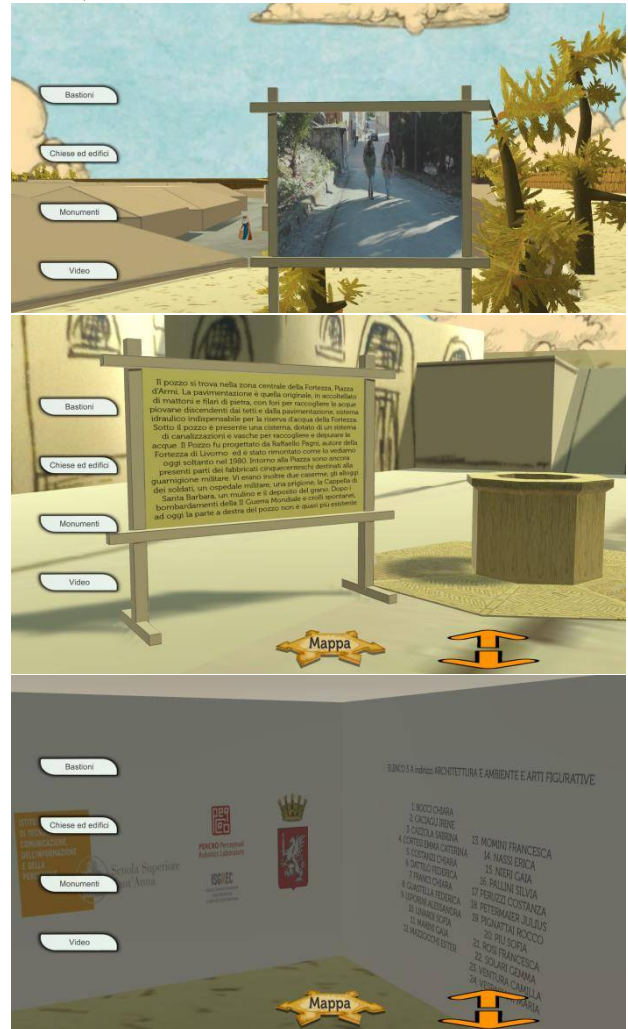

Figure 8: Virtual signboard displaying a video (top) and a text description (center). Easter egg with the participant names carved into stone (bottom).

6.3 User interface

As mentioned above, the project comes in two different versions: a web-based HTML page and a Kiosk version, i.e. a standard Unity executable file to be used on touch-screens. Although the versions share a similar design, due to the different devices on which they are hosted some elements of the GUI had to be positioned differently.

In both the web and the touch-screen version, a contextual menu called "Categories" is positioned on the left side of the main canvas, but while the web version did have enough space to avoid overlapping the rendered scene, the touch-screen application came with different proportions and the buttons had to be positioned on top of the rendering canvas. Once any of these category

button is pressed, a second menu called "Places" appears on the right side with the same parameters described for the category menu. Clicking on any of these places button applies a parabolic roto-translation transformation of the camera from its current position to the location of the specified element in the scene.

A third menu named "Navigation" is used to activate the navigation modes described in section 5.2, but while in the web version the menu is composed of three different icons positioned below the canvas, in the Kiosk versions two arrows have been added to move the camera forward and backward while in Free Mode, so that no complex gestures must be used to move the camera around the scene.

A different UI is presented while in Map Mode: once the camera reaches its top position above the model, users can no longer access the contextual menus and they cannot freely move around the scene; they can only select from some hotspots placed on the scene.

6.4   Code structure

Being the Unity Engine mainly used in game development, the design process has benefited from structuring the entire project as a videogame. However, this choice also presented its downsides, as Unity puts special restrictions on how elements interact with each other in the scene. Specifically, reserved folder names had to be considered to load assets at runtime, and the GameObject – Component relationship had to be taken into account while designing the scripts and their behaviour.

The entire scene is controlled by the singleton "Scene Handler", a component attached to an empty "GameObject". Main tasks of this script are:

- controlling the application status. In addition to the status described in section 5.2, the application also features other more specific statuses in which users watch a video, or the camera is undergoing an animation between two different positions, etc. Transitions between those status were handled by the component to ensure that only one status could be active at the same time;

- animating the camera. Once a transition is activated, a parabolic trajectory is computed based on the current camera position and rotation, the final position and rotation, the desired parable height and the animation duration in terms of time and frames;

- communication with the external functions (Web only). While the Kiosk version is completely handled by Unity, the web page is mostly independent and Unity takes only care of rendering inside the specified canvas element. However, external JavaScript functions can be called to interact with the component and modify the application behaviour;

7   Conclusions

The project ended in June and so far was only publicly presented once at a conference. The application is going to be published on the web in October and agreements are being taken with local cultural institutions to place two interactive kiosks running the application. In this phase we plan to run a user study in order to gather information about the efficacy of the application as a dissemination tool and to identify guidelines for future developments.

In the framework of the EU 2020-TWINN-2015 eHERITAGE project (grant number 692103), a number of possible future directions have been identified for the project and its possible extensions also to other urban contexts (the city of Brasov in Romania being an example), such as the implementation of a semi-guided navigation mode based on a suggestion system keeping into account user model statistics and location-based information and the support to user-generated content in order to expand and enhance the 3D model through a cooperative effort. The latter option might also suggests to continue with classroom experiences, oriented in this case to the realization of aimed and defined components rather than of the model of a whole urban context from scratch like in this experience.

8   Acknowledgments

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