APPLICATION OF DIGITAL PHOTOGRAMMETRY AND AUTOCAD TO SUPPORT OF HISTORICAL BUILDINGS

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Abstract: This paper describes how we could combine the two most available systems for the purpose of surveying and documenting the architectural heritage, historical buildings and monuments. The two systems are digital photogrammetry (applied in a close-range context) and CAD. The product of this integration is a 3-D GIS application. In this application, close-range photogrammetry is used for the acquisition of terrestrial photographs whereas the CAD system together with some in-house developed computer programmes are used for the manipulation of the captured spatial data. The economics of the proposed integrated system inevitably encourage the architectural organisations to use this type of mapping system for mapping activities. The user is able to perform the whole reconstruction of the 3-D objects without manual measurements. In this method of reconstruction, the redesign costs are less and, with more knowledge available, any required refurbishment is more accurate. The automatic data transfer of the photogrammetrically generated digital surface model of the CAD system gives a flexible 3-D geometric object description. For example, in the case of fire or other damage-taking place on cultural buildings, sometimes only small or partial examples of pattern detail remain. By combining photogrammetry and CAD, this detail can be recorded and repeated to reproduce the original design. Finally, this paper will present some potential applications of the proposed integrated system and present some case studies where photogrammetry is providing an important and successful tool to assist in the documentation, investigation and maintenance of cultural monuments.

Key-Words: Photogrammetry-Architectural-Archaeological-Historical-Cultural-CAD-GIS
1 Introduction
In surveying and documenting the architectural heritage of a region quick, accurate and not too expensive methods of image acquisition, analysis and representation have to be developed. For modern digital image processing methods to be applied, in the initial stages, it is necessary to build up an archive of terrestrial photogrammetric images for documenting the facades of the buildings. From this archive the corresponding orthophotos are generated. At the second stage, additional information is necessary to create a useful information system. This additional information is combined with the existing data archives to enable modelling of the cultural object. Using digital photogrammetry, the spatial model of photographed surfaces can be viewed at any time and accurate measurements made on the photos. Thus, the actual state can be preserved and reconstructed even if the original cultural object is destroyed.

Digital photogrammetry has matured to an extent that it can nowadays serve as a precise and reliable technique for non-contact 3-D measurements. Its ease and speed of data acquisition, inherent on-line and even real-time capabilities, high degree of automation and adaptability to varying requests have made it a possible measurement tool for a great number of different applications in science, art and industry. At both the conceptual and implementation levels digital photogrammetry permits properties of high precision and reliability to be merged with the dynamics of data acquisition and processing. Nevertheless, the potential accuracy versus the realised accuracy of such systems should be considered to be a topic of research in this field.

The practical application of digital photogrammetry supplies digital data, which can be used in CAD systems such as AutoCAD. In the case of fire or other damage, sometimes only small or partial examples of detail remain, but by combining photogrammetry and CAD this detail can be recorded and repeated to reproduce the original design. In this method of reconstruction, the sympathetic redesign costs are less and, with more knowledge available, the refurbishment more accurate.

2 General Aims and Objectives
The aim of this paper is to consider the enhancement of tools to give support to the documentation and conservation of 3-D objects using surface modelling and digital photogrammetry applied to cultural objects (e.g. statues, monuments, archaeological relics, etc.). In the surveying and documentation of historical buildings, monuments and excavations in the United Kingdom and Iran (both have an enormous number of these cultural objects) the problem of registering the architecture and the decorated walls of buildings is addressed.

Manual measurement and direct copying of pictures onto transparent foil have been the usual ways of doing this job, even today. But, this manual processing of terrestrial images is time consuming and frequently inaccurate. Nowadays surveying methods based on image data are used in many industrial metrology applications. But for surveying and documenting the cultural heritage, modern image acquisition and analysis techniques are rarely used [1]. The general aim of this research is the development of automated measurement routines that are adapted to the special needs of buildings and related to CAD databases, and in achieving this general aim it is expected that an assessment of the construction of an appropriate GIS (or even SIS - Spatial Information Systems, as the spatial extent of the information is more limited than in any typical GIS) and digital photogrammetry will have been executed [4].

CAD systems based on 3-D extracted features provide a first stage in the integration of photogrammetric knowledge with the interpretative process of evaluating the object and making decisions. The user is thus able to perform the whole reconstruction of the 3-D objects without manual measurements (apart from photo-control). The automatic data transfer of the photogrammetrically generated digital surface model to the CAD system gives a flexible 3-D geometric object description appropriate for eventual input to the GIS environment. The development of an appropriate architectural GIS is a subsidiary aim of this research. However, the detailed objectives of this research follows.

1. To obtain a very high precision of measurement from the architectural site using a proper camera
configuration. This approach to the acquisition of photographs has applications in recording cultural building and monuments. Then digitised co-ordinates of architectural features can be extracted using stereo digital photogrammetric techniques.

2. To input the digitised co-ordinates into a CAD model for further processing. Data structuring in a CAD system are not related to one another except by reference to a common co-ordinate system. That is, unlike GIS, topology is not recorded.

3. To render the walls of the CAD model by using digital orthophotography. All graphic elements that connect visually will connect digitally precisely and the intersections of all line and polygon data must be mathematically exact, in terms of their co-ordinates.

4. To implement and design a prototype architectural GIS environment by using the above CAD model and the modelling facilities of a 3-D drawing editor with a translator from the internal format into a GIS file format.

5. To augment the GIS with textual information and other data format on the architectural entities in the prototype.

6. To compare the proposed method for reconstruction of cultural building with the traditional approaches to measuring and achieving architectural information.

To obtain the above goals, it is essential to create an effective flow-line for the whole process from digitised data acquisition to the 3-D geometric object in a CAD system. CAD systems provide 3-D line models in their own DXF format with a potential for high accuracy. Digital images data can be acquired either with film-based cameras and then with scanning or with a digital camera directly. The result of the 3-D object description is passed to a CAD system (such as AutoCAD software, forming part of a GIS) for visualisation and further action for architectural and archaeological processing.

3 Materials and Equipment
The main materials for this task are the standard surveying tools, digital photogrammetry equipment and cameras. It is required to use an instrument like "Total Stations" as standard surveying equipment to obtain ground control points. Control points are required in photogrammetry to provide dimensional control for the photography and reference points to translate stereo photographs into measurements. In addition, a theodolite (one second) is used to obtain data from the control points. Those equipments can be considered for the use of applications involving the modelling of cultural monuments.

Digital photogrammetric equipment can be divided into two types; high performance workstations and personal computers designed for a particular application. Digital Photogrammetry Workstations (DPW) with the use of SOCET SET software from Helava Leica - a high performance workstation - is operated in this research. To take photographs over from the object, the Universal Surveying Camera UMK 10/1318 Zeiss Jena is used. This is a controlled metric camera with a picture format of 120mm x 166mm and uses a non-standard film width of 190mm. It has four fiducial marks located for photogrammetric purpose, middle bottom, middle top, middle left and middle right. The focal length of the used camera is 98.903 mm with a focus setting from ∞ to 1.4 m for long-range photogrammetry.

4 Data Acquisition and Processing
A part of Glasgow University Building (GUB) has been gathered to provide a basis to test and compare different digital techniques, software facilities and instruments in order to obtain geometric, topologic and thematic information of a building, methods for recording, retrieving and maintaining these data set. Practical handling of such a system and of the derived results in term of topology, consistency, accuracy and reliability must be considered in this work. The data set is adapted to be applied to all digital photogrammetric techniques for the reconstruction of monument, including 3-D building restitution, stereo photogrammetry, single image rectification, image mosaicing and CAD coverage.

The main purpose was to cover any detail of the object with at least two image rays to allow the restitution of the object from stereo
Two photographs were taken to give complete coverage and sufficient overlap between the stereopairs. These were positioned in a row of two shots forming a block of photography. At each station, the camera was set at its lowest position on the tripod, approximately 1.4 meters from the floor level. Fortunately, the photos, which repeat exposure needed, were a few and almost all photography was acceptable. The total photographic operation was completed in approximately an hour including the test exposures, setting up the control, photography processing, establishing the darkroom and finally disassembling all the equipment. The product of camera (film negatives) must be digitised (scanned) before more processing.

The photo control point coordinates are used for least squares adjustment of the model parameters. The residual errors in the adjustment will be analysed to determine the model fidelity. The locations of targetted and untargetted control points placed on the part of GUB are given in Figure 1. The control points were selected amongst the target points and natural (untargetted) points of the objects that are easily identifiable. The coordinates of the control points were determined by intersection measurements from, at least, two stations with a one second theodolite. The achieved accuracy can be assumed to be of millimetre in all three coordinates. It should be mentioned that the accuracy of the reconstruction is not the main purpose of this work. Table 1 gives the precise location and coordinates of control points with respect to the photograph.

<table>
<thead>
<tr>
<th>Point</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>27.178</td>
<td>12.260</td>
<td>100.926</td>
<td>Targetted</td>
</tr>
<tr>
<td>1002</td>
<td>19.777</td>
<td>14.289</td>
<td>100.95</td>
<td>Targetted</td>
</tr>
<tr>
<td>1003</td>
<td>12.611</td>
<td>14.269</td>
<td>100.936</td>
<td>Targetted</td>
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<tr>
<td>1014</td>
<td>25.165</td>
<td>14.362</td>
<td>105.82</td>
<td>Untargetted</td>
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<tr>
<td>1015</td>
<td>25.291</td>
<td>14.121</td>
<td>113.74</td>
<td>Untargetted</td>
</tr>
<tr>
<td>1016</td>
<td>16.715</td>
<td>14.505</td>
<td>105.17</td>
<td>Untargetted</td>
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</table>

The above control points are only appeared on a stereopair photograph obtained in the fieldwork. Initially, the chosen stereopair have been scanned and ready to model after processing with the Digital Photogrammetric Workstation.

Fig. 1, Shows the Location of Two Control Points on the Part of GUB

5 Orthophoto Generations
The first task where applying photogrammetry is to make orthophotos of given facades. Orthophotos can be obtained by a differential rectification of images. In this method, having information of 3-D models is needed. A simple projective transformation of a plane may be used where there is an assumption that a facade of building is plane. The errors built up by parts of the façade, which are not in this plane will be overcome by a part-wise rectification [3].

6 Mosaicing
For a building with too big facades, more than one single orthophoto is needed. In this case, the rectification for obtaining orthophotos must be done in several pieces. The results of these images need mosaicing for joining together. Mosaicing for a plane facade consists of two or more images rectified and joined together. Control points are used to conclude the coefficients for a projective transformation.

All digitised map/photo sheets must be edge matched, both visually and by coordinates, with all adjacent sheets. No edge match tolerance may be allowed. The layer assignments for adjoining features must be identical. All graphic elements that connect visually must exactly connect digitally. The intersections of all line and polygon data must
be mathematically exact. No overshoots, undershoots or offsets may be allowed. Lines that connect to polygons must intersect those polygons precisely. That is, the end point of the line must be connected to an intersection point of the polygon.

7 AutoCAD Environment
To create an urban information system, additional data are required. This additional information includes of alphanumerical and graphical data. Alphanumerical data consists of information about special objects such as the age of a building and its last restoration. Graphical data includes images of objects, orthophoto results, 3-D modelling representation etc. These data should be a standard application of a GIS, but acquisition, manipulating and representing of a 3-D graphical data is complicated. This information can be gained from another sources such as images, stereo analysis, generated orthophotos, maps and surveying. The additional data must be blended with the data archives. These combined data are required for obtaining an appropriate representation for cultural heritage. After creating a 3-D model, a simple representation of data can be obtained by using CAD software, which is able to combine the models with orthophotos by mapping the photos onto generated surfaces.

CAD system can be used to capture and translate data into a GIS format [2]. Successful translating of CAD system data to a GIS format requires planning and coordination in advance. CAD has presented an alternative to GIS in the fields of engineering, architecture and surveying. This was initiated in earnest in the early 1980s when improved PCs had introducing. There are many organisations using CAD systems instead of GIS techniques for mapping, although this situation is now changing rapidly in favour of GIS. Moreover, many other organisations that makes maps have a greater need for automated design and drafting functions than they do for spatial analysis. But, many organisations receive data from engineers and surveyors that will be added to their GIS files. Examples are subdivision plats, and as-built road and utility plans.

8 Integration of Digital Photogrammetry, GIS and CAD
GIS and related technology will help greatly in the management and analysis of these large volumes of data, allowing for better understanding of terrestrial processes and better documentation of monuments to maintain of cultural and historical objects. It makes possible an integration and combination of data captured throughout of digital photogrammetry and GIS. An integrated GIS and CAD with digital photogrammetry is shown together in Fig. 2.

![Figure 2. Schematic diagram of integration digital photogrammetry, GIS & CAD](image)

9 Conclusion
The surveying and documentation of cultural object is intended in this paper. This aim has been usually done, even today, by manually...
measurements and direct copying of pictures onto transparent sheet. Manual 3-D processing of terrestrial images is inaccurate, slow and it can only register relatively little information. In addition, it is a very time consuming task and requires the expertise of qualified personal. Therefore, the necessity to interpret, classify and quantitatively process terrestrial images and close-range photogrammetry.

This paper shows that how an ancient object can be documented without physical contact, either because the object is inaccessible or it is a fragile object. The photographic method of data acquisition is easy to take pictures without the architectural theory to draw, architectural materials and artefacts. It takes only half a minute per photo and therefore it is possible to take a lot of data a day. The paper also describes the components of a digital close-range photogrammetric system, in particular, the digital techniques associated with the calibration of the camera, control point target location and the least squares matching.

3-D geometric data for generation of geometric representations in CAD/GIS can be acquired by digital photogrammetry. The interface between digital image matching and CAD systems make it possible to transform the acquired digital surface model directly into an octree representation. The presented method can be applied in the field of archaeology and architect. The digital data captured by stereo photogrammetry can be used to create 3-D wire-frame models that would be used as a basis for producing the 3-D visualisation of the object. CAD system based on 3-D feature extraction routines provides a first step towards the integration of photogrammetric knowledge with the interpretative process of evaluating the object information and making design decision. The user is able to perform the whole reconstruction of the 3-D object without manual measurements. The automatic data transfer of the photogrammetrically generated digital surface model to the CAD system gives a flexible 3-D geometric object description to the GIS environment. The result can be transferred to AutoCAD using PhotoModeler Pro 4.0.

The major contributions of this investigation reported here include recommendations for the representation of spatial information, the appropriate architecture for a system-based tool, development of computational model for camera data capture. It is therefore important to examine the scale-ability and practical potential of this approach.

References: