Transporting the viewer into a 360° heritage story.

Panoramic interactive narrative presented on a wrap-around screen.

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***Abstract*—This paper illustrates the idea of applying interactive storytelling to a panoramic projection system. The story of a wedding that occurred in 1941 in Charles Church (Plymouth, UK) is presented on a wrap-around screen where the viewers are asked to make decisions about further developments of the narrative. The church was bombed in 1941 and was not rebuilt after the war. A virtual 3D reconstruction of this heritage site was undertaken and on the basis of this computer 3D model, a number of still and video panoramas were rendered inside the church. Video panoramas created using a spherical video camera were applied to the generation of the panoramic interactive narrative, the aim of which is to transport the viewers not only to the historic site, but enable them to interact with this heritage story. A 360° screen combined with an interactive device is a good solution for presenting non-linear panoramic narratives.**

Interactive storytelling; interactive narrative; panorama; video panorama; 3D reconstruction; 3D modeling; wrap-around screen; 360° screen; immersive; panoramic screen; 360° video; heritage.

I. INTRODUCTION

The developments in projection and camera technology make it possible to create 'digital' rotundas, where 360° still and video panoramas are displayed for the audience. Robert Barker, who patented the idea of the picture without borders, erected the first cylindrical buildings for his painted works at the end of the 18th century. Early trials that used projection systems and multiple screens in circular forms were noticeable at the end of the 19th century (Stereopticon, Cineorama, Electric Cyclorama, Electrorama, Photorama). Another century later, more advanced solutions for creating the illusion of being in the picture are recorded, where the technology enabled the creation of seamless multi-projector wrap-around displays. Artists have struggled to generate a space that will provide the viewers or 'readers' of interactive work with the complete illusion of being immersed within an interactive story. 360° screens appear to be the next step for the maximization of realism which artists tried to present in prehistoric caves, fresco rooms and painted panoramas [1].

This paper discusses the application of panoramic interactive narratives on wrap-around screens where the audience has the opportunity to decide what is going to happen not only in the next chapter of the narrative, but also in the next couple of seconds. Consequently, the viewers have to be ready continuously during the display of the panoramic story in order to make decisions in this branching approach to narratives.

The process of reconstruction of Charles Church and then rendering 360° images using 3D modeling software and 360° video is presented in the second part of this paper. The application of still and video panoramas and the method of creating such content are discussed in the third section of this paper. The story of a wedding (section IV) that happened in Charles Church (Fig. 1) had to be transferred to a non-linear branching narrative with multiple options. Notwithstanding the fact that story-graphs help to generate this type of the narrative, a number of different alternatives are necessary for the production. The last section (V) of this paper presents the method of displaying 360° narratives based on still and video panoramas in wrap-around image spaces. Arena360° and ICCI360° were two one-week long events which provided the opportunity for the researchers to apply the projection of interactive narratives. Both events happened in Plymouth (UK); the first one was an experimental week for testing projection of 360° images, whereas the second one – the actual festival, where interactive pieces of work produced by international artists were shown on a 360° screen.

II. RECONSTRUCTION OF CHARLES CHURCH

The building of Charles Church in Plymouth was completed in 1657 and consecrated in 1665. It burnt out on the night of 21st and 22nd March 1941, the fire being caused by some of the very many incendiary bombs that fell on the City of Plymouth that night. The church was not rebuilt, but it is the City's memorial to the civilians killed in the Blitz. Today, the ruin is situated in the middle of one of the busiest roundabouts in Plymouth (Fig. 2).

Figure 1. A frame from 360° video presenting the story of a wedding in a computer-reconstructed Charles Church in Plymouth, UK.

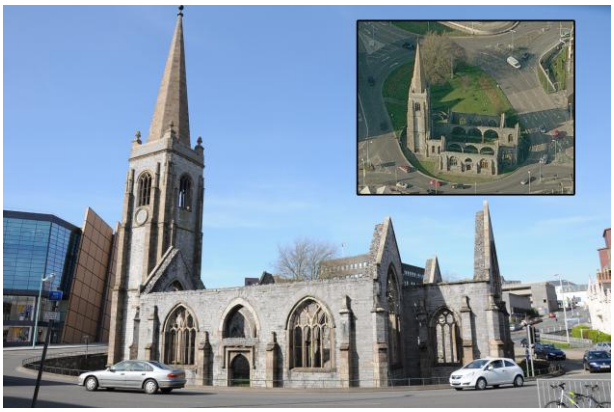

Figure 2. Charles Church in Plymouth located in the middle of a roundabout devoid of an easy access to the site. Aerial picture from: http://www.bing.com/maps.

A PhD researcher decided to locate a narrative in its interior, because it enabled the potential of applying interactive storytelling to still and video panoramas that were rendered in 3D modeling software. What is more, Glassner suggests to "bring the real world into the story experience" and "bring the outside world into the story environment" in order to generate a new and compelling interactive narrative [2]. Charles Church is a locally known site, but the access to its interior is limited. However, the researcher rendered a number of still and video panoramas in its interior to "set a story in a well known place" [2] for local communities.

The reconstruction of the church started from creation of five high resolution panoramas using DSLR camera and a panoramic head in order to generate basic 3D models of the interior in Autodesk ImageModeler software [3]. This application facilitates the creation of 3D structures on the foundation of images and still panoramas. Five 3D files were then exported from ImageModeler and merged together in 3D studioMax in order to generate photorealistic visualization of the interior [4] [5]. In view of the fact that the site is a ruin, the researcher's aim was to reconstruct the interior of the church as it was before 1941. A number of historical images (Fig. 3) were found in various Plymouth archives and this collection enabled the process of virtual reconstruction of Charles Church.

Figure 3. Historical images of Charles Church (19410, J.V. and 11370, J.V. from Plymouth Central Library).

"Digital reconstructions are particularly appropriate for simulating historical architecture that no longer exists" [6] and Charles Church is a perfect example of presenting the educational stories hidden in the inaccessible site in the centre of Plymouth. The reconstruction was not based on photogrammetric solutions proposed by [7], but more specifically it is an artistic composition due to the lack of archival images of the entire inner part of the building. As a result the 3D model of the church facilitated the researcher to render a number of still and video panoramas in order to build an interactive narrative with multiple alternatives.

The process of rendering 360° images using 3D modeling software and also using a spherical video camera is described in the next section of this paper. Consequently, such images act as the basis for the creation of a story-based panoramic interactive narrative that has the potential to be presented both in a panoramic viewer and on a 360° screen. This reconstruction of Charles Church provides the opportunity for spatially locating the spectators within a site that no longer exists. This project empowers the visitor to imagine the building before it was destroyed, and the story of the wedding triggers emotions that may have been experienced during the tragedy.

III. Still and Video Panoramas

360° images (still and video) are the foundation of the researcher's concept of generating interactive storytelling for heritage sites. Panoramas were included in heritage storytelling presented by [8], but video panoramas are a new method of presenting the movement within a 360° environment. Panoramic images are divided into cylindrical (limited vertical field of view – VFOV) and spherical (equirectangular, 360°x180°). Moreover cubic panoramas are different form of spherical images and are frequently used for faster presentation of interactive images in panoramic viewers (e.g. KrPano [9] or Pano2VR [10]). 360° video (video panorama) is a representation of a sequence of wrap-around images. In fact, between 15 and 30 panoramas per second must be taken in order to consider this set of images as 360° video. Video panoramas are frequently recorded in fixed locations, where the movement of the environment is recorded; however the 'mobile camera' approach [11] is commonly used to demonstrate the changing of the surrounding.

This paper discusses the application of still and video panoramas that were not only rendered in 3D modeling software, but recorded on the site to present the ruined condition of the building. Both types of 360° video were generated (fixed and mobile camera); some of them present the action that is happening around the camera, whereas others illustrate the process of moving through the heritage site (Fig. 4).

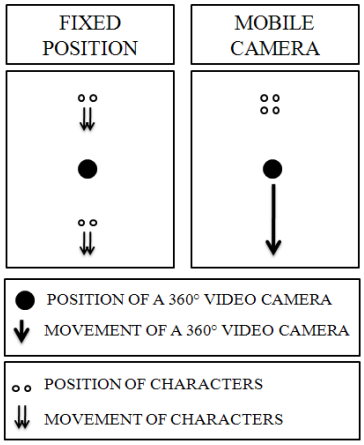

Figure 4. Fixed and mobile camera while rendering video panoramas.

The figure (Fig. 4) reveals that video panorama has the potential to illustrate the movement of characters that are visible on the footage, but additionally the movement of the 360° camera might represent the movement of a main character, displaying the view that he/she observes during the change of his/her position.

Recordings on the site (Fig. 5) were performed using a spherical video camera – Ladybug2, manufactured by Point Grey Research [12]. This camera has 6 lenses, where one of them is looking up to record the zenith area. One also should not overlook the fact that it generates a large amounts of data (approx. 2GB per minute; 30fps, uncompressed), which has to be converted to a sequence of JPG files or AVI files. Such files are editable in video editing software that provides the enhancement of the image quality and the sharpness. Despite the use of a trolley (Fig. 5) which fails to compensate for the vibrations when moving on the floor, LadybugCapPro software (provided by the producer of Ladybug2) repairs this inconvenience by using image stabilization function.

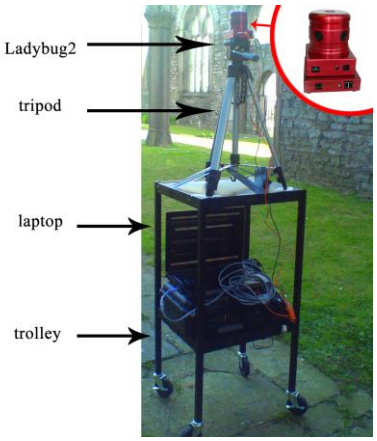

Figure 5. Ladybug2 – the spherical video camera inside the ruin of Charles Church. The application of a trolley for mobile camera approach.

Ladybug2 fails to record sound and moreover, is not equipped with a button to record 360° video. Additionally, it has to be operated from a powerful laptop with Firewire800 and RAID0. To enable the creation of the story for a 360° screen, the researcher employed Lucid Viewer [13] as a panoramic viewer that displays not only 360° images, but mainly 360° video. This application, based on Flash Player and XML coding, is necessary to add actions and interactivity to the project. This process leads to the generation of enriched interactive stories that are established on still and video panoramas. It is important to emphasize that the initial stage of the development of the story for a 360° screen has to be at first tested on a panoramic viewer and then, if successful, on a wrap-around projection system. One of the disadvantages of using Ladybug2 in this process is that images have to be cropped from the spherical format, which is acceptable by all panoramic viewers, to cylindrical format (limited vertical field of view). This problem can be omitted by the creation of cylindrical images, for example, using such cameras as Sensocto [14], Spherecam [15], Pan360 System [16] or Totavision [17].

The 360° heritage story located in a virtual reconstruction of the church is enhanced by the use of video recorded on the site. The creation of still panoramas in 3D modeling software is based on placing a virtual camera inside the 3D model and rotating the camera every 90° (Fig. 6).

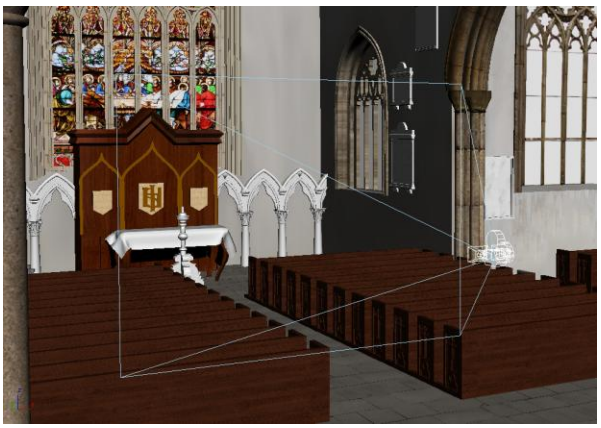

Figure 6. The virtual camera inside a 3D model of the church.

This process generates 4 horizontal images and if the camera is tilted 90° up or down, additional two images are rendered in order to create 6 cube faces that, when stitched achieve spherical (or cubic) panoramas. Such types of panorama (360°x180°) are appropriate for panoramic viewers, whereas they need to be cropped to a cylindrical format if they are to be used on a 360° screen. Similarly, the method for creating video panoramas is based on creating a number of individual panoramas, while the environment around the cameras is animated or alternatively the set of cameras is moving through the space. This sequence of spherical images is then imported to QuickTime Pro [18] and exported as MOV files using H.264 codec that is compatible with Lucid Viewer or without compression for the display on a 360° screen. One of the advantages of using 3D modeling software is that it facilitates the rendering of files with a resolution adequate for the 360° screen (max. resolution of 9600x1080 pixels for the Arena360° and the ICCI360°), whereas Ladybug2's video is limited to the resolution of 3500x1750 pixels.

360° videos and 360° images are the basic elements for the interactive storytelling presented in this paper. The researcher decided to present interactive narratives using 360° content because:

- 360° footage helps to visualize the site;
- a 360° screen provides sufficient illusion of the site;
- 360° narratives with spatial sound makes the audience constantly aware of all elements of the narrative during the presentation of the story;
- interactivity that is available in a cylindrical space provides for the creation of changing the story.

IV. A HERITAGE STORY IN CHARLES CHURCH

This section discusses the concept of creating a story-based panoramic interactive narrative which is illustrated using story graphs. The story alone defines the further development of the narrative. In contrast, a map-based approach to non-linear stories is described in [19]. This part of the paper will present the concept of interactive storytelling, story design and the method by which the story-graphs helped to generate a story-based panoramic interactive narrative. 3D modeling software was applied to this task in order to generate a number of options for this type of branching story.

A. Interactive storytelling

Interactive storytelling has a chance to become a significant form of art in the 21st century. Cinema is more than 100 years old, computer games are increasingly common and there is a need for interactive solutions. Advances in computing technologies provide opportunities for users to create their own stories on computers, even at home, which are then published on the Internet. Interactive storytelling is a cross-disciplinary area of research and entertainment [20]. Meadows [21] who also adds to this definition that it is an ambitious form of art, because it links interactivity, visual art and traditional stories.

The creation of interactive narrative is a laborious and complicated process because the author has to include a number of alternatives, which have to be generated (even if not used) and then tested before publication. Traditional storytelling is always linear, which means that the sequence of events is presented from the beginning to the end, without the story changing. In this paper, the researcher proposes the use of still and video panoramas that generate branching narrative in which the user makes a series of choices and in this way unfolds a story. This type of narrative is created for a computer screen and also for a 360° screen, where the audience has a possibility to choose the development of the narrative by using a touch screen on which two alternatives are displayed. This project will not only present the condition and beauty of the interior of a heritage site, but also will teach, provide information and entertain, and by this method become memorable.

B. Story design

The basic element of the interactive narrative that takes place in Charles Church is a panoramic linear movie which is played between decision points, which in turn define the further development of the story by asking the user or audience to make decisions. Fig. 7 illustrates the basic structure for this type of branching narrative, which is based on the story structure described by Ryan as a 'Tree' [22]. In this case, still panoramas are displayed as decision points, whereas video panoramas are defined as panoramic linear movies that are displayed between such points.

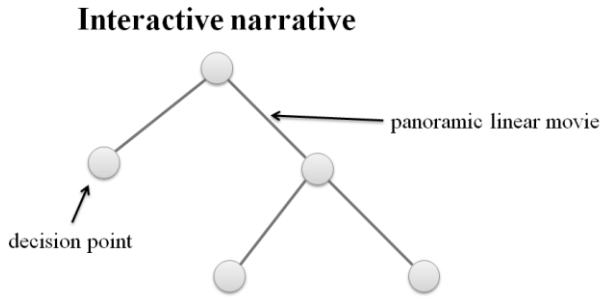

Figure 7. The diagram presents key elements of an interactive narrative.

Interactive narratives in the form of interactive movies are becoming increasingly common, because of electronic media [23]. Today, the Internet has the status of a mass medium and requires constantly new interactive content. The invention of CD-ROMs and DVD-ROMs revolutionized the generation of interactive stories, and Blu-ray disks seems to be appropriate for storing large amounts of data required for a number of alternatives. The story design described in this project is not based on the concept of presenting a "sequence of events" in a mass medium of the 18th century – a rotunda [24], but on the definition of interactive storytelling proposed by Manovich. He defines an interactive narrative as "a sum of multiple trajectories through a database" [25] and the story of the wedding in Charles Church has the potential to be presented in the mass medium of today, the Internet. Nevertheless, 360° screens are becoming more common due to the technical advances of computers and projectors. It seems reasonable to assume that the database proposed by Manovich is in this case a list of files stored in folders where the interactive actions applied to objects (360° images, 360° videos, images, video and sound files etc.) could be defined in an XML file. The unique approach to the branching interactive storytelling is based on the creation of individual panoramic linear movies that are played between decision points and create one whole experience of being in the story, especially when projected on a 360° screen.

This concept is based on the narrative presented on a 360° screen where the audience has the power to change the story using a special device. Generally, all-embracing screens are equipped with a number of speakers, which contribute to this idea. Speaker 1 and Speaker 2 located close to the 360° screen (Fig. 8) produce sounds in decision points. The sound corresponds to the animation presented in this part of the display. The audience has a limited time to make decisions about the next part of the story. Speaker 1 and Speaker 2 relates to two alternatives that occur during the presentation. Those two options are visible on a touch screen. The audience's task is to decide what button should be touched. After the decision is made the 360° still image projected on a 360° screen

switches to video panorama that introduces the audience to the next chapter of this interactive story.

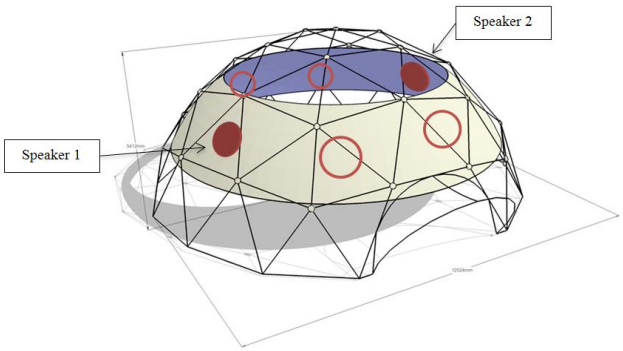

Figure 8. The position of speakers on a 360° screen. Source of image [26], edited by the researcher to present the concept.

C. Story of a wedding in Charles Church and a story-graph

The researcher chose a story of a wedding of Ken Beer and Phyllis Corry who married in the ruins of Charles Church on 22nd March 1941. The marriage was the last one that happened on this site in which the bride wore a wedding dress [27]. The Blitz began on the night of 20th and 21st March 1941. As a result, incendiary bombs left the church in a ruin. The vicar of Charles Church decided to have the wedding in the church, the morning after the bombing on the night of 21st and 22nd March, although the site was destroyed. After the ceremony, the photographer took this picture (Fig. 9).

Figure 9. The picture of Ken and Phyllis Beer that was taken after their wedding in 1941. Kind permission by Tony Rees [27].

Ken is now 97 years old and Phyllis is 91. They both survived the war. In 2010, they celebrated their 69th wedding anniversary. The researcher decided to adapt this linear story to the non-linear narrative that will occur in the virtually reconstructed church. In fact, the original wedding happened on the next day after the bombing of Plymouth and they had their wedding in ruined church, but the researcher decided to move this event in time to create a more dramatic atmosphere. The story is occurring one day earlier, when there is a threat of bombs. The church could be destroyed any time during the narrative.

Once the audience is introduced to the interactive narrative and the touch screen, the story begins and actors that were recorded in a green screen studio and applied to the 360° video of a reconstructed church [5] appear and the ceremony starts. Video panorama is presented on a screen and once Phyllis reaches the audience, a still panorama appears and sirens or alarms of potential bombing are played from all speakers. Then, two voices are played; one in the back saying 'Run away' and the vicar's voice in the front of the church which warmly encourages: 'Please, come to us! Let's continue the ceremony'. The audience has a limited amount of time to make a decision. They have two options that are illustrated on the story-graph (Fig. 10). The story continues – video panorama is then projected until the next decision point.

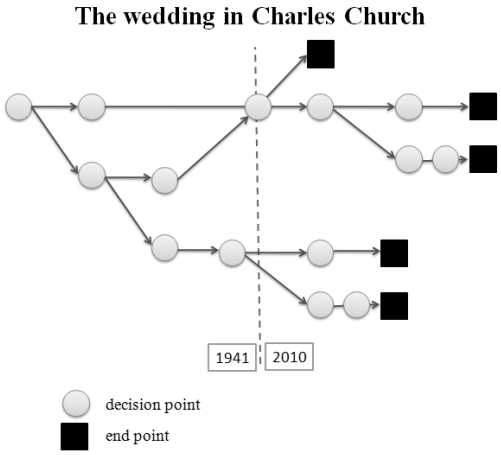

Figure 10. The story-graph of the interactive narrative about the wedding in Charles Church.

The narrative structure demonstrates the concept of a story-based panoramic interactive narrative where every decision point marked as a circle (Fig. 10) has a maximum of two options. This means that the touch screen is programmed for those options. A dotted line marks the border between the story occurring in 1941 and 2010, where Phyllis returns to the church and moves back 69 years in her dream while she is walking inside the ruin. Phyllis starts her journey and as she reaches the altar, the whole reconstruction of the church is visible, in her dream she is offered the opportunity to make new choices that she might have not thought of in the past. Fig. 11 reveals that merged video panorama created on the site and in 3D modeling software enhances the experience while watching 360° narrative.

Figure 11. Video panorama created in 3D modeling software merged with video panorama recorded on the site using a dissolve filter.

Chroma keying techniques enabled the researcher to use the same recording of a person walking in a number of stages of the narrative (Fig. 12). On one occasion the actors are displayed on a background of the reconstructed site, another time they have a ruined site behind them. The process of moving actors was recorded using Ladybug2 camera to achieve the same type of distortion that appears in spherical panoramas.

Figure 12. Recordings of actors in a green screen studio.

Panoramic environments facilitate users or an audience not only to be in a reconstructed site, but also to experience the narrative, in which they make decisions about further developments of the interactive movie. 360° screens with interactive devices provide for the powerful use of narratives to be projected in this innovative form. Moreover, spatial sound, played from six speakers, makes the audience constantly aware during the time of the presentation and this is a significant improvement in the method of telling compelling non-linear stories. At decision points, only two speakers play the commands.

V. BRANCHING NARRATIVE AND 360° SCREENS

Robert Barker, who patented panorama painting in 1787, introduced a method of immersing the spectators into a new world [28]. Circular paintings were one of the first trials of presenting remote locations. They also educated the audience by presenting military or biblical stories. More descriptive methods of presenting narratives were introduced with the invention of photography (1830s), cinema (1890s) and television (1920s). Panoramic environments are the next step in the maximization of realism relating to narratives. Taking 360° screens into consideration and comparing this digital medium with an older mass medium such as a panorama painting in a rotunda, it is discernible that this new form of art provides new perspectives for watching content. Panoramic spaces with 360° screens no longer address an individual, but the large audience [23]. Additionally, a point of view is different and not fixed. In contrast to television, theatre or even a photograph, the audience is no longer observing a fragment of their field of view. In the case of immersive environments, they are inside the image space; it is no longer possible to examine everything that happens around the spectators, who have the chance to change their location while watching immersive narratives. 360° stories [29] may become, not only a scientific and technological innovation but also a new art form.

The researcher presented the interactive narrative of a wedding in the Arena360° and the ICCI360°. These two events are based on 360° screens that were installed for the period of one week, the first one in February 2010 at the campus of the University of Plymouth; the second one in September 2010 in the Plymouth City Centre. Igloo Vision [26] which specializes in generation of portable immersive spaces provided the opportunity to interact with the content on the screen. The researcher recorded the audience gathered inside the screen space using a spherical video camera (Fig. 13). Fig. 14 presents the moment of watching a panoramic linear movie about Charles Church by a group of people gathered inside the Arena360°.

Figure 13. The presentation of a narrative about Krakow (Poland) on the Arena360° with the audience watching 360° screen. This is one frame of unwrapped interactive panoramic video [30].

Figure 14. The presentation of panoramic linear movie on the Arena360° screen. Kind permission by D. Hotchkiss.

Jeffrey Shaw, a pioneer in new media arts, who created a number of multimedia presentations for wrap-around screens [1] undertook a slightly different approach when rendering interactive virtual heritage narrative titled ‘Place-Hampi’ [31] [32]. In the case of iCinema Centre’s screens, “co-evolutionary narrative” [33] was rendered and was created “spontaneously and co-operatively” [34] which enabled the spectators of their narrative to be transported to the heritage site. Similarly, the researcher applied the story to a locally known heritage site, but the 3D model of a reconstructed church was the basis for the creation of a story-based panoramic interactive narrative which has the opportunity to be displayed on a computer screen

and on a 360° screen with simple interaction. This type of interactivity needs to be researched in the future.

To summarize, this section presented the application of an interactive narrative on two 360° screens. Table 1 illustrates main parameters of these screens. The ICCI360° screen is almost twice as large and more people have the potential to watch panoramic narratives.

TABLE I. PARAMETERS OF 360° SCREENS IN PLYMOUTH

Parameter	**360° projection systems in Plymouth**	
	Arena 360°	***ICCI360°***
Height [m]	3	6
Diameter [m]	12.5	20
Length of the screen [m]	39	63
Number of projectors	5	5

The application of a touch screen provided interactivity during the projection of a story-based panoramic interactive narrative about Charles Church. The viewers were provided with two alternatives. The third button (Fig. 15) is optional and can be used for adding additional options to the narrative.

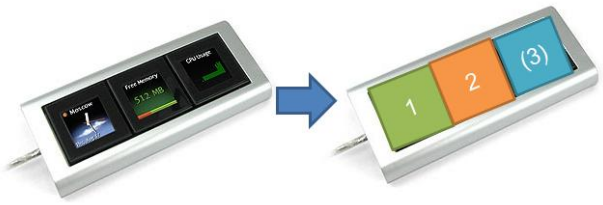

Figure 15. The application of Mini Three Keyboard as a touch screen where up to three alternatives are provided.

VI. CONCLUSIONS

This paper presented a method of generation of 360° interactive narrative, where the starting point is a 3D reconstruction of a heritage site. The researcher wanted to use a locally known ruin to promote not the building, but the event that happened there almost 70 years ago. This research proves that this kind of story can be undertaken by a one-person studio, where most of the work has to be completed by a computer. 360° screens are an appropriate medium for presenting story-based panoramic interactive narratives. Interactivity applied to the project enabled the audience to decide about further developments of the story, but this issue of group decisions needs to be scrutinized in the future. Recording of spectators while they were watching 360° narratives helped to improve not only the method of presentation and interactivity, but also the understanding of interactive stories presented in panoramic image spaces. Possible evaluation methodologies include the application of the touch screen in collecting feedback from the spectators. This research project could lead to the presentation of 360-degree stories not only on 360-degree screens, but also in the interiors of buildings (e.g. the story of Charles Church could be visualized inside the ruin of the church).

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