Environmental Analysis through integration of Geographical Information and Machine Vision systems

by

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Chapter 7

Concluding Summary and Future Work

In this chapter the contribution made by the thesis will first be summarised. After this, the limitations of the work in Chapters 2–6 will be discussed and suggestions for future work on the subject of each Chapter will be made. Finally a signal flow diagram for the overall system will be derived and discussed.

7.1 Contribution

General

1. A wide-ranging review of literature from many different research fields has been conducted. The background and historical development of all the technologies involved in the change detection system have been presented clearly and coherently in context with each other. This is particularly important for this system because parts of it are relevant to diverse fields of research; to be able to promote the system it is important to have a clear understanding of how it is regarded from different fields.

2. The data processing requirements for the change detection system have been analysed in detail. The required system structure has been identified and a signal-flow diagram derived for the overall system. This is important as the system is too extensive to complete as part of this work, but the signal flow diagram may be used as a starting point to enable the work to be continued by another researcher if necessary.

Specific

1. A convenient automated MATLAB-based implementation of a reliable distortion measurement algorithm has been implemented. This is an improvement on the existing documented method (Helferty et al., 2001), which did not have so much automation. Having a MATLAB implementation is important for convenient sharing of the work with other researchers.

2. A statistical analysis of the consistency of the sources of elevation data available from the Ordnance Survey of Northern Ireland has revealed substantial problems with the quality of the data. Both the traditional height above mean sea level data and the recent GPS-compatible geoid model exhibited problems that have not previously been reported. This is important to note as it may affect assumptions many GIS users in Northern Ireland make about the quality of the data they use.

3. Datum transformation capabilities have been added to the GRASS GIS. This is very important because it enables use of data sources referenced to different Earth ellipsoids. The most common application is to use GPS data and free data from American government agencies alongside legacy data in a conventional localised country datum. Much positive feedback has been received from other users and developers of GRASS regarding the usefulness of this improvement.

4. GIS 3-D visualisation software has been modified and extended to allow for modelling the characteristics of a real camera when creating a 3-D view. The software has then been further extended to enable inverse perspective transformations of an image to be performed, by using an extension to the 3-D reverse look-up capabilities of the visualisation software. This is important because it makes it very easy to use existing ground elevation and vector feature data in the GIS database and fuse it with the image content.

5. An improved inverse distance weighting interpolation algorithm has been designed and added to the GRASS GIS. This is an important replacement for the old algorithm which was extremely inefficient for large numbers of sites.

Many smaller contributions have also been made in terms of minor and incremental improvements to existing techniques. These have been referenced in the text where they are presented.

7.2 Limitations and Future Work

In this section the limitations of the work presented in each chapter will be discussed and suggestions for the future direction of the work made.

7.2.1 Chapter 2

1. The loss in image quality from DV compression was discussed but not measured. It would be useful to quantify any information loss by capturing images of a known test pattern.

2. Primarily for efficiency and to avoid at least one initial processing stage, it would be useful to investigate the possibility of performing image processing and feature detection on DV images in their native rectangular pixel format (taking proper account of their geometry) rather than first converting them to square pixel format. The processing could be done with a GIS that accomodated rectangular pixels or suitable image processing software could be found and used.

   This issue will become more important if using a camera with a higher resolution CCD array in future. In that case blurring caused by pixel re-sampling will become an important factor to consider.

3. It would be useful to quantitatively evaluate how much effect the correction of lens distortion actually has on position alignment and image matching with projected GIS features. E.g. if speed or processing power was limited it might be possible to use the images from some cameras in their uncorrected state.

4. Related to the above point, the distortion characteristics should be systematically compared for different cameras. This was not possible at the time the original work was being carried out but now there are four cameras available.

5. The suggestions for improvement to the re-sampling algorithms used in bi-linear interpolation (Section 2.4.4) should be tested.

7.2.2 Chapter 3

In this chapter it was discussed how, since there was no way of knowing which (if any) of the elevation data sources was most accurate, no measure of the absolute accuracy of the various sources could be made. This was therefore worked around by measuring the *consistency* of the data sources with respect to each other. An attempt was made to define the OSGM02 geoid model (based on the consistent GPS system) as a reference datum, but the large offset between it and spot heights measured against MSL Belfast (with which it was theoretically supposed to coincide) cast doubt on its reliability for this purpose.

In practice however any definitive vertical datum is likely to be based on the GPS system as this is fixed and consistent relative to the centre of the Earth. The techniques and methodologies needed to do this in a verifiable and fool-proof way should be a subject of further research.

Also in this chapter, the limitations of GRASS versions 5.0–5.4 with regard to vector data import were discussed. GRASS 5.7 with its much improved vector processing capabilities is now becoming a mature and stable piece of software, and a worthwhile subject of further research would be to represent the Ordnance Survey data in the 5.7 vector model. Methodologies for making use of the 3-D vector and visualisation support could be developed as part of this work.

7.2.3 Chapter 4

1. Some problems were noted with the inverse-distance weighted interpolation for flat scenes with sparse information. Alternative interpolation algorithms should be investigated to find an optimal interpolation algorithm that applies to all scenes.

2. It was noted that the demonstration of vector GIS data projected into the 2-D image frame and overlaid on an image might be of interest to geographers in validating simulation results. This could be an interesting research area and it may be worth developing software to make it easy to do this, e.g. with a graphical user interface and an easy way of calibrating a camera for focal length and lens distortion.

3. Inefficient MATLAB scripts used in the inverse perspective transformation were discussed. There is scope for further automation, scripting and batch processing of a sequence of video images.

4. The design of a database of images for change detection and view creation is mentioned—this could be developed further.

7.2.4 Chapter 5

The YPR sensor that was tested exhibited poor performance and an alternative to it should be found. To fully implement the proposed position determination system also requires further development of the MATLAB implementation of modified hough transform.

Even when the MHT technique is fully developed, however, it will not be of use in automated systems until it can be combined with reliable image processing methods for identifying features in ground-level images. The results of Chapter 6 indicate that this may be some way off.

7.2.5 Chapter 6

It was noted that the road visiblity (line-of-sight) GIS analysis did not take into account the direction the car would be facing and assumed omni-directional coverage. To

complete the evaluation of the technique it is necessary to perform another analysis where the camera is restricted to pointing along the direction of the road.

Further analysis of the test results on the illumination calibration object is possible and may reveal further useful data.

The 3-D vector capabilities in new GRASS version 5.7 have already been mentioned. There is scope for using these to help with image matching, particularly in urban areas where building facades could be represented as 3-D vector faces. The possibility exists for further and new work in this area, such as taking existing OSNI vector building data and converting it to 3-D vector format by adding a facade, using building height or surface texture information retrieved from image data.

Raster-based (using voxels) 3-D analysis is already available in GRASS and would also be an interesting area of research with respect to visualisation of change. The method would be to take the 3-D co-ordinates of all the pixels in changed area in the image and use these to define a voxelised area in 3-D space. Visualising the shape of a changed area in this way might facilitate human interpretation of the change.

7.3 Complete Structure of data and processing for future Change Detection

The diagram in Figure 7.1 illustrates the entire system that has been analysed and devloped component-by-component throughout this thesis. Datasets are shown as rectangles; processes as ellipsoids. Thick lines represent a flow of image data; thin lines represent non-image data.

Datasets and processes coloured green have been fully implemented in the work described in this thesis; those coloured orange have been partially completed, and those coloured pink remain as future work.

Almost all the data sources have already been discussed in detail throughout the thesis. However the diagram attempts to represent a possible plan for completion of the change detection system and to that end one additional data source, laser scanned data, has been included. A laser scanner may be mounted on a vehicle and data obtained from it used to augment image data. Tests have in fact been carried out with a 3-D laser scanning system as part of this work, but problems regarding inaccessibility of proprietary software (necessary to access the data) precluded its use in this thesis.

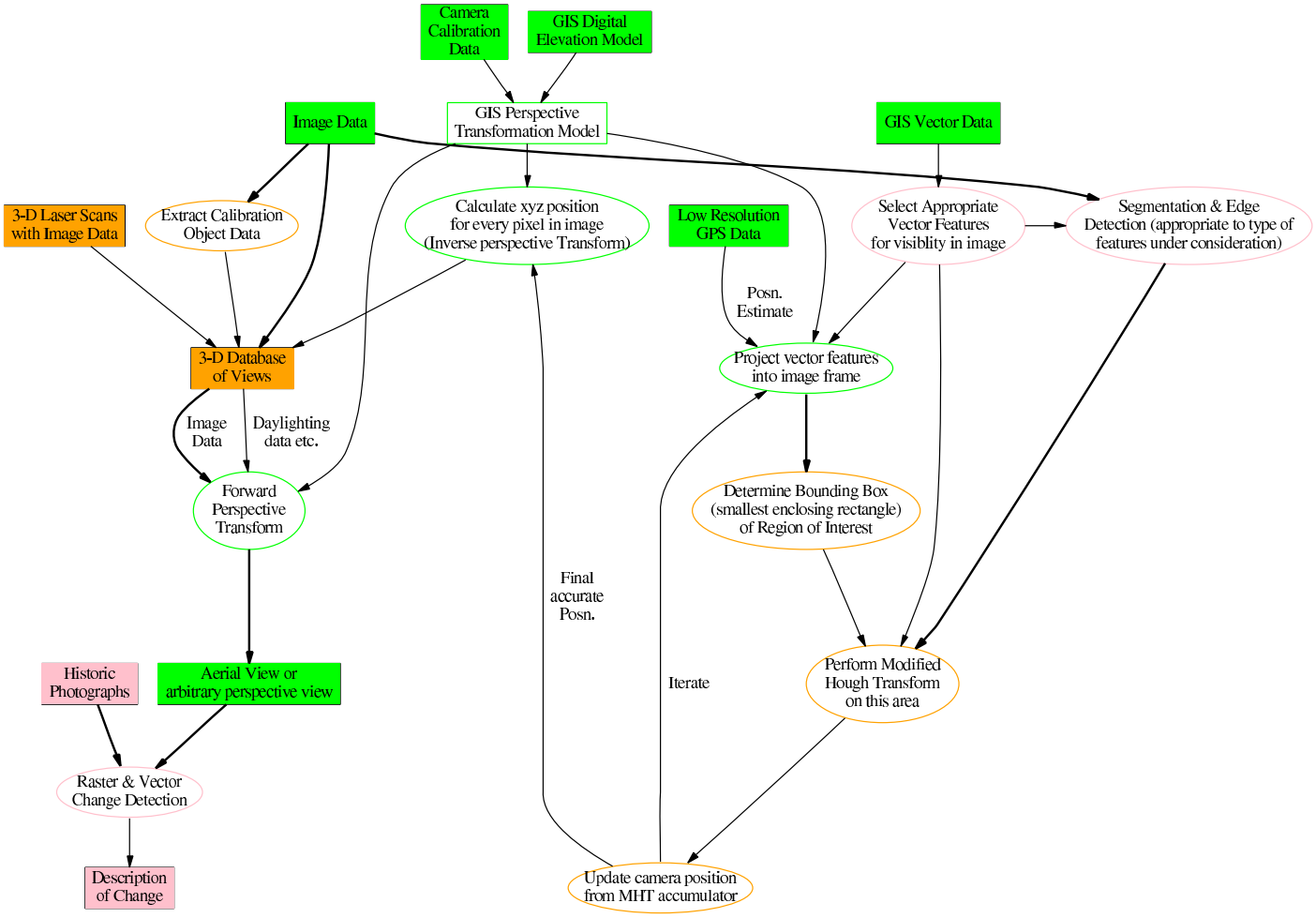

Figure 7.1: Signal flow diagram for Vision-based Environmental Analysis System (Green: completed areas of work, Orange: partially completed, Pink: only initial investigation peformed)