Automated Field Inventory for GIS Data Conversion

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Abstract

In data conversion projects for GIS much of the available mapping and textural data comes from sources that are inaccurate and out-of-date. When this is the case it is often necessary to perform a field inventory of existing facilities in order that the accuracy and currency of the data can be assured. This paper will discuss the implementation of an automated field inventory program for a major hydro-electric data conversion project in British Columbia. Specific issues that will be considered will be: system design, methodology, data integrity, quality control, digital data conversion, and migration to the host system.

Introduction

Automation is traditionally defined in terms of the reduction of human intervention in an industrial or manufacturing process. With the advent of the microprocessor and the adoption of digital systems in information management the definition of automation now extends to aspects of information collection, retrieval, and processing. The adoption of automated processes is driven by the need to increase production, lower costs, and improve quality. For an automating process to be successful it must, at minimum, meet one of these needs.

This discussion paper outlines the methods used by Underhill Geographic Systems Ltd. (UGSL) in automating the field data colection of attribute information for the field inventory of overhead electrical facility information. Facilities, in this context, are defined as the poles, conductors, transformers, switches, fuses and other items that collectively form the electrical infrastructure to be modelled in the Automated Mapping/Facilities Management(AM/FM) system, or Geographic Information System(GIS). The principles applied in this paper are applicable to virtually any AM/FM or GIS attribute data collection scheme.

Traditional Field Inventory Process

The field inventory process involves the creation of field inventory maps identifying the location and attributes of facilities relative to the features plotted from a digital cadastral land base. The creation of a digital cadastral land base generally precedes field inventory. Accuracy in the location of a facility is generally not considered as important as either the accuracy of its other attributes or its connectivity with other facilities. Sufficient positional accuracy in this situation is achievable via hand-plotting of the facilities onto the field inventory maps using the symbology convention employed in the final AM/FM or GIS mapping product.

A sequence of numbers referred to as "merge-keys" are used to identify facility/attribute combinations. A unique merge-key is assigned to each unique set of facility attributes. This procedure simplifies the field collection of attribute information as duplicated facility/attribute combinations need only be collected once (ie. the same merge-key can be used for several identical facilities). Merge-keys are annotated on the field inventory maps adjacent to their respective facilities along with the required attribute information.

Once completed, field inventory maps are subjected to a stringent quality control process to insure that proper circuit connectivity and phasing is maintained. Maps are indexed and filed away until needed for digitizing. The digitizing process is split up into three components. First, attribute data and merge-keys from the field inventory maps are key-entered into a database. The facilities mapped during field inventory are then digitized onto the existing land base with their merge-keys. Finally a digital merge process is used to associate the graphical facilities with their textural attributes.

The above process defines the traditional approach used in facility data conversion projects. The system is very efficient but it suffers from duplication of effort resulting from attribute data being both annotated on a field inventory map and key-entered. Additionally, the attribute data written on the field inventory maps tends to clutter the maps making it difficult for digitizers to interpret. Automation of the process through the use of hand-held field computers for attribute data collection, and digital data conversion and migration to the host GIS system, eliminates the duplication present in the manual process by allowing key-entry to be done in the field. Because the attribute data is stored in the field computer only the merge-key need be annotated on the field inventory map. This greatly increases the readability of the map.

For the implementation of an automated field inventory system to be successful, consideration must be given in the design of the system to insure its functionality. Once a field inventory project is underway it is very difficult to effectively manage major hardware and software changes. The ideal field inventory system must be designed to work flawlessly from its inception. This can be a daunting, if not impossible task, but with careful consideration of the hardware choices and software design it is achievable. Making the system fault tolerant by ensuring that data and program structures are flexible enough to allow for minor revisions, can help to achieve this goal. A properly designed system will maximize the achievable increases in production, reduction in costs, and improvements in quality.

System Design Considerations

At UGSL the approach taken in the implementation of an automated field inventory systems has evolved over a number of years through project related experience. A number of hardware and software requirements must be met before a system is put into operation. By careful consideration of these requirements a successful implementation can be assured. From previous experience in surveying and engineering field data collection systems the following requirements were deemed mandatory for the hydro-electric automated field inventory system:

Hardware Requirements

Portability. Field data collection units must be small enough to hand-carry and light enough not to contribute to operator fatigue.

Reliability. The units must be able to withstand rough handling, operate under environmental extremes of temperature and humidity, stand up to chemical solvents present in insect repellants, and have long battery life. As well, data integrity must be assured via backup systems for power to memory, shielding from radio frequency interference, and external backup capability.

Compatibility. The units must support standard data communications with office personal computers (PCs) for data validation, edit, and archive, preferably by direct connection through existing serial ports. Backup medium and format should be compatible with office PCs.

Capacity. The computers must have sufficient memory hold a fairly large program (this is due to the considerations outlined under software requriements) as well as maintain several map sheets of data.

The human interface (ie. the keyboard and screen) is also an important aspect of the hardware choice. Most hand-held systems are limited in at least one, if not both, of these areas. Small keyboards are difficult to use and can result in much frustration on the part of operator. Small screens limit the amount of data that can clearly be presented at one time. The ability to be able to read the screen in varying light conditions is required. Given the requirement for portability it is often difficult to avoid these limitations. Their impact must be assessed and system chosen which best suites the application.

Software Requirements

User Friendly. The software should be designed for use by people with little or no experience with computers. To facilitate this requirement the user interface must be consistent, intuitive, and unintimidating. Complex or convoluted coding schemes should be avoided. Data entry fields should be identified in a manner that is clear and concise. Menu systems incorporating definitions of "hot-keys" for short cuts are useful and provide the means for users to improve their data collection performance at their own pace.

Minimize User Effort. The software must allow data collection operations to be carried out in an efficient manner. Minimizing the number of keystrokes required for a given operation, elimination of repetitive or redundant entries, and user definable defaults for data fields and menus are some of the methods that can be used in this regard. Multiple menu layers or question/response cycles should be avoided. The software must allow data to be collected at speeds at least equivalent to manual collection methods.

Error Checking. Simple error trapping involves the automated checking of the validity of an entered attribute via an algorithm (ie. checking that data entered in a numeric field is in fact numeric) or a table look-up (ie. a particular attribute may have a known set of values, which can be used to automatically screen data in the field). More sophisticated checking can be employed when the validity of particular combinations of attributes is known. The best method of error checking results when the user must select an attribute value from a given set of valid values assigned to that attribute. In some situations existing attribute information is available from databases. If this data can be correlated with field observable facilities then the software should allow for the update and edit of this information in the field. File transfer protocols that incorporate some form of error checking (ie. kermit, xmodem, ymodem, etc.) should always be used when transferring data between field unit and office PC or a backup unit. An annunciator should be employed to make the user aware that an error has occurred and no further entry should be allowed until the error is corrected.

Reliability. The software must be designed to avoid conditions that could result in lost or corrupted data files. This usually implies that keystrokes must be captured and analyzed by the program to check if they are valid for the current series of operations. This aspect of the software design is referred to as making the program "Bulletproof". There is always a way for a user to purposefully abort or "crash" a program. This situation must be anticipated in the software design so that any effect on the data is minimized.

Editing. Data editing functions should be incorporated into the software. If possible the original records, prior to any field edits, should be tagged and kept in the file.

Software development is required for the office PC field data management system. This is most easily done using one of the many PC database products. The office system allows for more expanded editing capabilities as well as further automated quality control processes to enhance the existing manual checking for connectivity and phasing. File indexing and tracking functions are incorporated into this system.

Additional software development may be required to convert the field collected attribute information into a format suitable for use with the GIS conversion software. For the hydro-electric facility data conversion project undertaken in British Columbia this step was necessary as the conversion was done on an IBM mainframe computer. The software written to migrate the field inventory data to the mainframe platform for use in the merge process resulted in an additional quality control point in the conversion of the data.

Results

The result of considering the above requirements in the development of a field inventory system for the hydro-electric conversion project was complete success. During the field collection portion of the contract over 2,100 map sheets containing some 300,000 facilities were inventoried with not a single data file lost or corrupted. The dozen hand-held field units employed performed admirably with only one breakdown in over 30,000 hours of operation. No loss of data resulted from this breakdown; proving the effectiveness of the backup procedures. Users were initially skeptical and some complained that the system was slower than the more familiar manual methods. Within one week of implementation virtually all users, none of whom had any significant experience with computers, matched or exceeded their manual attribute collection rates. Users were also pleased with the in-field error trapping features which reduced their error rates and therefor the need to reinventory a map sheet.

Future Considerations

The system and methodology employed in field data collection of attribute information described in this paper represented the state of the art in early 1990. Since that time the development of ruggedized full-screen portable "notepad"computers with pen-based operating systems has started to shift the focus away from the hand-held computers. CAD software is already available for these computers which will encourage the replacement of the traditional field inventory map with an electronic equivalent. What the effect of these systems will be on the data conversion industry and conventional digitizing in particular is yet to be seen. Certainly the ability to collect both graphical and textural information quickly and easily in the field will have an impact. The advent of cost-effective GPS geo-referencing systems will complement this field digitizing capability by allowing accurate positional information to be easily attached to digitized facilities.