Digital Interactive Contents with Adaptive Interaction System for Developing Virtual Museum Applications

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***Abstract*— Interactive contents are widely developed through Virtual Reality (VR) technologies. Hardware devices and digital contents are significantly increasing and support interaction system to immerse users into a Virtual Environment (VE). In order to develop interactive application, interaction is always defined before creating application up to selected platform. It depends on a given content and devices which is limited when considering switching platform. We proposed a novel method for developing an application providing digital storytelling template to create interactive content and adaptive interaction system where an application is exportable into any selected device. Our framework has 4 components: Data model, Storytelling model, VR model and Devices connection. We provide flexible editing tools for developer to manage the content structure. The interaction usage will be interpreted into a high-level abstraction and run on a low-level hardware device where interactions have been adapted. Storytelling will specify interaction behavior which can drive interaction in a virtual scene even device may be switched. Here a use-case of digital heritage application in Virtual Museum (VM) will show the development process different interaction system and allow to access respect to devices.**

***Keywords*—Virtual Reality, Virtual Museum, Interaction System, Digital Storytelling**

I. INTRODUCTION

Virtual reality (VR) technologies are used for various purposes. Archaeology is one branch that applies VR for demonstrating actual objects or architecture with mock-up as three-dimensional models. Virtual Museum (VM) applies VR concepts with multimedia information and computer graphic technology. The objective of a VM is to provide more information about historical artefacts to complement, enhance, or augment the museum experience through personalization and interaction. The design and development of VM considers interactivity in the system to allow users to learn about collection of archaeological artefacts. Interactive VM becomes a large multimedia center where users easily access the artefacts and can convey the contents through interaction [1][2]. VR technologies may play an important role to develop VMs that allows history more attractive for learning along with entertainment. By the way, the keystone remains a good storytelling while interaction is the modality to follow history. A Virtual Museum exhibition must be designed making collaboration between creator who specify story and contents with technologies. It is thus a collaborative sign issue.

In the digital content era, thousands physical bricks of information about cultural heritage are converted to digital content. Moreover, there are many devices and technologies which allow users to access data and to visualize it, but there is no real support to transform these data and tell users a nice story and why not history. Museums are storyteller [3] and VM could be performed on the same way, we need a storytelling to drive virtual environment behavior in VM. Interactive digital storytelling projects have been successful when applied to games, films, or multimedia [4]. Thus, interactive digital storytelling should be applied to enhance learning potential in VM as well. However, in VM, user interaction is strongly related to virtual environment to create the storytelling. Interactive storytelling should transform exhibitions which present different points of view based on arrangements and user interaction. By the way, the tools to support interactive digital storytelling development are indeed required and could also be compatible with interaction system.

Interaction emphasizes things to enable users to get into virtual environments. However, interaction system which combines several devices together leads to investigate common interaction usage for developing adaptive interaction system. Different visualization becomes complicated problem to define user interface (UI) to represent the given content. Different input devices are another complexity to enable interaction usage for given devices. Furthermore, interaction system should support interactive storytelling to select suitable interaction usage for devices.

This paper focus on defining high-level abstract functions for storytelling to support creating interactive content and interaction designing which can use with different devices. There are some limitations of devices thus the level of presence and interaction must be analyzed to classify interaction usage. However, to address adaptive interaction system issue requires not only to solve the problem of both UI and interaction but also to support interactive content development. Hence, we need to investigate what storytelling structure is expected for developing interactive content and also device classification is organized to specify interaction behavior then the application will be adapted suitable on provided devices. Eventually, the interaction system will be evaluated to find each potential which one is good for learning in VM.

II. RELATED WORKS

A development of VR application in the context of adaptive interaction system must let switch between devices but interaction must be adapted to device capacity that can be classified. By the way, interactive content must ensure that storytelling involve interaction as a part of the application.

Device classification for interaction support will be essentially issued to normalize interaction behavior. [5][6] classified various systems to explore the potential of 3D visualization techniques to become the right support tool. Visualization has a different impact on user perceptions which mean also having distinct potential. Indeed, not only visualization but also input devices should be classified to interaction capability which consist of both its input and output devices. In order to have more understanding of interaction, [7] has introduced taxonomies of interaction techniques for tasks which are selection, manipulation and navigation. Tasks and subtasks must fit interaction techniques. Then we can determine behavior which will be a high-level abstraction of interaction.

In parallel it was developed frameworks for developing user interfaces adapted to multiple contexts of use that classified tasks and concepts. In [8] Calvary et al. have classified UI supporting multiple devices and support some adaptation to change the context of use applied four levels of task and concepts, abstract user interface, concrete user interface and final user interface. While [9] Coutaz and Calvary extended model and design using Model-Driven Engineering (MDE) to define meta-models, transformations and mappings to address the problem of UI plasticity. In this case traditional 2D display applications are the main focus.

There are several platforms for creating a VE by developer who handle several kinds of devices. VR Juggler [10] is a virtual platform providing a virtual reality system-independent operating environment. This platform supports many graphics engines and network distribution through NetJuggler but no high-level support for application distribution. AVANGO/NG [11] is a distributed scene graph framework. It applies a generic field container programming interface based on OpenSceneGraph and develops an entire application with Python scripting support. Vizard [12] is VR toolkit for interactive 3D content, scripting with Python undertaking many commercial devices and also achieving extraordinary rendering including multi-user, clustering, and multi-channel abilities. InVRs [13] implements Collaborative Virtual Environments (CVEs) approach in the form of a highly extensible, flexible, and modular framework with pre-defined navigation and interaction techniques. Configurable via XML, it has a network distributed virtual world using OpenSG as a scene graph engine. pSIVE [14] platform allows easy setting up of VEs with interactive content and also has a generic model to be applied in different contexts by non-expert users.

These several platforms are considered to be an idea for creating a digital heritage application by taking an advantage of each platform. Storytelling component will be compatible with interaction system for supporting interactive content. Therefore, a system should meet the following requirements

- A storytelling structure which provides high-level specification for application distribution over interaction system.
- A flexible display that supports amongst others a variety of different screen configurations.
- A supported tool for multimedia and interaction handler.

Storytelling is the art to present the content by telling a story which is an effective educational tools [15] for teaching and learning. To be easily translated into a virtual environment, the story must be modeled into a structured framework. The storytelling must be evaluated into an instantiation of ontology. The ontology should be connected to the interaction system to make interactive environments able to transfer context understandable for user.

III. Interaction System in Virtual Museum

Device technologies have emerged as areas of significant interest to be deployed as tools providing advance interaction for the generation of virtual museums. Designing a virtual museum exhibition will use several devices as information conveyors for knowledge construction, acquisition and integration. According to museum visitor study [16], virtual visitor's behaviors in the virtual environments were identified as similar to the behaviors of real visitors in a real museum environment. Visitor behavior is an important indicator about interaction in virtual museum which provides learning ability that devices relate to.

On-site Installation is the type of virtual museum where high level interaction is expected. Visitors will interact to access the content that they are interested in. Then the research question could start from this point to investigate the needs of interaction and devices potential. Interaction system has a loop process to receive and respond to user action through devices. Therefore, we expected to analyze devices will be studied, to get the factors improving learning of users and enabling selecting of devices in the application.

Differences of input and output devices become complicated problem to find good interaction to retrieve content. There is no model to select interaction tasks where several devices and display can be changed. We proposed to separate consideration for output devices to present content and input devices to interact with content. Difference kinds of device lead to have different characteristic that must be investigated. Characteristics of output displays are from presentation capacity up to space and environment of display while input devices characteristics are about interaction techniques up to degree of freedom of device. Here the main research questions are:

- How can we define high-level abstraction for interaction system development where and interaction are different to supports displays and devices switching adaptability?
- How to transform interaction of each device which has different degree of freedom to enable the tasks even if device is changed?

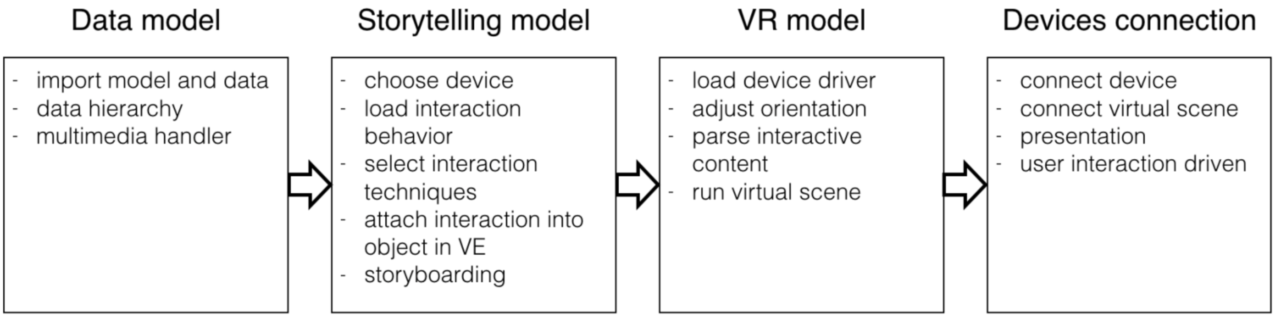

Figure 1. Adaptive interaction system based on storytelling

In order to study interaction process, Collaborative Virtual Environment (CVE) is expected to manage device connection in the system. Usually, CVE is used to for collaboration and interaction of multiple users to work together on VR application [17]. However, CVE does not provide only multiple users in the system, but also enable using multiple devices together in the same application. Thus, CVE is a tool which facilitates flexibilities of using devices.

IV. Research Proposal

The objective of this research is to advance the state of the art about interaction within virtual environments to support learning in virtual museum. The essential aspects are interacting system and contents ontology. Storytelling model will become the abstract level definition of the virtual environment. The CVE is the intermediate technical brick to connect media content and user interaction through devices. A CVE platform will be used to join multiple devices and manage all tasks of interaction. Furthermore, the content structure must be defined within ontology to get interactive environments leaded by this content structure during user interaction. Hence, there are two main sub objectives:

- To develop the adaptive interaction system provides high-level abstraction for switching devices to investigate suitable devices for manipulating an environment in the virtual scene.
- To develop a complete process of Storytelling for designing interactive content dedicated to virtual museum which allow users interact efficiently with the proposed knowledge.

The suitable interaction device must be selected thanks to a knowledge adapted to digital heritage applications. The potential difference between devices is part of this knowledge. The contents of digital heritage application would be efficiently accessed with selected devices providing better knowledge to the users. Device classification will provide interaction techniques for selected device to access interactive content. The study of the devices capabilities will define interaction flexibility and limitation. By the way, we develop a storytelling ontology useful for modeling the specification of expected interactions for virtual museum users. It is assumed that users will get more understanding about digital heritage contents.

Adaptive interaction system is developed with the proposal to transfer data from history resource provide to user through interaction. First, Data model will retrieve historical data to the platform to create a story which handles multimedia and represented by hierarchical data to make easier management. Afterward, in Storytelling model we can select the devices and a template to provide the interaction behavior from high-level abstraction adapted to device. At this point each object in VE can be attached with interaction. It allows developers to make a flow of story by supporting tool for multimedia and interaction handler where storytelling will specify interaction behavior in the scene. Virtual scene is thus an instantiation of the Storytelling model which provides knowledge representation transformed to be a new structure of interaction and multimedia. In VR model, CVE becomes an intermediate connection between story and devices. Driver of the selected device will be loaded and tuned such that orientation follows visualization where content has been parsed and run as a virtual scene. Finally, an application will be compiled at a low-level respect to interaction behavior, devices are launched allowing user to interact in the virtual scene.

When we have a new content or story the process will return to Storytelling model to provide a new environments and devices able to switch to. Each application is evaluated to find devices capabilities. The overall scheme to build an application is in Figure 1.

V. Interaction Transformation

Adaptive interaction system from Storytelling model to Devices connection has two types of transformation data which have different characteristics. A vertical transformation [18] is a transformation where the source and target models reside at different abstraction levels. The vertical transformation is changing level of interaction behavior as see from T1, T2, T3 and T4 in figure 2. It is a transformation into a lower level of interaction. First, device classification produces a formal high-level interaction abstraction to be the same interaction techniques where devices are distinct. Then interaction behavior was created by Storytelling model to specific interaction into virtual scene. Here, T1 will be transmitted to VR model, interaction behavior is loaded from high-level and will be transformed to specific device. In VR model device has been selected through CVE application, interaction is

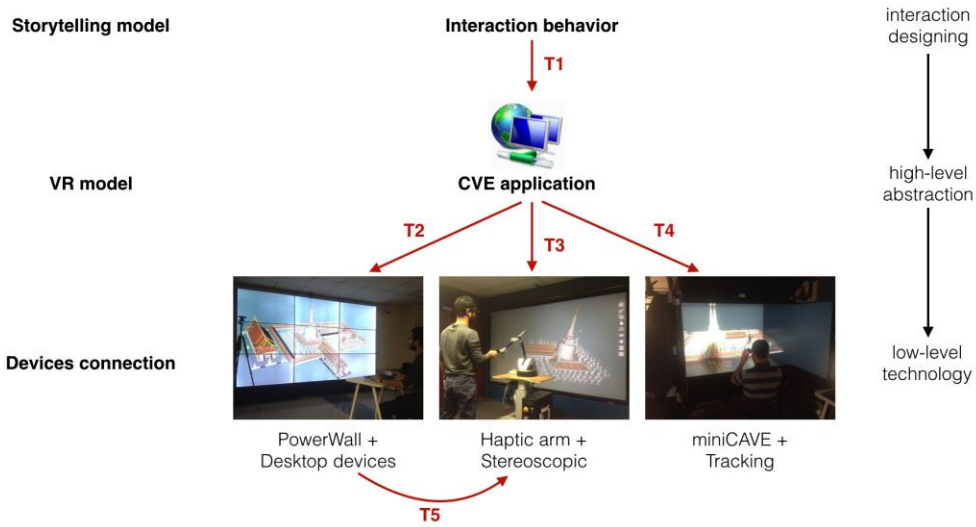

Figure 2. Model transformation from high-level to low-level abstraction

transformed to new characteristic which apply to the device. T2, T3 and T4 are the interaction transformation from selected device. Here, we can approach these transformations to study capabilities of different devices.

A horizontal transformation [18] is a transformation where the source and target models are at the same abstraction level which changes the internal function of interaction. Considering T2 and T3 are interaction transformation using PowerWall + Desktop devices and Haptic arm + Stereoscopic display respectively. The T5 is a horizontal transformation passing through T2 to be another transformation which has different characteristic compare with T3. Here, T3 and T5 use the same devices that are Haptic arm + Stereoscopic display, but use different interaction functions.

In figure 2 at low-level technology we presented interactive digital heritage application applied to distinct devices connection. Storytelling assigned interaction behavior to the content through CVE with high-level abstract functions and transforms interaction according to selected devices. Transformation of each level will be studied to investigate devices capability.

VI. Evaluation Tools

Our concept is concerned with storytelling and interaction system to ease user learning abilities and cognitive absorption. To ensure this interaction system is efficient for virtual museum application both storytelling and interaction system must be evaluated. The first assessment is about scenarios from Storytelling model. All impact variables of story and 3D environments must be studied to find good storytelling style. When scenario is performed in VR model, the system is able to toward using any devices where high-level abstraction of interaction functions is provided. Then devices will be evaluated to study learning potential when using different devices. Finally, all evaluation will be managed to finalize how to develop an immersive digital heritage applications which have efficient storytelling and devices.

A. *Scenario evaluation*

Scenario evaluation [19][20] is interactive content testing, transformation data from Data model to Storytelling model correspond to the CVE application. 3D models were imported to specify interaction behavior in scenario by storytelling. Thus, to confirm Storytelling model provides good narrative story we should explore and analyze factors of storytelling that influence user learning. Immersion evaluation may be processed on a set of users thanks to questionnaire as applied by several authors to ease:

- Comprehension [20]: Understanding the structure of content by discovering story flow.
- Curiosity [21]: Attraction to explore the story in the scenarios and how interesting content makes visitors try to discover knowledge.
- Concentration [22]: The flow of story makes attention to visitors with focusing on the content.

Typically, game immersions evaluation assesses challenge and control. Our scenario unlike game playing, challenge and control factors are not considered in this case because we have no mission to conquer. Therefore, only comprehension, curiosity and concentration are considered to find good assessment criteria.

B. *Device evaluation*

When information from Storytelling model is transformed into CVE application and all devices are connected then user interaction will start. User interaction is concerned about Interaction Techniques (ITs) and devices. ITs evaluation [23] has been proposed already that will be used to be a part of evaluation in this research. Thus, our research will extend ITs

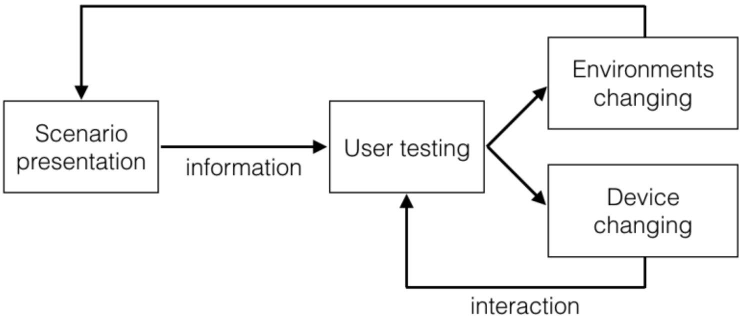

Figure 3. User testing and evaluation process

evaluation to explore device performance while using ITs to find capability of devices. There are two categories of factors related to the devices evaluation that are separated to be quantitative and qualitative value for convenient of measuring the performance.

Quantitative factors:

- Movement: In human-computer interaction, Fitts's law [24] will be used to evaluate movement with time, speed and accuracy of devices used.
- Information gathering: Device's ability to obtain information, questionnaire will be used measure the amount of reminded information.

Qualitative factors:

- Ease of use: Complexity of technique using from user's perspective. User should be able to control VE as desired with all functions when the device is used to interact with.
- Ease of learning: The ability of a novice user to use devices and experienced user. We separate 2 cases of using without explanation and briefing how to use the device before interacts to see the differences and formulate learning score of the device.
- Awareness: User's knowledge through devices orientation and performance. Especially, output devices that user does not interact with. This value helps us to formulate passive device score when use a device without interaction.
- User comfort: Discomfort or sickness while using devices. In VR system many devices have an effect for user and this comfort evaluation will be involved to develop application in practice.

VII. Conclusion

The direction of virtual museums development is mostly based on On-site Installation since the device technologies are coming to support user interaction. Interaction has been used into the applications but level of immersion is still low for learning in virtual museum. Reading, listening or watching are traditional passive learning modality for transferring knowledge to users. Interaction within virtual environments is an active learning that should be the new way to get knowledge. User interaction, therefore, play an important role to help user transfer knowledge by themselves. Furthermore, storytelling will be used to support user understanding in context of story using ontology. This paper proposed a high-level interaction abstraction model where storytelling model specify interaction behavior to drive interaction in scenario where devices may be switched. Our adaptive interaction system supports to identify devices capabilities and storytelling expectation which could be selected for efficiency learning system and improve level of immersion. We claim that the development of adaptive interaction system will help us to find good presentation and interaction for any given content and devices capacities can be evaluated. This implementation is useful to deploy not only for the development of digital heritage applications but also for industrial engineering where interactive content and collaborative working are required.

VIII. Acknowledgment

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