

MODELS AND VISUALIZATIONS IN A VIRTUAL HABITAT

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ABSTRACT

The Earth is still rather „flat“. Therefore geographic data still tend to be two-dimensional and are stored in 2-dimensional information systems. But we do live in a three-dimensional world. In technical systems, the 3rd dimension has long been merely an attribute of 2-dimensional graphical data. This is subject to rapid change. Three-dimensional models of the human habitat are emerging. The required tools to create and use such models are the topic of the paper. This is at the intersection of computer graphics and computer vision and reflects a recent trend in computer science, where vision and graphics increasingly tend to meet. The paper discusses procedures for a fully automated creation of 3-dimensional models of today's buildings and cities, but also of interior spaces, even of microscopic worlds and of the lost cities of the antique. Methods will be described, but also their performance, accuracies, limitations and costs, to better understand what it takes to create and use a „virtual habitat“.

1. INTRODUCTION

An industry is developing to produce 3-dimensional models of existing industrial and non-industrial structures. This may include oil drilling platforms in the ocean, refineries and chemical plants, space structures, cultural monuments or city scapes of interest to the telecom application or to vehicle navigation. And new man-machine interfacing ideologies such as augmented reality are rapidly developing their own need for capabilities to produce 3D models of the human environment, resulting in so-called „virtual habitats“. Challenges like Web-3D and mobile 3D result from a desire to visit far away places via the Internet.

Models of the environment may concern entire planets such as Venus or Mars, and of course the Earth, or entire continents such as Antarctica with its significance for the Earth's oceans and weather patterns, entire countries and cities, buildings, building interiors, monuments, and going on to small objects to include microscopic structures (Figures 1-4).

These interest are often driven by technologies, not necessarily by urgent needs. The most significant such drive is Moore's law. It in essence states that a computer system and performance which today may cost €200,000 will be available in 10 years for the purchasing power of today's €1,000.--, in combination with the enormous miniaturization of all computer related solutions. Powerful palm-sized computers in combination with 3D navigation, portable keyboards or intelligent speech interfaces, large foldable monitors or monitors integrated into a pair of optical glasses, and broadband wireless data transfers will create the ability to have, view, use

and enjoy 3-D data of remote or local habitats for a variety of applications.

2. CREATING 3D MODELS

Creating 3D models is easily feasible using standard surveying or photogrammetry techniques which develop such models by a tedious manual process. The same is a non-trivial task if to be done at low cost and thus automatically. Current approaches start off with an imaging sensor which produces images to cover an object of interest with multiple images to ensure that sufficient redundancy is provided for multi-ray stereo procedures. Such images are being combined with information about the object, such as targeted points to define a world coordinate system. A typical current tool is Foto-G, a commercial product to collect imagery, administrate the images in an image data base that defines the relationships among the data sets (Figure 5), such as overlaps, then computes the camera stations using relationships between images and with points on the object (Figure 6). Finally the data of interest about the object get collected with semi-automated procedures so that a 3D CAD model comes into existence as points, lines and curves get extracted from the images and configured to complex objects (Figure 7).

This type of approach is depending highly on a participating human to collect and organize sensor data, support geometric procedures, decide on the interpretation of object features and generally guide the 3D modeling process.

3. GEOMETRIC CALIBRATION AND ACCURACIES

Any 3D model needs to be associated with accuracy measures. For this to work one needs to calibrate the sensors. Figure 8 illustrates a typical calibration scenario. A known object gets modeled so that unknown sensor parameters can be determined. Points will be defined with uncertainties that should be in the sub-pixel range. This is a non-trivial issue when considering the fuzziness of objects in the digital domain (Figure 9). However, automated centering on symmetric objects will be feasible with errors of 1/20 of a pixel.

The accuracy of 3D models can be in the range of 1:10,000, thus with an error of 1 cm at a distance of 100 m between sensor and object. Often, models are far less accurate, more in the range of 1:2,000 and less, due to a disregard for proper geometries, calibrations and measuring methodologies.

4. AUTOMATION OF 3D INFORMATION EXTRACTION

The cost of 3D models is often prohibitive when produced by hand. It may take manual labor in the range of 20+ hours and more to develop a detailed 3D a set from a single image pair in stereo. It is no

wonder then that significant research efforts are being expended to reduce the amount of manual labor required or a 3D model. Several avenues of research are being pursued.

The most radical approaches are with the use of low resolution video image sequences from uncalibrated video cameras. Pollefeys (xxx) has presented persuasive evidence that 3D models can be created fully automatically, for example of building ensembles or from statues. Karner et al. (xxx) are demonstrating that full automation is feasible also with the use of less redundant image sequences from larger format digital images (Fig. 10). A range of methods and innovative algorithms is being integrated into a system called MetroGIS. One is searching for vanishing points in individual images, performs multi-ray matches to first connect the separate images into image blocks and second to develop so-called point clouds (Fig. 11), or even edge clouds. These „clouds“ get then converted to planes and shapes, such as windows, doors, walls or ornaments on building facades.

The type of object and its required accuracy determine the type of algorithms used for automating the modeling process. Building shapes and facades contain many very specific elements that may not exist indoors. A classical indoor structure such as a statue has very little predictability (Fig 12), and outdoors vegetation is even less defined.

5. RENDERING LARGE DATA SETS

A city with 20,000 buildings, and imaging each building on 20 photos results in a data set with 400,000 photos. This is the entire catalog of photos collected over many decennia or all of Austria in the Vienna Bundesamt für Eich- und Vermessungswesen. Yet such a city is as small as Graz with its 250,000 people. At 16 Mpixels per image, this will be in excess of 6 Tera-pixels. This may be the largest component of the data base, and it is significant.

The geometric information may consist of 100 points per building. This results in a mere 8 Mbytes. However, vegetation may add another complexity in such a data base. While buildings can be described by geometric shapes and made looking realistic via image contents, vegetation cannot be reasonably modeled tree and shrub per tree and shrub. Therefore generic vegetation must replace the true vegetation. Figure 13 illustrate such generic vegetation. If the „bald Earth“ is being covered by such vegetation, there is hardly a significant storage requirement. It becomes possible to render a vegetated scene at real time rates, thus at 20 images per second.

6. ABOUT SENSORS

Cameras are the most obvious tools from which to build 3D models. However, there is currently great interest also in using laser scanners such as those by Leica-Cyrex (ground based) or Optech (airborne).

There exist many other sensor technologies, besides cameras and scanners, from which to get a 3D model. This includes airborne and spaceborne radars, special-kinds of cameras with non-traditional sensors such „push-broom“ devices, and the wide field of medical imaging.

For the creation of urban 3D models one occasionally thinks of setting up a mobile mapping unit to collect images and non-image data from a vehicle on the fly. Besides regular rectangular fields of view, there can be panoramic sweep cameras, various kinds of radiometric imaging, ultrasound and the likes.

7. AUGMENTED REALITY AND 3D MODELS

A „hot“ requirement for 3D models of interior spaces and also of outdoor scenes derives from an increased interest in so-called augmented reality. Whoever operates in a virtual space embedded in real space needs to know the details about that real space. Figure 13 explains a scenario where virtual objects get manipulated by two persons, both looking at the same virtual object. The real world surrounding the augmented reality operators needs to exist in the computer to avoid conflicts between virtual and real objects.

Augmented Reality can be a demanding customer for methods to easily, accurately and automatically produce 3D models of typical AR-environments, such as offices. Figure 14 explains how two persons co-examine some medical situation in a virtual set-up, yet including the real space.

But AR can also be part of the creation of the 3D model itself. The AR-scenario includes a camera, thus this can make the images for later analysis of the real world. The computational results of the stereo process to model the object can be displayed on the AR-Head-Mounted Display, get superimposed by the real world, and we have a useful editing set-up to improve the virtual data with inputs from the real world.

8. CONCLUSION

Medical training, pre-operative surgery planning, arm-chair tourism, architecture, urban planning and public administration, vehicle navigation, and many more of these topics all benefit from improvements of the data on which this work is built.

Such data are increasingly 3D. In the urban scene, such transition is from the 2D GIS (Geographic Information System) to a fully 3D data base. And once the data all are digital it will not take long to take advantage of the source imagery and use it to improve the appearance of the scene of interest, using image-based texture for „photorealistic rendering“.

REFERENCES

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Karner K.,

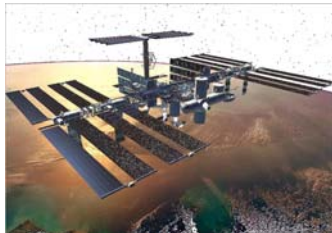


Figure 1: Space Station as a domain for 3D „as-built“-modeling of the scene.

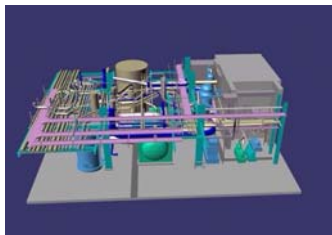


Figure 2: A paper mill modeled in 3D from images, for use in a CAD-software application

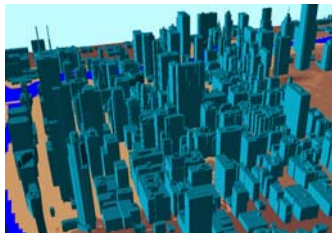


Figure 3: A „city model“ for use in analyzing signal propagation for telecom applications

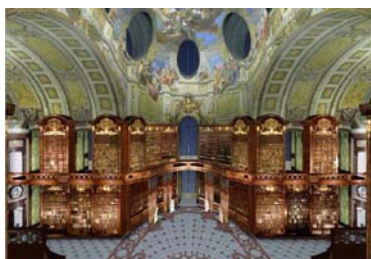


Figure 4: An indoor 3D model of a historical monument, the National Library in Vienna.



Figure 5: Graph showing the images taken for a particular scene, and the relationships between those images (overlaps, orientations).

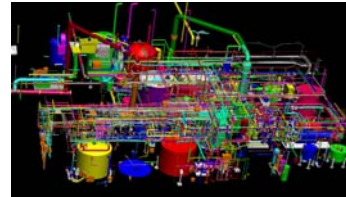


Figure 6: 3D model created by Foto-G from 10,000 photographs, taken of a chemical plant



Figure 7: Calibration set up for a digital camera.



Figure 8: Measuring accuracy is compromised by the ambiguity from pixel patterns.



Figure 9: MetropoGIS uses a fully automated approach to create 3D models of urban spaces using a limited number of images. This example is of Graz Hauptplatz.



Figure 10: A point cloud extracted from a set of images of an urban scene in MetroGIS



Figure 11: 3D model of a statue situated inside the National Library in Vienna



Figure 12: Generic trees for quick rendering of large numbers of objects

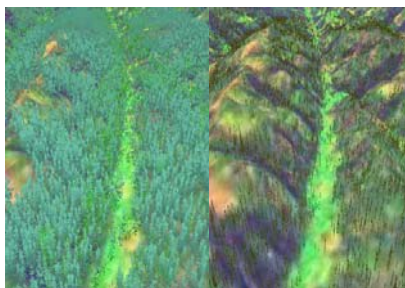


Figure 13: Rendering of a landscape with two different models of generic trees.

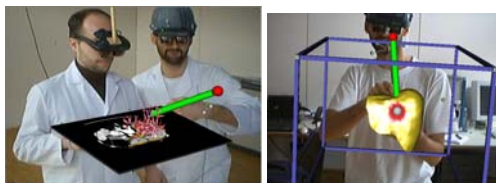


Figure 14: Augmented Reality for cooperative work. This example shows the analysis of a 3D model of a liver with its vessels (left) and of its surface, marking a tumor.