Space, Place and Digital Media

Towards a Better Simulation for a Disappeared City

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Abstract:
Digital media enable researchers and designers to derive more accurate processes in solving problems of historical architecture restoration and virtual archaeology. However, the insufficiency of the main technologies, such as 3D modeling, high-quality rendering and animation has also been found lately. Given these limitations, this paper attempts to explore a digital reconstruction procedure for historical architecture and cites using 3D scanning, virtual reality cave and motion capture technology. This case study is based on a collaborative project invited by National Palace Museum, Taiwan and China Times, Taiwan. The five steps involved in this project include data collection and analysis, three-dimensional digital inferences, digital reconstruction of static and motional models, scenarios dynamics by integrating the two kinds of models, and visual-spatial immersion by a VR-cave representation. Finally, a preliminary digital reconstruction procedure is presented.

1. INTRODUCTION

In the traditional practice, historical architecture, both in the East and the West, is first represented and then recorded by writings, paintings, drawings, pictures and physical models[1,2,3]. On the other hand, the content of historical architectural knowledge is reported to include building structures, forms, scales and materials. Recent research endeavors have also attempted to apply digital technology into historical research and restoration. For example, Potier[4] established a computerized procedure of restoration which utilized computers to restore historical remains. Tang and Liu[5] later applied Potier's computerized procedure to a practical restoration project of a building in Taiwan. They find that 3D visualization can resolve problems and conflicts which occur by using 2D drawings, and that it can perform a more accurate inference of historical facets during reconstruction processes. In their study, the application of digital simulation is further elaborated to solve the visual harmony of colors and materials for restoration[5].

With respects to the restoration of a historical city, the procedure and media of recording data are basically identical to those stated above; however, the data content expands from a single building to an entire city. In addition to the design principles, historical background information such as the social systems, the cultural activities and the city life at that certain particular time should also be collected and studied in order to reach a more comprehensive understanding of the historical city for the conducting of its restoration. Based on this information, architects are able to restructure architecture and cities as well as the related cultural activities of that particular time. Recently, thanks to the developments of digital media technology, many researchers have attempted to use computer simulations to virtually reconstruct ancient cities, such as the city Chang-An of Tang dynasty in the 8th

1. Millon, H.A., The Renaissance from Brunelleschi to Michelangelo: The Representation of Architecture, Rizzoli International, New York, 1997.
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2. Liu, Y.T., Understanding of architecture in the computer era, Hu's Publisher, Taipei, 1996.
3. Potier, S., Computer Graphics: Assistance for Archaeological Hypotheses, Automation in Construction, 2000, 9(1), 117–128.
4. Tang, S.K. and Liu, Y.T., The Visual Harmony between New and Old Materials in the Restoration of Historical Architecture, , in: Gero,J.S., 5. Chase, S. and Rosenman, M. eds., Proceedings of the Conference on Computer Aided Architectural Design Research in Asia, University of Sydney, Sydney, 2001, 205-210.
6. Heng, C.K., A Multimedia Package on Tang Period Chang'an, in: Bearman, D. and Trant, J. eds., Archives and Museum Informatics, ICHIM1999, Washington, D.C., 1999, 79-83.
7. Serrato-Combe, A., From Aztec Pictograms to Digital Media- the Case of the Aztec Temple Square, in: Wassim, J. ed., Reinventing the Discourse, ACADIA, Buffalo, New York, 2001, 34-43.

century[6] and the Aztec Temple Square[7]. The so-called virtual archaeology has already become a new methodology of archaeological study. According to the previous experience, no matter whether the ancient cities will be physically reconstructed or not, computer simulations can always present the result of restoration procedures more accurate and understandable[4,5,6,8]. It can even reveal hidden problems that cannot easily be uncovered and solved by using other traditional or conventional research methods.

2. PROBLEM AND OBJECTIVE

As discussed above, digital media enable researchers and designers to derive more accurate processes in solving problems of historical architecture restoration and virtual archaeology. However, the insufficiency of the so-called main technologies, such as 3D modeling, high-quality rendering and animation has also been found lately[9,10,11]. For examples, producing 3D models of static crafts, buildings or even an entire city is very much time-consuming, and, it is hard to reconstruct the motions of people to simulate the activities in the city life. In addition, the perception of high-quality rendering images or animations still cannot satisfy the human visual reality. Further, the restoration of a city usually involve architectural data such as palaces, blocks, markets, and streets as well as cultural activities such as dancing, singing, chess, and sports. However, the interactions between people and the city as well as between human bodies and their surroundings still remain unknown. Given these limitations, a serious problem emerges: how can we seek, use and integrate the newly-developed digital technologies, including 3D scanning, virtual reality cave (VR-cave) and motion capture, to make the reconstruction procedure for historical cities more thorough and complete? The objective of this paper is therefore to propose a digital reconstruction procedure for a disappeared city and the activities in it.

3. RESEARCH METHODOLOGY AND STEPS

This study was a collaborative project invited by National Palace Museum, Taiwan and China Times, Taiwan; the project started from August 2001. The research team included two groups: the humanity group involves researchers from architectural design, architectural history, art history, and archeology; and the technical group involves researchers from computer graphics (VR-cave and motion capture) and digital media (3D scanning and animation). The final product was a VR-cave exhibition called *Virtual Chang-An: Representing High Tang*, which was exhibited together with the largest art exhibition of Tang dynasty in Taiwan. 183 pieces of Tang antiques were delivered from China to Taiwan; 44% of them belong to the first-class national antiques. The exhibition started from April to September 2002 in Taipei. More than one hundred thousand people saw and experienced the VR-cave visualization of art and architecture of Chang-An. Invitations for exhibitions of the *Virtual Chang-An* have been sent from France, Japan, and China.

The main objective of this research is to construct a digital procedure for the restorations of architecture and city. For this goal, it is critical to analyze and infer traditional files, which are available in forms of writings, paintings, drawings, pictures, and physical models, and transfer these data to digital formats to be further simulated by various digital media. Five steps involved in this project are as follows:

1. Data collection and analysis of Chang-An: architectural and cultural depictions.

   For a disappeared city like Chang-An, most of its historical data and information are already lost and therefore segmental. Thanks to the assistance from archeology and art history, we were able to collect data in various forms from

8. Tang, S.K., Liu, Y.T., Fan, Y.C., Wu, Y.L., Lu, H.Y., Lim, C.K., Hung L.Y. and Chen, Y J., How to Simulate and Realize a Disappeared City and City Life? A VR Cave Simulation, in: Eshaq, A.R.M., Khong, C.W., Neo, K.T., Neo, M. and Ahmad, S.N.A.S. eds., CAADRIA 2002, Prentice Hall, Selangor, Malaysia, 2002, 301-308.
9. Achten, H., De Vries, B. and Jessurun, J., DDDOOLZ. A Virtual Reality Sketch Tool for Early Design, in: Tan, M. ed., Proceedings of the Fifth Conference on Computer Aided Architectural Design Research in Asia, National University of Singapore, Singapore, 2000, 451-460.
10. Chan, C. S., A Virtual Reality Tool to Implement City Building Codes on Capitol View Preservation, in: Clayton, M. and de Velasco, G. eds., Eternity, Infinity and Virtuality in Architecture, ACADIA, Washington D.C., 2000, 203-211.
11. Liu, Y.T. and Bai, J.Y., The Hsinchu Experience: a Computerized Procedure for Visual Impact Analysis and Assessment, Automation in Construction, 2001, 10(3), 337–343.

seven sources: archeological studies, historical literature, relics, remains, cave paintings, stone inscriptions and new research findings.

2. Three-dimensional digital inferences: architectural and cultural realizations.

   Because the current findings from the seven sources stated above were still segmental, it was extremely difficult to realize the 3-dimentional forms of all pieces of art and architecture. We then inferred, piece by piece, the complete 3D forms and structures of all needed components based mostly on their 2D pictures and drawings.

3. Digital reconstruction: static and motional model reconstruction.

   When all pieces of figures, art/crafts, architecture and streets/plazas were fully realizable in the 3D world, we began to assemble digital models from their segmental data, by producing both static and motional models. In the static modeling process, male-female figures, buildings, streets and plazas were produced by regular modeling processes; whereas small-scaled antiques and crafts were all directly scanned by a 3D scanner, in order to reduce producing time and simultaneously increase accuracy. In the motional modeling processes, on the other hand, the equipment of motion capture was essential to acquire digital data of a number of body motions from male polo game players, female chess players, expert mid-Asia style dancers, and son on. As stated in the previous section, the digital motions as motional models are crucial to simulate activities in spaces, in that they represent the interactions between people and their surroundings.

4. Scenarios dynamics: integration of static and motional models.

   Based on the studies in archeology and art history, we designed and integrated six scenarios in order to create more understandable contexts for both ordinary viewers and researchers:. These six scenarios include foreign diplomats entering the main gate of Chang-An, foreign and local habitants drinking in the residential community area called Li-Fun, foreign diplomats approaching the main palace called Lin-Te Palace, royal family playing polo game in the Li-Te plaza, ladies playing Chinese chess, and finally the dances and banquets in the palace. These are all one-minute animations representing six historical scenarios.

5. Visual-spatial immersion: VR-cave representation.

   Not only did this project provide researchers from various fields with new methodology for studying ancient space and time, it also attempted to transform the results which were already in the digital form, into a better understandable, visualizable and experiencable digital environment9,10. Previous studies have shown that animation and regular VR technologies (e.g. quicktime VR, VRML, and any VR programs in desktop monitors) failed to afford realistic and vivid visual-spatial immersion and real-time interaction4, 5,11. Although the VR-cave had been used as a space simulator in different fields, we were probably among the first who applied a three-screen positive VR-cave technology to provide researchers and museum visitors with immersive visualization and spatialization of a disappeared city.

3.1 Data collection and analysis of Chang-An

<u>Architectural depictions</u>

After analyzing a number of historic archives and collecting meaningful but still segmental data recorded by the seven resources mentioned above, we were able to outline the city layout of Chang-An and briefly realize the typical Tang architecture. Chang-An, located in the current city Xi-An in the northwest of China, was the original name for the capital of Tang dynasty (618-907 A.D.) as well as the biggest city in Asia and probably in the world during the 7^{th} to 9^{th} centuries. As roughly

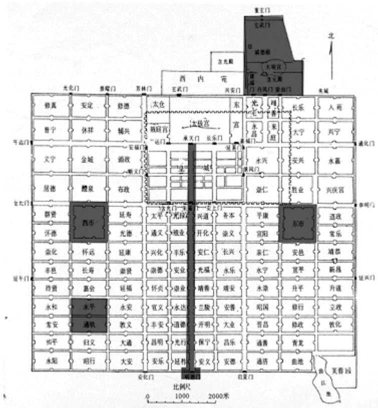

Figure 1: The original master plan of city Chang-An founded in a cave painting.

illustrated (Figure 1), the form of Chang-An was a 9km-by-8km rectangular city; inside the rectangle was a crossing street system. The street in the middle of the system was the 155m-wide main street called Chu-Chuai Boulevard. Min-Te Gate locating at the south of Chu-Chuai Boulevard was the main gate of the city. The blocks separated equally by the crossing street system were the residential community area called Li-Fun. Additionally, two blocks located on each side of the Chu-Chuai Boulevard were East and West Markets, which were the main business centers of the city. The trapezium on the top of the rectangular area was the Imperial Palace where many palaces located and the imperial families lived. In summary, Chang-An was a well-planned great city where one million Chinese people and many foreigners, from more than 400 countries mainly via the famous Silk Road, lived. This project focused on city gates/streets, residential houses, and palaces/plazas, which were the three most important types of architecture in Chang-An.

Cultural depictions

In addition to architectural depictions, from the same seven kinds of resource mentioned earlier, we also analyzed cultural data including pieces of arts, antiques, crafts, costumes and dances, polo game, Chinese chess, and so on. As we claimed in the above section, the cultural depictions are the key for understanding the activities of the city life in Chang-An. That is, we could better realize the interactions between people and their surroundings in the city space through these cultural depictions. For example, wall paintings from various grave caves illustrated the scenarios of Tang diplomats leading the foreign tributaries (Figure 2a), lady dancing, and imperial banqueting. The unearthed pottery figurines and gold antiques show the diet habits of Tang people and the game-playing of polo which was imported from the middle East and promoted to be a royal sport and later exported back to England (Figure 2b). In addition, plenty of well-protected relics currently preserved in Japan, such as the chessboard (Figure 2c) and other equipments, musical instruments and royal furniture also uncover various sophisticated activities in Chang-An. It should be mentioned here that the selection of cultural data out of a huge range, to be further simulated by digital media was based on the discussion and decision made by a team of experts in archeology, art history and architecture.

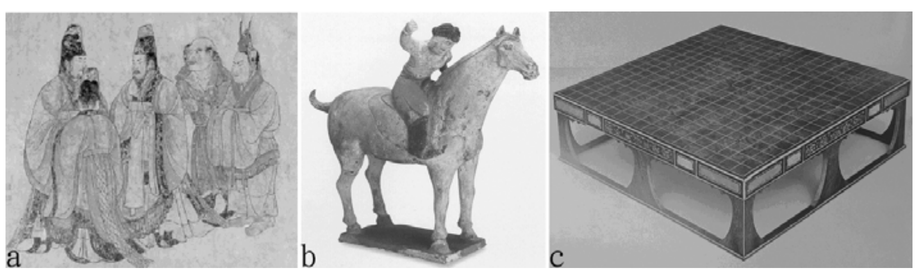

Figure 2: Cultural depictions: (a) a cave painting, (b) an unearthed craft and (c) a well-protected antique

3.2 Three-dimensional digital inferences

Architectural realizations

In step one stated above, all the currently available drawings and graphical/verbal descriptions for various buildings were collected and managed. These conventional representations of architecture involve plans, elevations, sections, details and non-scaled perspective sketches (Figure 2a, b, c). After a thorough discussion based on the examination of design processes in terms of conventional design media in Renaissance, Millon[1] claimed that each individual design medium can only represent certain aspects of architecture, and that there does not exist any single medium, such as drawings and physical models, which is able to reveal all architectural information. Similar to Millon's findings, recent studies in digital media have also shown that although digital media including 3D models, animations, and real-time VR presentations still cannot represent all architectural information, they could function as a good platform to integrate various conventional and digital data[2,12,13].

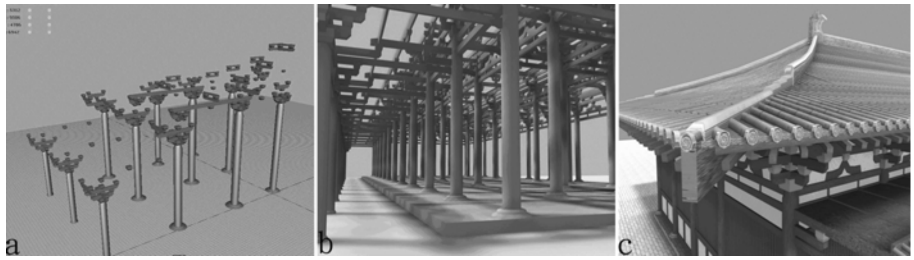

Figure 3: The process of computer modeling: (a) a structural framework, (b) its basic form, and (c) an integrated model.

In this research, the processes of computer modeling were especially valuable when we tried to realize the overall 3D buildings, which are in the form of 2D segmental drawings and pictures. Take the main palace, Lin-Te Palace, as an example. Even we had measured the remains on sites, checked the drawings that archeologists had already approved and cross-checked relevant research papers, it was still deficient to make a completed 3D model to realize the building. Therefore, we could simply make a structural framework (Figure 3a) and a basic form of it (Figure 3b) based on the data in the architectural field. Since more data from other fields were needed in order to make the model more accurate, detailed and complete, we approached to archeological sites in order to collect more relics including tiles of roof and ground, and to observe the structural details of Tang-style buildings, and to analyze the color of building from several cave paintings. At the end, the segmental data could be gradually integrated thanks to the digital processes (Figure 3c).

<u>Cultural realizations</u>

Architectural and urban design, in a sense, concerns spaces and activities which are likely to be happened around them. It is commonly known that *spaces* are constituted by architectural elements[12,14]; whereas *places* are constituted by spaces and activities of people around the spaces[15,16,17,18,19,20]. Rather than merely representing architectural characteristics in the architectural realization processes described above, a further goal of this project was to attempt to realize cultural activities in a digital form, so that all the mysterious parts that archeology and art history cannot yet explain well could be inferred and integrated by adequate digital processes. Again, note that, various methodologies in digital media, architecture, archeology, and art history should be collaborated in order to obtain better research-oriented outcomes of digital cultural realization by analyzing interior settings, piecework of arts, antiques, crafts, costumes and dances, polo game, Chinese chess, and so on.

There are six sub-steps of processes termed as “cultural realization” in this research. Taking chess-playing as an example, we first took a painting describing the interior scene of chess-playing in Five-Dynasty period of the 11th century as the starting point (Figure 4d) because researchers had not yet found any Tang painting illustrating the same subject activity in art history. Second, we replaced the antiques in this Five-Dynasty painting with those found in Tang paintings (Figure 4a). Third, we re-assembled parts of some crafts when we discovered that those crafts in Five-Dynasty were very similar to the ones in Tang dynasty (Figure 4b). We further tried to replace the rest crafts, which had not yet been found in the history of Tang dynasty, with the ones significant in Tang (Figure 4c). In the fifth step, we drew a reconstruction hand-drawing for the scene of chess playing where architectural and cultural elements all belong to Tang (Figure 4e). Finally, its corresponding digital space and place were then considered in form of 3D models and animations (Figure

12. Liu, Y.T. Spatial representation of design thinking in cyberspace, in: Gero, J.S., Tversky, B. and Purcell, T. eds., <u>Visual and Spatial Reasoning</u>, University of Sydney, Sydney, 2001, 43-55.
13. Liu, Y.T., ed., <u>Defining Digital Architecture: 2001 FEIDAD Award</u>, Birkhäuser, Basel, Switzerland, 2002.
14. Chen, S.C., Liu, Y.T. and Lee, H.L., Comparisons of User Experience and User Interface between Physical Space and Cyberspace: A Case Study, in: Wrona, S. ed., <u>Connecting the Real and the Virtual</u>, eCAADe, Warsaw, 2002.
15. Tuan, Y.F., <u>Space and Place: The Perspective of Experience</u>, University of Minnesota Press, Minneapolis, 1977.
16. Carter, E., Donald, J. and Squires J., <u>Space and Place: Theories of Identity and Location</u>, Lawrence & Wishart, London, 1993.
17. Bourdakis, V., Making Sense of the City, in: Junge, R. ed., <u>CAAD Futures 1997</u>, Kluwer, Dordrecht, 1997, 663-678.
18. Li, F. and Maher, M.L., Representing Virtual Places - A Design Model for Metaphorical Design, in: Clayton, M. and de Velasco, G. eds., <u>Eternity, Infinity and Virtuality in Architecture</u>, ACADIA, Washington D.C., 2000, 103-111
19. Clark, S. and Maher, M.L., The Role of Place in Designing a Learner Centered Virtual Learning Environment, in: de Vries, B., van Leeuwen, J. and Achten, H. eds., <u>CAAD Futures 2001</u>, Kluwer, Dordrecht, 2001, 187-200.
20. Liu, Y.T., Chang, Y.Y. and Wong C.H., Someone Somewhere Some Time in the Middle of Nowhere: Some Observations of Spatial Sense Formation in the Internet, in: Penttila, H. ed., <u>Architectural Information Management</u>, eCAADe, Helsinki, 2001, 37-41.

4f). (The process of the final step to integrate digital models and animations will be discussed in the section of Scenarios dynamics below.)

3.3 Digital reconstruction

<u>Static model processing</u>

As mentioned in the methodology section, we largely applied the newly-developed 3D scanners to acquire 3D digital model for all architectural and cultural objects in

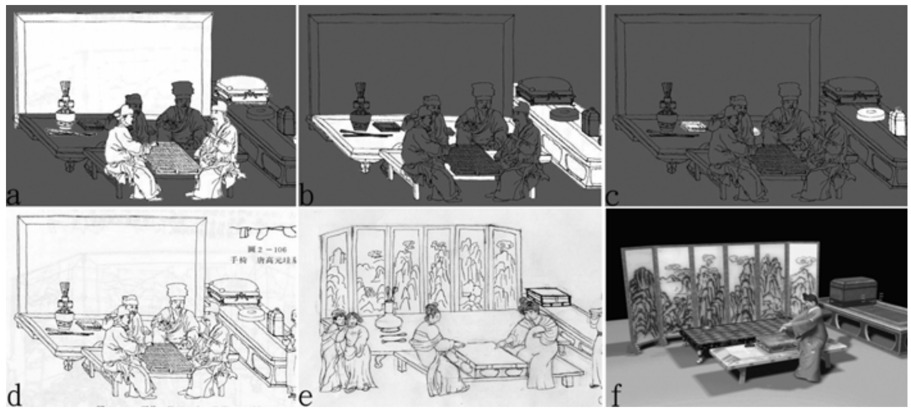

Figure 4: The six sub-steps of the cultural realization processes, starting from a painting to infer to produce its corresponding digital scene.

order to reduce producing time while at the same time increase accuracy. There were three kinds of 3D scanners in our laboratories: a 4-axis scanner for scanning within the volume of 45cm-by-45cm-by-45cm with high resolution and automatic text-mapping capacity, a mobile scanner with high resolution and the integrating software for bigger objects and a body scanner which could scan the 190cm -by100cm-by-100cm volume with regular resolution in 12 seconds. In this static model processing, we applied the 4-axis scanner because of its full features for 3D accuracy of wire-frame, colors, and materials (texture-mapping). The other scanners would be discussed in due course.

There were three sub-processes for completing all the static models we needed. The first process is to scan all the available figures, antiques, and pieces of arts/crafts within which $45cm^3$ was manageable. Because there were many well-protected unearthed relics preserved in museums, we can use 3D scanner (figure 5a) to transfer the real physical objects into 3D digital data directly (figure 5b). The accuracy of resolution was 0.1mm whereas the colors and materials were accepted for further simulation. The second process was to apply ordinary 3D modeling for all objects whose 3D measurements, colors and materials were already available and accurate. We could make their digital models easily and manually. Note that although the physical objects of many important relics were still not available at that time when we were making the digital models, we could still acquire accurate measurements and textures from some relevant publications of photography and research papers.

The third process was a speculative modeling. Still, the 3D data of several items of important antiques were not available at the time of producing the digital models. The 3D data for the perspective shapes and faded-out colors of some human figures on paintings and antiques appeared on cave paintings in the graves (figure 6a) were either missing, inaccurate or inconsistent. Again, the digital modeling process, under this circumstance, provided us crucial assistance to speculate and further infer the 3D construction, structures, measurements, colors, and materials of these objects thanks to the digital modeling capacity in physicality, materiality and spatiality[5,11,13]. For example, to make the 3D digital model for the royal chariot appeared in a famous cave painting as shown in Figure 5c, we made best use of computer's capacity of spatiality to trace and adjust the original non-scaled perspective shape in computer in order to acquire its realistic 3-dimensional structured frame. We also observed the construction of the two wheels and speculated their possible middle axis and the machinery underneath the seat. The dynamic construction of the wheels for the chariot was further simulated and outlined by computer animation, again, thanks to the capacity of physicality allowed by computer technology. Finally, the faded-out color of the entire chariot was studied by adjusting the color of the whole painting including the chariot and its background which contained trees and mountains. The final magnificent colors of the royal chariot (Figure 6b), which are mainly in pure red, blue and white, were acquired (this time, thanks to the materiality enabled by the computer), when the colors of the background were changed from its faded-out original color back into a condition where thee were green and mountains were brown as human cognition normally recognized and retrieved[21,22]. As mentioned earlier, all these kinds of inference by digital processes in this project were worked together with researchers from archeology and art history. (Actually, after this digital media simulation and inference, the first author was invited to teach how to apply the digital media in the processes of historical reconstruction in both fields in China.)

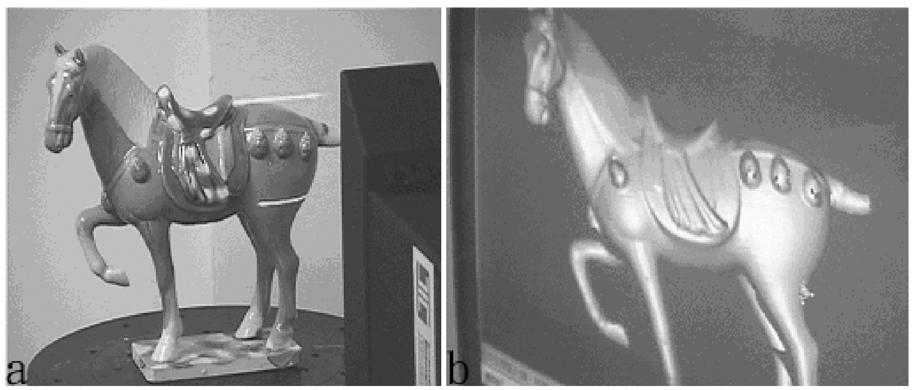

Figure 5: The process of 3D scanning: (a) the equipment of the 3D scanner and (b) the result of 3D

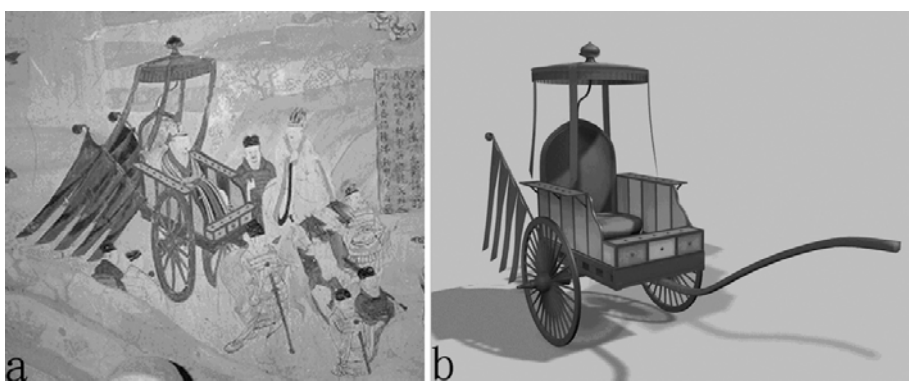

Figure 6: The reconstruction process for the colors: (a) the original cave painting and (b) The reconstructed colors of the royal chariot.

Regarding the other two 3D scanners, the mobile and body ones, the body scanner was used in human expert dancers and the other human figures as will be discussed in more details below; the mobile scanner, however, has not yet applied into this project. The main target of mobile scanner is to scan objects which are bigger or outside the laboratory. It should be critical not only for all reserved pieces of arts/crafts and antiques in museums but also for the related buildings including a few Tang remains, some Tang-style new buildings, and some archeological structure. However, due to the time limit of the project for exhibition opening in April 2002, we did not did not have any chance to return to China to try it. We instead followed the second static model processing to acquire 3D models, because their measurement and texture information were all available. The use of these three kinds of scanners

21. Anderson, J.R., Cognitive Psychology and its Implications, 4th edn., Freeman, New York, 1995.
22. Kosslyn, S.M., Image and Brain: The Resolution of the Imagery Debate, The MIT Press, Cambridge, MA, 1994.

for practical projects, separately or in combination, should be examined and discussed in future studies.

Motional model processing

As stated above, the development of architectural theory, in a way, could be seen as an elaboration of the discoveries of interaction between people and people within a space as well as between people and their surroundings[23,24]. Therefore, the digital motions and even some gestures as motional models are crucial in simulating activities in spaces (that is, the interactions between people and their surroundings) because the human normally perceives and cognitively understands the outside world through these interactions[25]. The mechanism of the motion capture contains eight infrared cameras to sense the locations of 32 reflex balls stuck on important joints of a human body. After calculating the digital data of 32 reflex balls, a computer then traces and captures the 3D motions of the human body within the 8m-by-8m recoding area surrounded the 8 infrared cameras.

In this motional modeling processes, the equipment of motion capture technology was applied to acquire all digital data of a number of body motions for foreign diplomats (when they entered the main gate of Chang-An and approached to the emperor in the main palace), the polo game players (when they shook on the horseback in the palace plaza), and lady chess players (when they played the chess in the patio beside the main palace), and the mid-Asian style dancer (when she danced in the main palace). Regarding some detailed motions, especially gestures, this project recorded human gestures for polo game players, lady chess players, and the emperor. Let us look at another example— mid-Asian dancing which was very famous because the emperor liked this imported art very much. There were three steps after a warm-up by asking the second author to perform some dancing motions to test. First, we used motion capture technology to record the 3D spatial motional data of the performance of an expert dancer (Figure 7b) who is familiar with the mid-Asia dance of Tang dynasty (figure 7a). We then incorporated the data into a digital model of a lady dancer. Note that the 3D data of the digital lady (or often-called virtual lady) was acquired first by scanning the expert dancer by means of the body scanner and by adjusting the 3D model to fit the figure on the cave painting. Finally, the software calculated the interactions between the lady dancer and her costume and corresponding shadow in order to reveal the live actions of the expert lady dancer in motion (figure 7c).

23. Zimring, C. and Dalton, R.C., Linking Objective Measures of Space to Cognition and Action, Environment and Behavior, 2003, 35(1), 3-16.
24. Bell, S., Spatial cognition and scale: A child's perspective, Journal of Environmental Psychology, 2002, 22 (1-2), 9-27.
25. Goldman, G., Reconstructions, Remakes and Sequels: Architecture and Motion Pictures, in: McIntosh, P. and Ozel, F. ed., Design Computation: Collaboration, Reasoning, Pedagogy, ACADIA, Tucson, Arizona, 1996, 11-21.

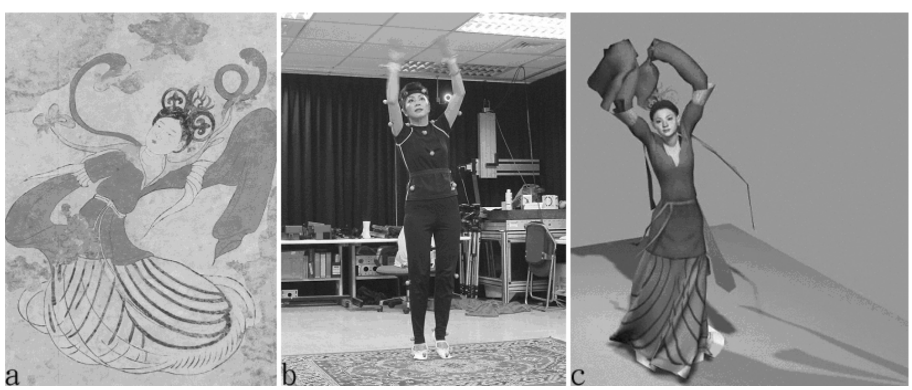

Figure 7: The motional modeling processes: (a) the mid-Asia dance of Tang dynasty shown in a cave painting, (b) the data of an expert dancer recorded by motion capture, and (c) the motional data incorporated into a digital model of a lady dancer

3.4 Scenarios dynamics: integration of static and motional models

Based on the previous four processes which had obtained both static and motional digital data of all architectural and cultural components for the six scenarios decided together with the archeologists and art historians in the very beginning of this project, we started to integrate the huge amount of the digital data into a historical and understandable contexts scripted in the as six scenarios in form of animations. Here we take the scenario integration for chess playing as an example. In the beginning, based on a painting describing the Tang-style arrangement of furniture in an interior space (figure 4d), we tried to put the models of all antiques and crafts together into a 3D digital environment where we could move objects and viewpoints freely. By doing so, we were able to realize the actual location and relationship of every object in that particular space. We then put the arranged interior models into an architectural model of the patio beside the main palace which we produced earlier (figure 4e). Please note that no one could be certain where was the accurate location to put the chess game setting. Discussed with the archeologists who still needed further research to confirm the possible layout, we assumed that the center of the patio was suitable for the current study. Finally, based on the descriptions of chess playing appeared in some Tang literature and novels recommended by an expert Tang historian, we integrated the human models that were performing the motion of playing chess with the whole architectural models (figure 8e). In this way, the *space* became a *place,* full of the cultural, artistic, architectural, and literary characteristics of high Tang of the 8^{th} century.

Table 1: The three spaces and their corresponding six cultural scenarios

Place	**Spaces**	**Activities**
City of Chang-An	The main gate of the city	foreign diplomats entering Min-Te Gate (Figure 8a)
	The residential community	drinking in Li-Fun (Figure 8b)
	The main palace and its plaza	foreign diplomats approaching Lin-Te Palace (Figure 8c)
		playing polo game in Li-Te plaza (Figure 8d)
		ladies playing Chinese chess (Figure 8e)
		dances and banquets inside the palace (Figure 8f)

As sated in the beginning of this paper, the main objective of this study is to re-represent the city Chang-An and its city life in a digital way in order to constitute a new reconstruction procedure for historical city restoration. Once again, for the purpose of revealing the diversity of a city, which includes varieties of interior/exterior spaces, inside-/outside-city spaces, civil/memorial spaces, and streets/plazas, the final animation includes six scenarios in three places (table 1), the three places and six cultural scenarios presented were not produced merely by our imagination but based on our discussions with the archaeologists and art historians.

3.5 Visual-spatial immersion: VR-cave representation

Previous studies have shown that VR-cave demonstration cab increase the visualization and spatialization for people whose perception processes rely cognitively on more interactive and immersive feedbacks from the outside environment[21,23,24]. It is also reported that the recognition of architectural spaces, the live-inside perception plays a critical role for both designers and novices who cannot form such an architectural perception in front of a computer monitor playing animations[12,13,26,27]. The immersive capability of VR-cave technology bridges the gap of the live-inside feeling. Therefore, the final procedure of this research was a VR-cave demonstration which aims at enhancing the visualization and spatialization for the viewer.

Figure 8. The six cultural scenarios.

We applied the six animations into a 7m-by-9m VR-cave space simulator. The viewers with 3D polarizing glasses could thus experience more realistic and interactive visual-spatial effects of the six architectural, artistic and cultural scenarios of Chang-An. Please note that because real-time interaction needs huge computation capacity and will inevitably reduce the resolution, we did not yet simulate the real-time interaction between physical viewers and virtual figures-environments to guarantee the visual-spatial quality for thousands of visitors in the museums. In the VR-cave process, we first developed the six-scenario animation into two versions of two-eye animation, each having 5 degrees of viewpoint which were different from each other. By means of the polarizing filters, each eye would solely receive its corresponding animation. Due to the two-eye distinction, the viewers could perceive a more realistic 3D volumetric space (Figure 9a). Second, we divided the two versions of two-eye animation into six partial versions to fit the three projection screens of the VR-cave. The VR-cave system was produced by the Opto-Electrics and Systems laboratories of the Industrial Technology Research Institute, Taiwan. It was composed of three projection screens and six projectors (Figure 9b). Each screen received simultaneously two projections from the two associating projectors to fit the left eye and right eye respectively. Thus, due the enclosure of the three screens, the live-inside perception of a space could be effectively improved.

In order to test the immersion and one-way interaction of the VR-cave demonstration, we initially studied all scenarios in the laboratory and viewed by all team members (Figure 10a). Further adjustments were made based on the suggestions of the members to guarantee the architectural and cultural interaction and accuracy. Finally, the updated VR-cave presentation was exhibited in the National Palace Museum, Taiwan during April 20 to September 20, 2002 (Figure 10b).

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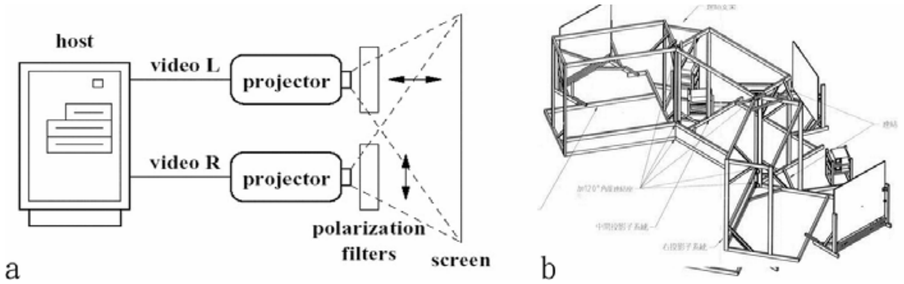
27. Anders, P., Places of Mind: Implications of Narrative Space for the Architecture of Information Environments, in: Clayton, M. and Guillermo, P. ed., Eternity, Infinity and Virtuality in Architecture, ACADIA, Washington D.C., 2000, 85-89.

Figure 9: The mechanism of the VR-cave: (a) the concept of polarizations and (b) the three-screen VR-cave system designed by ITRI, Taiwan.



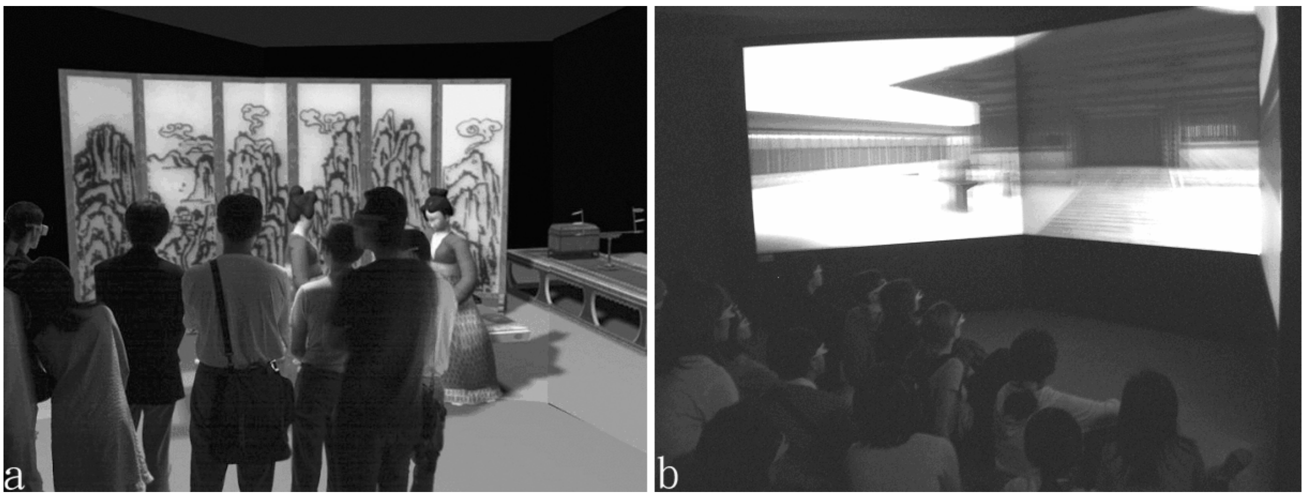


Figure 10: the immersion and one-way interaction of the VR-cave demonstration: (a) the laboratory study and (b) the exhibition in the National Palace Museum, Taiwan.

4. CONCLUDING REMARKS

This study aims at proposing a digital reconstruction procedure for historical cities and their activities. As a case study, this paper outlines the procedure associated in the project *Virtual Chang-An*, the know-how embedded in the sub-processes and the digital media required in these processes. To sum up the discussion, a preliminary digital reconstruction procedure is presented in Table 2.

In addition to its prompted impacts to the fields of archaeology and art history mentioned earlier, the significance of the proposed procedure of this paper could be discussed in different directions of architecture and city. Given the rapid developments of digital media in design, this study attempts to explore several cutting-edge technologies, which has been well-applied in other fields, and to apply them in architecture and urban design processes. It can be expected that the application and influence of 3D scanners, motion capture and VR-cave in architectural design and research will increase in the very near future. For the restoration of historical architecture and cities, which are mostly still represented in texts, drawings, pictures, videos, and physical models, this digital reconstruction procedure could be a powerful supplement to the current procedure, given its potential in increasing the quality of the realization of spaces and interactions. For the architectural design, which has long been the core of architectural study, the demonstration and discussion on the issues of spatiality, interactivity, and materiality might extract some interests and further examination on the concept of space[28,29], including physical spaces, virtual spaces, or cyberspaces (sometimes called networked spaces).

28. Eisenman, P. and Liu, Y.T., Hsinchu Museum of Digital Arts, A+U (Architecture and Urbanism), 2002, 382, 8-11.
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Table 2: a preliminary digital reconstruction procedure for historical architecture and cities.

Procedure	Method
Data Collection and Analysis Architectural & cultural depictions	**Conventional Media** collecting data from archaeological studies, historical literature, relics, remains, cave paintings, stone inscriptions, and new research, etc.
3D Digital Inferences Architectural & cultural realizations	**Digital Modeling** completing 3D forms and structures of all needed works based on their 2D pictures and drawings.
Digital Reconstruction Static & motional model processing	**3D Scanning - Motion Capturing** acquiring the static models of small-scaled antiques by the 3D scanners and the motional models by the
Scenarios Dynamics Integration of static and motional models	**Animation** integrating several scenarios in order to create more understandable experiences.
Visual-spatial immersion VR-cave representation	**VR-cave space simulator** applying the VR-cave to provide immersive visualization and spatialization of the city space and city life

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