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5D GIS virtual heritage

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Abstract

In recent decade, a wave of apprehension swept across the Pearl of Oriental with regards to the disappearance of high value tangible and intangible heritages due to urban renewal and redevelopment. The flourish of computer science and engineering, however, offers a rosy spectacle for heritage preservation. Virtual heritage is no longer an idea in cloud-cuckoo-land. In this research paper, we propose the ground breaking five dimensional GIS virtual heritage. Whilst traditional two dimensional GIS stores the information of X and Y axis, the recent three dimensional GIS includes the information of building height and other information is useful to urban planners when they make decision in change in use of land. The fourth dimension includes time with collective memories of Hong Kongers. The invaluable intangible heritage can be kept by record of oral history. Changes in ethnic minorities, different walks of lives provide dazzling and interesting angles of the modern city. We also include the concept of the fifth dimension of automated virtual and augmented heritage with drone and robots' help in taking 360 degree virtual reality videos and photos. Whilst strand of literatures on VR, AR, 3D GIS and memories scatter in different areas of research, combination of all these technologies is the first of its kind. Research on automated VR and AR is scarce or non-exist. It is expected that the 5D GIS virtual heritage offers a new angle to historian, economists, sociologists, urban planners.

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1. Introduction

Digital technologies are a source of innovation and development for the heritage sector. Popularity in information and communication technologies has profound influence on how heritage collections are managed and made visible

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to the public[1]. Heaps of the historians, surveyors, architects, economists have an article of faith that preservation of building heritage can go hand in hand with modern development. Moreover, the parade of mobile technology has turned a new leaf for heritage management. Digital heritage is neither blue-sky research nor simply castle in the cloud driven by passion of ideas. In hindsight, digital heritage is an inevitable shift in heritage conservation. Despite data heterogeneity is one of the main characteristics and a major challenge with regards to database interoperability [2], the current development of innovative technologies such as wearable computing, robots, 3D printing, virtual reality, robots encourage us to think outside the box[3]. Shocks and chaos between modern technology and traditional heritage sparks our enthusiasm in proposing five dimensional GIS virtual heritage.

1.1. Virtual heritage: A fusion of traditional heritage and modern technology

Virtual heritage is a fusion of virtual reality technology with traditional heritage. With the help of computer-based interactive sites, technologies, artefacts, and historic actors, artistic, cultural and religious significance are recorded, preserved. Traditional practices, knowledge, representations, skills, artefacts and cultural spaces and the recreation of what used to be there are included. Simulated objects offer specific meaning to cultural perceptions of traditional inhabitants. Indeed, virtual heritage not only records the physical appearance but also cultural artefacts through the use of interactive digital media[4].

Similar to virtual exhibition, virtual heritage allows participants from different parts of the world to view it at any time. New materials can be added quickly and updated easily [5]. Internet infrastructure and networked readiness are conducive to scientific co-operation and preservation of digitised cultural heritage [6]. According to the International Council on Monuments and Sites, virtual heritage restores historic buildings' memory, promotes the application of technology in monuments' assessment and recovers archaeological heritage. Experiential archaeology makes someone who is not physically there "being there" possible. By using image-based 3D model to record monuments, archaeological landscapes and excavations, visual reconstruction, illuminates the 3D heritage and cultural heritage sites. All facets of heritage must be researched and incorporated with experiences via intangible reconstruction. The virtual heritage includes intangible values which need to be protected. With the help of VR, an impressive, immersive, interactive product with personal presence of the user in its environment can be turned to reality. Application of VR technologies to cultural heritage has high potential to become a powerful tool for archaeological reconstruction. No wonder archaeoacoustics emerges as a new discipline that enriches the intangible heritage by applying sensual technology to monuments [7].

In recent few decades, different places around the World have developed their own virtual heritage system, e.g. South African Heritage Resources Information System was developed by the South African Heritage Resources Agency in 2011 as a repository for heritage sites. It also serves as an integrated tool for reporting and tracking heritage crimes[8]. In Iran, digital surrogates of historical Persian include HARAM online manuscript service of the National Library and Archives of Iran[9].

1.2. Five dimensional virtual heritage

2. Conventional two and three dimensional GIS heritage

High monetary return from demolition and reconstruction of new buildings often blaze the trail for urban renewal. Nevertheless, event as such is also blamed for heritage sites isolation and removal of important cities' memories. In view of this, it is important to develop a digital GIS-based documentation system with all the spatial and non-spatial information for heritage buildings. This database includes information for each of the heritage building: geographic location, construction date, number of floors, construction material, current building usage and current building status. It provides the basis for monitoring the heritage buildings' status and useful information to prioritize heritage buildings' maintenance and rehabilitation. Geodatabase as such can also act as a ground for protecting the threatened heritage from unintended urban growth and sprawl[10]or gild the lily in some of the heritages which can move up with times. As a matter of fact, the Geodatabase can also open the dialogues between different stakeholders who may speak different languages due to different standpoints as the feast of reason and make common cause.

Fig. 1. Three dimensional map of mutli-story buildings in heritage area [10]

Fig. 2. Side view of the three dimension virtual heritage site[10].

Categorized by heritage's building height and modern urban fabric nearby, the three dimensional X-Y-Z GIS heritage database records the distribution of modern multi-story buildings in study area which can be presented in a 3D-GIS based map,[10]. The X axis refers to the horizontal axis which is parallel to the wall, Y is the vertical axis and Z indicates the horizontal axis perpendicular to the wall. Based on PhotoModeler Scanner software, Photogrammetry helps us generate a digital model of the wall based on a three-dimensional georeferenced point cloud. The centre of coordinates on one of the wall panels can be determined for orientation purposes and cloud scaling. These coordinates lay the ground for GIS georeferencing. ArcGis with Spatial Analyst module can be used to raster layers, generate with the scaled and georeferenced point cloud that yield a digital surface model[11]. Figures 1 and 2 illustrate the examples of 3D GIS map for built heritage.

Height information is useful when we are at the cross road with regards to rebuild and further development. Construction of new skyscrapers potentially affects the visual balance of heritage and deteriorates the heritage value as modern buildings are usually characterized by taller building height where older such heritage buildings are characterized by lower elevations[10]. The picture of Gyeongbokgung in Seoul shows one vivid example. Consider the high redevelopment value, the blame for visual destruction is not hard to assign. In part, the decision as such may have grown out of the power of selfish, monetary-hungry motivation.

Fig. 3. Modern buildings are built next to the Gyeongbokgung, impose negative visual impact to heritage (Thayer, 2016).

3. The fourth dimension of virtual heritage in GIS: time machine that cast our memories back

Memory is essential in the functioning of any social entity[12]. Unlike most of the information online, digital cultural content includes memory institutions which are of high quality and useful for education and research. It also has a broad appeal to many different audiences [2]. Memory forms the basis of action, opinion and a tool to think for present situation. Inquiries into the workings of community memory-making provide insights into communities of the present through employing past conceptions [12].

In recent years, the rapid urbanization frames sustainability practices at the urban level. To achieve the goal of sustainability, three major aspects of win-win-win economic, environment social benefits need to be maximized 13,14). To enhance living standard, sustainability, socioeconomic equity and environmental limitations, sustainable development paradigm includes social and intangible themes and cultural heritage[15]. Cultural heritage is recognized as an important element the sustainable urban development (SUD) at the global level and has been included in the international agenda for sustainability. That being said, little attention has been given to cultural heritage. The lack of systematic assessment methods for cultural heritage management and SUD reflects an academic gap which needs to be filled[15]

In view of this, the four-dimensional space is obtained by adding time dimension to the traditional three spatial dimensions X, Y and Z. It embraces the technology of GIS, important events and memories that mark the changes of heritage over time. It signifies a unique humanity approach for data acquisition where information is logged at different time[11] to visualize the changes in society, ethnic groups, structural or territorial parameters. Oral history recording acts like a time machine, provides useful channels to ancestors with regards to dazzling changes and memories in society. Sensible and collective wisdom can also be displayed based on a whole army of people's thought.

4. The fifth dimension of virtual heritage: automated virtual reality / augmented reality

In general, VR is a technological system that generates virtual representations and scenes which can be visualized through Headset Mounted Display (HMD), such as cardboard, virtual representations, Google cardboard, Samsung Gear VR, Oculus Rift VR, Neo Pro, Sony VR headset[16]. Alternatively, the user in a CAVE is a monitor-based system built on a three-wall projection-based system. Projection of Q' of point Q(Q1,Q2,Q3) in the front wall is given by:

Q'1= Q1+(PP-Q3)(e1-Q1)/(e3-Q3)

Q'2=Q2+(PP-Q3)(e2-Q2)/(e3-Q3)

Hence, the general projection matrix will be [17]:

$$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \dfrac{e1}{(e3-PP)} & \dfrac{e2}{(e3-PP)} & 1 & \dfrac{1}{(e3-PP)} \\ \dfrac{e1PP}{(e3-PP)} & \dfrac{e2PP}{e3}-PP & 0 & \dfrac{e3}{(e3-PP)} \end{matrix}$$

In recent years, rapid advancement in mobile technologies and high-speed networks offers insight on heritage management (Addison, 2000). Modern heritage management can surely run with the ball of automated technologies. Virtualized heritages can be built upon heritage in real physical forms. Theorized historical and virtual interpretations provide useful information to viewers (Addison & Gaiani, 2000). 360 degree VR video of the interior heritage can be taken by robot with VR camera whilst the external part can be taken by drone with video and photo taking devices.

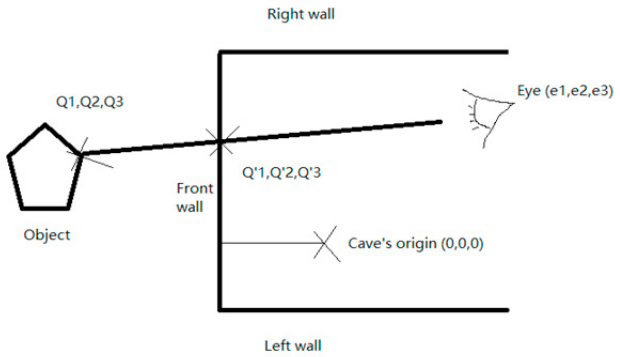

Fig. 4. Projection based VR in CAVE [17].

Inclusion of VR to GIS enables user to move through modeled and real information with spatial accuracy. The use of GIS turns the traditional static man–machine mode to outdoor dynamic mode. It is a technology that adds the dimensions of interactivity and immersion to three dimensional computer generated models allow exploration that is not possible based on traditional forms of representation. Virtual design studios compensate for the lack of space [18].

Augmented reality (AR) is a visualization technique which synthesizes multimedia information with real view. It reinforces the real world sight by overlaying virtual objects such that the virtual object forms part of the real environment. It strengthens the contiguity of time and space by superimposing virtual information to spaces and objects in reality. Recent developments in wireless, computer graphics and mobile technologies lead to a fast growth of AR applications on smartphones. Based on these capabilities, AR applications of spatiotemporal contiguity appear in architecture, education and medical science. Beyond doubt, AR technologies have growing importance to reproduce on-site historical experiences and monuments [19].

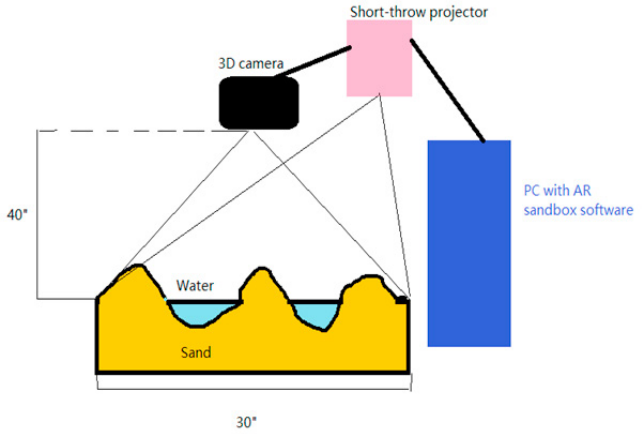

Fig. 5. Tools required for AR heritage production [20]

Table 1. some of the Tools required for five dimensional virtual heritage

Tools	Justification
Tools for 3D GIS	
ArGIS	For making the GIS database
PhotoModeler Scanner	To generate a digital model of the wall based on a three-dimensional georeferenced point cloud
Tools for making VR heritage	
VR camera	To take the photos and videos of the heritage sites
VR gear	For viewing the VR videos and photos
VR viewing device	For viewing VR videos and photos
Cloud storage device	Digital storage of VR videos and photos
Double Robot, 9.7 inch iPAD, 360 Panorama	To take automated 360 degree VR videos steadily on ground in absence of camera man's obstruction.
DJI Inspire 1 RAW (Dual Remote)	To take videos for the heritage from outside and produce VR
VideoStitch Studio - v2	To edit the VR clips
Infrared camera	To monitor the building structure over time.
Tools for making AR heritage	
A computer with a high-end graphics card which can be run with any version of Linux	Linux-based installations are more stable than other types.
Microsoft Kinect 3D camera and AR Sandbox software	For producing Augmented Reality heritage.
A digital video projector with 1) a short throw length and 2) a native 4:3 aspect ratio	To improve the image quality.
SARndbox-2.2 with sand	To match the fields-of-view of Kinect camera and projector

5. Summary

Traditional heritage management mainly sheds light on cultural and built heritage in physical form, this paper offers a new perspective on heritage management via an innovative approach called 5D GIS virtual heritage based on 1) 3D GIS with X-Y-Z dimension, 2) time dimension with memories about the heritage, such as ethnic minorities and other local's stories and 3) virtual heritage built by automated VR and AR techniques. The virtual model made by the early three dimensional GIS also has potential to print out via additive manufacturing, turning some of the heritage which has already been demolished based on oral history recorded and reconstructed in 3D GIS database. Last but not leaste, as [21]commented "affordability, accessibility and a user-friendly platform are all determinant virtues for any technology", it is expected that our proposed 5D virtual heritage shall provide viewers these advantages.

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