OPERATIONAL EXPERIENCES OF DIGITAL PHOTOGRAMMETRIC SYSTEMS

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Commission II Working Group III

KEY WORDS: Digital, Experience, DEM/DTM Comparison, Parameters, Urban, Rural.

ABSTRACT:

The Institute of Engineering Surveying and Space Geodesy (IESSG) is working on a collaborative project with the British Geological Survey (BGS) and the National Remote Sensing Centre Limited (NRSC) Airphoto Group. During this project experience of using the Intergraph ImageStation and ERDAS OrthoMAX and SoftPlotter is being obtained. This paper discusses some of the more important issues of this experience before concentrating on the quality aspects concerning the automatic generation of Digital Elevation Models (DEMs) which are available from the systems. The effects of changing DEM parameter settings highlight the potential strengths and weaknesses of such automatic procedures.

1. INTRODUCTION

The latest developments in hardware and software technology have opened up a new area for photogrammetrists in the last few years. The advances in digital photogrammetry now mean that it is possible to view scanned aerial photography in stereo at high resolution and carry out interactive on-screen interpretation and digitization. Software technology has led to the ability to automatically identify control points, generate digital elevation models and produce orthophoto products, leading to a potential efficiency revolution in the photogrammetric workplace. Associated interest has been stimulated in areas outside of photogrammetry with the possible benefits of these digital products creating a new interest in aerial photography.

The success of digital systems will only be fulfilled if it can be seen that the financial outlay will be recompensed by an improvement in workflow, both in time and efficiency.

The Institute of Engineering Surveying and Space Geodesy (IESSG) is working on a collaborative project in digital photogrammetry with the British Geological Survey (BGS) and the National Remote Sensing Centre Ltd. (NRSC) Airphoto Group. The research involves the use of the Intergraph ImageStation at BGS and ERDAS Imagine OrthoMAX and SoftPlotter at NRSC. This paper will provide a highlight of the work undertaken so far and present experiences obtained whilst carrying out the research.

2. BACKGROUND

The three institutions involved in the project have differing backgrounds in photogrammetry, but have been brought together by the development of digital techniques. The IESSG is involved with the teaching of traditional photogrammetry alongside research into current fields, making use of its Leica SD2000 analytical plotter. Further analytical experience, including semi-automatic DEM generation, has taken place on a Zeiss P3 at NRSC. BGS have moved into the field of photogrammetry relatively recently with the acquisition of an Intergraph ImageStation. Their background in remote sensing helped identify digital photogrammetry as a potential aid to geological interpretation and geographical and environmental analysis. With respect to geological interpretation, their aim was to increase productivity, reduce costs and to provide mapping geologists with the opportunity to spend increased time on areas which are particularly problematic (Tragheim and Westhead, 1996). Fundamental to the interpretation and analysis is the use of Digital Elevation Models (DEMs) to aid the task directly, by producing orthophotos or, in combination with the orthophoto, perspective views. NRSC Airphoto Group are a more traditional mapping establishment who have made the step into digital photogrammetry in an attempt to increase productivity and establish new product areas. At present they are concerned with orthophoto products, of which DEM acquisition is fundamental.

Consideration of the interests of BGS and NRSC, coupled with early trials on the instrumentation, indicated the importance of DEMs, and more particularly their accuracy. The potential of digital systems is clearly associated with their ability to perform traditional photogrammetric tasks automatically. This paper aims to present some experiences of using two digital photogrammetric systems.

3. EARLY EXPERIENCES

Prior to undertaking the specific research project, preliminary training periods were undertaken on both systems to gain general experience and to identify benefits and limitations.

The imagery used was a single stereopair of colour 1:25000 scale photographs of an area of Manchester, UK, scanned at a resolution of 1016 dpi (22.5 microns). The model contained a mix of topography, including undulating terrain, urban features, water bodies and forested areas. The scanned images were utilised on both the digital systems with the parent diapositives being set up in parallel on the Zeiss P3 analytical plotter. On the digital systems the basic photogrammetric procedures were performed, from basic 'setting-up' of the imagery to digital terrain modelling and orthoimage generation.

With respect to the orientation procedures, all three systems (the two digital and the one analytical) produced comparable results. It must be said that the control points used were coordinated terrain features, clearly visible on both images of the stereomodel. Experience has now shown that problems occur when using imagery where control points only occur on one of the two images i.e. mono pug marked control. This makes it difficult to perform relative orientation monocularly, particularly with the ERDAS system, where only mono measurement is possible. With the ERDAS system, control points, used in the triangulation, must be identifiable on both images. With the ImageStation it is possible to perform the procedure in either mono or stereo. The procedure is quicker and easier in mono rather than in stereo.

Investigation from just visual inspection (through stereosuperimposition of the DEM on the stereomodel) identified that the automatic DEM generations were tremendously variant with respect to the viewed stereomodel. The consistency of the results varied according to the terrain being viewed/analysed, with the greatest consistency appearing to be achieved over rural areas, compared with urban environments.

Different parameter settings varied the standard of DEM produced drastically. Notable problem areas included areas of homogenous texture, shadows, dark slopes and water features. Urban environments proved particularly difficult to model, whether attempting to obtain just ground heights or just roof heights. This did however improve with the generation of grids with minimal spacing. This lead to processing times being increased, but individual buildings were modelled reasonably well, rather than possibly being completely missed, which occurred with previous spacings. It was concluded that the photo scale of 1:25000 was too small to allow reasonable modelling of the urban features. Clearly some form of statistical measure is required to analyse the DEMs produced, rather than only visually checking them against the stereomodel.

With the use of digital images, the photogrammetrist is forced into recognising the features which will affect the accuracies of the output products. The geometric and radiometric characteristics of the image must be equivalent to those of the traditional hardcopy photography. Output may be affected by such things as scanning resolution, whether the imagery is colour or monochrome, image compression, image resampling or various other filtering techniques which are now available with the movement into image processing.

The image file sizes involved are large. A colour image (whole photograph) scanned at 10 microns occupies in the order of 1.7 Gbytes whereas one scanned at 20 microns requires approximately 432 Mbytes. This issue is obviously significant when large projects are encountered. Experiences with back-up procedures have indicated errors with tapes and significant variability in the time taken to back-off or restore data, especially over busy networks.

4. CURRENT RESEARCH

4.1 Input Data

Continued experimentation is focused on the accuracy of the automatic DEM. Two new stereomodels have been selected with larger scales than previously used and with a wide range of topographic characteristics. It is important to analyse the merits and limitations of these algorithms with respect to a diverse collection of physical phenomena. The imagery includes a pair of black and white photographs at 1:3000 scale containing a mixture of residential and industrial features which is used for analysis of results in an urban area. The second pair of images are from colour 1:10000 scale. These are used for parallel testing within a rural environment. The terrain encountered has substantial topographical variations with sudden changes of slope, areas of homogenous colour/texture and a scattering of rural buildings.

Both sets of imagery were initially scanned at 12.5 micron resolution, but problems occurred with the use of mono control, as previously described. For consistency, both sets of imagery were pugged in stereo and rescanned. The black and white imagery being scanned at 10 micron resolution and the colour imagery being scanned at 20 micron resolution. This was performed on NRSC's recently purchased XLVision OrthoVision 950r digital scanner. This produced file sizes for each image of 576 Mb for the black and white imagery and 432 Mb for the colour imagery. Clearly, the storage required for only two images is large. If a number of models are utilised in a project then careful planning is required. A feature of future work will be the use of a run of overlapping imagery to introduce the testing of DEM consistency over a number of models.

4.2 Parameter Variations

With both digital systems there are a large number of variable parameters, for which the user must select a value prior to DEM generation. It is important for system users, whether they be trained photogrammetrists or scientists grasping the benefits of this new technology, to appreciate the tremendous variations in output available due to altering these parameters. This 'black-box' technology must be treated with caution before acclaiming the benefits of the output.

With OrthoMAX and SoftPlotter there are 16 and 17 variable parameters respectively, most of which accept a range of values. With the ImageStation, the automatic generation software is known as MATCH-T, which itself has 28 variable parameters.

With these numbers of parameters the possible variations are almost endless, so any structured testing of their effects must be focused, methodical and extensive. Besides the large number, it is difficult to identify from their title or from the manual exactly their meaning and effect, even with knowledge of image matching techniques. The two techniques follow slightly different methods, the explanations of which are beyond the scope of this paper. For suitable information on various correlation techniques the reader is referred to Lemmens (1988) and Krzystek (1991).

5. DEM ANALYSIS

The method adopted to analyse the quality of the DEMs involved the comparison of the automatic DEM with respect to the current production procedure i.e. semi-automatic generation on an analytical plotter. The coincidence between the automatic and semi-automatic generations is seen as the initial test of precision and the specific use of the DEM as the definition of the required accuracy. Differences in DEMs produced with changes in the parameter settings were investigated. From these, height anomalies were obtained at each node of the grid which are then statistically analysed.

6. RESULTS

Work is still being undertaken on DEM quality analysis, but the following results show some of the work to date. The results are split into two sections which reflect the instrument used. Section 6.1 is concerned with the ERDAS experimentation and Section 6.2 focuses on the ImageStation results. Each of these sections is further split into sub-sections reflecting the topography of the imagery: rural and urban. The results highlight the variations obtainable by altering individual parameters. The results presented are only part of an extensive program of investigation and have been chosen to give an insight into the potential differences which can occur rather than to achieve the optimal quality of result.

6.1 ERDAS

6.1.1 Rural

The nature of the imagery was such that the DEMs produced were slightly larger in size than what was required. This was due to the stereopair not being oriented to north. Effectively the software creates a best fit northerly oriented boundary around the actual defined grid boundary and generates points to this secondary boundary. The DEMs thus generated and used in the comparisons contain points which were unrequested. These points may have an effect on the statistics presented, but continuing research will ascertain this effect. This point clearly highlights the fact that what is requested is not always provided.

The first option the user is prompted for when starting a DEM is the choice for the **Source** of the imagery. It may appear to be quite unimportant, but results suggest otherwise. There are two options; **Block** or **Stereopair**. Even with only one pair of images, both options are available and they produce considerably different results, as shown in Figure 1. There are a large number of points, 8.8%, with ± 2m difference. It is clear that this seemingly insignificant parameter does make considerable difference to the resultant DEM. The manual explanations of the effect of these options is unclear.

With colour imagery there is the choice of which colour band to use to perform the correlation. Generations with each band were compared with each other. Figures 2 and 3 show some of the statistics.

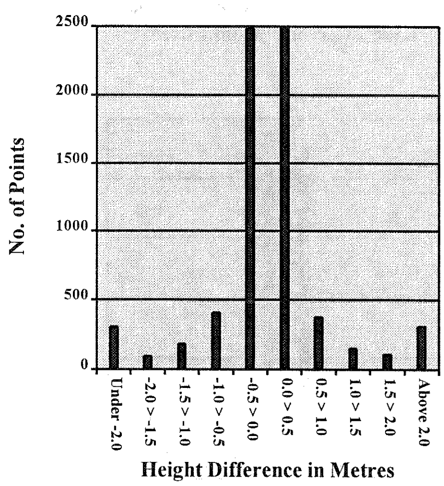


Fig.1 Histogram of Height Differences Stereopair - Block (Rural)

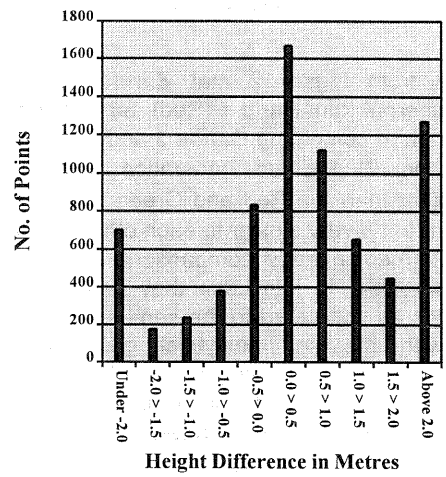


Fig. 2 Histogram of Height Differences Band 3 (Blue) - Band 1 (Red)

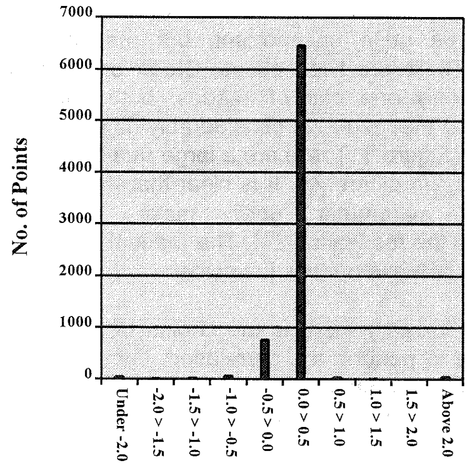


Fig. 3 Histogram of Height Differences Band 2 (Green) - Band 1 (Red)

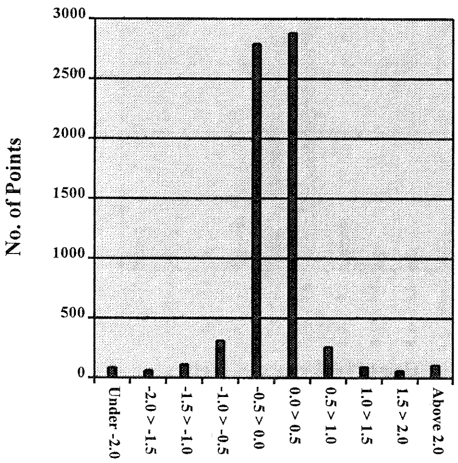


Fig. 4 Histogram of Height Differences Stereopair - Block (Urban)

It is obvious from Figure 2 that **Band 3** (Blue) is significantly different from **Band 1** (Red). Similar statistics are produced when comparing **Bands 3** and **2** (Green). In both cases the Blue Band generation was formed noticeably higher than the Red and Green. **Band 1** and **Band 2** appear to be very similar to each other (Figure 3). This was confirmed in early comparisons with a semi-analytical generation. In this case they both displayed similar statistics as compared to the semi-analytical grid. Comparing with the semi-analytical grid, the Blue generation is significantly above, noticeably worse than the Red and Green. Continued testing will produce results without the influence of these unwanted DEM points and will attempt to ascertain in which terrain characteristics each band performs the best.

6.1.2 Urban

With the urban imagery, two situations will be presented here. Firstly, the **Block/Stereopair** problem is tackled again and secondly **Minimum and Maximum Template Sizes** are described.

With the **Block** and **Stereopair** comparison the statistics are perhaps more representative than the corresponding comparison with the rural imagery, since all the points generated were within the predefined boundary and were all relevant to the comparison. The magnitude of height differences is illustrated in Figure 4.

In this case 2.9% lay outwith ± 2m of each other, but it must be remembered that this imagery was at a scale of 1:3000 and should therefore be within a smaller tolerance than the rural 1:10000 imagery. Approximately 8% of points are outside ± 1m, which is a more suitable level to consider. This is a significant difference when considering the parameter.

Minimum and Maximum Template Sizes refer to the dimensions of the correlation template, which is square in shape. For each point to be correlated, the algorithm starts the calculation with the **Minimum Template Size**. If the correlation is unsuccessful, the template size is increased. Further failures mean that the size is increased up to the **Maximum Template Size**. If this to proves unsuccessful, the height of the point in question is interpolated from neighbouring points.

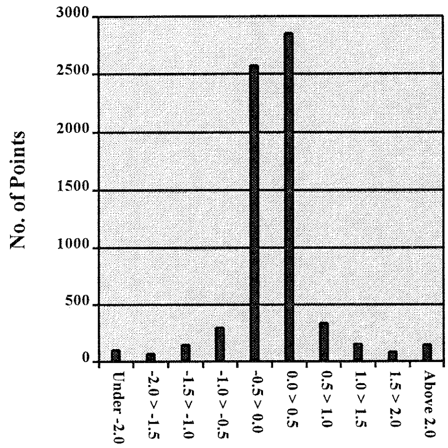
Figure 5 shows the comparison between the default settings and the next setting up i.e. **Minimum and Maximum Template Size** of 7 and 9 compared with 7 and 11. This appears to be quite a small parameter change, considering the limits are 5 and 20 respectively, but it does have a considerable effect. 10.5% of points lie outside ± 1m. of the other surface.

6.2 ImageStation

6.2.1 Rural

Similar to the ERDAS approach, the MATCH-T correlation may be performed on any one of the three bands of colour imagery. Comparisons between all three of the generations provided similar conclusions to the corresponding ERDAS comparisons. Selected statistics are shown in Figures 6 and 7. Again, **Red** and **Green** are very similar and **Blue** is significantly poorer - predominantly above **Red** and **Green**.

Within ImageStation MATCH-T the software has been designed to make the operator's task of parameter selection much more simplistic. Here, the operator is required to select a **Terrain Type**, which best describes the terrain present in the area to be modelled. The options available are **Flat**, **Hilly** or **Mountainous**. On selection of one of these three, two parameters are influenced by the decision, namely **Parallax Bound** and **Epipolar Line Distance**. These govern how much above and below the predicted position of the point the algorithm will search and along how many of the epipolar lines of the stereo image the algorithm will operate.



Height Difference in Metres

Fig. 5 Histogram of Height Differences Min/Max Template Sizes 7 and 11 - 7 and 9

These are particularly dependent on the terrain in the imagery, with an increase in **Parallax Bound** and a decrease in **Epipolar Line Distance** required with an increase in terrain diversity. This effectively increases the search area of the algorithm.

Comparing results from the three against each other, **Flat** and **Mountainous** show the greatest differences, **Hilly** and **Mountainous** are closely related and **Flat** and **Hilly** lie in between. With the nature of the terrain in the imagery being quite varied and undulating, it was expected that the three generations would be markedly different if compared against a benchmark surface. Comparisons against the semi-analytical generation show remarkably similar statistics, with all three obtaining approximately 64% of points within ± 1m of the semi-analytical attempt.

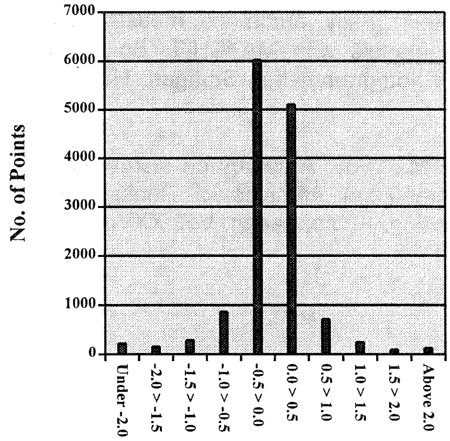
6.2.2 Urban

Due to problems with the loading of the urban imagery, testing has been limited on the ImageStation and no results had been obtained at the time of submission of this paper.

7. CONCLUSIONS

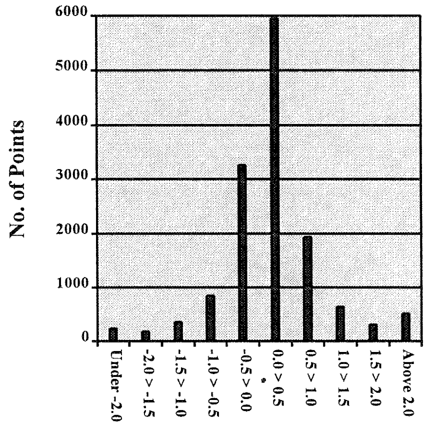
Clearly there is a large number of possible variations in the accuracy of the automatic DEM produced when we consider there are in the order of 16 and 28 parameters in the two systems. As has been shown in this paper, even what appears to be quite a small parameter change can have a significant effect. It must be appreciated by users from all backgrounds that the variations in results are significant and that resultant DEMs may in fact be significantly incorrect.

Investigation is continuing into the points which have been raised in this paper, including comparisons with a benchmark surface, integrity of results, specific successful/unsuccessful terrain characteristics for certain parameters and the effects achieved by altering other parameters. Parallel to these investigations will be research into the effects of scanning resolution, compression techniques and resampling of imagery scanned at differing resolutions.



Height Difference in Metres

Fig. 6 Histogram of Height Differences Red - Green



Height Difference in Metres

Fig. 7 Histogram of Height Differences Blue - Red

8. ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the British Geological Survey (BGS), in particular Dr. D. Greenbaum and Dr. D. Tragheim, the National Remote Sensing Centre (NRSC) Airphoto Group, in particular Mr. M. Holt, and the Natural Environmental Research Council (NERC). The views expressed in this paper are those of the authors which are not necessarily those of BGS, NRSC or NERC.

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