Automation of Photogrammetric Tasks
항공사진측량의 자동화

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Abstract

Automation of the mapping process is a major concern in the geomatics discipline as the role of geospatial information is becoming more important in the information society. Automation has been successful in some tasks of the mapping process, whereas it is faced with difficulties in other more complex tasks. Some of the automation technologies which have been applied to the production of maps are reviewed in later paragraphs.

要 旨

최근 정보화 사회로의 변신이 점차 가속되면서 지형공간정보의 역할이 중요시되고 있다. 이에 따라 항공사진측량에 의한 지도제작과정의 자동화에 대한 필요성이 많이 인식되고 있는 실정이다. 지도제작의 일부 과정은 자동화에는 많은 성과가 있는가 하면 복잡한 작업과정에서는 아직도 많은 발전의 여지가 있는 것이 현 실정이다. 본 글에서는 지도제작과정에 적용시킨 자동화기술에 대해서 고찰하였다.

1. Introduction

Before the introduction of computers, the production of a map was a very labour intensive task. One of the major difficulties involved in this process was the wide variety of activities involved. The production process was a sequence of tasks including surveying, aerial photography and photo processing, stereo compilation, cartographic design and editing.

It is important to understand the mapping process in the traditional environment and its inherent problems to be able to understand why automation has become an important issue in the mapping discipline.

With the many problems that were inherent in traditional map production, it is obvious that automation could benefit the process to a great degree.

In an ideal automated mapping system, it is possible to imagine that an unmanned robot aeroplane equipped with necessary sensors will be controlled from a base station and the acquired images with position data will be transmitted back to the base station in real time. Subsequently spatial objects will be extracted automatically from the received images, and these will populate the GIS database.

2. Automated Mapping System

An **automated mapping system** is, for the purpose of this paper, defined as a composition of subsystems which apply the concepts and the techniques described below. The system is composed of the image acquisition subsystem, positioning subsystem, image point referencing subsystem, object extraction subsystem and the visualisation subsystem.

In this paper, a practical level of automation is assumed where human interaction is still required at many stages.

2.1 Image acquisition subsystem

The image acquisition subsystem of the automated mapping system, involves a human operated platform, such as a fixed wing airplane or a helicopter. The imaging sensors are a key component of the imaging subsystem. Some examples of imaging sensors are CCD digital cameras, video cameras, linear array scanners, laser profiling scanners and multi-spectral scanners. Use Case diagram of this subsystem is shown in Figure 2.1.

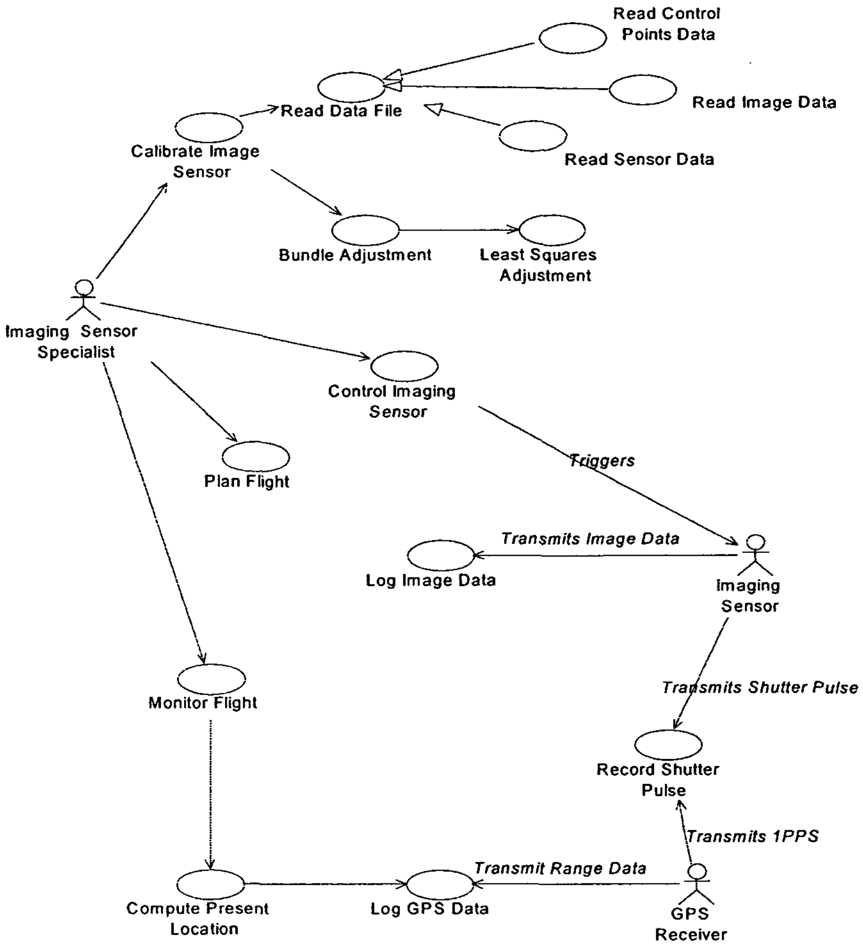

Figure 2.1 Use Case Diagram of Image Acquisition Subsystem

2.2 Positioning subsystem

In an automated system these imaging sensors (eg CCD cameras) are synchronized with the

positioning sensors to compute the attitude and the position at the instant of the image capture. Some of the most popular positioning sensors in use today are GPS (Global Positioning System) receivers and IMU (Inertial Measurement Units). The GPS receivers provide the positional coordinates of the exposure stations whereas the IMU provides the attitudes of the images at the instant of exposure. The observations from these sensors are synchronised and integrated through the Kalman filtering process. This process will compute the integrated result in an optimal sense [Schwarz, 1998][Schwarz et. al, 1989][Schwarz et. al, 1994][Skaloud, 1994].
Another role of the positioning sensor in an automated mapping system is the navigation of the platform vehicle. The real time capability of a differential GPS will make control and monitoring of the flight simple and this will result in the improved coordination of activities between the pilot and the photographer. Use Case diagram of this subsystem is shown in Figure 2.2.

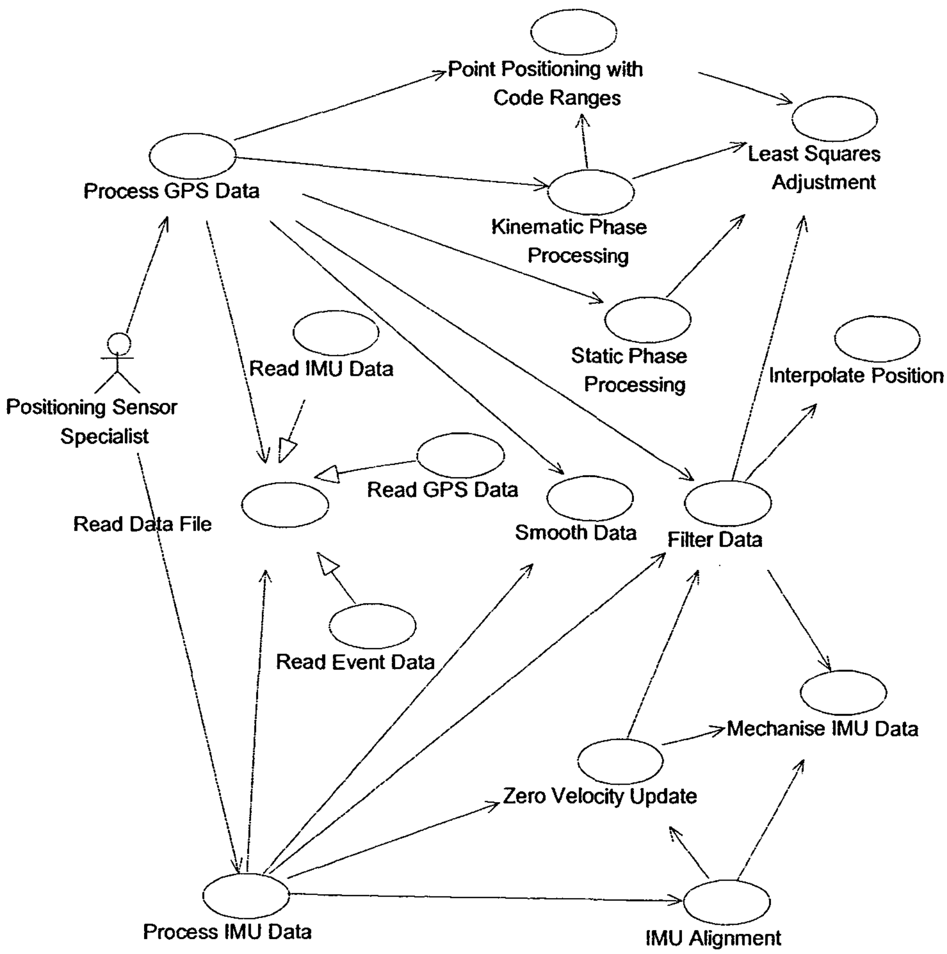

Figure 2.2 Use Case Diagram of Positioning Subsystem

2.3 Image Point Referencing subsystem (Triangulation subsystem)

In Geomatics the term triangulation appears in many contexts. In land surveying it is the term used for control extension and exploits the geometric properties of two-dimensional triangles

[Wolf et al., 1997 (pp. 249-274)]. In photogrammetry the term aerial triangulation is also a means for control extension, but exploits the projective geometry of the camera [Kraus et al., 1993 (pp. 247-295)]. In some digital photogrammetric systems the term is loosely used to describe relative and absolute orientation as well as aerial triangulation [GDE-Systems, 1997]. Use Case diagram of this subsystem is shown in Figure 2.3.

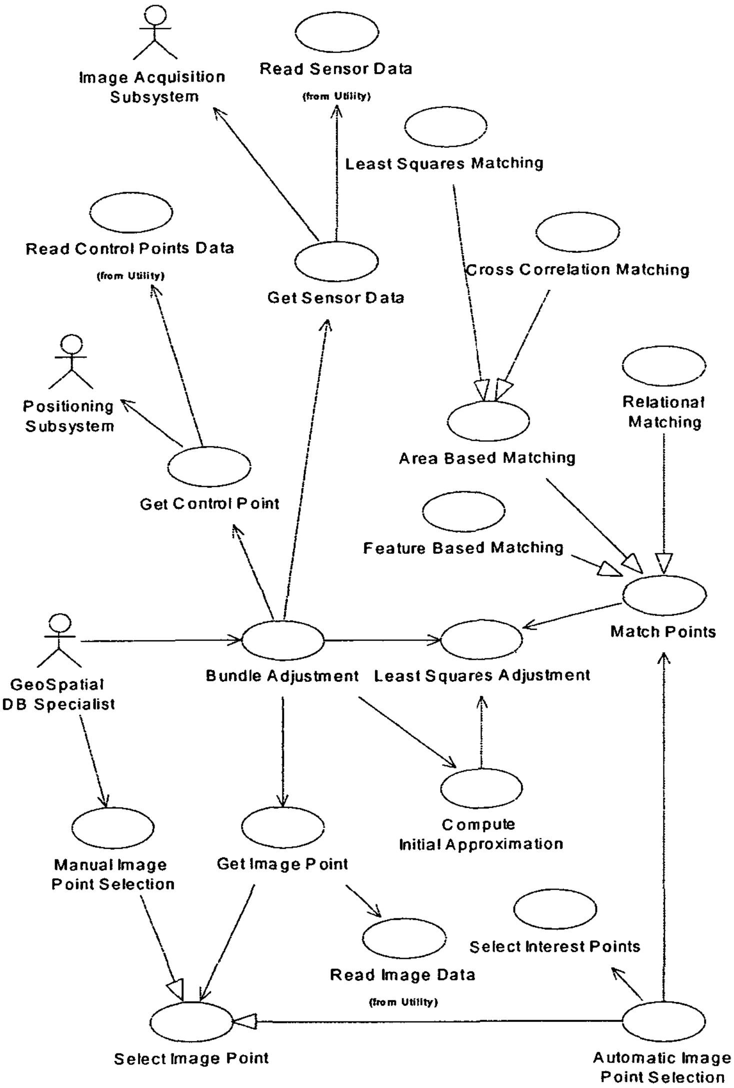

Figure 2.3 Use Case Diagram of Image Point Referencing Subsystem

However in this work, the term image point referencing has been selected to refer to the task of locating the ground position of any points seen on the image by using their observed image coordinates and the values obtained from the positional sensors.

In the image point referencing process of an automated mapping system, the perspective point coordinates and the attitudes are not computed indirectly, but are observed directly by the positioning subsystem.

Image matching techniques are used to automate the process of determining the coordinates of an image point. In the interior orientation process, they are used to determine the pixel coordinates of the fiducial points. In the aerial triangulation process image matching is used to measure the pixel coordinates of targeted ground control points. Image matching can also be used to compute the relative orientation of stereo pairs. In this process interest operators (a mask of functions, or kernel, used to process the radiometric values of pixels in a region of an image) are used to locate points of interest, such as road corner points, in one image. Then a matching technique is applied to locate the corresponding conjugate points from other photographs which include the same scene.

Image matching is especially appropriate for the generation of a digital terrain model from stereo aerial images. The manual task of creating a digital terrain model is very simplistic in nature but tedious and error prone, making the effort of automation relatively easy but producing much benefit as its result.

The automation of stereo compilation is still a challenge to many researchers in both the photogrammetric field and the computer vision field. Object recognition techniques are used by the photogrammetrist to capture the semantic information at a certain location and populate the GIS database, which is identical to the task of the human stereoplotter operator. The automation effort in this field involves research into image segmentation, feature extraction from images and grouping extracted features such as points and edges. Detection and interpretation of simple features such as road centrelines has been successful, but other spatial objects, buildings in particular, are still being researched [Roux et al., 1994][Gruen et al., 1996][Boichis et al., 1998][Haala et al., 1998].

2.4 Visualisation subsystem

Schroeder et al. [1998 (pp. 1-15)] define visualisation as ... the process of exploring, transforming, and viewing data as images (or other sensory forms) to gain understanding and insight into the data . . The concept of automation and the involvement of computer processing are inherent in this definition of visualisation. The activity of visualisation resembles closely the activity of a cartographer, except that a cartographer deals mainly with geospatial data.

The end product of a visualisation process in a mapping system might be a three dimensional perspective view of a landscape processed from the digital terrain model and a scanned aerial image of that area. The images of the mountains could also be marked with contour lines, streets could be labelled with street names and commercial buildings could be coloured red. In other words, the traditional cartographic process of symbolising information on paper maps is incorporated into the visualisation process as symbolising information on three dimensional image views.

3. Software Design of the Positioning Subsystem

The main role of the positioning subsystem is to tag each image with the attitude, or the rotations, of the images and the position of the perspective centre of the image at the instant of image capture. For a laser scanner sensor, the positioning subsystem will compute the attitude and the position of the sensor for each pulse. The attitude of the images is obtained by using the data from the IMU. The position of the perspective centre of the image sensor is obtained by using GPS receivers. Kalman filtering and smoothing of data are applied in kinematic phase processing and also in GPS/IMU data integration, in order to get the optimal estimates of the unknown parameters as well as to accommodate measurement updates from different sensors.

After the use cases of the automated system software components are identified each use case should be further investigated to produce sequence diagrams. An example is shown for Reading IMU data file in Figure 3.1.

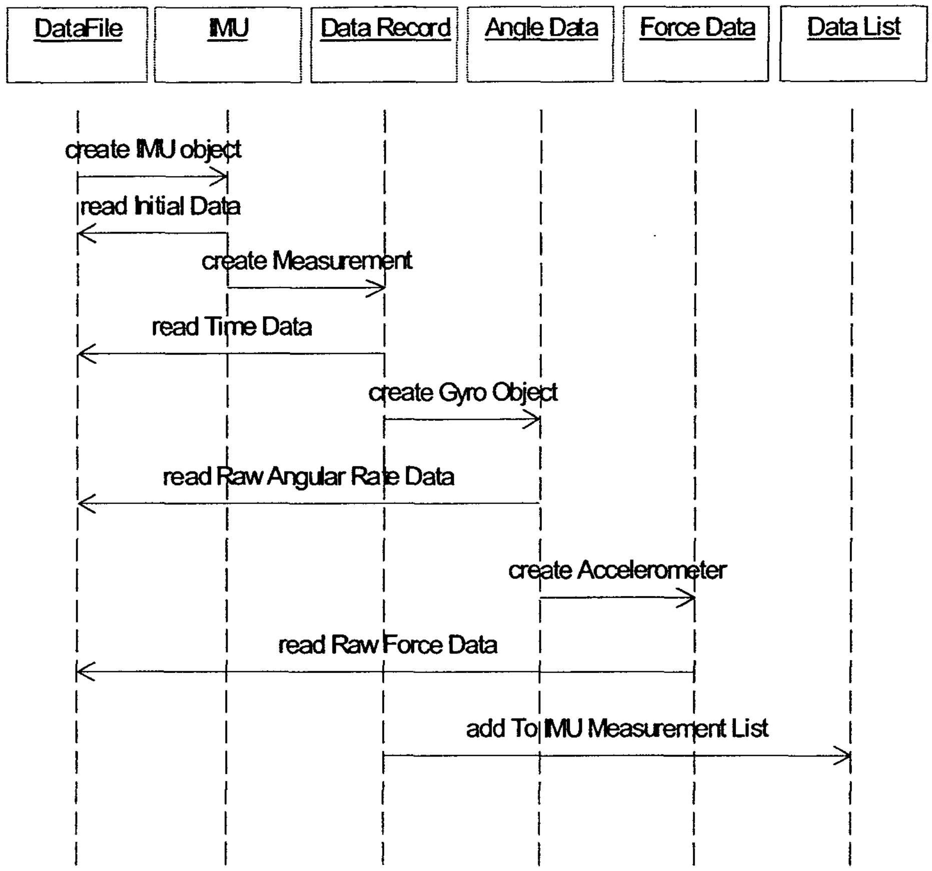

Figure 3.1 Sequence Diagram of Reading IMU Data File

The sequence diagrams are then used to identify and design classes which will be the core component in the software subsystems. An example is shown in Figure 3.2.

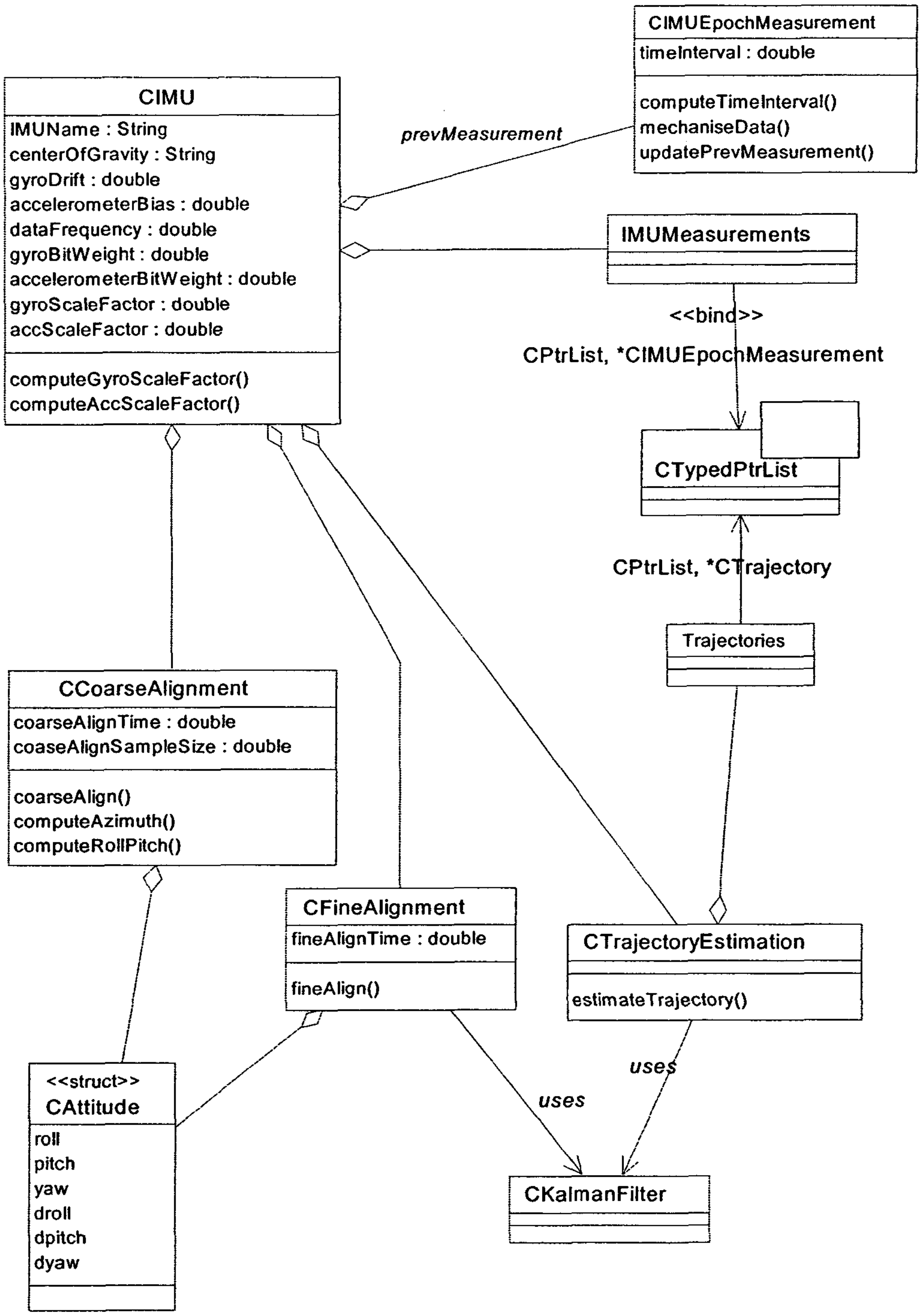

Figure. 3.2 Class Diagram of CIMU and related classes

4. Concluding Remarks

In this paper, an integrated approach was taken for the design of an automated mapping system. Past research by different sub-disciplines of the Geomatics discipline has focused only on specific tasks of the mapping processes. Photogrammetrists focused on camera calibration, aerial triangulation, and automatic object recognition from images. Surveyors and geodesists mainly carried out research in GPS and IMU data processing. Cartographers focused their activities on GIS modeling and visualisation. These dispersed efforts, although appropriate for gaining a deeper understanding of each sub-discipline, were not very effective in terms of software development for the whole mapping process. The integrated approach of this study was taken with an ultimate aim of producing a software design that automates the mapping process, from the initial data acquisition to the visualisation of geospatial data.

The objective of taking such an approach was to produce a software design prototype for the automated system which is:

- accurate in terms of meeting the user requirements;
- rapidly implementable; and,
- flexible in terms of extendibility, compatibility and reusability.

To this end, the conventional mapping process was analysed. An automated mapping system was defined and then structured into the Image Acquisition Subsystem, Positioning Subsystem, Image Point Referencing Subsystem and the Visualisation Subsystem.

The Object Oriented design methodology was applied to the design of these subsystems (except for the Visualisation Subsystem) and UML notations were utilised to produce examples of Use Case Diagrams, Sequence Diagrams and Class Diagrams. Just as architectural design blueprints reflect different aspects of a building, these software design drawings serve to explain to a domain expert, a software designer or a programmer the different aspects of the automated mapping software artifacts.

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