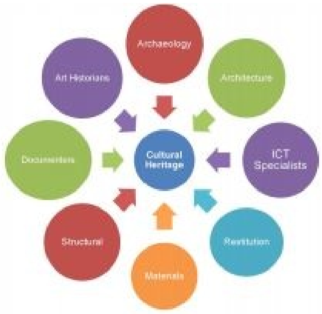
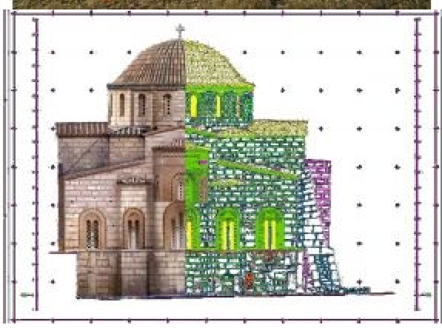
THE IMPACT OF MODERN MAPPING TECHNOLOGIES FOR CULTURAL HERITAGE

Preserving the Past Using Geomatics





ICT advancements have driven progress in many aspects of geomatics, such as 3D documentation and modelling. This article explores how contemporary digital technologies contribute to the conservation of cultural heritage.

Over the past decades, the tremendous progress in information and communication technologies (ICT) has totally changed the way we live, communicate and indeed measure and model the world around us. Prof Andreas Georgopoulos from the National Technical University of Athens in Greece maintains that this progress has influenced the traditional land surveying profession more than any other in the engineering business. Geomatics and geoinformatics are a consequence of this technological advancement, and today's professionals should feel privileged to have experienced this radical change first-hand. But how has the progress influenced specific parts of the profession and related applications such as the 3D documentation and modelling of cultural heritage? This article aims to examine the beneficial impact.

Monuments and other cultural heritage objects are valuable assets of world history. The thorough study, preservation and protection of them is an obligation of our era to mankind's past and future. However, these records of human history are greatly endangered, both by natural and manmade factors, as various incidences have painfully demonstrated recently. Over the past few decades, international bodies and agencies have passed resolutions concerning obligations for protection, conservation and restoration of monuments. UNESCO and the Council of Europe have formed specialised organisations for taking care of mankind's cultural heritage. The International Council for Monuments and Sites (ICOMOS) is the most important one, but also CIPA Heritage Documentation, the International Society for Photogrammetry & Remote Sensing (ISPRS) and the International Union of Architects (UIA), among others, are all involved in this task. Today the traditionally involved experts, like archaeologists and architects, tend to accept and recognise the contribution of geomatics to the cultural heritage agenda. Hence the geometric documentation, preservation and conservation of cultural heritage are rapidly becoming interdisciplinary and intercultural issues (Figure 1).

Figure 1, The interdisciplinary contribution to cultural heritage.

It was in the Venice Charter (1964) that the necessity of the geometric documentation of cultural heritage was set as a prerequisite for the first time. In Article 16 it states "…In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs…". It should however be stressed that, since there is as yet no generally acceptable framework for specifying the level of detail and the accuracy requirements for the various kinds of geometric recording of monuments, every single monument is geometrically documented based on its own accuracy and cost specifications. Therefore, it is imperative that all disciplines involved should cooperate closely, exchange ideas and jointly formulate the geometric documentation requirements, while deeply understanding the monument itself and each other's needs.

Contribution of Geomatics

The rapid ICT advancements have provided today's scientists with powerful new tools. We are now able to acquire, store, process, manage and present any kind of information in digital form. This can be done faster and more completely than before, and it can ensure that the information is easily available for a larger base of interested individuals. Those digital tools include instrumentation for data acquisition, such as scanners, digital cameras, digital total stations etc., software for processing and managing the collected data and – of course – computer hardware for running the software, storing the data and presenting it in various forms.

The introduction of digital recording technologies for geomatics applications can contribute to all steps of traditional archaeological practice, although the extent of ICT's contribution differs in the various stages and in the various cases. Modern technologies of remote sensing and archaeological prospection assist the touchless and rapid detection of objects of interest even before digging. Spectroradiometers or ground penetrating radar, or even the simple processing of multispectral satellite images, may easily lead to the rapid location of underground or submerged objects of interest. Contemporary non-contact survey technologies, such as photogrammetry, terrestrial laser scanning and digital imaging, can be used to produce accurate base maps for further study, or 3D virtual renderings and visualisations. The collected data may be stored in interactive databases, either georeferenced or not, and be managed according to the experts' needs. Last but not least, ICT can assist in the presentation stage, by producing virtual models that may be displayed in museums or be included in an educational gamification application or enable disabled people to admire the treasures of the world's cultural heritage, for example. Since 2003 UNESCO mandates the use of digital technologies in the preservation and curation of cultural heritage. With its Charter on the Preservation of the Digital Cultural Heritage, this global organisation proclaims the basic principles of digital cultural heritage for all civilised countries of the world. At the same time, numerous international efforts are underway with the scope to digitise all aspects of cultural heritage, whether large monuments, tangible artefacts or even intangible articles of the world's legacy (Stylianidis & Remondino 2016).

Figure 2, Examples of contemporary data acquisition instrumentation (digital single-lens reflex [DSLR] cameras, the FARO Focus 3D and the ZScanner 700 CX).

The instrumentation necessary to support heritage conservation activities should always be at the cutting edge of technology. Modern instrumentation includes data acquisition instruments (Figure 2), processing software and powerful computers. Data acquisition instruments should include devices which are capable of digitally collecting (i) images or image sequences, (ii) points in 3D space and (iii) other pieces of information related to cultural heritage objects.

The impact of digital geoinformation technologies on the cultural heritage domain has increased the speed, objectivity and automation of the procedures which involve processing of the digital data and presentation of the results. At the same time, accuracy and reliability have been substantially enhanced. However, most important is the ability to provide users with new and alternative products, which include two-dimensional and three-dimensional products, such as orthophotos and 3D models. The use of 3D models is becoming increasingly common nowadays in many aspects of everyday life (cinema, advertisements, games, museums, healthcare, etc.). Overall, the tangible and intangible digitisation of the world's cultural heritage is now possible.

Data Acquisition & Processing

Recording techniques are based on devices and sensors which perform the necessary measurements, either directly on the object or indirectly by recording energy reflected from the object. In the latter category, one can broadly distinguish between active and passive sensors. Active sensors send their own radiation to the object and record the reflectance, while passive ones rely on the radiation sent to the object from some other source. Usually, the latter are image-based sensors which record the visible light reflected from the objects of interest. Rapid technological progress has provided scientists with sophisticated instrumentation including calibrated high-resolution digital cameras, digital high-resolution video recorders, accurate angle and distance measuring devices, GNSS receivers, terrestrial laser scanners, 3D non-laser scanners for small artefacts, film scanners and printed document scanners. Moreover, instrumentation such as thermal and range cameras, material sampling devices and ultrasonic non-destructive inspecting instruments are also contributing to data acquisition. Terrestrial image-based surveying comprises all those methods, techniques and technologies that use images to extract metric and thematic information from the object in question. The main focus nowadays is on digital cameras and sensors, the contribution of the unmanned aerial vehicles (UAVs), remotely piloted aircraft systems (RPASs) or unmanned aerial systems (UASs), and also the useful role that image-assisted total station (IATS) technologies are playing in the recording, monitoring and documentation of cultural heritage (Figure 3).

Figure 3, A typical UAS carrying a DSLR camera.

Processing of all acquired multi-source data includes positioning calculations, processing of the digital images or image sequences and working with point clouds. For these actions, related software has been developed to cover all possible needs. The processing stage is supported by powerful computing units that are available today. Processing usually aims to store, archive, manage, visualise, present and publish the collected data and the information derived. In recent years, many research efforts have been directed towards multi-image matching techniques, thus complementing terrestrial laser scanning technology.

Common image-based 3D modelling of the current state of a monument requires data acquisition in the field. Surveying, photogrammetry and laser scanning techniques can be combined to produce a full and accurate 3D model of the object. Modern photogrammetry and computer vision techniques manage to create realistic and accurate 3D models of objects of almost any size and shape by combining robust algorithms and powerful computers. Multiple images depicting the object from different viewpoints are needed and the so-called structure from motion (SfM) and multi view stereo (MVS) procedures are implemented (Figure 4). However, these images do not necessarily have to be captured by calibrated cameras; compact or even smartphone cameras can also be used. A variety of recent studies examine the creation of 3D models of cultural heritage objects and sites with the use of SfM algorithms (Remondino et al. 2012). The lack of images or other surveying data, especially in cases of lost cultural heritage objects, has led to the use of random, unordered images acquired from the web (Figure 5). Some recent studies deal with the 4D (space-time) virtual reconstruction of cultural heritage objects using web-retrieved images (Stathopoulou et al. 2015).

Figure 4, Lost heritage retrieved from crowdsourced data. (RecoVR Mosul Exhibition, courtesy: Nichon Glerum)

This interrelation between heritage objects and their geographic location is extremely important nowadays and has bridged the gap between geoinformatics and monument preservation. A geographic information system (GIS) is the scientific tool with which monuments and related information can be connected to a place, and this has led to the evolution of monument information systems (MISs). However, the connection of intangible information to tangible cultural heritage is highly important and definitely required. Hence intangible cultural heritage can also be 3D digitised and may also be linked to location, while important attributes of both forms of cultural heritage are preserved and interrelated at the same time.

Alternative Products

Contemporary digital technologies have made alternative documentation products possible. Initially the conventional line drawings were enriched with orthophotos (Figure 5), carriers of rich qualitative and quantitative information. The interpretation of the necessary information can be carried out on these products by any interested experts at will. The virtual environment of computers has opened new horizons in terms of alternative products. Realistic 3D textured models (Figure 6) are common nowadays and can be used for visualisations, for virtual visits and for development of serious games (Kontogianni et al. 2016) which push cultural heritage documentation into the realm of 'edutainment'. Moreover, virtual restorations (Valanis et al. 2009) and virtual reconstructions can be used to help experts to reach the correct decisions after examining numerous alternative solutions in the virtual environment. Finally, augmented reality and virtual reality implementations help visitors to 'see' cultural heritage ruins in their original state, thus increasing their appeal, especially among younger generations.

Figure 5, Combination of traditional 2D line drawing and orthoimage (Georgopoulos et al. 2004).

Concluding Remarks

It has been shown that digital contemporary technologies can contribute decisively to the conservation of cultural heritage. The final products are 3D models and virtual restorations or reconstructions of monuments that either no longer exist today or are at risk. Consequently, digital technologies and interdisciplinary synergies are of utmost importance. Equally important are the discussions and suggestions of scientists who have studied the monuments from a historical and archaeological point of view, proving once again that such interventions are a multidisciplinary process.

On the other hand, virtual reconstructions, virtual restorations, monitoring and 3D models support many other disciplines involved in cultural heritage. They help architects and structural engineers in their work for monuments especially in cases of restoration, anastylosis, etc. Archaeologists and conservationists have a very good tool at their disposal for their studies. Many applications can be generated from a virtual reconstruction, such as virtual video tours of the monument for educational and other purposes for use by schools, museums and other organisations, for incorporation into a GIS for archaeological sites, for the design of virtual museums and for the creation of numerous applications for mobile devices (e.g. smartphones, tablets, etc.).

Figure 6, 3D model (Tryfona & Georgopoulos 2016).

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