

Modelling Virtual Heritage Environments Using Hierarchy-Embedded Virtual Objects

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Abstract

Nowadays, heritage is eventually inexistence, inaccessible and design decision due to the constructions of new buildings and sites. Various techniques in virtual reality have been proposed in producing virtual heritage. Improper management of virtual heritages in their virtual environments in terms of location and link may cause delivering information unsystematically. This paper is purposed to model virtual heritage environments for one case study of sheltered pavilion using Hierarchy-Embedded Virtual Objects technique. This technique is a hierarchical, tree-structured approach that emulates a tree structure with a set of linked nodes. Three different virtual heritage environments have been published through the tree structure in HEVO Editor. Organizing Editor has enables virtual heritages to be managed in terms of location and link. The resulted virtual heritage environments can be visualized, interacted and navigated through Viewing Editor. These virtual heritage environments are believed to be significant for learning the VH and presenting the values inculcated inside them. Challenges of the modelling technique, research quantification, modelling goals and VH attractions also have been discussed for advanced consideration to model VH.

Keywords: *Virtual reality, virtual heritage, virtual heritage environment, Hierarchy-Embedded Virtual Objects*

1. Introduction

Our earth is rich with the traditional heritages which are still in existence, preserved, conserved and even practised. There are various forms of the traditional heritage including building sites such as palaces, religion houses, government and military buildings; archaeology sites such as caves and national parks; and object sites such as boat, traditional games and dances [1]. The heritage symbolizes cultures practiced by certain races at certain places. Therefore, the heritage is really crucial to be preserved, conserved and maintained so that it remains exists, practiced and inherited to the present and next generations. The heritage is however eventually inexistence, inaccessible and design decision [2] due to the constructions of new buildings and sites.

Virtual reality (VR) is a tool that can be used for the conservation of the heritage. VR allows the elements of heritage created in 3D called Virtual Heritage (VH) to be navigated and interacted by users. Beside its representation in virtual, the values and meanings inculcated in certain heritage can be delivered to the users.

For that purpose, various techniques have been proposed by researchers to model VHs. To model VHs, the heritage has to be constructed and modeled in detail in 3D Tools such as 3D Studio Max, CAD and VRML. However, the costs of them become the main issue in the objects' making of [3-5]. Furthermore, these 3D Tools need high technical efforts as well as relevant knowledge in creating the 3D objects. The VH has to be managed properly in terms of location and link. Improper management of VHs in their VHE may cause delivering information unsystematically.

This research explains in detail a method to model VH using Hierarchical-Embedded Virtual Objects (HEVO). Through this method, VH which is elements of heritage can be managed, positioned and published in VH environment (VHE). HEVO also allows the users to navigate in the created VHE and to interact with the VH for the purpose of learning.

This paper is constructed as follows: Section 2 will discuss on national heritage while Section 3 will highlight the virtual reality and virtual heritage. The proposed methodology will be discussed in Section 4 which is followed by a case study in Section 5 and development of virtual heritage environment for the case study using the proposed method in Section 6. Section 7 will conclude the study.

2.National Heritage

Heritage is what we inherit from the past. The heritage can be implicitly presented in forms of artefacts, sites or places and actors which have historic, artistic, religious and cultural significance to be highlighted to the public [6]. The other forms that can also be referred to the meaning of heritage are building sites, archaeology sites and objects which are traditionally and culturally inherited by a race at a certain place [1]. In Malaysia, Department of National Heritage is a government department committed in the protection, promotion and conservation of Malaysia's rich national heritage. The department has been registered under the Ministry of Culture, Arts and Heritage (KEKKWA).

The heritage requires sense of place to appear its uniqueness and beauty as well as to attract people. To create the sense of place in heritage, it needs elements of Setting, Activities, Meaning, Authenticity, Cultural Elements, Memory, Cognitive, Perception, Orientation, Feelings/Emotion, Time, Experience, Social Interaction, Personalization and Symbolism [7].

It is crucial to preserve, conserve and maintain the heritage for the purposes of structural assessment of architectural heritage buildings [8], formative educational experience [6] and inheritance for the present and future generations. All these purposes need to be performed because the heritage is eventually inexistence, inaccessible and design decision [2]. In certain places, when the new treasures emerge, the cultural heritage is diminishing continuously because of the constructions of new buildings and sites [9]. The public as well experiences hard learning the heritage [7] as it denotes intangible qualities of memories, symbolism, meanings, emotion and senses [10].

3.Virtual Reality and Heritage

Virtual reality (VR) is defined as a computer-simulated environment that can simulate physical presence in real or imaginary worlds [11, 12]. Users are able to visualize and interact with the computer and complex data such as graphical objects and virtual agents as well as navigate in the virtual world [12].

There are five important elements of VR which are virtual environments (VEs), virtual objects (VOs), Viewing, Manipulation and Walkthrough [12]. VOs refer to models or objects that exist in virtual environment [13] for instance people, animals, buildings and

things. Many VOs are available online and ready to use. Users may download for free or purchase the ready-made VOs to be used in the VR applications. Some of the ready-made VOs URL available on the internet is shown in Table 1.

VE is an environment where the VOs exist [13]. House and room are two examples of real world objects that often become the VEs [12]. The VE provides a 3D space which contains x, y, and z coordination. Therefore, understanding of the coordination system is important to locate precisely the VOs in the VE. The movements of the VOs in the VE are manipulated and controlled by the values of x, y and z. The x, y and z can also give the values of width, height and depth of the objects.

Table 1. URLs for the Ready-made VOs

| URLs | Descriptions |
|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| http://www.amazing3d.com | Provides services to build 3D models or VE for multimedia project, movie, animation, video game, magazine, website, 3D simulator and accident reconstruction. |
| http://www.3dmodelfree.com/ | Offers free 3D models for home decorations including furniture, cookware, bathroom products, electronics and outdoor. |
| http://archive3d.net/ | Offers free 3D models for categories of doors and windows, structures, companies and collections and people. |
| http://www.sharecg.com/ | Offers products of 3D models, tutorials, animation and art. |
| http://www.planit3d.com/source/meshes_files/meshes.htm | Provides free 3D products of workshop, seating, household, transport, furniture, aviation, aquatics and plant. |
| http://www.3dmodels.com/ | Offers 3D contents and services. |
| http://www.turbosquid.com/ | Provides services to sell 3D models, 3D modelling textures and plug-ins. |
| http://www.exchange3d.com/ | Offers products of 3D models, texture collection, blueprints, rendering materials and tutorials. |
| http://www.fallingpixel.com/ | Sells 3D Objects such as aircraft, anatomy, military, plants, electronic, interiors, architecture, vehicles and marine-craft. |
| http://www.the3dstudio.com/ | Provides services to sell 3D models, images, textures, tutorials and software. |

Viewing element helps explain the field of view, position and orientation and distance of the objects. All operations or tasks exercised in the VE can be visualized through this element. Some VR systems have multi-views or multi-displays which contain of several viewings at certain time.

Walkthrough element allows the users to explore and navigate in the VE [14]. The users may go forward or backward and may turn left or right as if they walk or run in the real environment. Besides feeling fun during the navigation in the VE according to the users' desires, this element is also essential for collision detection to walk on surface and to stop the walkthrough.

Manipulation element refers to the users' interactions of VOs in the VE [14]. Examples of manipulation activities are selecting an object, changing the position of an object, rotating and scaling an object. This component mainly highlights the particular ways users interact with VOs in the VE. Since VOs can be manipulated or interacted, the users can examine the VOs to comprehend more in depth.

In the last decades, VR systems have been receiving much attention as useful tools for the conservation of the architectural heritage. This effort can be seen through the studied researches and created VR applications called Virtual Heritage (VH) including for structural assessment [8]; for reconstruction of monuments [15]; for reconstruction of total physical loss of the monument [16]; for recreating a loss human environment [17]; for immersion in a computer-generated world [18]; for presenting and monitoring the structural changes through time [19]; for creating the sense of place in VHE [7]; for studying users requirements in VR for architectural heritage learning [20]; and the last but not least for measuring user experience in VE [21]. The researches have been carried out due to the difficulty of interpreting the numerical models for visualization of VH [8], requirements of return to the site to re-measure, re-photograph and re-record for accuracy of the created VH [2] and the incompatibility of user interaction and difficulty to trigger the sense of place in VH [7]. VH refers to the use of computer-based interactive technologies to record, preserve or recreate artefacts, sites and actors of historic, artistic, religious and cultural significance. It aims to deliver the results to the public for provision of formative educational experiences through electronic manipulations of time and space [6].

Even various VH applications have been developed for the visualization, interaction and navigation as offered in VR tools, the management of heritage elements called Virtual Objects (VOs) should be considered as well. This is because the main motive behind the visualization, interaction and navigation in VH specifically and the creation of VH applications generally is aimed for presenting and learning the values inculcated in VH. In this research, a technique to manage VOs in VH called HEVO has been discussed in details for the purpose of learning.

4. Hierarchy-Embedded Virtual Objects

In this research, Hierarchical-Embedded Virtual Objects (HEVO) method has been proposed and discussed in detail to model VH. This method allows VH that refers to the elements of heritage to be managed in its virtual environment called VHE and provides the users to view, interact and navigate in the created VHE.

HEVO is a hierarchical, tree-structured approach that emulates a tree structure with a set of linked nodes [12]. Each element in the tree is attached to one or more elements beneath it. The connections between elements are called branches. Trees are often called inverted trees because they are normally drawn with the root at the top. Meanwhile, the leaves refer to the elements at very bottom of an inverted tree. In term of hierarchical file structures, the leaves often refer files and the other elements above the leaves refer to directories [22].

HEVO method allows the root node to become main VHE. The sub-nodes in the tree structure may represent the other VHEs or VHs. Parent node may turn out as VHEs. Child node may become VHs. These two situations apply to all parents and child nodes in the tree structure. The leaves nodes certainly represent as VHs [23, 24].

HEVO method furnishes six benefits in VR system [23, 24] as follow:

- Categorization of VHs. It is based on parent nodes and their own child nodes. The child nodes are said to be grouped or classified in their own parent nodes' category. The parent nodes that contain of their child nodes are defined as a collection of groups or categories.

- Areas of interests (AoI). Categorizing the objects will also produce a number of levels or depths. Each group or category which contains of parent and its child nodes is defined as an AoI. In this case, any AoI will be a VHE while the child nodes will turn out as the VHS in the VHE.
- Addition of More Information. Detailed information can be inserted for each VH in each area (AoI). By separating the areas, all nodes that are resident inside each area will be more obvious to display. Other descriptions of a VH may include its name, location, path, parent node, child nodes, a number of child nodes and clarifications of VH.
- Modifications of Information and VHS. Any modification on the information or VHS especially in terms of their positions and orientations can be made independently. The modification only affects at the particular infected area. The rest of areas are not influenced by the modification.
- Iterations of VHS. A VH in the tree structure can be reused or repeated. There is no limitation in the duplication of VHS. The duplicated VH then can be manipulated to produce a unique VH that differs from the other VHS. For such purpose, a mechanism in HEVO to manipulate the VHS' rotation, translation and scale is used.
 - Synchronization of VHEs. In HEVO, the VHS is managed and arranged in synchronized. A systematic flow of VHS' node can be seen in the tree structure from the root node till the leaves nodes. Each area of interest produced according to parent-child concept is managed in sorted. Therefore, it leads to the synchronization of VHEs. HEVO method involves four modules as illustrated in Figure 1 and 2 which are divided into the modules for facilitators (the first three modules) and end-users (the last/fourth module).

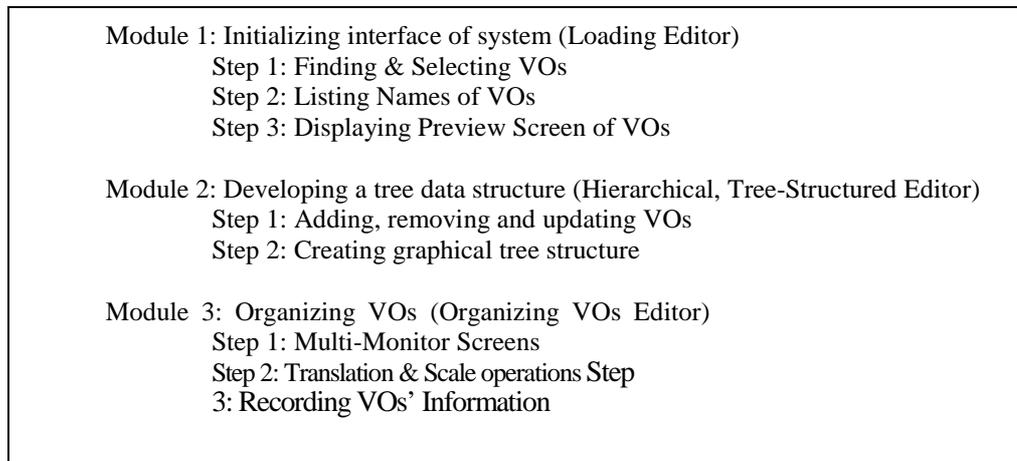


Figure 1. Modules for Facilitator Using HEVO

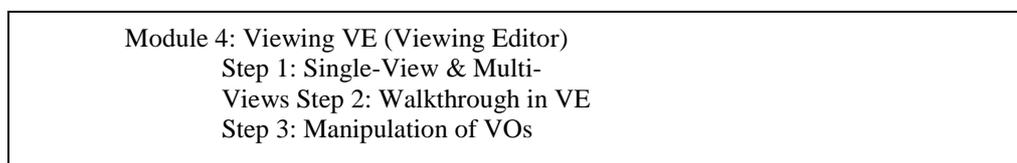


Figure 2. Modules for End-users Using HEVO

In the first module, an interface of virtual reality system called Loading editor is initialized. This interface allows the facilitator to search the location of VHS and select the

desired VHs to be loaded in the system; list the names of VHs that are successfully loaded; and display the sample of VHs selected from the list.

The second module provides the use of data structure using hierarchical, tree-structured editor. The facilitator can create the graphical tree structure through several types of operations provided in this editor such as adding new VHs in the tree structure, adding new group of VHs, removing unneeded VHs and clearing all VHs in the tree structure.

Organizing VOs editor in the third module works to manage the VHs in the VHE in terms of position and orientation. The facilitator can view a certain VHE in multi-monitor screens to help precisely locate the VHs at the desired places. Each monitor screen projects different viewing such as front, left, top and perspective views. Through translation and scale operations, the selected VH can be moved at new location in the VHE and resized. Information about VHs such as file, caption, description, parent, path, location, scale and rotation can also be saved systematically in the text file with extension *.hevo for reference, distribution and display in future. Thus the users do not need to rebuild the VHE from the beginning.

The last module allows the end-users to view the final results of VHEs either in single-view mode or multi-views mode. They can walkthrough in the VHE using arrow keys on the keyboard. Mouse can be used to allow the students manipulating and interacting with VHOs in the VHE. Figure 3, 4, 5 and 6 show the interfaces of editors in the VR system which implements the four modules as described above.

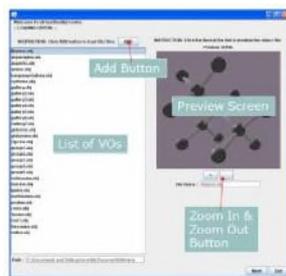


Figure 3. Interface of Loading Editor

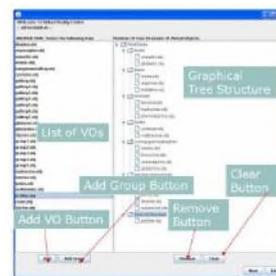


Figure 4. Interface of HEVO Editor

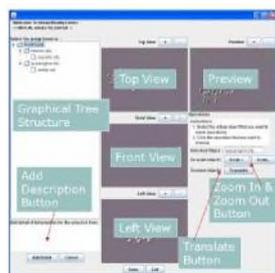


Figure 5. Interface of Organizing Editor

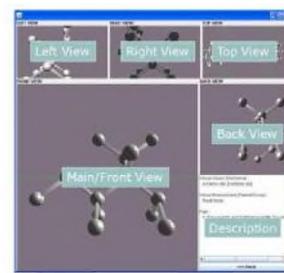


Figure 6. Interface of Viewing Editor

5. Case Study

In this research, HEVO method has been utilized to model VHEs of a sheltered pavilion of Pak Badol. The sheltered pavilion of Pak Badol is located in a village called Pak Badol/Jirus, Kelantan state, Malaysia along the road between Pasir Puteh and Kota Bharu within a padi field. It has been used by farmers to rest and relax, taking showers, pray and eat especially in times of harvesting and planting of rice. It has been built in 1050s through generous contribution and cooperation of the community. For conservation of the sheltered

pavilion, it has been relocated to the Kelantan Museum of Royal Traditions and Customs in Kota Bharu, with its stilts now being raised and supported with new concrete foundation. The original site of the sheltered pavilion saw a new replicated design erected as its replacement [25].

The structure of sheltered pavilion is based on Islam which prompts moderation, hospitality to fellow human beings and the sanctity of communal contributions. It uses *cengal* hardwood (Neobalanocapus heimii) in building the roof and column structure. The roof is fitted with *senggora* clay tiles with the crown on the apex roof made of concrete. For decorative elements, all four corners of the square-sided roof structure have identical *punggung itik* (duck bottom upward curve) design. Lattice pattern using the crown motif are run intercrossing on the topmost-tiered roof [25].

These beauty and uniqueness of its creation ought to be conserved, shown, immersed, taught and practised to/by the present and next generations for the heritage continuity and survive. Figure 7 illustrates the sheltered pavilion of *Pak Badol*. For this reason, a technique called Hierarchical-Embedded Virtual Objects (HEVO) is proposed.



Figure 7. The Sheltered Pavilion of Pak Badol [26]

6. Results and Discussions

Using HEVO method in developing VHE of sheltered pavilion of Pak Badol has resulted three different VHEs since the tree structure has produced three parent nodes which are root, roof1 and duck1. Many VHs can be selected using Loading Editor. Figure 8 shows that VHs of platform, a sheltered pavilion, four coconut trees, two grass_01, two grass_02 and two grass_03 have been positioned and managed as well as the VHs of roof1 and duck1 in the main structure. HEVO method also allows the same VH to be used frequently as done for coconut trees, grass_01, grass_02 and grass_03. In the tree structure, VHs of roof1 and duck1 have their own child nodes which respectively are roof2 and duck2. In this case, both VHs may produce two different VHEs in Organizing Editor as illustrated in Figure 9.

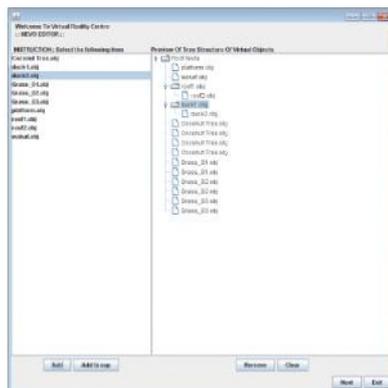
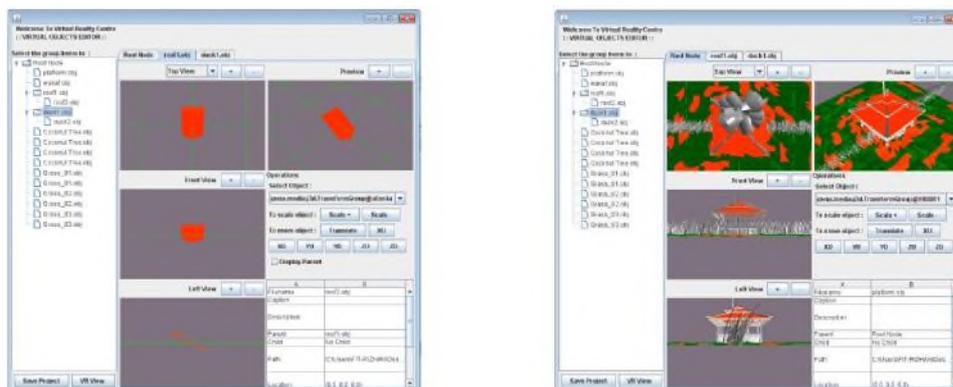


Figure 8. The Managed VHs Using Tree Structure in HEVO Editor

Therefore, the generated VHEs in the HEVO Editor can be represented as follows:

VHE1 is a finite, non-empty set of nodes, $VHE1 = \{r\} \cup VHE2 \cup VHE3$, where, a designated node of the set, r , is called the root of the tree; and the remaining nodes are partitioned into $n \geq 0$ subsets, $VHE2$ and $VHE3$, each of which is a tree.

Each VH in VHEs can be positioned and oriented using Organizing Editor as illustrated in Figure 9. Detailed information about VHs can also be added. The position, orientation and information about VHs can be saved for access in the future (Figure 10).



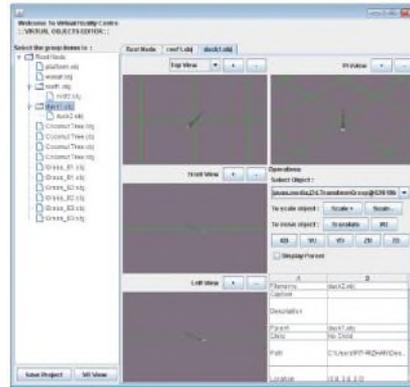


Figure 9. The Positioned and Oriented VHEs of Root, Roof1 and Duck1 in Organizing Editor

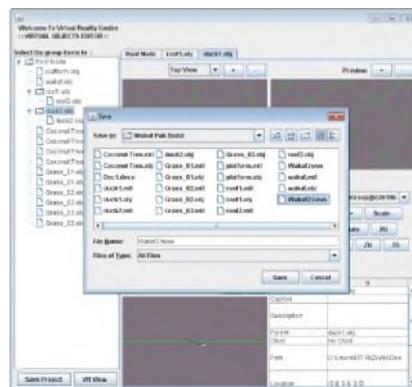
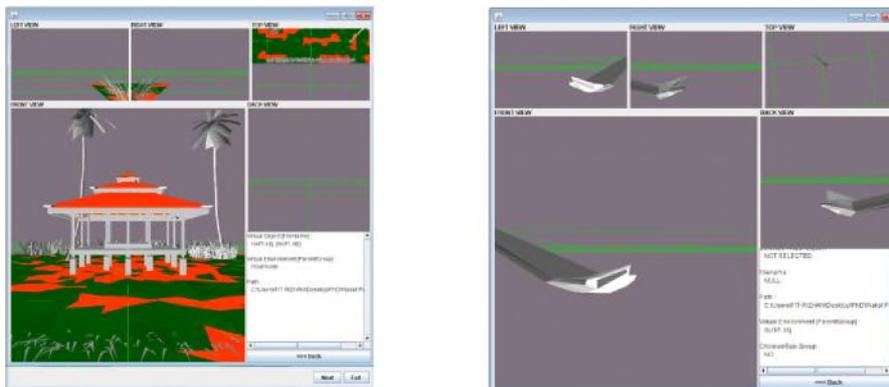


Figure 10. Saving as *.hevo for Access in Future



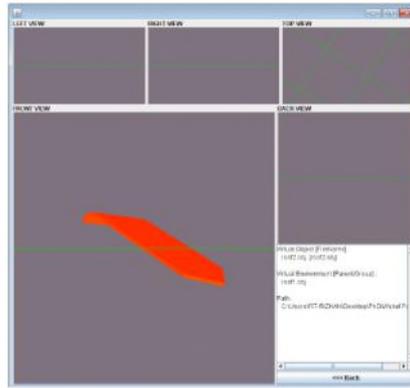


Figure 11. Visualizing, Interacting and Navigating the VHEs of Root, Roof1 and Duck1 in Viewing Editor

The saved file containing VHEs of root, roof1 and duck1 can be visualized using Viewing Editor as illustrated in Figure 11. The users can choose either single view mode or multi-views mode for visualization of the VHEs. Each of viewing modes has its own features for facilitating the users to visualize VHEs. This editor allows the users to navigate in VHEs using arrow keys on the keyboard. They can maneuver as if walking in the VHEs. Up, down, left and right keys on the keyboard respectively transform the users to go forward, reverse, turn left and turn right. The users may also interact with and rotate each VH in its' VHE for obtaining clearer perspective of VHEs and for linking to the other VHEs. VHEs of roof1 and duck1 can be linked when the users use right mouse click at the roof1 and duck1 VHEs. Details of information about each VH can be obtained by clicking the desired VHEs. From this point, learning the VH can perhaps be happened since detailed information of VH can also be accessed besides expressing the feeling fun during the navigation and interaction of VHEs.

From the resulted findings, the issues emerged (as experienced by the prior researches) have derived new challenges for our advanced research. These challenges can be seen in terms of the following:

Enhancement of the modelling technique.

Prior researches respectively have contributed their own technique to model VHEs and VHEs as proposed by [15]. Tree structure is the main operation in HEVO method which successfully has been implemented to model VHEs of the case study discussed previously. This technique can produce the child and parent nodes to represent the VH and VHE respectively. The heritage however has its own characteristic describing the uniqueness, meaning and beauty of the heritage. This HEVO method can be considered to be a basic model to create the VH but modification or enhancement of this model should be highlighted to explain the characteristic. Therefore, a concept of metadata can be suggested and proposed in HEVO model which considers the inculcation of characteristic in the heritage to develop effective VH and VHE.

Research Quantification.

The modelling of VH should be tested and evaluated using quantitative and/or qualitative studies. Various techniques to develop and model the VH have been proposed for visualization, interaction and navigation purposes [15] but they are still lack of empirical findings [7]. The evaluation is required for proving its feasibility and performance of the proposed techniques. Previously, HEVO method has been implemented to create VEs of a group of amino acids, computer hardware, virtual forest and underwater

world. Usability studies of the amino acids group VE [23, 24] and computer hardware VE [12] have been executed to test the HEVO model in terms of feeling fun, help learn, easy to use, help understand better, without demonstration, suitability for learning, use in future, differentiate VOs, Suitability of VE to be navigated, importance of interactivity technique, effectiveness of interactivity technique, importance of navigation technique, effectiveness of navigation technique using keyboard, contrast of VOs and comfortability using multi-views mode factors. Our next phases for this research are to evaluate the created VHEs of the sheltered pavilion of *Pak Badol*. The data collected afterward will be analyzed and presented to the responsible parties such as *e-Warisan Senibina*, Ministry of Culture, Arts and Heritage (KEKKWA), Ministry of Science, Technology and Innovation Malaysia and museums.

□ Goals of Modelling VH

In order to model VH, it is crucial to define the main goals of its development besides the purposes of visualization, interaction and navigation. Perhaps the goals for dissemination, manipulation and personalization as proposed by [7] and for education by [12, 23, 24] can be studied more in advanced to be considered in developing the VH. Determining the right goals can help in choosing the right software and hardware to create effective VH and VHE.

□ VH Attractions

As issued by [7], the study of real elements needed in VH should be further implemented to create sense of place. It is because typical VEs are often criticised for being lifeless, empty and lacking live contents [27, 28]. The insertion of the right elements in VH may attract users to explore the VHE and at the same time to encourage learning to be happened.

7. Conclusion

This paper has discussed in detailed the creation of VH using HEVO technique. Three different VHEs, root, roof1 and duck1 have been created to be visualized, interacted as well as navigated by the users. In HEVO Editor, each VHE is categorized based on parent and child nodes and two levels of AoI have been created. From the resulted AoI, VHs can be exposed, explained and delivered in detailed to the user. Meanwhile Viewing Editor is used for visualization, interaction and walkthrough of the generated VHEs. Discussions on new challenges arose from the findings especially in terms of enhancement of the modelling technique, research quantification, modelling goals and VH attractions have been done as well for advanced consideration to model VH. The next phases for this research are to evaluate the created VHEs of the sheltered pavilion of Pak Badol using usability and system performance studies.

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