Realism vs. Reality in Digital Reconstruction of Cities

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1 ABSTRACT

The digital reconstruction of existing cities using virtual reality techniques is being increasingly used. For consultants, municipalities and planning departments these models provide decision support through visual simulations (El Araby, 2001). For academia they provide a new tool for teaching students urban design and planning (Okeil, 2001). For authorities they provide a tool for promoting the city on the world wide web trying to attract more businesses and tourists to it.

The built environment is very rich in detail. It does not only consist of open spaces surrounded by abstract buildings but it also includes many smaller objects such as street furniture, traffic signs, street lights, different types of vegetation and shop signs for example. All surfaces in the built environment have unique properties describing color, texture and opacity. The built environment is dynamic and our perception is affected by factors such as pedestrian movement, traffic, environmental factors such as wind, noise and shadows. The built environment is also shaped by the accumulation of changes caused by many influences through time. All these factors make the reconstruction of the built environment a very complex task.

This paper tries to answer the question: how realistic the reconstructed models of urban areas can be. It sees "Realism" as a variable floating between three types of realties. The reality of the physical environment which we are trying to represent. The reality of the digital environment which will host the digitally reconstructed city. And the reality of the working environment which deals with the problem of limitation of resources needed to digitally reconstruct the city. A case study of building a 3D computer model of an urban area in the United Arab Emirates demonstrates that new time-saving techniques for data acquisition can enhance realism by meeting budget limitations and time limitations.

Keywords: Virtual Reality – Photo Realism – Texture maps – 3D Modeling – Urban Design

2 REALISM

As defined in the dictionary, "Realism" is "The representation in art or literature of objects, actions, or social conditions as they actually are, without idealization or presentation in abstract form." Realism could be seen as a variable floating between three types of realties. The reality of the physical environment which we are trying to represent. The reality of the digital environment which will host the digitally reconstructed city. And the reality of the working environment which deals with the problem of limitation of resources needed to digitally reconstruct the city.

3 REALISM VS. REALITY OF THE PHYSICAL ENVIRONMENT

The built environment is very rich in detail. It does not only consist of open spaces surrounded by abstract buildings but it also includes many smaller objects such as street furniture, traffic signs, street lights, different types of vegetation and shop signs for example. All surfaces in the built environment have unique properties describing color, texture and opacity. The built environment is dynamic and our perception is affected by factors such as pedestrian movement, traffic, environmental factors such as wind, noise and shadows. The built environment is also shaped by the accumulation of changes caused by many influences through time. All these factors make the reconstruction of the built environment a very complex task.

Developments in the field of Virtual Reality in recent years has brought us very close to representing the physical environment in a realistic way. Modern 3D modeling software provide modeling techniques using mesh-based, Spline-based and NURBS (nonuniform rational B-spline) models. These modeling techniques can create smooth, curved, organic, and geometric forms. The realism of architectural 3D models is accomplished by manipulating certain properties of textures, such as color, reflectivness, transparency, refraction, procedure mapping, and bump mapping in building materials (Heim, 1993), as well as different rendering algorithms such as raytracing and radiosity. Present-day computer imaging systems have enhanced immersion dramatically (Dong, 1998). Hardware for stereo vision and complete immersion such as head mounted displays and six-sided CAVES have been tested for several years. Research in this field is not limited to visualization but addresses other human senses, some of which could be relevant to urban design such as hearing the virtual acoustic environment influenced by heavy traffic.

Virtual reality techniques allow not only perceiving the digital model but interacting with it as well. Free navigation through its spaces and manipulating objects using input devices is common practice in online virtual environments. Multi-user virtual environments allow communication with other users using text-, voice- and video-based chatting capabilities. Building 3D worlds online by groups of users as seen in many online virtual worlds is a new phenomena worth monitoring by architects and city planners.

Although these techniques have brought us very close to the realistic representation of the physical built enveronment, they have not reached perfection yet.

4 REALISM VS. REALITY OF THE DIGITAL ENVIRONMENT

A digitally reconstructed city will most probably be hosted on a server linked to the internet and accessed by users from different locations using their computers. Such a digital environment usually has limited capacities in terms of storage area, bandwidth, and processing power. Although the computer industry has been offering a rapid increase in those capacities, there are still limitations that have to be considered. For example standard modern computers cannot perform raytracing or radiosity of a complex 3D model in realtime and a choice must be taken either to sacrifice smooth navigation or sacrifice photorealism. The "highly realistic" 3D model of a digitally reconstructed city with hundreds or even thausands of buildings and tens of thausands of texture maps could be found "non-realistic" if:

- Its size exceeds the storage space available on the hosting server or the user's computer
- Its download time exceeds the time the user considers acceptable
- Its processing is so demanding that the user's CPU is overwhelmed and navigation becomes sluggish or impossible.

This has put pressure on developers of digitally reconstructed cities and prevented implementing much of what has been achieved in the field of virtual reality.

5 REALISM VS. REALITY OF THE WORKING ENVIRONMENT

Digital reconstruction of cities involves modeling of tens, hundreds and in some cases thousands of buildings. It requires a well organized working team with knowledge from several deciplins such as architecture, urban design, CAAD, GIS, photogrammetry, digital image processing and programming. It involves a big deal of resource management. Experience gained from modeling single buildings might not be relevant when dealing with a bigger area and a bigger number of buildings. The process also involves providing training to team members. This complex task requires enough time, funding and know-how, which could affect the degree of realism if not available. Time constraints require implementing working techniques that are fast and simple. Funding constraints require implementing working techniques that are fast, consume less material, need no costly hardware, software, datasets and a minimum of highly paid personel. These techniques are either developed or adopted.

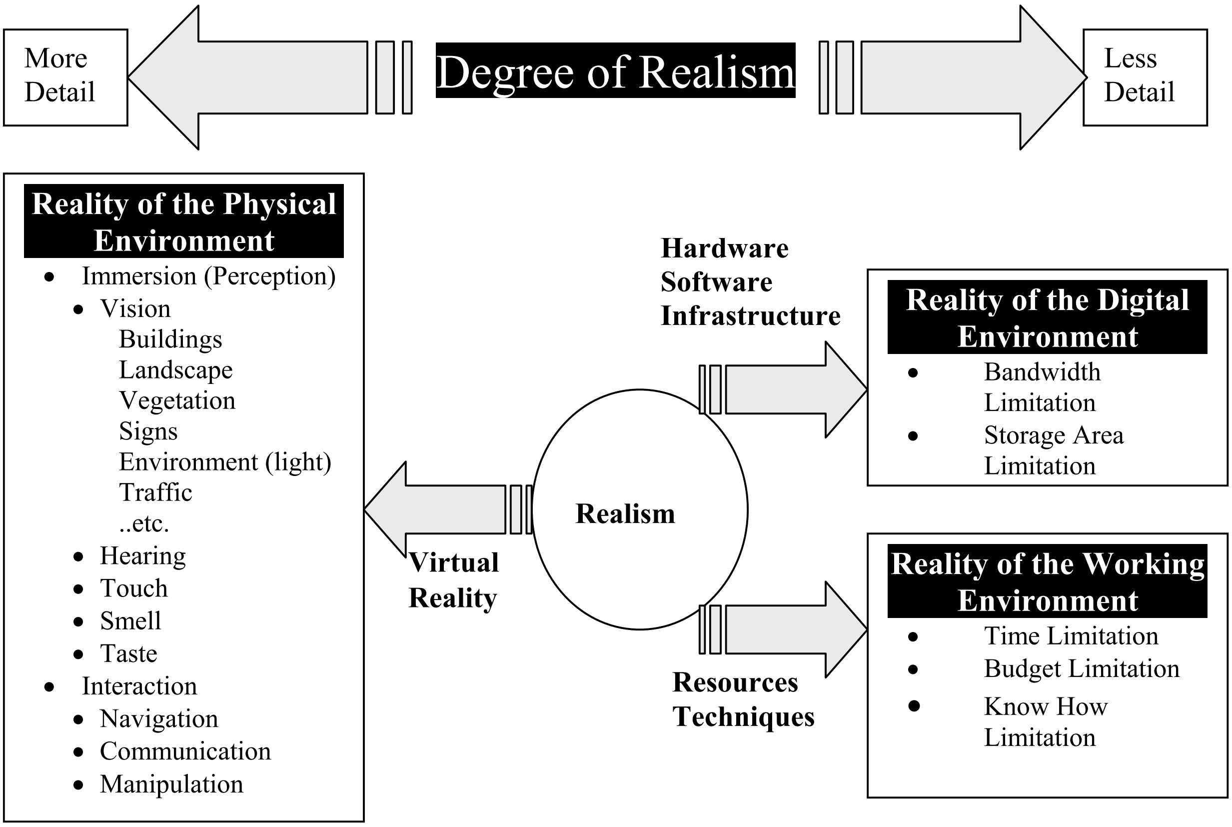


Figure 1: Realism as a variable floating between three types of realities.

6 CASE STUDY

6.1 Scope and description of the study area

Al Ain is a rapidly developing desert city in the United Arab Emirates. In a research project funded by the UAE University aiming at implementing virtual reality in enhancing the image of the city, a 250 x 1000 meter area was selected as a pilot model. It was decided that the area of Khalifa street in the down town area be selected as a starting nucleus which could expand later on by adding additional areas. Khalifa street was selected not only for its importance to the city but also because it is the most dense area in terms of buildings, building details, vegetation, landscape elements, street furniture and traffic. Experiences gained from reconstructing this area would help set guidelines and develop techniques to face easier situations existing in other areas of the city. It was also decided that the virtual model starts at a low level of detail which would increase over time as more aspects of the built environment are addressed. The selected area contains 64 buildings, 745 trees and palm trees in addition to many landscape elements and landmarks. The time frame and available funds were very limited that unconventional data acquisition and processing techniques were sought. In this paper we will concentrate on discussing realism in modeling the buildings existing in the study area.

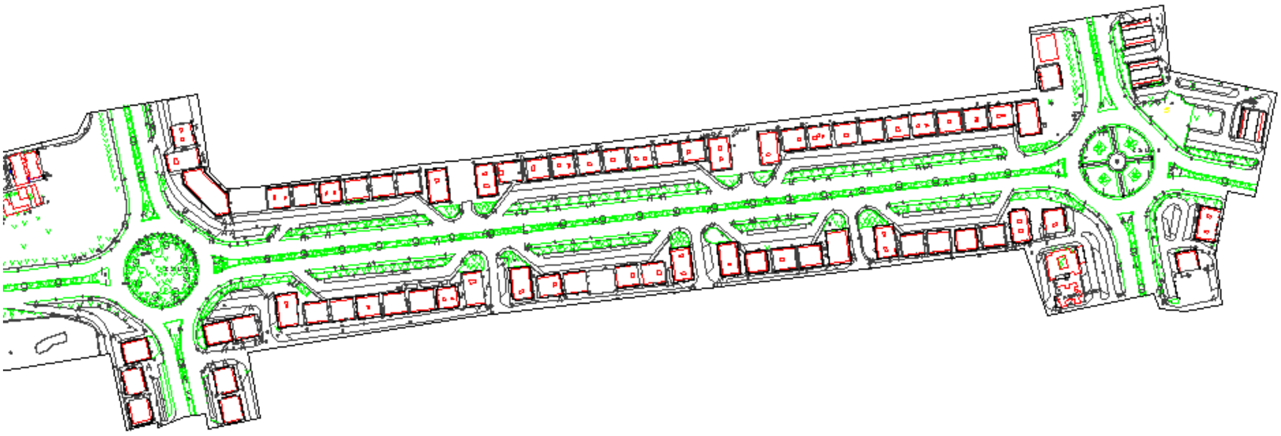


Figure 2: Selected study area at Al Ain down town with 64 buildings and 745 trees.

6.2 Selecting the degree of realism

Prerequisites for photo realism in representation of buildings include accurate geometric modeling and textural accuracy (Henricsson et al, 1996). Accurate geometric modeling deals dealswith the level of detail in which the geometry of the building will be described. A 3D model where each and every detail of projection or recession of architectural features would come on top of this scale and a simple cubiod would come at the bottom of that scale. Different degrees of realism on that scale could be used. For example modeling balconies or overhangs that project more than 1 meter but ignoring windows recessed 20 cm. Texture accuracy deals with the level of detail in which the surface properties of the building will be described. A 3D model where a real photograph is maped on the building surface to describe its texture and color would come on top of this scale and a monochromatic building would come at the bottom of that scale. Different degrees of realism on that scale could be used. For example giving different materials different solid colors or different generic textures. A fully articulated model would require intensive CAAD work and assumes that full dimensiones of each building is either available or obtainable. A photo-textured model would require intensive work for acquiring photographs and processing images in a desktop photogrammetry program or a digital image processing program. Different combinations from both scales could be used. For this research project a partially articulated model with photo-textures was selected for several reasons. Non-articulated photo-textured models contain visual information describing the building geometry which is not modeled. For the same degree of realism this type of model appears to be less demanding in terms of storage area compared to fully articulated models. It is also possible to automate some of the processes involved in image acquisition and processing. Non-articulated photo-textured models are also easier to construct since intensive CAAD work is not required. They require less training for the team members but required some investigation and experimentation.

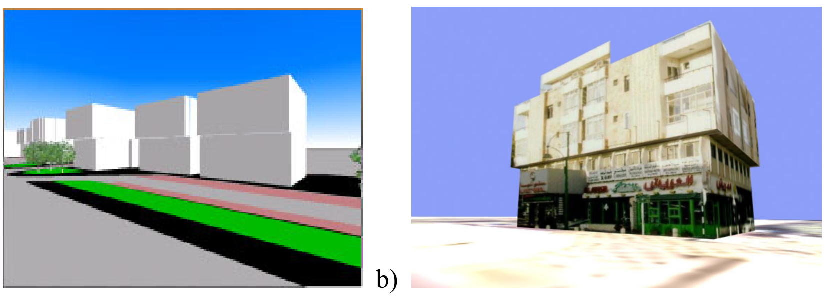
a)  b)

Figure 3: Degree of Realism in representing building surface properties. a) Al Ain – Non-articulated monochromatic blocks,

b) Al Ain – Partially articulated photo-textured blocks.

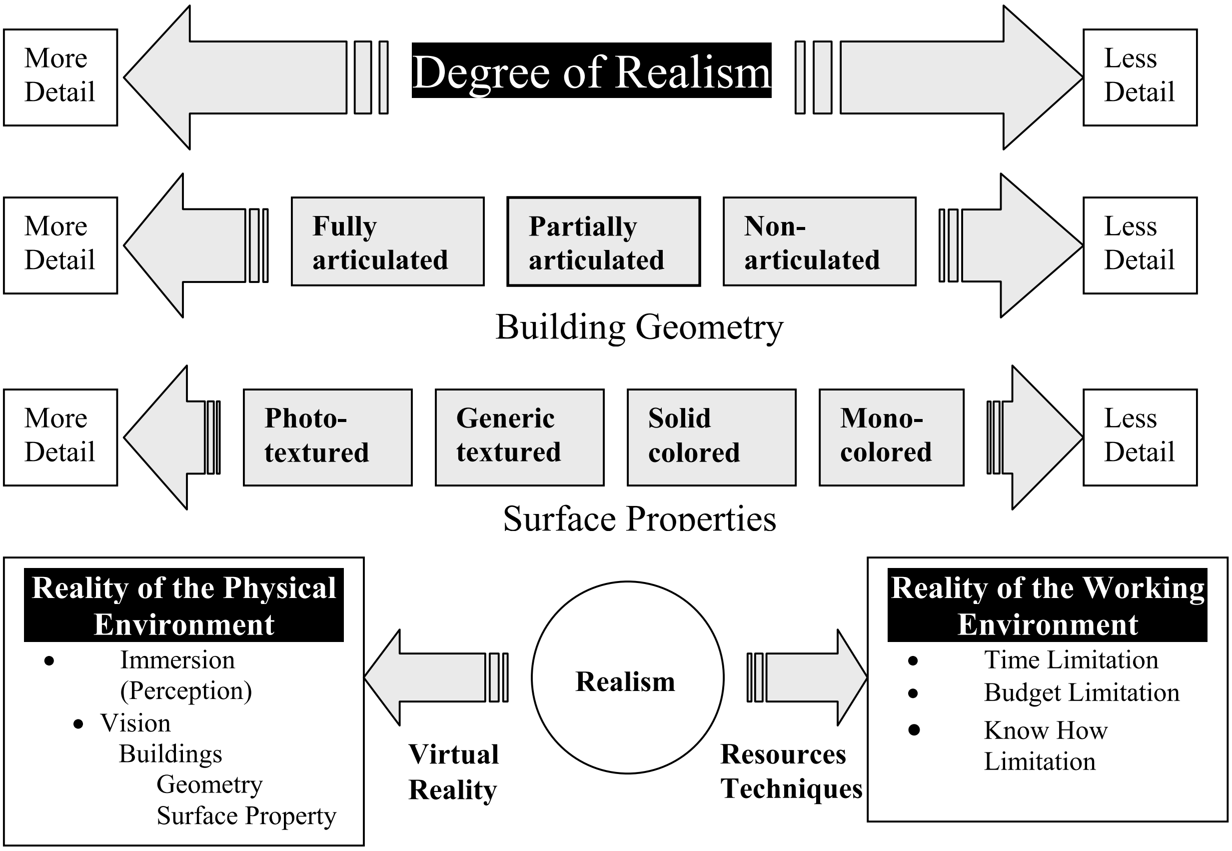


Figure 4: Selecting the degree of realism for building representation.

6.3 Representation of building geometry

The 2D digital map obtained from Al Ain Municipality in the DWG format appeared to be an excellent starting point to build the 3D model on. But the first modeling trials using Autocad and 3D Max showed that the map is suffering from two major problems.

- Many entities (Lines, Plines, Arcs, …etc) in the digital map did not meet each other in a neat way. The problematic end points, though invisible, prevented converting these entities into closed polygons to be treated as surfaces. The tedious task of finding and correcting these errors had to be done manually.
- Arcs and Plines in the digital map resulted in segmented Splines in the virtual model. Although this did not stop the VRML model being built, it caused an unnecessary and dramatic increase in its size. Again, this tedious task of identifying problematic areas and decimating unnecessary vertices had to be done manually.

The third dimension of objects were obtained in various ways. Most buildings followed building regulations and were four floors high. An ultrasonic range finder was sometimes used in the case of masses projecting from buildings. Judgment was used in the case of vegetation. Additional 3D information was obtained using desktop photogrammetry software such as photomodeler and photo3d.

The geometric 3D model of the study area with streets, curb, walkways, green areas, trees and buildings but without textured maps and many other details was finished and tested on the internet.

6.4 Still image photography vs. vehicle born video capture

A pilot model of a selected building was finished using Photo-based texture-maps obtained from two separate sessions of still image photography. The purpose was to judge the time, effort and costs required for completing one building and to define the problems that would face the research team in completing the entire model. The results of this experiment could be summarized as follows:

- The two Photography sessions of one building took 90 minutes and was followed by time for processing and printing the the photos and scanning them into a digital format. It was concluded that a faster technique was needed.
- Due to the high processing and scanning costs it was concluded that digital equipment should be used.
- After examining the photos it was found that many of them are either totally or partially unusable due to different types of unavoidable obstacles between the camera and the building such as parking and moving cars, walking and standing people, traffic signs, trees, and lanterns. It was concluded that another method resulting in a bigger number of photos per building from different locations is needed hoping that textures hidden by one obstacle such as a tree in one photo would appear unobstructed in another photo.

- Long photography sessions in a limited area with the camera always pointed at building facades drew peoples' attention which was feared to cause problems specially in a society where privacy is highly valued. It was concluded that a faster and less visible technique for image acquisition was needed.
- Still image photography resulted in high resolution photos all exceeding 1 MB in size and had to be reduced before being used for texture mapping. It was concluded that a technique for image acquisition resulting in photos with less resolution was acceptable if not desired.

The use of camcorders in acquiring images for architectural photogrammetry has been described by Streilein (1993). A technique was proposed and tested to overcome problems associated with still image acquisition. It is based on a digital video camera mounted on the side of a moving car in order to capture building facades. The captured movie is then digitized and de-compiled into thousands of still images. This method allowed scanning both sides of the entire street in 15 minutes which solved many of the problems mentioned earlier. Three problems had to be overcome before acceptable results were achieved. The first was a degradation in image quality due to video compression. The second problem was storage space overflow due to the flood of thousands of still images. The third problem was the narrow field of view of the camera that did not cover the whole building façade due to the unavoidable close trajectory of the car to the building. After some experimentations and modifications all problems were solved. Video compression was canceled. Adjustment to the frame rates and decimation of unwanted frames were used. A semi-fisheye lens was mounted on the digital video camera to increase the field of view.

Figure 5: De-compiling the video stream into thousands of still images taken from slightly different locations on the vehicle trajectory.

Figure 6: Manual and automated decimation of acquired still images into a manageable number of frames.

6.5 Photogrammetry vs. digital image processing

To produce orthographic texture maps the captured images must undergo some processes such as barrel distortion correction, orthographic rectification, cropping and stitching. Two techniques were tested to extract photo textures from the acquired images. Desktop Photogrammetry and Digital Image Processing.

Two Desktop Photogrammetry software packages were used; the high-end software Photomodeler and the simpler low-end software Photo3D. Both programs try to build a 3D model based on information present in groups of digital images. Clues in different photos have to be picked up manually. Cameras have to be calibrated. Available information such as known dimensions, constraints such as verticality of a line, …etc. must be entered manually. After processing these inputs, a virtual 3D model with its textured maps is produced. This approach was found to be time consuming and with no potentials for automated processing. Many details such as camera calibration was found to be very tricky and caused difficulties in barrel distortion correction, image rectification and image cropping. Differences between dimensions of the resulting 3D models and the official 2D map from the municipality were always detected. Still this approach was found very useful in measuring building heights that were missing from the municipality map.

Digital image processing is a rapidly developing field. Commercial and free software for barrel distortion correction, image orthographic rectification, image stitching and image cropping were obtained and tested. It was found that the resulting images were comparable to those obtained by desktop photogrammetry but the time for processing was much lower. This approach was found to have a high potential to be automated through scripts and batch processing. It was therefore selected for obtaining the final orthographic texture maps.

6.5.1 Barrel distortion correction

This type of distortion is typical from wide angle lenses (any lens with a focal length less than 45 mm). Very wide lenses (focal length less than 28 mm) are the extreme cases. Images taken through the semi-fisheye were found to be unusable without barrel distortion correction. The two programs Lensdoc and Pano-tools were tested and gave acceptable results.

Figure 7: Barrel Distortion Correction using digital filters and image processing software. a) before correction, b) after correction.

6.5.2 Image orthographic rectification

Orthographic rectification is the process that attempts to remove perspective effects from images. After orthographic rectification parallel lines in reality should not appear as vanishing towards image edges. In other words they should be parallel in the image. Perpendicular lines in reality should be perpendicular in the image. Horizontal lines in reality should appear horizontal in the images. Architectural elements equally spaced in reality such as columns and windows should appear equally spaced in the image.

6.5.3 Image cropping

Image cropping is the process of eliminating unnecessary areas from the image and concentrating on the planar surface to be processed. This process has to be done manually with special care.

Figure 8: Texture map orthographic rectification and cropping using image processing software. a) Process, b) final texture map.

6.5.4 Image stitching

Image stitching was necessary in cases when it was impossible to capture the whole planar surface in one image either due to its big size or in an attempt to avoid an obstacle covering parts of the façade.

6.6 Management of the photo-realistic 3D model

The final photorealistic 3D model of the entire area would include hundreds of texture maps. It was therefore necessary to rename the image files containing the texture maps using a code that facilitates their identification in the future. A pilot building was selected to be modeled using all proposed techniques and is ready to get integrated into and linked to the abstract model of the study area already available online. All 64 buildings in addition to other elements such as vegetation will follow using the same techniques.

7 CONCLUSION

In this paper "Realism" as a variable floating between three types of realties has been discussed. The reality of the physical environment which we are trying to represent. The reality of the digital environment which will host the digitally reconstructed city. And the reality of the working environment which deals with the problem of limitation of resources needed to digitally reconstruct the city. A case study of building a 3D computer model of an urban area in the United Arab Emirates has been described to demonstrate demonstrates that new time-saving techniques for data acquisition can enhance realism by meeting budget limitations and time limitations.

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