

# Heritage Preservation Through Indoor 360° Views: A GIS Approach

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## Abstract

This paper seeks to explore the feasibility of creating a digital archive of heritage sites in the form of photospheres using a spatial database created on a panorama software -- EasyPano. Through our case studies of Yueh Hai Ching Temple and Fuk Tak Chi Museum, we aim to explore the advantages and disadvantages of using panorama technology to digitally document heritage sites. Although panorama technology has its own limitations and constraints, this paper argues that digital spatial database created on panorama softwares are more suitable than traditional GIS database in documenting heritage sites in an immersive and semantically-enriched way. This can be attributed to panoramic software's capabilities of creating 3D virtual tours that immerses users into the setting and layout of the site, allowing them to visualise the heritage site as if they were there. We will also highlight several limitations encountered during the study and propose alternative design practice and choices that future research can consider. These alternative suggestions underscore the point that the design of a heritage preservation project is ultimately contingent upon its project goals and objectives.

Key words: 3D GIS, Immersive, Semantic, Virtual, Panorama, Historical, Heritage, 360°, Preservation, Temples



Yueh Hai Ching Temple



Fuk Tak Chi Museum

## **1.0 Introduction**

To combat the threat of cultural homogenisation that globalisation brings, and the potential damage of natural disasters and general wear and tear, both local and governmental agencies have made efforts to preserve significant cultural and heritage sites (Bauer, 2009). One such current heritage preservation effort is the development of immersive virtual site tours with 2D and 3D pictures (Akçay et al., 2012). In our project, we attempt to document two Chinese temples in Singapore that have significant heritage value -- *Yueh Hai Ching Temple* and *Fuk Tak Chi Museum*. Located in the heart of the Central Business District, Yueh Hai Ching Temple was established in 1826 by the Teochew community while Fuk Tak Chi Museum was built in 1824 by the Hakka and Cantonese communities (Lee, 2002). Upon their arrival in Singapore, these temples were the first stops for Chinese immigrants as they come to offer thanks for their safe sea voyage to Singapore (Liu, 1996). Fuk Tak Chi temple was later converted to a museum in 1998 and both sites were preserved and restored by the Singapore government to uphold their historical and cultural significance (Oon, 1998).

Before the sites were renovated in the 1990s, they were slowly degrading due to Singapore's harsh tropical climate. Consistent rainfall and high humidity throughout the year have led to termite infestations and architectural degradation of the temples (Naidu, n.d). Apart from gradual degradation, the permanency of religious sites in Singapore is largely dependent on the government's master plan that shapes Singapore's physical development. As pragmatism is the guiding principle of the government in land-use planning, some temples were slated for relocation or demolition to make way for future developments (Kong, 1993). For instance, since the expiry of its 30-year lease in 2009, Mun San Fook Tuck Chee temple, which was built in the 19th century, has been issued yearly licence extensions until the site is required for redevelopment (Zaccheus, 2014). Given the uncertain future that Chinese temples are confronted with, this study seeks to explore an alternative design choice of using panoramic technology to digitally document the heritage value of these temples in a semantically-enriched and immersive way before the

sites are relocated or demolished. Through the use of 360° images, virtual tours of the sites are created to preserve the present operational status of these sites and they serve as alternative platforms to educate present and future generations about these heritage sites.

## **2.0 Literature Review**

Geographic Information System (GIS) is a computer-based technology and methodology to "collect, store, manipulate, retrieve, and analyse spatial data or georeferenced data" (Elangovan, 2006). Traditionally, 2D GIS has been used to conduct spatial analysis to aid decision making, and observe and predict spatio-temporal trends (Heywood et al., 1998). Although 2D GIS is useful in analysis and visualisation, it is unable to provide an immersive real-world experience of the area of interest. Following recent technological advancements, researchers are increasingly using 3D GIS technology to fill that gap. In fact, 3D GIS technology has been identified as an effective way for the documentation of heritage artefacts and for cultural dissemination as it offers an effective means to observe and analyse the heritage site with accuracy and completeness (de Luca, 2013). Digital spatial documentation of cultural heritage sites is well-established and digital libraries and museums now host large quantities of digital data of heritage sites (Ott et al., 2010). Researchers are spatially documenting heritage sites with cultural values to preserve the sites before they get threatened by catastrophic events such as earthquake and floods (Rüther et al., 2014). While heritage preservation activities are increasingly felt worldwide, there exists a lacuna among existing literature about spatial documentation of Chinese temples in Singapore. Therefore, this project seeks to fill the literature gap by digitally documenting the heritage values of Chinese temples in Singapore using panoramic technology.

## **3.0 Methodology**

The Conceptual-Logical-Physical design framework (Arctur and Zeilaer, 2004) was adopted to develop the methods employed in the design of our GIS project, from the conceptualisation to the execution phase. Although this design framework is based on traditional 2D GIS, the connection between 2D GIS and 3D GIS allows for elements in this framework to be adapted to 3D GIS projects.

### **3.1 Conceptual Design of Project**

To conceptually design the project, the spatial information product that will be produced with GIS was identified. As the project goal is to propose a design choice for heritage documentation, we conceptualised the output to be a digital archive of spaces in Chinese temples in the form of 360° panorama pictures to provide semantically enriched and immersive experiences for users. We set the criteria that the output must have 3D images that appear to surround the user (i.e. immersive) and important spatial features are tagged with informative attributes (i.e. semantically enriched).

Based on the spatial information product to be produced, the key elements that will be required were identified—(1)

360° panoramic views of spaces in Chinese temples, (2) items that have significant heritage value, (3) 2D photos of these heritage items, (4) heritage information (attributes) of these heritage items, and (5) floor plan of the Chinese temples.

Although the spatial representations of these key elements will not be in the traditional points, lines and polygons feature sets, we conceptualised that the scale ranges for our designed GIS product are important. The extent of the panoramic views displayed must not be too zoomed in or zoomed out, so as to provide a comfortable immersive experience for the users.

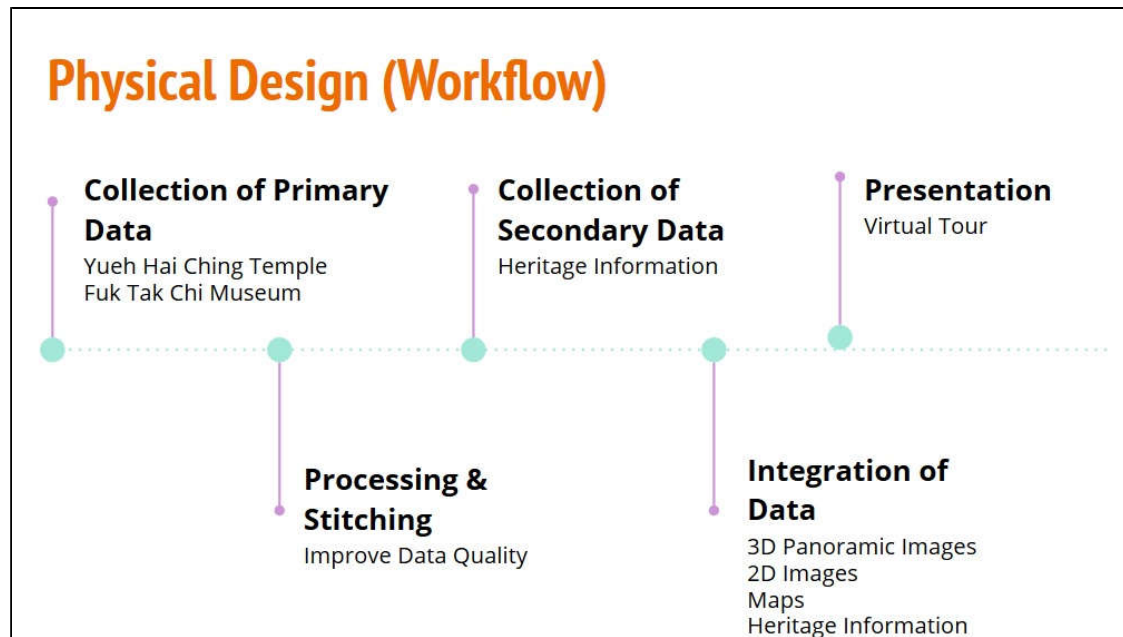
### **3.2 Logical Design of Project**

For the logical design of the project, we first defined the kinds of heritage information to be included in the spatial database. For the purpose of this project, the heritage items identified should embody the ancestral or migration histories of the Chinese pioneers and elements of Chinese heritage and culture. Descriptive attributes on the heritage value of items should thus encompass the historical stories of the heritage items and highlight how the process of creating these items captures Chinese culture and heritage, in addition to the two elements embodied by the heritage items.

We also defined the spatial relations of the datasets as part of the logical design of the project. To offer an immersive and semantically enriched experience, individual datasets need to be integrated together. The 2D photos and heritage attributes have to be tagged to the respective heritage items in the 360° panoramic view; the 360° panoramic views have to be linked to the floor plan so that users will be able to know which part of the temple they are viewing.

Having outlined the conceptual and logical methods in designing the project, we then explored possible virtual tour softwares and identified the most appropriate spatial database design to logically present the datasets. *Marzipano* and *EasyPano* were explored and evaluated. Due to the presentation requirements of the key elements as outlined in the conceptual and logical design framework, EasyPano was selected to be the spatial database.

### **3.3 Physical Design of Project**



To execute the design of the project, the above workflow was implemented. The following sub-sections will delve in greater details for each phase.

### **3.3.1 Primary Data Collection**

Primary data in the form of 360° photos were collected using a dual-lensed 360° camera to capture the indoor spaces of Yueh Hai Ching Temple and Fuk Tak Chi Museum. As quality of data is a key emphasis of GIS practice, special attention was paid to the positioning of the 360° camera. The tripod stand attached to the 360° camera was extended to the maximum length so that the camera could be positioned above waist level. This positioning ensures that the image captured will give the user an eye-level point of view. The importance of offering users this perspective of image will be discussed in a later section of this report.

In addition to positioning, the 360° camera was also placed in the middle of the room so as to minimise the possibility of the scenes captured in the output panorama being too zoomed in or zoomed out. This precaution enhances the quality of primary data by ensuring that the details of the space and heritage items are clearly captured.

Furthermore, to collect the ideal panoramic photo that captures only the spaces and items in the temple, the timer countdown setting of the 360° camera was set to 5 seconds. This setting provided sufficient time for us to hide and also reduced the possibility of any visitors entering the scene. To complement the

function of time setting, we also collected multiple captures of each scene in the temples at different timing. This step was taken so that in the event that any humans are captured in the scenes, the various panoramic images can be overlaid to eliminate the presence of humans from the final output image.

Primary data in the form of 2D photos of heritage items (Fig. 1) were collected using digital phone cameras. The floor plan of Yueh Hai Ching Temple was also captured (Fig. 2). There was no available floor plan for Fuk Tai Chi Museum.



The words on this plaque Shu Hai Xiang Yun mean "Auspicious Clouds above the Sea at Dawn". It was conferred to Yueh Hai Ching Temple by Emperor Guangxu of the Qing Dynasty in 1899 as a token of appreciation to Singapore's Teochew community in raising funds for a devastating flood in China in 1899. Yueh Hai Ching Temple is one of the two temples in Singapore that has received such honour and this signifies the importance of the temple to the Qing court.

Figure 1: Example of 2D image of a heritage item

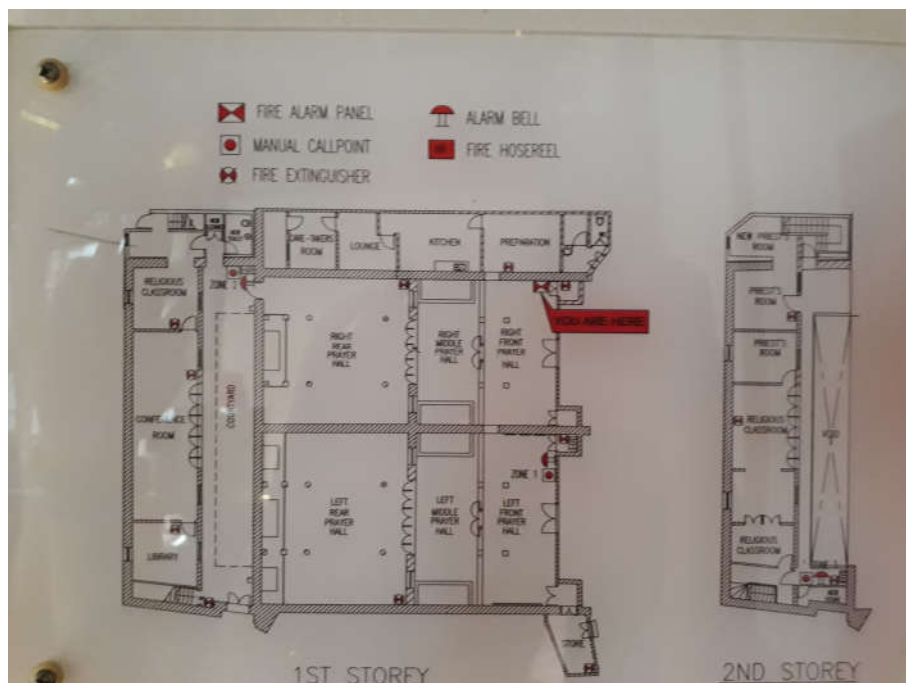


Figure 2: Raw Yueh Hai Ching Temple Floor plan

### **3.3.2 Secondary Data Collection**

The secondary data required for this project is the heritage information of the heritage items. The list of important heritage items in both temples were selected from the list given in the document titled “Chinese Epigraphy in Singapore 1819 - 1911”, published by Dean and Hue (2017) from the NUS Chinese Studies Department. The heritage information on these selected heritage items were also retrieved from the above-mentioned document. Additional details on the heritage items in Yueh Hai Ching Temple were sourced from the official websites of Yueh Hai Ching Temple and Ngee Ann Kongsi, as well as articles published in The Straits Times. Only credible sources were used during this process to enhance the quality of the data attributes collected.

### **3.3.3 Processing of Primary Data**

The raw 360° panoramic photos produced in section 3.3.1 were processed using two tools – ActionDirector and Photoshop – to improve the quality of these spatial data. The floor plan taken previously was digitised using Microsoft Word.

#### **3.3.3 (a) Tool: ActionDirector**

As the 360° camera is dual-lensed, the output photo is made up of two spheres (Fig. 3). As this dual-spherical raw photo is not aesthetically pleasing for users to view the space, ActionDirector was used to stitch the two spheres together. The raw photo can be conveniently imported into ActionDirector by navigating to the “File” and “Import” options (Fig. 4). This is an important step to transform the raw output photo into a continuous rectangular photo (Fig. 5).



Figure 3: Raw dual-spherical photo produced by 360° camera



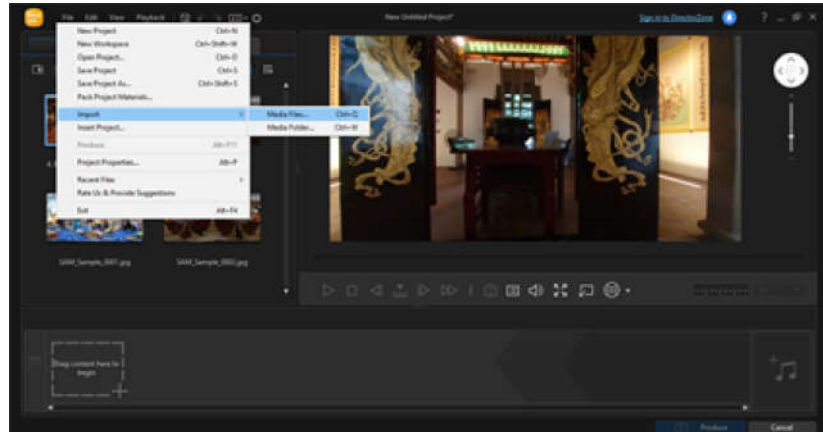


Figure 4: Importing the raw dual-spherical photo into ActonDirector



Figure 5: Output of panoramic image from ActionDirector

### **3.3.3 (b) Tool: Adobe Photoshop**

The quality of the 360° spatial data can be further improved by utilising the tools offered in Adobe Photoshop. There are two key issues with the stitched image output from ActionDirector; the presence of a tripod stand and a rather dull looking photo.

As mentioned in Section 3.3.1, the panoramic image was captured with the equipment positioned at the waist level. The tripod stand was thus inevitably captured in the panoramic image (Fig. 6). The Clone tool in Adobe Photoshop was used to remove the tripod stand from the photo. The processed photo (Fig. 7) is then of a higher quality as it removes traces of the equipment which are not part of the temple's natural scene.





Figure 6: Presence of tripod stand in panorama image

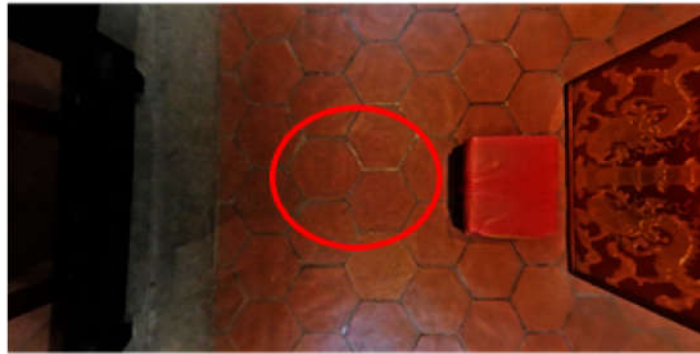


Figure 7: Tripod stand removed from panorama image

Additional steps were then taken to improve the vibrancy of the image's colour to give it an aesthetically pleasing look (Fig. 8 and 9). This was done through a multi-step process of creating additional layers of different lighting settings and then merging them back together to get a high dynamic range image.



Figure 8: Output photo with inconsistent lighting



Figure 9: Processed photo with improved lighting

### 3.3.3 (c) Digitisation of Floor Plan

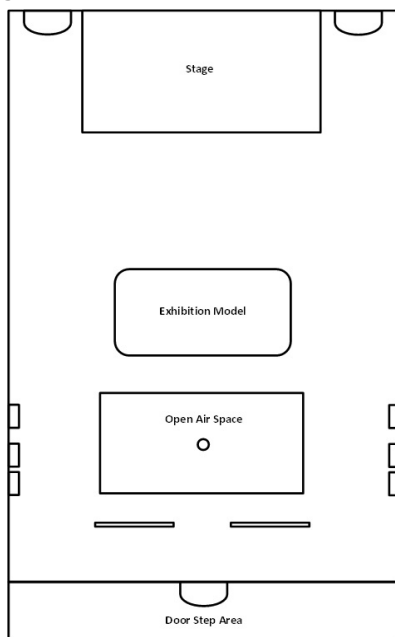


Figure 10: Digitised floor plan of Yueh Hai Ching Temple

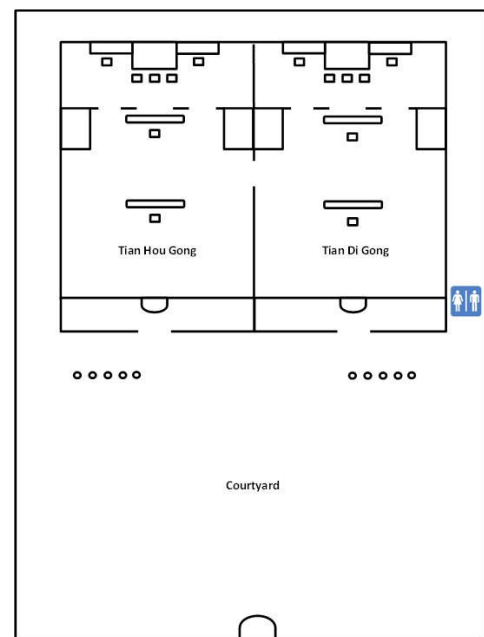


Figure 11: Digitised floor plan of Fuk Tai Chi Museum

The floor plan of Yueh Hai Ching Temple (Fig. 10) and Fuk Tak Chi Museum (Fig. 11) were digitised using Microsoft Word Document. As the floor plan of Fuk Tak Chi Museum is unavailable, we created the floor plan with reference to photos taken during on-site visit. The floor plans were digitised to enable users to plan their route in our final GIS product. It is thus essential for the digitised floor plan to only include permanent items that can aid users in navigating around the temple. Labellings such as “Tian Di Gong” and “Tian Hou Gong” are included to enable users to understand the general layout of the Yueh Hai Ching Temple (Fig. 10). The floor plans will also inform the users of their relative position in the heritage sites.

The symbols used in the digitised floor plans are highly abstract as the purpose of the floor plans is primarily for user navigation rather than an accurate depiction of objects found in the sites.

### **3.4 Integration of Spatial Data and Attributes**

The processed panoramic photos, 2D photos of heritage items, heritage items and digitised floor plans were integrated on our chosen panorama software EasyPano (<http://www.easypano.com/>).

#### **3.4.1 Insertion of Panoramic Photos**

The processed panoramic photos can be inserted into the Scene Viewer of the EasyPano interface through the “Add” icon labelled in Fig. 12. In order to provide the user with an immersive experience, the initial view of the panoramic photo has to be the scene which the user will first see when “entering” into the space. This initial view should also present the heritage items which the user is looking out for. With reference to Fig. 12, the default initial view of the panoramic photo captured at the main courtyard of Yueh Hai Ching Temple is “Pan: 0; Tilt: 0, Fov: 120” which shows the path leading to the temple’s exit. However, as this photo is placed right after the “Main Entrance” panoramic photo, the initial view should present the scene which the user will see when he steps through the gate of Yueh Hai Ching Temple. As such, the initial view setting was changed to “Pan: -180; Tilt: -3, Fov: 120” to present the façade of the temple building and censors to the user (Fig. 13). The changing of initial views can be done in the Immersive view of the photo.

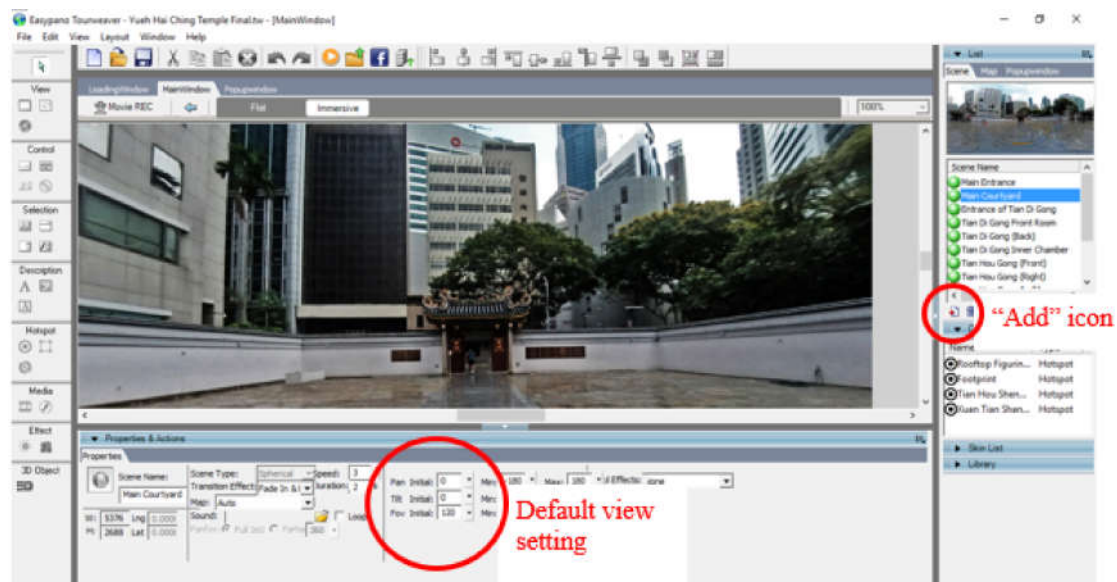


Figure 12: Panoramic image with default view setting



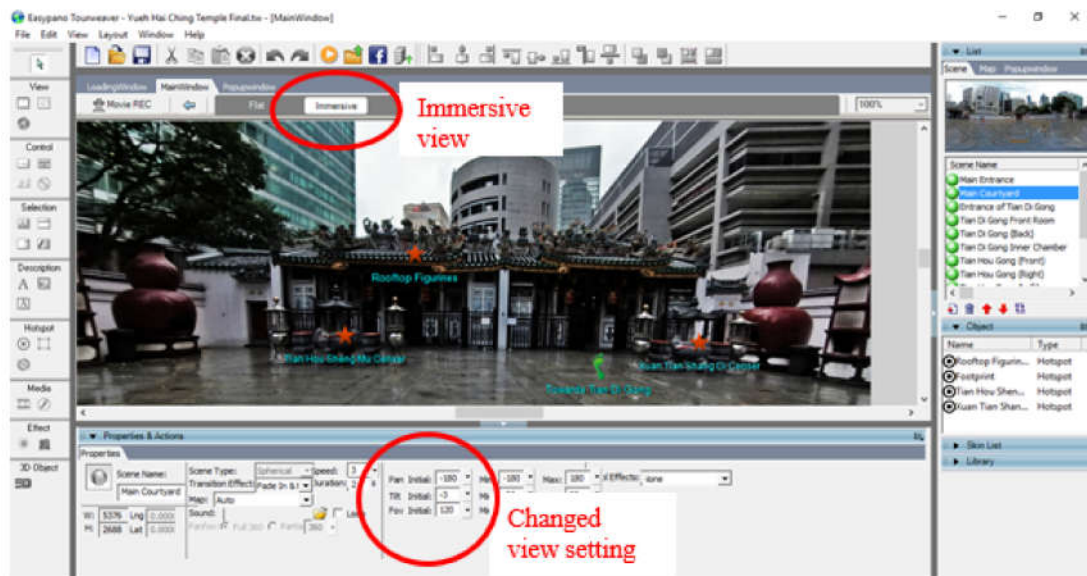


Figure 13: Panoramic image with changed view setting

### 3.4.2 Data Attributes Tagging

Data attributes such as the 2D photos of heritage items and the heritage information can be tagged to the heritage item in the panoramic photo through the insertion of hotspots. To tag heritage information to heritage items, the Scene Viewer has to be changed to “Flat” view (Fig. 14). Click on the hotspot icon labelled in Fig. 14 and tag it to the heritage item to be identified. In the example shown in Fig. 14, the heritage item identified is the Shu Hai Xiang Yun plaque which is found at the top of Tian Hou Gong room. As this is the “Flat” view of a panoramic photo, items found at the top of the photo will be heavily distorted. To check if the hotspot is tagged directly onto the heritage item, we verified the location of the hotspot by changing back to “Immersive” view.

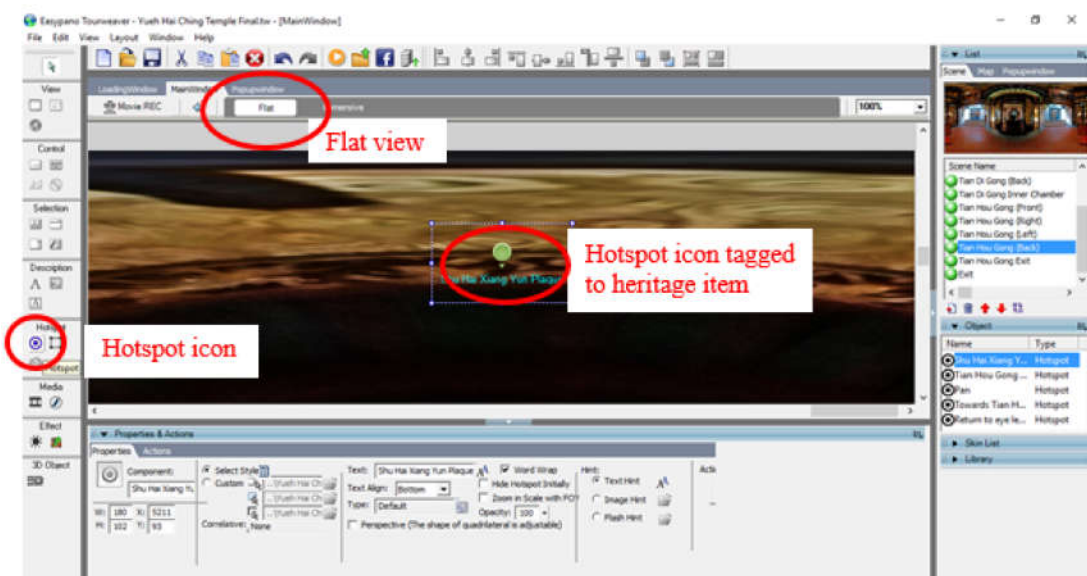


Figure 14: Tagging of information hotspot to heritage item

To allow the user to clearly identify the hotspot so as to have a semantically enriched experience when looking out for heritage items, a more prominent icon was selected. EasyPano offers a variety of hotspot styles (Fig. 15) under the “Select Style” option, but as the purpose of this icon is to signal to the user the presence of an important heritage item, the brightly-coloured star icon was selected. To complement the hotspot icon, the name of the heritage item was inserted into the “Text” option (Fig. 15) so that the user can be signposted on the type of heritage item that they are about to find out.

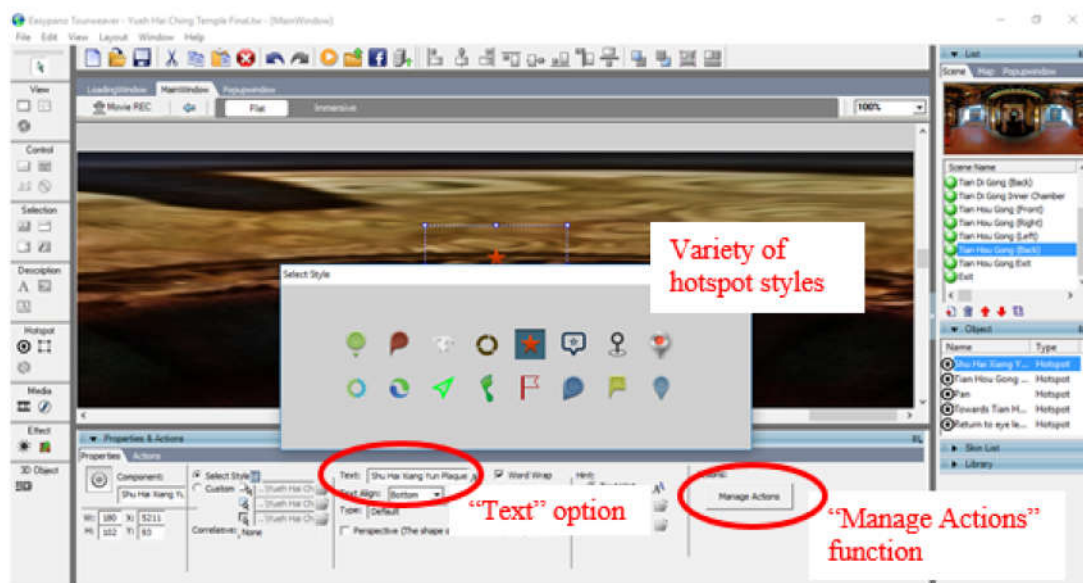


Figure 15: Selection of hotspot style and insertion of name of heritage item

After tagging the name attribute to the heritage item, the 2D photo together with the heritage information can be tagged by clicking on the “Manage Actions” function labelled in Fig. 15. A dialogue box will appear and by checking the “Pop up image” box (Fig. 16), the relevant primary and secondary data can be tagged to the heritage item in the panoramic photo (Fig. 17). Alternatively, the above action of check “Pop up image” box can also be achieved through double-clicking of the selected hotspot.

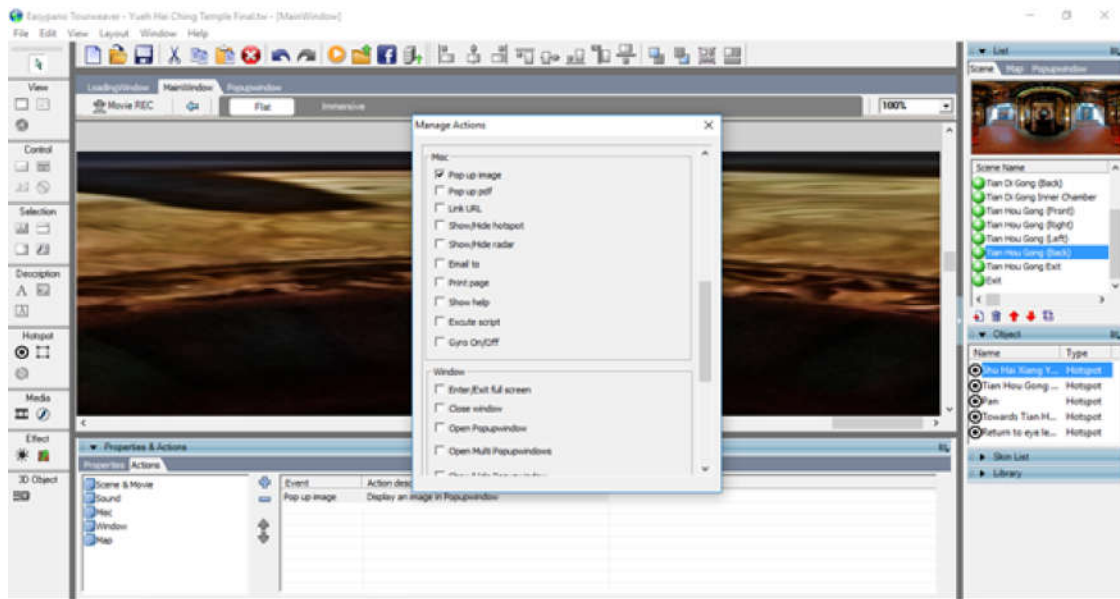


Figure 16: Manage Actions dialogue box

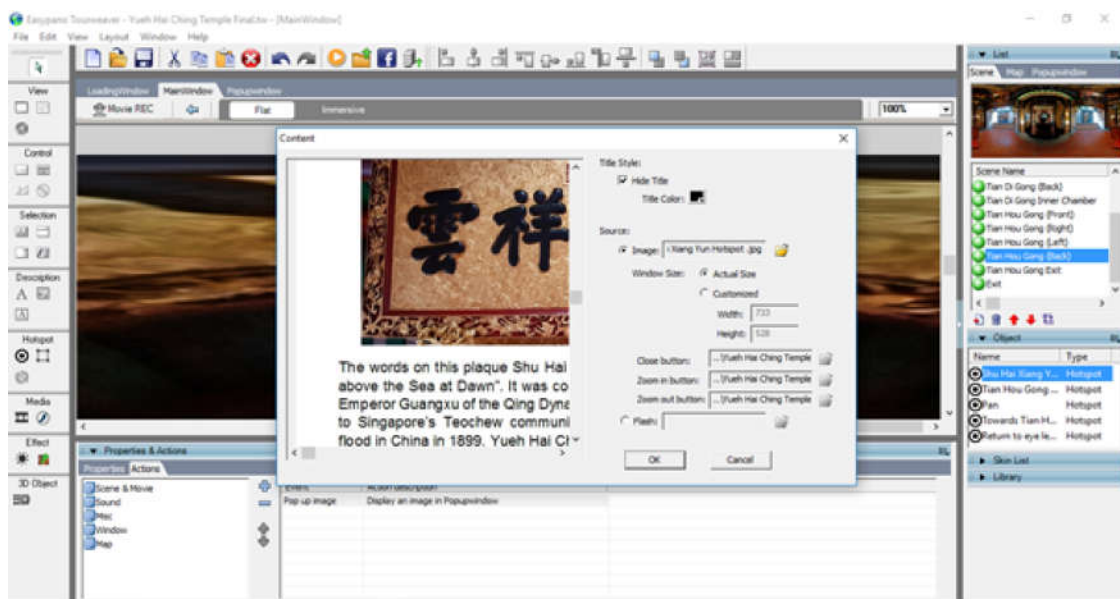


Figure 17: Tagging of heritage information and 2D image onto panoramic image

### 3.4.3 Designing for Route Planning

The different panoramic photos were linked together through the hotspots mentioned in the previous section. However, to give a clear distinction between a heritage item hotspot and a transition hotspot, a footprint hotspot style was selected (Fig. 18). Texts such as “Towards Tian Di Gong” were inserted so that the user can be informed on the next scene that they will be “walking” to.

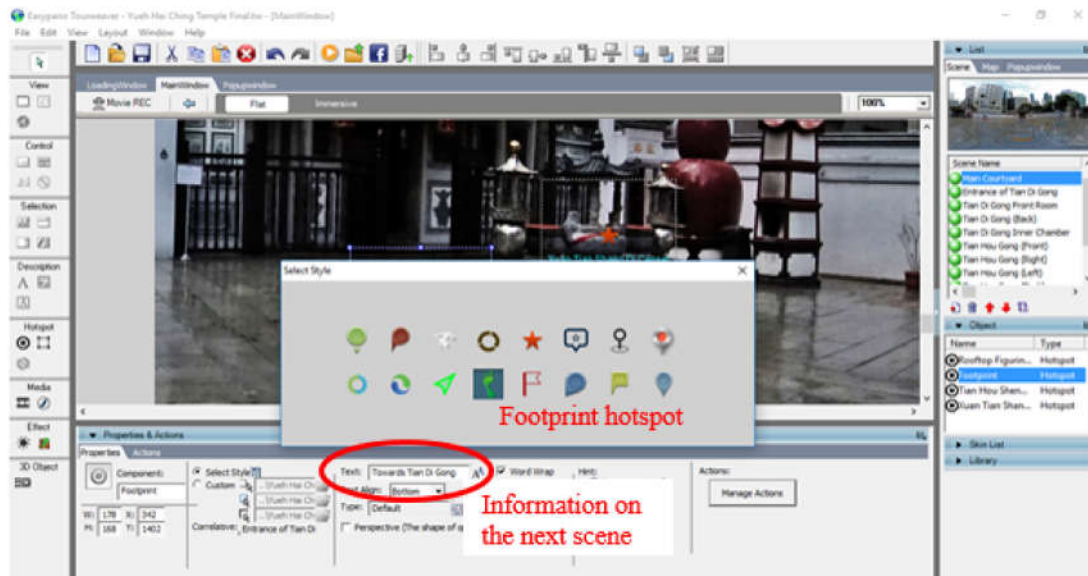


Figure 18: Footprint hotspot and insertion of information on the next scene

Thereafter, the “Manage Actions” function was clicked and the “Link to Scene” option was checked. The scene shown in the Scene Viewer was previously carefully adjusted so that the initial scene before the transition will focus on the footprint icon (Fig. 19) rather than the default view of the panoramic photo (which requires an unnecessary 180° turn, Fig. 20). This precaution was taken to ensure that the way the spatial data are linked together can provide an immersive experience to the users by accurately showing them the direction they are “heading to”.

The panoramic photo that will be linked to the current scene can be selected from the drop-down list under “Target Scene”. The view settings of the target scene were checked against the initial view settings that has been set in Section 3.4.1. The “Walk Through” transition effect was then selected (Fig. 19).

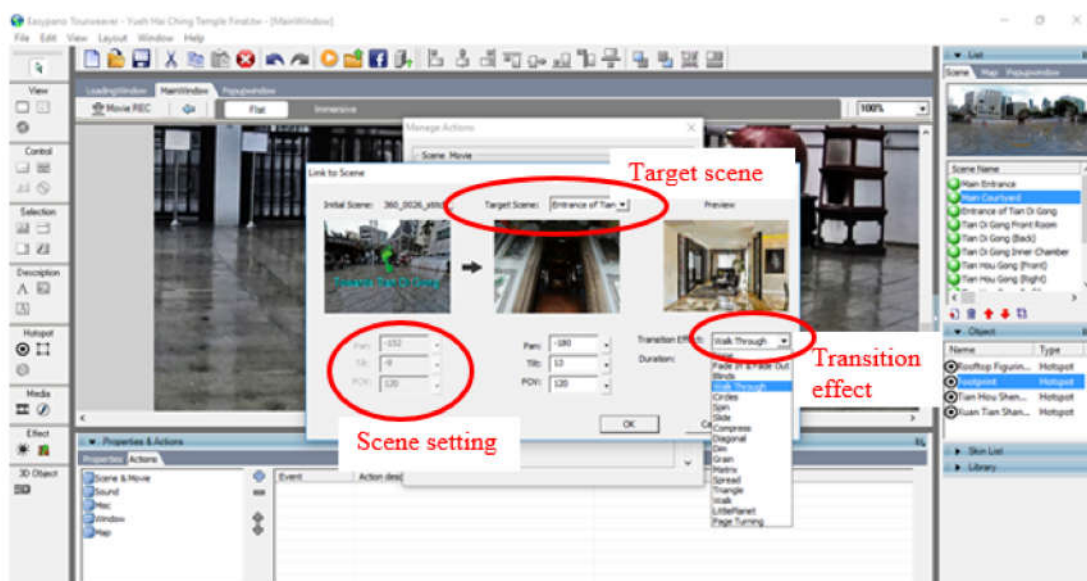


Figure 19: Integrating different panorama images together



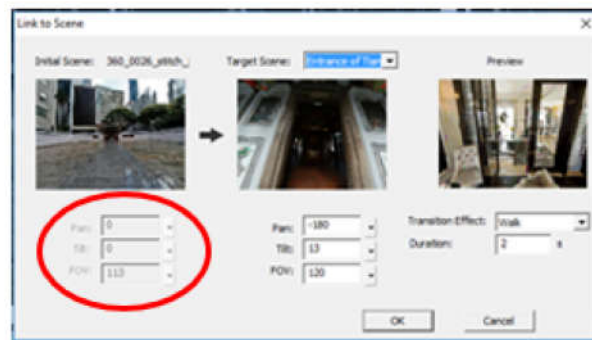


Figure 20: Default view of panorama photo

The next step involves the incorporation of the digitised floor plan into the Map Viewer (Fig. 21). The floor plan can be added into the Map Viewer through the “Add” icon and its size and positioning were adjusted so as not to cover too much of the scene in the Scene Viewer.

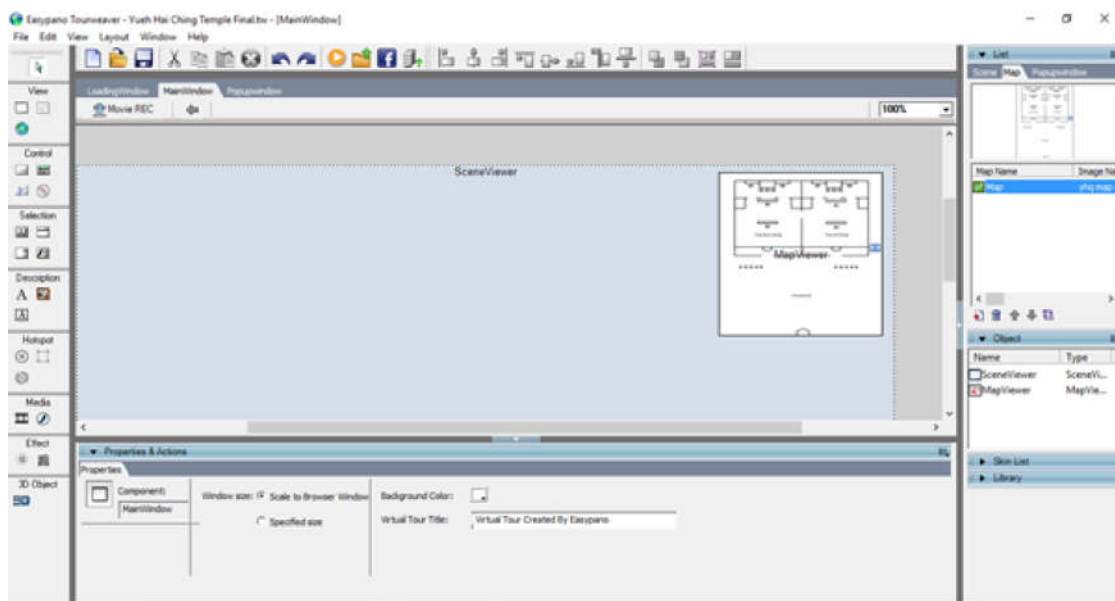


Figure 21: Incorporating digitised floor plan into EasyPano through Map Viewer

To integrate the panoramic photo to the floor plan, the radar hotspot was selected and tagged to the centre of each room in the floor plan (Fig. 22) as the 360° camera was also positioned at the centre of the room during the data collection process.

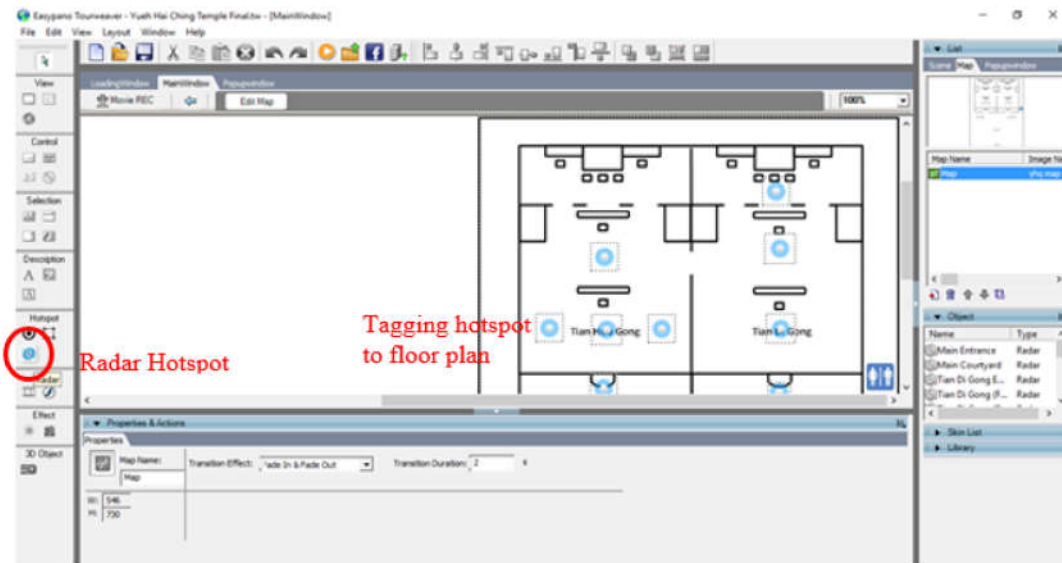


Figure 22: Tagging radar hotspots to digitised floor plan

The radar hotspot was then synchronised to the respective scene name (Fig. 23). This step links the radar hotspot on the digitised floor plan to the panoramic photo in the Scene Viewer. The hand tool was activated to drag the scene and radar so as to synchronise their orientations. The “Set Scanning Area” tool was then set to “circle” rather than “rectangle” so that the area covered by the scan area can have the same shape as a human pupil.

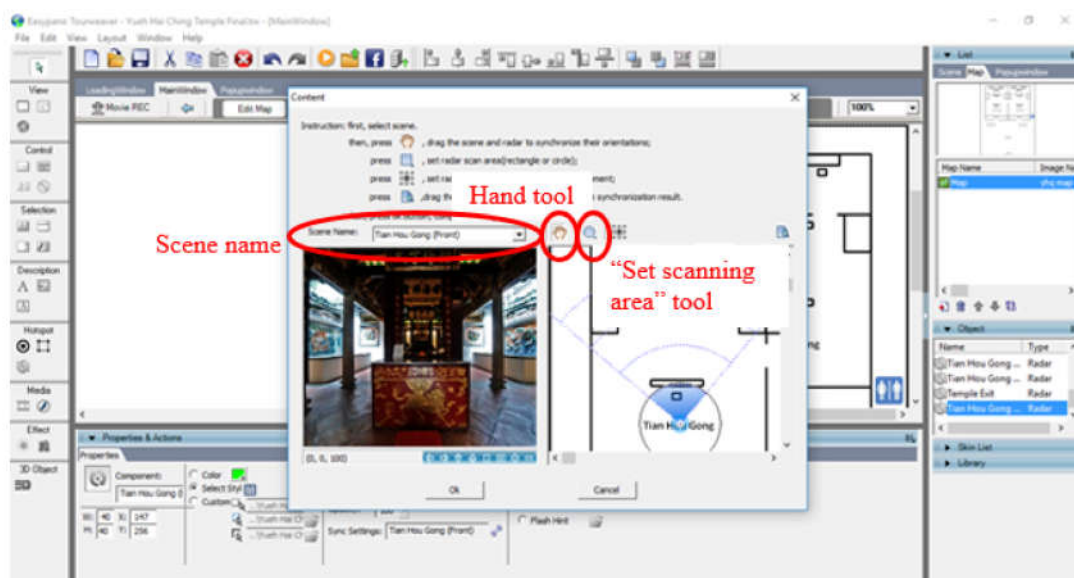


Figure 23: Synchronising radar hotspot with orientation of scene

### 3.4.4 Publishing as Virtual Tour

Having integrated the data attributes to the panoramic photos and synchronised the floor plan with the panoramic photos, the EasyPano project was then published. Under the Publish Settings dialogue box,

the Flash (exe) and HTML versions were checked (Fig. 24).

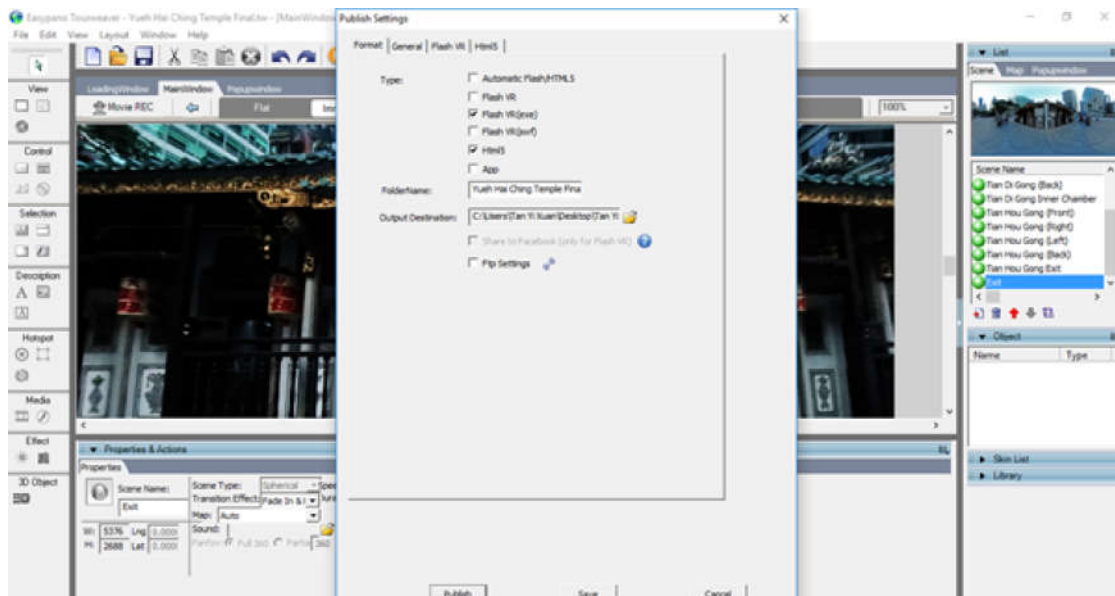


Figure 24: Publishing the virtual tour in different formats

## **4.0 Results and Discussion**

This section will discuss the advantages and disadvantages of the tools used to document heritage information in the temples. More specifically, it will evaluate how the combination of different tools have allowed for the stories of important items in the temple to be encoded and represented in an immersive and semantically-enriched manner. Comparison with the traditional 2D GIS tool will also be included as part of the discussion.

### **4.1 Discussion on 360° Camera and ActionDirector**

#### **4.1.1 Advantages of 360° Camera**

The 360° camera used in the spatial data collection can produce sharp and clear panoramic images which allows for the details of the scenes to be displayed vividly. This is due to the technical characteristics of the equipment – the camera lens work with a 15-megapixel sensor that enables for the camera to capture still images of high resolution (O’Kane, 2016).

This tool is also user-friendly as user can simply operate it with a three-button set-up: a power button, a menu button to change shooting modes and settings and a black-and-red record button. Researchers who are not technologically savvy should be able to utilise it with relative ease.

Moreover, the Bluetooth function embedded in the 360° camera enable researchers to adjust various settings of the camera to control the quality of the output image (Fig.25).



Figure 25: Various camera settings on the left and right sidebars (Source: <http://sea.pcmag.com/samsung-gear-360>)

In addition, researchers can access the image captured instantaneously after the picture is taken. This improves workflow efficiency and spatial data quality as researchers are able to check the quality of the captured image and verify if the scene needs to be retaken immediately.

On a practical note, the collection of primary spatial data using the 360° camera is inexpensive and comes at a cost of approximately USD \$349 (Nickinson, 2016). This is relatively affordable as compared to other spatial data collection tools such as an entry-level Light Detection And Ranging (LiDAR) sensor system that costs USD \$16,000 (Higgins, 2016). Beyond its price, the camera has an expandable memory capacity of 256GB that can store large amounts of still images and videos. This offers an opportunity for the project to be scaled up without incurring substantial financial cost.

#### **4.1.2 Disadvantages of 360° Camera**

Although the Bluetooth function of the 360° camera improves workflow efficiency, the potential of this function is hindered by the camera's battery life. When the Bluetooth function is turned on, the battery life of the 360° camera reduces drastically from 130 minutes to 30 minutes. This surfaces a huge problem as the battery may run out before all the necessary data is taken during data collection process. Due to this limitation, researchers may be forced to choose between quality data collection by using Bluetooth function or a longer battery life by disabling the function.

#### **4.1.3 Disadvantages of ActionDirector**

The ActionDirector tool produces stitching errors that leave slight distortion on the stitched photo. With reference to Fig. 26, the buildings are nicely captured by the 360° camera but after processing the raw photo in ActionDirector, the facade of the building is distorted (Fig. 27). Faced with this stitching error, we first hypothesised that the issue was caused by strong light exposure present in the late afternoon. However, we realised that the raw photo (Fig. 26) has no distortion issue even though it was taken under

light exposure so it is unlikely that the issue lies in the lighting of the site. Furthermore, as the stitching error occurs at the same spot for every image, it is more likely that the stitching error is caused by a bug in the ActionDirector tool. Due to this issue, the data quality of panoramic images is compromised and this will have slight negative implications on the immersive experience of users.



Figure 26: Raw photo without distortion



Figure 27: Stitching error near exterior glass building after processing with ActionDirector

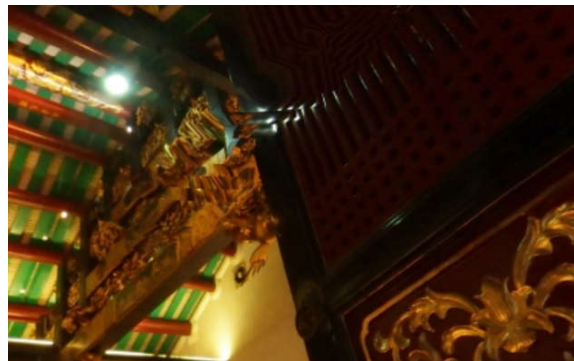


Figure 28: Indoor image with distortion issues

## **4.2 Discussion on Panoramic Images**

### **4.2.1 Disadvantages of Panoramic Images**

The use of panoramic images may reduce efficiency of the workflow as human and vehicular elements present at the scene may be captured. As panoramic images capture every visible elements in the surrounding (Fig. 29), the unintended inclusion of human and vehicular elements will reduce image data quality. As alluded to in Section 3.1.1 Primary Data Collection, there is a need to capture the same scene multiple times to facilitate subsequent processing procedures to improve the data quality. This prolongs the process of collecting primary data and it will also slow down subsequent procedures as multiple raw



panoramic images have to be overlaid and processed before they can be integrated into the database. As each panoramic image captured has its unique elements that contribute to data quality, the overlaying using Photoshop cannot be automated. This inevitably translates to longer editing time and reduces overall workflow efficiency as subsequent procedures can only be executed after all photos are processed and suitable for integration in EasyPano.



Figure 29: Human obstruction in photo-taking process

Additionally, the raw panoramic images are also faced with lighting issues (Fig. 30). Due to the presence of spotlights and excessive natural lighting exposure at certain parts of the temple, some heritage items may be too bright while others may be too dark. The inconsistent lighting throughout the raw panoramic image affects the visibility of heritage items and spaces of the temple, which reduces the overall immersive experience of users.



Figure 30: Natural light and spotlight resulting in inconsistent lighting

#### **4.2.2 Advantages of Panoramic Images**

However, with the light enhancements made to the raw panoramic images produced by the 360° camera and stitched by ActionDirector, the processed panoramic images are able to vividly and realistically

present the place to the user. As the panoramic image allows for the user to pan around freely, the place is brought “alive” as it enables the user to visualise the layout and setting of the place. The spatial distribution of the artefacts can also be observed by the user due to the positioning of the camera at the waist level which produces an eye-level perspective of the place (as alluded to in Section 3.3.1). This simulation of the user standing in the physical space of the temple and enjoying its seamless 360° view is thus able to immerse the user in a life-like information space. In contrast, the vector data model used in traditional 2D GIS is only capable of presenting the layout of the room through feature classes that have discrete boundaries. The place will be inappropriately segmented through the vector data model, which substantiates our use of processed panoramic images in offering an immersive experience for users.

Furthermore, the panoramic images offers an interactive medium for the user to zoom in and out of the image to experience the place at different granularity. This complements the immersive experience of a 360° view because users can have the autonomy to examine the details of items and experience the place on different scales. Comparatively, the static points, lines and polygons used to digitise the temple in traditional 2D GIS only allow the user to have a closer view on the topology of the feature classes rather than the details of the area bounded by these feature classes.

#### **4.3 Discussion of Easypano**

##### **4.3.1 Advantages of Easypano**

The discussion on its advantages will be centred on how EasyPano allows for the creation of an immersive and semantically-enriched GIS product through its various functions as mentioned in Section 3.4.

##### **4.3.1 (a) Integration of Different Datasets to Create An Immersive Experience for Users**

As mentioned in previous section, EasyPano allows the researcher to link different 3D panoramic images together. EasyPano also enables the researcher to insert a digitised floor plan to complement the 3D panoramic images. The map is then synchronised with the panoramic images through the use of a radar hotspot (Fig. 31). The seamless integration between the different datasets create a final GIS output that is immersive and semantically enriched. In the final GIS product, users are able to spatially visualise the layout of the temple spaces and experience how it is like to be ‘there’ in reality. The final GIS output gives the user the autonomy to navigate around the temple space by selecting directional hotspots that will bring them to other scenes. This closely mirrors the actual experience of visiting a temple in reality and produces a level of immersiveness that cannot be achieved on traditional 2D GIS tool.



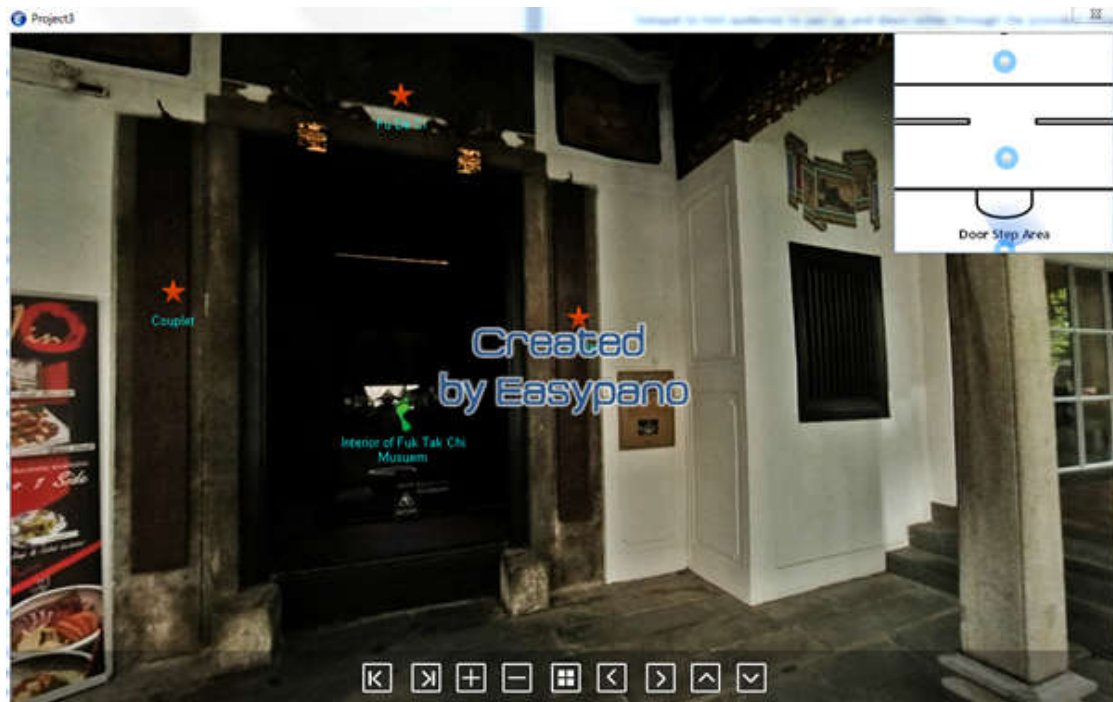


Figure 31: Viewing and synchronising of map with the panoramic image

#### **4.3.1 (b) Semantic Enrichment Tool**

EasyPano also serves as a semantic enrichment tool as it allows for combination of the 3D data (i.e. panoramic image) and information related to the object in the 3D data to be represented. In other words, EasyPano enables researchers to conduct semantic tagging (Clarke and Harley, 2014) which is the process of adding semantic metadata to the panoramic images so as to further improve users' understanding of the content of the image. This semantic tagging can be achieved through the information hotspots and pop-up image function as mentioned in Section 3.4.2. In addition to the tagging of 2D images, heritage information and the name of the heritage item to the panoramic image, EasyPano allows for the insertion of music that aligns with the ambience of the temple (Fig. 32 and 33). This process of tagging information to the panoramic image allows for the various data attributes to be shown to the user through one interface. This undeniably offers a semantically-enriched experience for the users as they will be able to access appropriate and useful information that aid in their understanding of the heritage item in the temple. This hence surfaces the point that alternative spatial technology tools such as EasyPano are more desirable than the traditional 2D GIS tools such as ArcGIS when the goal is to offer a semantically-enriched experience for users because 2D GIS tools are only capable of letting users see the digitised heritage item in data view and access other information through the attribute table (a separate interface).

#### **4.3.1 (c) Various Publishing Formats**

Besides being able to offer a semantically-enriched experience for users, users can also publish the end

product in multiple formats such as Flash VR, Flash.exe and HTML (Fig. 32). Such multiple published platform of Easypano ensures convenience in usage and meets the different needs of users in their course of project. For example, the HTML format allow users to embed the link and information into other web platforms or tools such as JavaScript to create a webpage while flash.exe provides a more movie-like experience, benefiting the use in a presentation.



Figure 32: Formats available for Easypano Publish Settings

However, though Easypano is a useful platform, there are also several limitations in the software which will be highlighted in the following section.

#### **4.3.2 Disadvantages of EasyPano**

While the EasyPano tool is a professional software with many detailed functions that are able to effectively and comprehensively document the heritage value of the temples, its disadvantages pertain more to the its user-unfriendly aspects.

##### **4.3.2 (a) Outdated User Guide**

Although there have been efforts done to produce the user guide, such guides may not always be comprehensive. They tend to be structured for the older version. For example, the current trial version is Tourweaver 7.98 Professional Edition, but the latest user guide available online is for Tourweaver 5.00. Therefore, substantial amount of time was needed to explore the EasyPano software and many functions could only be performed through multiple trial-and-errors. Most of the problems encountered were also only solved through numerous tries and exploration which consumed much time and effort.

#### 4.3.2 (b) Lack of Input Text Function

EasyPano also does not contain a function to input any form of text description for the panoramic image, hence researchers are not able to insert historical artefacts description directly into Easypano. It would be inappropriate to input the heritage descriptions in the “Text” option (Fig. 15) as this function will display the wall of texts on the panoramic image itself under the hotspot icon (Fig. 33). This will affect the immersive experience of users and aesthetic view of the panoramic image as scenes of the temples will be blocked by the texts. Instead, researchers will be required to first insert the heritage information into Microsoft Word or any relatable platform and convert the text document into an image file recognisable by Easypano (Fig. 34). This reduces workflow efficiency for researchers as additional procedures have to be done to integrate these semantic information with the panoramic image. (Perhaps a simple model in ModelBuilder will help reduce the time spent on this problem. I am also wondering if EasyPano allows customization of the user interface to dashboard-like.)

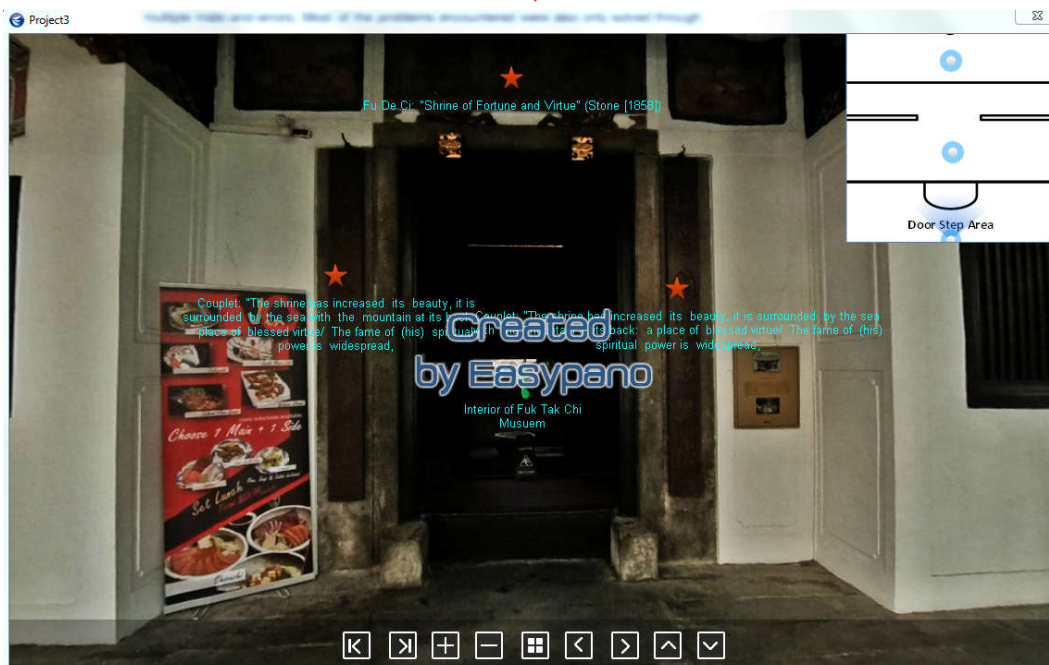


Figure 33: Panoramic view with heritage description input in the “Text” option of EasyPano

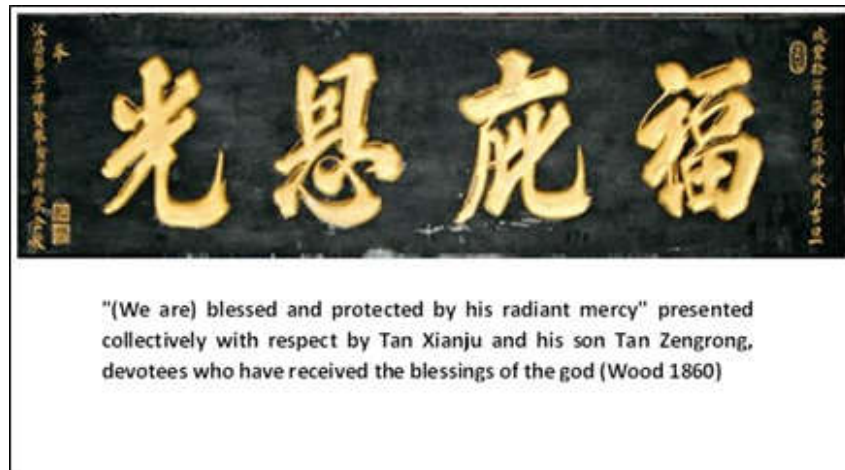


Figure 34: Example of an image file created

#### **4.3.2 (c) Limited Rotation and Hotspot Function**

EasyPano also restricts the auto-rotate view of the end product, providing only auto-rotate horizontal view, which excludes the top and bottom view without hints to pan up and down. Hence, researchers will have to insert additional hotspot to hint user to pan up and down either through the provided hotspot or manually.

In addition, the radar hotspots tagged to the digitised floor plan are not able to fully offer an immersive experience to the users as the scan area does not show the corresponding direction when users are looking at the top or bottom view of the panoramic image; it can only reflect the corresponding direction at the eye-level position (Fig. 35). This is most probably due to the 2D map image and Map Scene function being unable to fit with the 360° and 3D effect of panoramic image.

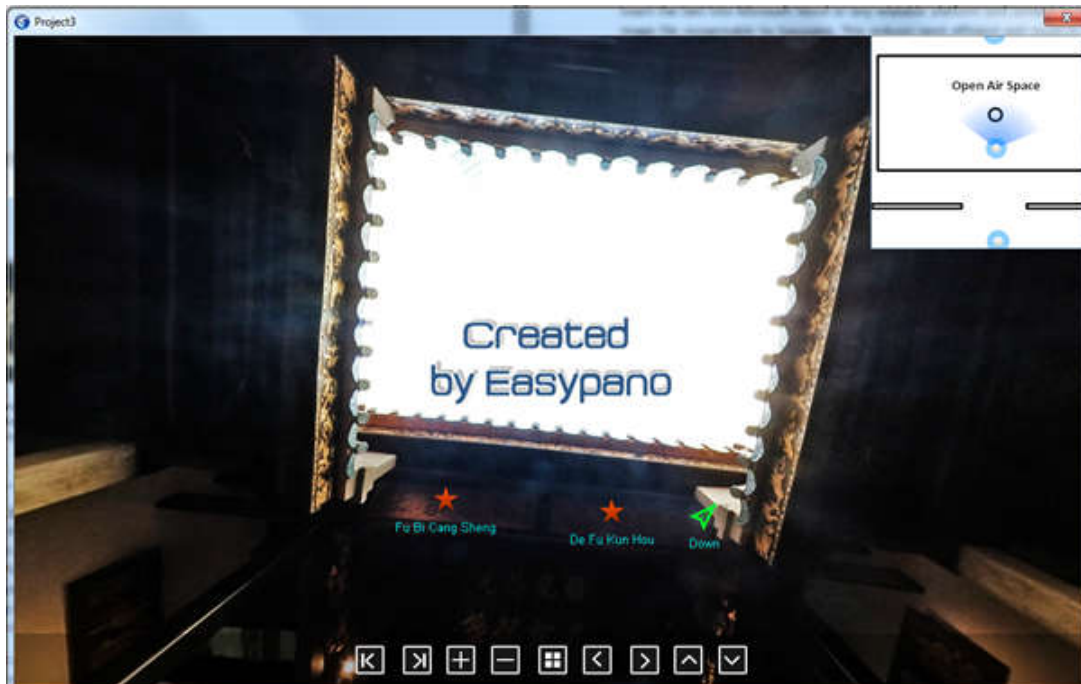


Figure 35: The scan area in map reflects eye-level direction even when users are looking at the top or bottom view of the panoramic image

#### 4.3.2 (d) Limitation in Published Formats

Though Easypano is able to publish the end product in a few forms, there are a few inconsistencies between the different published formats, and different formats have their own limitations in displaying the virtual tour. We will further discuss the different formats in the next section, in particular Flash.exe and HTML which we have explored in detail over the course of the project.

#### 4.4 Evaluation of Published Versions - Flash.exe vs HTML

For Flash.exe version, its main flaw lie in its inability to display all hotspots tagged to the panoramic image. This issue only occurs for one of the scenes in the Yueh Hai Ching Temple version. As shown in Fig. 36, information hotspots have been tagged to the Xuan Tian Shang Di Deity and the Xuan Tian Shang Di Bronze Bell, but these hotspots are not displayed in the published Flash.exe version (Fig. 37). With the absence of these information hotspots, the users will not have a complete semantically enriched experience as they will not be able to retrieve information on the important heritage items. Furthermore, the transition hotspot that links user to the next scene (Tian Hou Gong) is absent from the published Flash.exe version. This reduces the level of immersiveness that can be enjoyed by the user as he has to manually pan the floor plan and click on the centre radar hotspot before he can be linked to the next scene. Multiple attempts such as removing and adding the hotspots again had been done but the issue could not be resolved. Although only one scene faces this issue, it reflects the inconsistency of the EasyPano (trial) software.



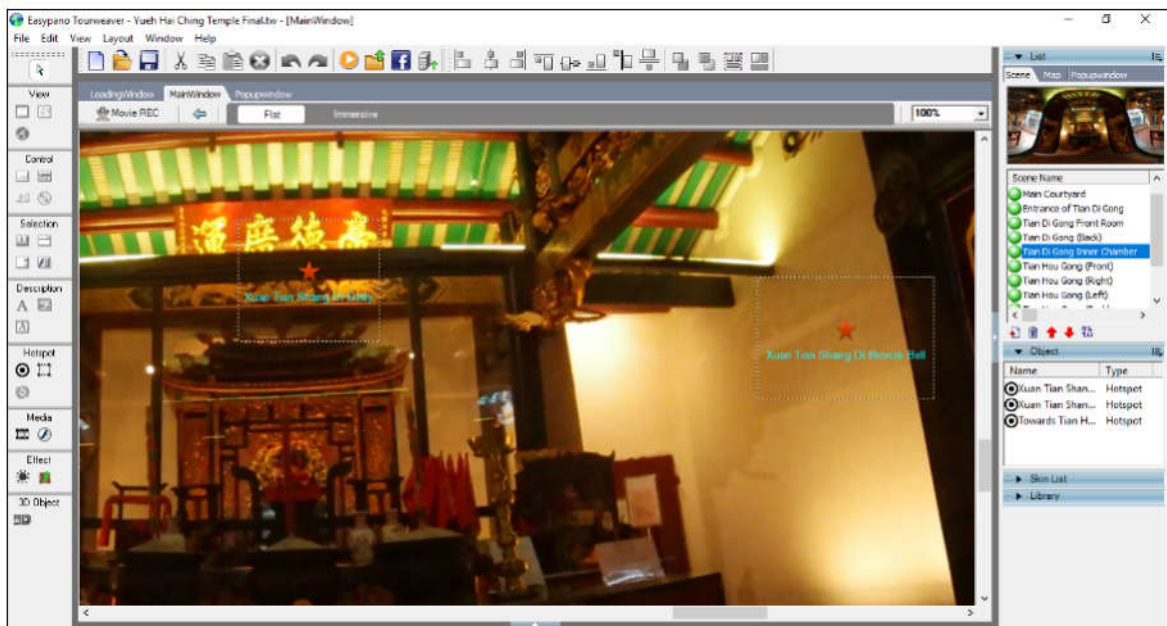


Figure 36: Hotspots tagged to heritage items in the inner chamber of Yueh Hai Ching Temple

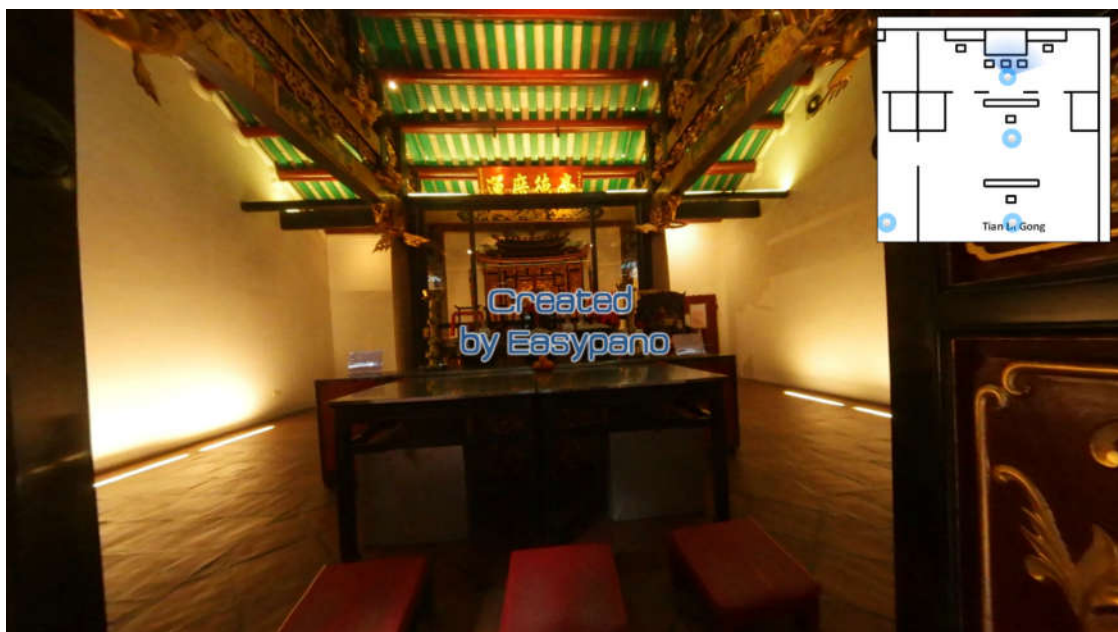


Figure 37: Hotspots are not displayed in the published Flash.exe version

Despite this flaw with Flash.exe version, it is still preferred as the HTML is plagued with more problematic issues. For instance, text hints were inserted to provide simple navigation for the user by hinting them to click on the hotspot once his cursor hovers over it. However, these text hints are not able to be displayed in the HTML version of the GIS end product, possibly due to a software error.

Furthermore, in the HTML version, some directional hotspots such as those that automatically help users

to pan back to the eye-level could not function properly. As a result, when the user clicks on such hotspots, no effects will be shown, which will affect the level of immersiveness experienced by the users. In addition, the HTML version also altered the initial view of the panoramic images previously set by researchers. Hence, whenever the footprint hotspot is clicked to link user from one panoramic image to the next, the initial view of the next image is often altered 90 to 180 degrees away from the view set by researchers. In other words, the first scene which users will see through this virtual tour will deviate from the scene that they would see in the physical space. Such removal of functions by the HTML version can affect the user's visual experience when viewing the virtual tour and visualising the connectivity of the physical spaces.

The HTML version also occasionally faces issues due to Internet connection thus affecting the speed of displaying the panoramic and 2D images. Due to the problems in connecting and accessing the raw information and image tiles in the desktop's HTML folder, the HTML version may face a 30-second to 1-minute lag time in retrieving and displaying image tiles whenever user pans up and down or zooms in and out of the panoramic image, during which a blank white space is displayed in the virtual tour. The cause of this problem is still unknown due to its occasional occurrences, affecting our means to further explore the issue. However, the problem is suspected to be due to software limitation or even a bug issue in the trial version of Easypano.

## **5.0 Alternative Design Practice and Choices**

### **5.1 Human-free images?**

One of the project's procedures was to strive for a 'human-free' image during the image capturing process. This is to ensure that no parts of the scene will be blocked, nor divert user's attention away from the the heritage items. However, as we (the research team) consist of only Chinese and the temples that we surveyed are Chinese temples, we realised our positionality as Chinese gave us an edge in understanding the heritage objects, rituals and practices of the temple-goers. As such, it is on hindsight that we realised the usefulness of including humans in the imaging process as the inclusion of humans can provide additional information and educate the user on religious practices at the heritage site. For instance, in Buddhist temples, temple goers would burn incense to pay one's highest respect to Buddha. The act of lighting incense also serves as a reminder to free oneself from the mental afflictions, reincarnation and attachment to material desires (International Buddhist Society, n.d). Informative attributes can be tagged to people performing religious practices and a brief description about the practices and its significance can be added. Through this, users will be able to gain a deeper understanding about the religion and its practices. Although a 2D image with description can achieve similar educational agendas, we believe that the realistic and immersive experience provided by



panorama tools will incentivise more people to learn about heritage sites. Researchers that adopt this design practice should seek consent from respective authorities and individuals performing religious practices before taking images.

## **5.2 Virtual Reality and LiDAR**

Over the course of our research, we also came across other potential GIS design choices; Virtual Reality (VR) technology, and Light Detection And Ranging (LiDAR) technology.

An alternative design choice that can be adopted would be one that integrates interactivity into heritage preservation projects. For instance, previous heritage preservation projects such as *Discover Babylon* lets a user interactively explore a virtual museum as part of a game and learn about Mesopotamia in the process (Lucey-Roper, 2006).

Following technological advancements in Virtual Reality (VR) technology, VR headsets are becoming more affordable (Halls and Betters, 2017) and it is projected by experts that the VR industry is six to eight years away from mainstream adoption of VR gadgets (Terdiman, 2016). Researchers can take advantage of VR technology to reach out to more audience about heritages sites. With VR, user experience will be more realistic and immersive by engaging both sight and hearing senses. To integrate panorama technology and VR, virtual tours can be published in a VR-readable version and users can load the virtual tour and immerse himself in the virtual environment of a heritage site. While the technology has yet to mature, researchers should not dismiss the potential of VR technology as an interactive platform for heritage preservation projects.

Another potential design choice would be Light Detection and Ranging (LiDAR) which is a surveying method that measures distance to a target by illuminating the target with laser light. The resulting point cloud data can then be used to build a 3D model of the indoor and outdoor temple environment. This is especially useful if one seeks to build a precise 3D model. However, LiDAR requires substantial financial resources and not all projects have the financial ability to purchase it. Another drawback is that the 3D computer-generated graphic model is not life-like enough as it is just a representation of reality. As such, the immersive experience of the user would be affected.

## **6.0 Conclusion**

This report has examined the reasons for our design choice -- using 360° panoramic image technology to digitally document heritage spaces, and has outlined the spatial data collection process with emphasis on the planning and quality aspects. It has also examined the advantages and disadvantages of the tools used to support the documentation of heritage, and questioned some of our underlying practices. This has

thus demonstrated that there is no specific GIS design and practice with regards to digital heritage documentation because it would largely depend on the project's objectives and intended user experience.

In closing, while this project focuses specifically on Chinese temples in Singapore, it could be further extended to cover other significant cultural or historical spaces. Other organisations could also employ such an inexpensive digital documentation approach for their own legacy or historical record purposes.

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