PHOTOGRAMMETRIC DATA ACQUISITION: THE INTELLIGENT APPROACH

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Abstract

The majority of techniques presently used to capture digital data at a photogrammetric acquisition station are based on simple data capture methods that restrict the operator's interaction with the captured data. This has led to the development of inexpensive workstations. However, in order to produce an acceptable "final plot" or in the most exacting case, a topologically correct topographic database, intricate batch processing and extensive interactive graphical editing procedures have had to be employed. This has proven to be a very expensive process. In an effort to reduce the amount of post-processing required, intelligent data capture and verification techniques can be used to create a cleaner dataset directly at the acquisition station. In the implementation of such a system there is a fine balance between complex data capture and efficiency. This strategy is gaining acceptance with the recent emergence of hardware with advantageous price/performance ratios. The method also has application in the direct revision of digital topographic databases. The paper describes the functionality to be made available in the next generation of intelligent photogrammetric acquisition stations and details the hardware and software components necessary to achieve this solution. Emphasis is placed on areas within the production process where efficiency is to be gained by using this approach.

Introduction

Photogrammetric data acquisition is the process of extraction and storage of information significant to the application using photogrammetric techniques. Any station used for photogrammetric data acquisition will be hereinafter referenced using the acronym PAS (Photogrammetric data Acquisition Station). This paper describes a global classification scheme applicable to all known PASs and outlines the most important characteristics of stations within the various categories. Upon this basis, a new approach to data acquisition is described which depends on the concept of intelligent data acquisition.

Intelligent data acquisition is defined herein as the technique whereby the process of interactive data acquisition is supplemented by system supervision, prediction and decision using contextual information. Within this paper this technique is addressed in the context of photogrammetric data acquisition.

Existing Approaches To Photogrammetric Data Acquisition

In this section a classification scheme is described for the various types of PAS currently in use. The primary delineation of categories is based on the form of storage employed for the data. There exists a natural hierarchy of methods of data storage which is correlated to the actual functionality achievable in the system. It should be noted that the references made in the three categories defined below are by no means exhaustive lists but merely examples of stations within the categories.

1. PASs where the acquired data is not permanently stored in digital form. Stations classified under this category may retain some digital data for the purposes of computer assistance during data acquisition but this is a strictly temporary storage. This category encompasses stations which produce as a final product a plot generated on some form of electronic table at the stereoplotter. The quality of plot achievable varies from a conventional manuscript with simple hardwired computer drawn symbols and lines, to a highly refined directly scribed fair drawing with user defined symbology and such features as closed polygons and parallel lines. Examples of stations classified in this category are:

   - Stereoplotter with semi-intelligent plotting table (eg Wild Aviotab TA [13], Zeiss DZ-7 [8])

   - Stereoplotter with computer assisted plotting (eg Wild Avioplot RAP [6])

   - Some analytical stereoplotters (Zeiss Planimap [2]).

2. PASs capable of storing unstructured digital data. The key discriminator in this category is that the station does not build a database in real time. The end product of such a station is generally still a plot of the captured data or could be a sequential file of coordinates describing that plot. Some examples of this category are :

   - Coordinate recording devices (eg Wild EK22, Kern MAPS 100 [7])

   - Simple table oriented data acquisition stations which collect sequential files (eg Wild RAP 2, Kern MAPS 200 [7])

   - Most analytical plotters (eg Kern DSR-1 [9], Wild Aviolyt BC1 [5],[10], Zeiss Planicomp)

   - Stations from most custom built systems (eg the Hunting Digital Mapping System [4])

3. PASs which store data in a database in real time during data acquisition. The end product of stations classified in this category may be one or more of the following :

   - A computer assisted plot directly produced at the workstation
   - A digital extract or plot from the unmodified database built at the stereoplotter workstation
   - A digital extract or plot from the enhanced and edited database

   Since the functionality of stations classified under this category is closely correlated to the architecture adopted in the design of the host system, a further natural sub-division is applied. These sub-categories are:

   (a Standalone stations with no hardware interconnection facilities. Stations under this category communicate data by means of some portable storage media. They are generally designed for a specific application and very few are actually commercially available. An example is the Kork system [11].

   (b PASs based on stations from existing general purpose interactive graphics systems. The architecture of the host systems to which stations in this sub-category belong is a centralised structure based on a single large mini-computer at the hub with strictly limited intelligence workstations. A generalised and essentially invariate functionality is likewise inherited from the host system while the databases generated are not topologically correct. In fact, the origins of the base systems are such that the databases show a marked graphics orientation. Two major examples exist :

      - WILDMAP station (developed jointly by Wild Heerbrugg AG and Synercom Technology Inc. based upon Synercom's INFORMAP interactive mapping and information management system [12])
      - The Intermap station based on the Intergraph Interact station [1] (created by Intergraph using the IGDS /DMRS database)

   (c Standalone PASs with networking and second generation database management. There are currently no stations in this category. This paper outlines an approach to data acquisition which falls within with this sub-category.

Application Characteristics Of Existing Methods

Based on the categories of PASs described in the previous section, the characteristics of stations in their particular application areas will be summarised in this section. For the purposes of this paper, the characteristics of interest are those where inadequacies or inefficiencies of existing stations lead to performance and/or quality degradation in the final product.

Interaction Permitted With The Dataset - Stations from categories 2 and 3 allow a certain amount of interaction with the dataset. The effectiveness of such interaction is generally dependent upon the efficiency and applicability of the data storage structure. In category 2 stations, the dataset access is sequential and restricted to the last few entries. Under category 3, stations may access the entire dataset but the performance inhibits the regular use of this feature. Some manifestations of inadequacies in the design and/or use of the data storage structure include : inefficient inter-model connections, non-existent model management (ie handling of datasets), more editing and/or batch processing and inability to trap gross blunders and to automatically trap identification errors.

Application Of Interactive Graphics - It is very rare for a station outside category 3 to support interactive graphics. Category 1 stations simply have nothing to offer in this field. The most capable raster graphics station in category 3 has no overlapping, moveable, or scaleable viewports and problems stemming from database design in the application of colours as graphic attributes of the data. Performance becomes an issue in the case of large datasets.

Performance Characteristics - The performance characteristics to be expected of a PAS are generally indicated by the category of station. Category 1 and to a lesser extent category 2 stations have relatively strictly defined performance barriers relating to hardware characteristics. Stations from category 3b have a performance very heavily correlated to the software efficiency and the station load upon the system. It is very easy to add a station to a system but the extra load implied manifests itself in a general degradation of the system performance. In category 3a and 3c stations the optimum solution is realised wherin the software efficiency and hardware performance have a realistic influence upon the general system performance.

Human Interface Factors - Photogrammetric operators the world over have been trained to understand and effectively operate a relatively complex and delicate instrument called a photogrammetric stereoplotter. The addition of a PAS should disturb this efficiency as little as possible. In this respect no current stations are optimal.

Correction And Editing - Category 3b stations here suffer from the disadvantage of already having some application range designed into the system while category 2 stations have no fast data access. The correction of photogrammetric data may thus consume more time and effort, since the editing facilities are not designed to allow efficient correction of characteristic photogrammetric acquisition errors. For this reason data correction in all except 3c type stations becomes a substantial load.

Batch Processes - Many category 2 and 3a stations lean very heavily on the approach of lessening the operator and computing load at data acquisition time by performing data checks and manipulation in a batch mode at a later stage. Some disadvantages of this technique are : no immediate verification of the system computed and modified data, no immediate check of gross errors in the data input to the process (which could lead to having to restart the entire batch job or even to having to reset the model) and inability to provide a completely correct result.

An Approach To Intelligent Data Acquisition

The primary objective of intelligent data acquisition is to create a clean dataset as efficiently and simply as possibly. This is achieved by : extending and customising the traditional functionality to compensate for inadequacies occuring in existing systems outlined in the previous section; providing a physical and logical human interface designed around the specific needs of the photogrammetric operator; implementing some traditional batch oriented processes in real time to allow context checks with the source material; including monitoring procedures to ensure that operator related errors are minimised; automation of some data entry procedures and increasing communication with other related phases of the digital mapping process. The goal is not necessarily to reduce the data acquisition time to an absolute minimum, but rather to reduce the entire mapping process to a minimum. Any extra effort implied during data acquisition can in most cases be carried out by intelligent software rather than the operator.

A more detailed explanation of some of the possibilities involved in each of these aspects is given below :-

Automatic Monitoring Of Data Entry -

- **Intersection detection**
  This facility monitors the spatial validity of data being entered by comparing it with previously entered data. If there is a conflict, such as a river penetrating a road, then the operator can be immediately warned or the data flagged for future investigation. These spatial relationships between features can be specified by the project manager and optionally invoked.
- **Feature mis-classification**
  Although an object oriented approach to the specification of feature classes combined with the use of a variety of graphical representations during verification reduces the

number of mis-classifications, a facility is still required to validate that the feature being digitised corresponds with the current feature class. A knowledge base of feature characteristics can be defined, which is continually refined by the system, and used to check the consistency of the data being entered. Clues such as dimensional extent [16], shape and relationships with other features can be used to infer that a feature is mis-classified. For example, railways do not have right angled bends and rivers do not have humpbacks. In an advanced implementation, the system could probably predict the correct classification.

- **Feature closure**
  When entering polygonal features, this facility optionally enforces feature closure prior to entering the next feature.

Automated Data Entry -

- **Duplication of feature clusters**
  Groups of features that occur often throughout the landscape can be digitised once, then repeatedly instanced whenever they reoccur. This can save substantial digitising times in large scale urban applications.
- **Attachment of descriptive attributes**
  Non-graphical attributes that are consistently associated with features can be automatically entered as descriptive or calculated information. For example, the area of a polygon; the path length of a line segment; contour elevations; spot height elevations; and descriptive text.
- **Accuracy hiererchy level**
  As features are acquired, the system can estimate and attach a level of accuracy based upon criteria such as source material, instrumentation, operator experience, feature class and mode of acquistion. This information can be used as weighting during data manipulation (eg where a house acquired by photogrammetric means is meaned with a version acquired by hand digitising on a tablet) and is invaluable when delivering data to foreign databases.

Prediction Of Operator Requirements -

- **Display following**
  To minimise the interruptions to the operator work sequence required to control the display of data during data acquisition, the display device(s) should support continuous roam of the working window (field of view) over the entire model dataset. The centre of the window should always correspond with the floating point mark during data entry. The performance of the database and graphical device should support this facility even with large datasets of around 200,000 entities. An overview of the dataset can be instantaneously available.
- **Dynamic Menu Structuring**
  The primary method of command entry should be through soft menu facilities. This method has traditionally been hindered by rigid hierarchical implementations.

Cross-tree links, derived from dynamic historical traces, can alleviate the problems of this technique by allowing fast access to and from the most frequently used menus.

- **Operator Default Values**
  Operator dependent defaults can be automatically set to facilitate the customising of the station for a specific operator.
- **Contextual help**
  This implementation of the help facility can continually track the context of the operator and when called, details the precise options available to the operator in the present situation.

Human Interface -

- Human interface hardware devices and supporting software can provide a simple, but highly efficient man / machine interface designed around the specific functionality of the workstation. The extensive and sometimes complex functionality suggested in this paper can hide behind an easily understood and consistent communication path called the human interface.
- Wherever possible, time consuming command entry through devices such as a keyboard should be minimised.
- Multi viewport techniques can allow the user to view several graphic displays or information sets simultaneously, thus reducing the time lost in context switching eg. the overview, working area and status information can be viewed simultaneously.
- The level of system "interference" can be tuned to the experience level of the operator allowing a greater efficiency.
- The function of particular input devices can be changed by the user to simulate other input devices allowing the human interface to be user customised.
- Menus, the main method of command entry, can appear in a standard dialogue area (on a seperate device) by default or can "pop up" (on the graphic screen) in the operator's current area of interest.
- Logging and journaling can be enabled and can form the basis for "macro" creation and recovery techniques.

Real Time Interaction With The Entire Dataset -

- **Connections to Any Feature in the Dataset**
  Since a topologically correct database is being created in real time, it is essential that the operator can "tie" the current feature to any other previously captured entity. This must take place in realtime, otherwise the efficiency of the operator will be jeopardised or the advantage of context lost.
- **Connections to adjacent datasets**
  The data surrounding the model can be made available to the operator to allow on-line connections. Depending on the policy of the organisation, the "tying" procedure may involve real time complex merging algorithms or just simple connects.

- **Correction and editing facilities**
  As described in the previous section, present interaction with the dataset is usually limited to just the current feature or a buffer containing the last n entities entered [14] . This limits corrections to only immediately recognised errors and does not allow the correction of errors that only become obvious when viewed in the context of subsequently digitised feature classes.
  It is generally agreed that the use of full interactive editing facilities on the PAS is inefficient. However, several organisations [17] prefer to edit at the PAS. Therefore, the choice of the level of editing to be offered at the PAS should be the prerogative of the user and is dependent on his environment.
  Even if the user only uses low level correction functions, the ability to interact with the entire dataset is essential to allow errors to be flagged. This reduces the error search times at the editing phase and enforces remedial action.
  A journaling facility can help to effectively recover from substantial blunders by "rolling" forward to a previous state.

Communication With Other Phases In The Mapping Process -

- **AT information directly available with the dataset**
  Project control and orientation information derived from AT can be directly integrated with the corresponding datasets for ease of information flow throughout the digital mapping system.
- **Data Flagging**
  During the data acquisition process, features may be flagged to indicate that they require further attention in later phases eg. editing and field verification. The reverse should also be possible ie. editing may isolate errors requiring verification at the stereoplotter.

It is believed that if the above functionality is integrated into a PAS then it will allow digital techniques to aid in the compilation process instead of just emulating present manual methods or in some cases hindering the operation.

Resources Essential In Realising Intelligent Data Aquisition

The functionality to be realised through the implementation of intelligent data aquisition at the PAS includes the following essential hardware and software resources:-

- High performance CPU in the supermicrocomputer range operating in a standalone environment.
- High performance, high resolution, intelligent graphic sub-system providing a true interactive graphics environment. The optimum solution can also include a device to inject the digital data into the stereoplotter optics to combine the photographic and graphic images.

- Spatial database
  An objective of intelligent acquisition is to create and maintain a topologically correct topographic database locally during data capture. The database can provide a mapping style interface between the user and the storage structure. Access to the database should not be primarily based upon artificial subdivisions of the dataset such as geometric type elements. It should be oriented towards how a user naturally sub-divides and classifies the components of a landscape. This object style of storage and access allows more efficient manipulation of the dataset during data capture and the subsequent editing phase. The realtime interaction with the dataset for contextual checks imposes a very high performance characteristic on the spatial database.

Conclusions

The paper has isolated flaws in the present implementation of digital data acquisition systems and has suggested techniques to improve the efficiency and acceptance of this process necessary to met the ever increasing demand for digital data. Hopefully these concepts will be implemented in the next generation of conventional PAS systems before the introduction of pure digital photogrammetry.

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