AN INTEGRATED DIGITAL SYSTEM FOR SUBSURFACE EXPLORATION DATA COLLECTION AND BORING LOG GENERATION

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Introduction

Traditionally civil engineers and earth scientists record field data using pen and paper. This leads to inconsistencies in field measurements and terminology as well as time intensive data input into computers. LawLog shifts the paradigm towards digital data collection. Consequently, larger quantities of consistent and complete data can be acquired rapidly and reports generated in a more timely manner. This paper discussed the design and implementation of the LawLog system from conception at Georgia Tech through practical application on several large projects.

LawLog is an integrated digital system that facilitates the generation of geotechnical boring logs by digitally managing the entire dataflow process from field data collection via a personal digital assistant to a desktop database for storage of all boring log data to a direct interface with gINT for generating boring logs. LawLog was conceived based on the PLog system that was originally developed at Georgia Tech and licensed by *dataforensics*, L.L.C. Using the PLog system design, MACTEC Engineering personnel created a comprehensive data structure that included the attributes typically recorded by MACTEC personnel while performing soil and rock borings as well as monitoring well and slope inclinometer installations.

Project History

During pursuit of the several large geotechnical contracts by MACTEC, fka LAW Engineering, the Chief Engineer Chris Giese identified the anomalies often associated with the input of field data from multiple loggers during large field investigations. After several discussions with the client regarding general quality assurance and standards during the field investigation, MACTEC pursued the development of a PDA application that could both increase the quality of the field data and reduce the amount of input time normally associated with the construction of gINT boring logs. During the proposal stage of the project MACTEC estimated 2,500 borings would be required to adequately explore the project limits. At an average rate of thirty minutes per log and an average billing rate for clerical support of $40 per hour, MACTEC estimated the application could reduce project costs by up to $50,000.

MACTEC has produced gINT borings logs for several years in a format clients have become familiar with. In order to produce final borings logs that were in the same format as traditional manual logs, MACTEC designers had to identify parameters for field input that would yield a similar gINT boring logs when extracted from LawLog. MACTEC designers compiled lists of inputs traditionally used by field personnel for use in the

design of LawLog. After reviewing hundreds of boring logs previously included in MACTEC reports, designers settled on a standard format for field description of samples. This review and development of standard descriptors and formats was used to produce templates for soil classification, rock classification, monitoring well installation, slope inclinometer installation, and other sample collection procedures. Although the program's conception was driven by a several large projects, the input and design from MACTEC personnel focused on use of LawLog for multiple projects in all MACTEC service sectors.

System Design

Figure 1 illustrates the functionality of the entire system. It consists of three modules: a field data collection module utilizing handheld digital technology; a conduit module for uploading field data to a personal computer; and a Microsoft Access database that allows exporting data for gINT as well as creating a comprehensive boring log database for all projects.

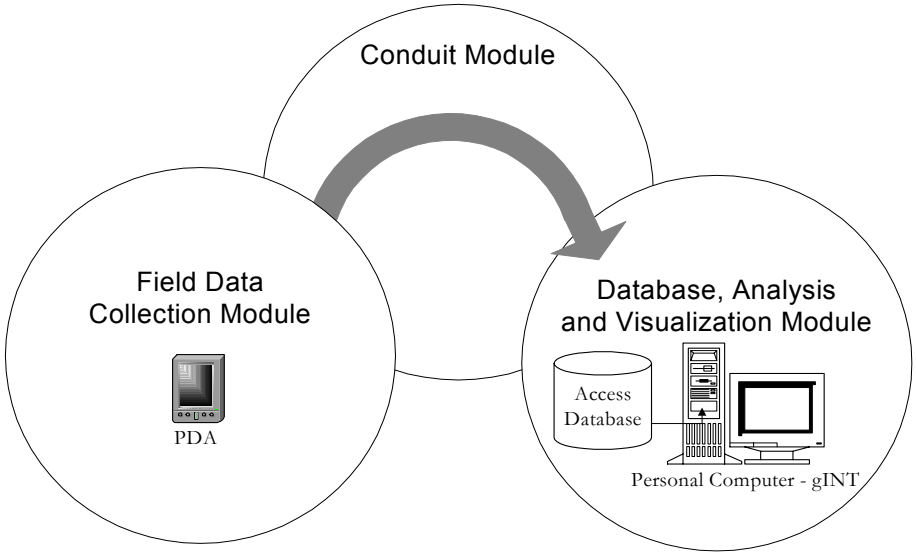

Figure 1 –Design of LawLog System

LawLog was designed based on the PLog system modified to account for the terminology and data types recorded by MACTEC personnel. It allows users to digitally document soil and rock stratigraphy; samples such as split spoon, Shelby tubes, bulk, wash, other and rock samples; ground water information; problems encountered during drilling; slope inclinometer installations; and monitoring well installations. Following field data collection, personnel synchronize the PDA with the Microsoft Access database on a desktop computer, which facilitates importing data into gINT for borehole log generation.

Hardware Considerations

The field data collection module of the LawLog system was designed to operate on Palm OS based personal digital assistants (PDA) because the devices are extremely small,

inexpensive, reliable, easy to use, programmable, expandable, and have a battery life of several weeks. Conversely, Pocket PC devices are typically more expensive, slightly larger, have faster processors to support functionality unnecessary while doing field data collection, and have limited battery life (typically 4 to 8 hours).

The conduit module was designed to operate on Microsoft Windows 9x, NT, 2000 or XP based desktop computer, laptop computer or server. The Database, Analysis and Visualization Module was designed using a Microsoft Access database, because it is the only database that gINT supports directly.

Database and Graphical User Interface Design

The LawLog application was developed through an iterative process involving the relational database modeling and graphical user interface design. For a desktop application, these two components may be completely unrelated due to the large screen size and the resources for processing and manipulating significantly more data. However for complex PDA applications with multiple forms and databases with multiple tables, these considerations should be intimately involved in the design.

In order to store the various attributes within LawLog, a relational database was used. First, a unique identifier was determined for each type of feature within the data structure developed by MACTEC personnel. After determining the primary key for each entity such as a Project, Borehole, SPT Sample, etc. and the attributes associated with each entity from the set of choices specified by MACTEC personnel, a logical organization of the data structure and the graphical user interface was created. The intrinsic relationships of the data significantly impact the data and interface design. For example, a project can have many boreholes and a borehole can have many SPT samples, rock samples, soil layers, etc.

For the user interface, several goals were defined in order to maximize its functionality. The software should:

- Account for the small screen size present on PDAs.
- Minimize the text input required for documenting the damage.
- Minimize the number of stylus taps for making selections to further facilitate the data input process.
- Be algorithmically efficient by using efficient logic
- Be able to be seamlessly synchronize with an Access database stored on a local machine or on a remote machine on the MACTEC network.

These goals were instrumental throughout the design process. To account for the small screen size on PDAs, data was divided into logical groups, such that the screen was not too crowded nor was the screen to sparse which would require additional navigation between screens i.e. minimizing the stylus taps for navigation. Text input was minimized using a series of lists, buttons, checkboxes and other interface elements, which allowed

the user to make selections from these various items instead of writing the descriptions. Lastly, the software should not require the user to wait for the software to complete a task, because entering data should be a rapid process. Once familiar with the software, users should be able to document soil and rock borings faster using the LawLog system than writing the data on paper.

Figures 2 and 3 illustrate the rapid input capabilities where the input generally proceeds from the top to bottom of the screen. Once you have input the 'Borehole Options' then proceed to 'Soil Samples', 'Rock Samples', 'Ground Water Table'. Once within each of these entities, the user is then prompted for the appropriate inputs as seen in Figure 3 for developing the soil description. Simply by making selections, the user can input a significant amount of data very rapidly.

Additional standardization is promoted for attributes that are commonly re-used such as boring type, engineer name, etc., by allowing the users to create look-up lists such that once the item has been entered, it can be selected from a list for subsequent data entries. Accordingly, the standardization within LawLog ensures consistent and complete documentation such that boring logs generated by differing field personnel are consistent in the ordering of the descriptions as well as the terminology utilized. Lastly, LawLog enables more efficient use of personnel via automated reporting through gINT. Instead of manually inputting the data into gINT, the data is already in digital form, which does not require subsequent digitization.

Benefits of LawLog System

The system has many advantages compared with traditional methods. LawLog provides direct digital entry such that data is only entered once, not written once in the field and then entered into a computer once. It minimizes the data input time on the PDA by providing a standard set of choices in lists, buttons and checkboxes from which user can select. The software essentially acts as a "smart" form which ensures consistency and completeness of the field data by prompting the user for the appropriate values to be documented.

The efficiency of boring log compilation has been dramatically improved. Once the field data is imported into the Sterling office, computerized boring logs can be generated in a matter of minutes. There is still the need for engineer review and clerical editing; however, the time associated with both of these processes has been reduced as the sample descriptions and raw data outputs are in a standard format. From a logistical standpoint, the electronic transfer of data has greatly reduced the headache normally involved with process of entering field data. The project site is located seven hours from the Sterling office and oftentimes, several weeks pass between field visits of office personnel. Field logs are often marred by mud and water making the paper logs impossible to copy and fax legibly. The mailing of field logs to the office has proven difficult because multiple rigs working seven days each week produce a large quantity of boring logs. If logs are mailed twice per week and the package takes four days to reach the Sterling office, it can be up to two weeks before logs are produced. With LawLog, computer-generated boring

logs can be produced within two days of completion of the field log. The project team is comprised of multiple engineering firms and near real-time data has made the transfer of field data and boring results between firms a reality.

Figure 2. Borehole Summary Form

Figure 3. Soil Description Form

Implementation Problems

There were two types of problems that occurred during implementation, erroneous data input and synchronization difficulties. The erroneous data input was caused by field personnel who did not understand the nuances of the software. For example, field personnel were not unselecting the option for a 4th interval of penetration on the SPT. Accordingly, the percent recovery and the sampler penetration depth were incorrect. This was easily remedied by instructing the field personnel and performing some additional quality control once the data was uploaded to the Access database. This highlights the necessity for on-site software training of the field personnel by *dataforensics*.

The second problem that occurred during implementation was caused by a lack of bandwidth in the MACTEC virtual private network. Synchronization of the PDAs with the Access database functioned properly if the database was stored locally on a machine or on the network within the office. However, the project required that the field office be able to synchronize the data remotely using the MACTEC Virtual Private Network (VPN). Connection speeds were too slow to facilitate this option, which required *dataforensics* to create replication ability within the Access database. This allowed the field personnel to synchronize the PDAs in the field office to a local database which could then be compressed and emailed to the Sterling office for import into the master Access database and generation of final boring logs.

Conclusions

The LawLog system developed by *dataforensics* streamlines the data flow process by providing the capability to digitally document geotechnical boring log data. It provides a means for rapidly entering field data in a consistent and complete format and then automatically uploading the data for final boring log generation. Accordingly, it results in cost savings associated with manually entering field logs into gINT as well as decreased time associated with quality control. LawLog is completely operational and has been used to document over 1,200 borings.

The implementation of a program of this magnitude and complexity has been a tremendous undertaking from a management and training standpoint. On a project that witnessed over 5,000 feet of rock drilled in the month of February, this application has been a necessity. For a project team that is separated by seven hours and 400 miles, this application has been a lifesaver. As a company, increased production, automated quality assurance, and cost savings means this application is a success.