EXTRACTING INFORMATION FROM VERY LARGE DATASETS

Modelling the Erechteion

Modern terrestrial laser scanners (TLS) generate between 10 and 50 million 3D coordinates per minute: about 500Mbytes of data. Together with high-resolution images for texturing purposes, this is enough information to choke high-end PCs running commercial software. The National Research Council in Canada has developed a framework for extracting information from very large TLS and imagery datasets, an evolution demonstrated in the Erechtheion project. This monument has been modelled in 3D to a spatial resolution of 2mm. The fully textured 3D model containing 348 million polygons can be interactively visualised and analysed in real time.

Creation of an accurate representation of 3D geometry and object texture is key to many disciplines and areas, including the automotive industry, space exploration, medical, manufacturing, forensics, construction, and cultural heritage. Sensors and algorithms for 3D imaging and modelling are thus of great interest to both researchers and practitioners. The National Research Council Canada (NRCC) develops, tests and refines 3D solutions through challenging demonstration projects, the Erechtheion project being one.

Cultural Heritage

Cultural heritage has been a central factor in the NRCC research and development programme in 3D technologies, and similar projects include the Neolithic cave ‘grotta dei Cervi', a Byzantine crypt, 3D modelling of castles, and paintings such as the ‘Mona Lisa'. Many of the technologies developed have been adapted for commercial applications, such as the Space Shuttle inspection laser scanner. The challenge lies in the billions of 3D points and hundreds of gigabytes of digital images making up one model.

Erechtheion Project

Erechtheion, also known as Erechtheum, is on the Acropolis, next to the Parthenon in Athens, Greece (Figure 1), and is just a remnant of the construction completed in 406BC. Its restoration was completed in 1987. On the north side there is a large, columned porch. The ‘Porch of the Maidens' on the southern aspect comprises six draped female figures; these Caryatids are cast copies of the six originals, five of which are on display at the Acropolis Museum and one at the British Museum in London. Figure 2 shows various views of Erechtheion generated by laser scanning.

The Erechtheion project is part of ‘Development of Geographic Information Systems at the Acropolis of Athens', financed by the European Union and the Government of Greece and supervised by the Acropolis Restoration Service, Hellenic Ministry of Culture. The partners are Elliniki Photogrammetriki Ltd (Elpho), Athens; Geotech O.E., Athens; ETH (Swiss Federal Institute of Technology), Zurich; the National Research Council, Canada; the Institute for Mediterranean Studies, and the Foundation for Research & Technology (FORTH), Rethymno, Crete, with external co-operation from Leica Geosystems, Switzerland, Basis Software Inc, USA, and Innovmetric Software Inc.

Atelier3D.ca

On the Erechtheion project NRCC has developed algorithms for 3D-image processing, management and real-time visualisation as part of Atelier3D.ca, a general framework evolved for the acquisition, processing, modelling, analysis and visualisation of very large 2D/3D datasets built from 3D point-clouds and imagery. Compatibility with commercial package Innovmetric Modeler accelerated development of the tools and helped avoid reimple-mentation of operations. Atelier3D.ca emphasises a high degree of automa-tion, interactivity, scalability and measurement accuracy. It facilitates or fully automates many operations, including registration of multiple scans, image processing before texture draping, accurate registration of texture imagery with the geometric model, and interactive visualisation of the full-resolution 3D-model.

Data Acquisition

The height of the 20m×10m×5m monument made scanning top parts from ground level difficult. Most parts were captured using phase-based time-of-flight (TOF) mid-range TLS (Surphaser 25HSX) (Figure 3). The top and other parts unreachable by this scanner were scanned using a long-range pulse-based TOF TLS (HDS3000). The choice of spatial resolution 1-5mm at 5m range was determined by the laser footprint and size of the bas relief sculptures. High-resolution scanning uncovers a high level of detail, but also generates a lot of data. Figure 4 shows the effect of scanning at 2mm as compared to 20mm. A preliminary photographic campaign before start of the work helped plan TLS scan positions and calculate fieldwork time. Nevertheless, obstructions and terrain caused delays and resulted in missed areas. Complex shapes caused occlusion of parts of objects, and the presence of plants and trees resulted in holes. Erechtheion is made mostly of marble, with artificial and natural stone. The surface is marked by a number of cuts, gunshot damage and impact from cannon-balls. A study of material effects revealed that TOF-based TLS produced an apparent laser penetration of about 6mm on marble. It is necessary to correct for this, which requires further study; the mechanism differs from triangulation-based TLS, which we studied ten years ago in the ‘Digital Michelangelo' project.

Processing and Modelling

Processing and modelling large datasets requires rethinking existing algorithms. A central concern is the maximal automation of all steps, since human interaction is costly and time-consuming. High-precision linking of pose, camera parameters and residual deformation of 3D TLS data and 2D images is one of the most difficult and time-consuming activities for a human operator. We recently succeeded in effecting a fair degree of automation in this alignment process. An efficient user interface allows an operator to complete the work in minimal time. Other advances include data integration and correction of errors and deformation due to intrinsic scanner characteristics.

Visualisation

Atelier 3D.ca allows view-dependent, real-time visualisation of multi-resolution models. For example, the renderings shown in Figure 5 are created from the 348-million polygon model of the monument using this system. The resolution and visual quality of the textured 3D-model should ideally match what is perceptible by the human eye during a real visit, even at close range. For interactive visualisation the 3D-model must be viewable on standard workstations or laptops. Algorithms have been developed for displaying these datasets interactively at full resolution on inexpensive laptops or desktop computers. The rendering algorithm is capable of delivering images in real time; at least twenty frames per second, even at full resolution. Photorealism, defined as showing no difference between the view of the model and a photograph taken from the same viewpoint, goes further than simply draping static imagery over the 3D geometric model. For instance, images need to be processed for varying illumination before being mapped onto the 3D-model created from point-clouds. We are now improving these technologies to make them entirely automated for use by non-experts. We have also worked to overcome the resolution limitations of current projectors by implementing stereoscopic multi-projector display technologies for showing 3D-models at full resolution.

Multi-resolution

The further a viewer zooms in, the more detail he or she wants to see. This means that full resolution should be shown when the 3D-model is viewed at close range. Resolution should be gradually reduced as the model is moved away from the observer. This part of the software is based on the Geomorphing of Levels of Detail (GoLD) system. Fine surface detail and variation need to be accessed within a larger context and hidden in global surface features. Thus simply displaying the 3D-model in a photorealistic manner is not enough. To enhance viewer understanding and maximise the value of the dataset, the model should also be transformed using techniques such as shape-preserving filtering (Figure 6). In this project we have implemented numerous real-time data transformation techniques on GPU (Graphics Processing Unit) that enable real-time extraction of all the information available in the models.

Further Reading

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NRCC R&D contributors to the Erechtheion Project included F. Blais, L. Borgeat, L. Cournoyer, S. El-Hakim, D.Gamache, G. Godin, P. Massicotte, M. Picard and G. Poirier.