REAL TIME GEOTECHNICAL FIELD DATA ACQUISITION USING A DISTRIBUTED APPROACH

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Summary
A distributed geotechnical remote analysis of data system (Distributed G-RAD) can benefit both owners and contractors in providing better quality control and assurance on geotechnical projects. The Distributed G-RAD approach involves efficient data acquisition using PDAs with GPS capability, radio frequency identification (RFID) tags for labeling soil samples, laser scanning for measuring lift thickness and volumes of stockpiles and borrow pits. Spatial data storage is provided using a geographic information system (GIS). Portions of this system are already developed while other parts are still being considered. This paper also describes how RFID and laser scanning technologies can be used in the larger Distributed G-RAD system.

1 Introduction
This paper provides a vision of a distributed geotechnical remote analysis of data system (Distributed G-RAD) that can benefit both owners and contractors in providing better quality control and assurance on geotechnical projects. Portions of this system are already developed while other parts are still being considered. The Distributed G-RAD approach involves efficient data acquisition using PDAs with GPS capability, radio frequency identification (RFID) tags for labeling soil samples, laser scanning for measuring lift thickness and volumes of stockpiles and borrow pits. Spatial data storage is provided using a geographic information system (GIS).

Figure 1 reveals the entire concept showing the various input data, storage in a central spatial database, and output involving decision support systems that use data stored in the GIS. Inputs include data from a pocket PC linked to GPS (G-RAD), lab test results, soil bore log data, inspection records, and laser scanned images. Outputs include decision models for determining sampling patterns for achieving desired reliability; failure diagnostic tools; and significant maps, graphs, charts. The distributed system involves a hierarchical (multi-level) approach that uses mobile terminals, mobile centers and a fixed center for efficient data acquisition and analysis of data (refer to Figure 2). This system will be constructed based on the wireless network allowing multiple parties to collaborate together in real time. This will result in greater accuracy, security and efficiency. This paper describes how G-RAD, RFID, and laser scanning technologies can be used in the larger Distributed G-RAD system.

2 G-RAD
The remote geotechnical field data collection and analysis system (G-RAD) is used to assess soil conditions in a real time fashion. The current approach involves taking field notes of dynamic cone penetrometer (DCP), Clegg hammer, Geogauge^{TM}, and nuclear density gauge data and manually entering these data into a spreadsheet for analysis. This system allows the field team to enter these data into a PDA device with GPS capabilities and provide near real time analysis of soil properties for each test site. The benefits for such a system include faster analysis and more intelligent test site selection capabilities. This system is seen as a pilot for a much larger geotechnical spatial data collection and processing system. It has the following features:

- Mobile solution;
- Standard system interfaces;
- Friendly user interfaces;
- Direct communication with GPS;
- Validity check of user data;
- File format compatible with a spreadsheet software;
- Data safety/save confirm before close; and
- Project-based multilevel file management system.

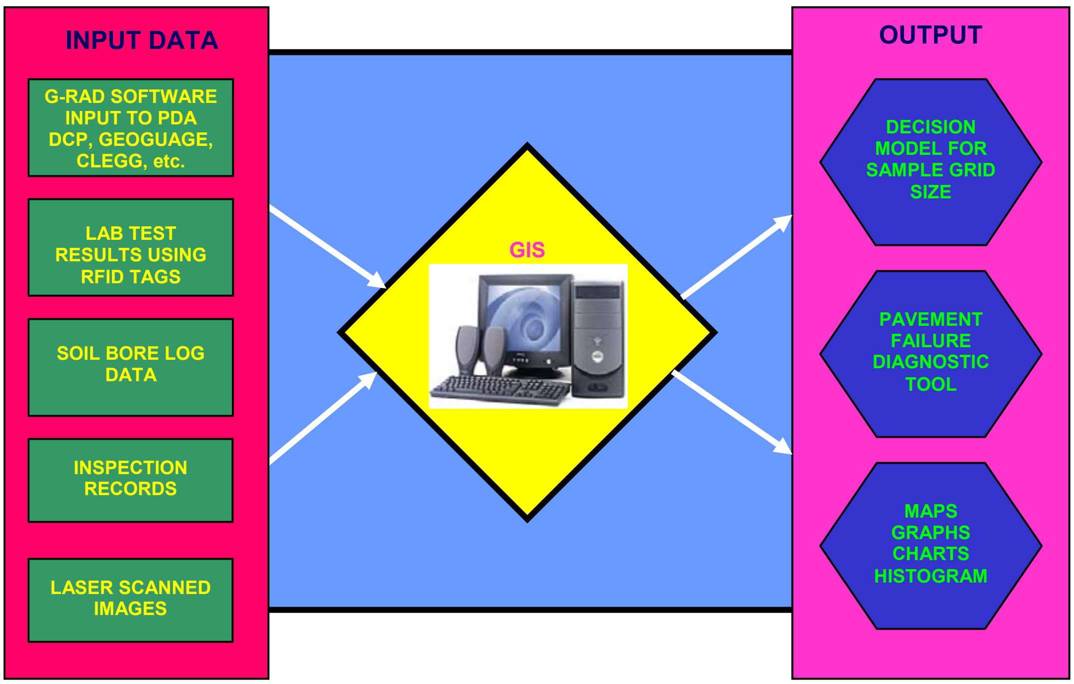

Figure 1: Distrubuted G-RAD System

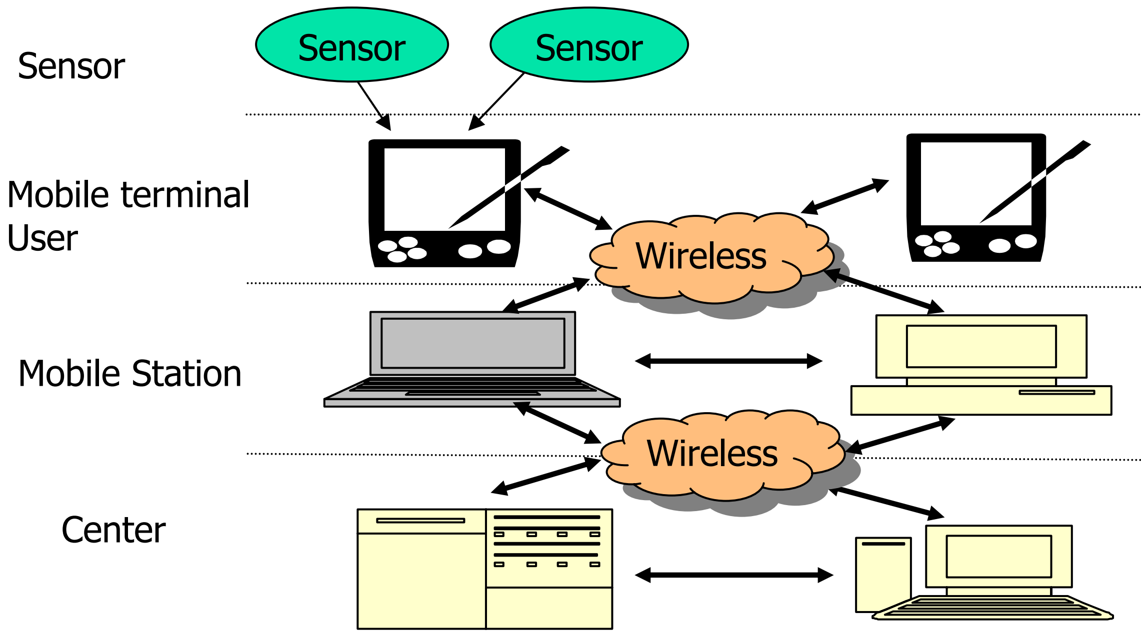

Figure 2. Distributed G-RAD Multilevel Hierarchical Approach

3 System Architecture

This system is developed for a mobile device, which is currently running on a Pocket PC, the latest version. The G-RAD system consists of four parts: 1. GPS receiver, 2. PDA, 3. Data collection and analysis software, and 4. Host storage system.

In this system, the GPS receiver is used to acquire the satellite signal and generate the location information. The PDA is the basic platform used to connect and support other parts of the system. Data collection and analysis software accept the user input, and then process the data according to the specific user requirements. It also reads the GPS information from the serial port and combines these parts as one data unit. It then stores this data back to the PDA. Finally, the user can backup all data from the PDA to the host storage system, such as the central database or file system running on the network.

Microsoft Embedded Visual Tools are used to develop the G-RAD software since these tools provide efficient development capabilities. Both the interface and high level modules can be created using this tool. Embedded Visual C++ is used for low level and complex computation modules. This software allows field data collection and analysis using a standard dynamic cone penetrometer (DCP), Clegg hammer, Geogauge™, and nuclear density gauge to assess soil conditions. The current approach involves taking field notes and manually entering these data into a spreadsheet for analysis. This new system allows the field inspector to enter data into a PDA device with GPS capabilities and provide analysis of soil properties for each test site (refer to Figure 3). G-RAD complies with ASTM D 6951-03 (Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications). The primary benefit of such a system includes more rapid analysis of site conditions.

Figure 3. G-RAD Collecting Dynamic Cone Penetrometer Data

4 Radio Frequency Tagging (RFID)

Radio frequency identification (RFID) refers to a branch of automatic identification technologies in which radio frequencies are used to capture and transmit data from a tag or transponder. These tags are typically affixed to assets to assist in the identification and tracking process. Tags are classified as active or passive tags and may have read-write or read-only capability. Passive tags are powered solely by the magnetic field emanated by the reader. Active tags, on the other hand, contain a battery that powers the tag. Read and write ranges for passive tags are generally less than six feet; in most configurations, the read range is only 2 to 12 inches.

As a portion of this distribute G-RAD system that is under consideration, RFID tags can be used to more efficiently label soil samples taken from the field. It is not uncommon to mislabel soil samples in the field or be unable to read someone else's handwriting. It is envisioned to have one RFID tag included with each sample which will include the following information: sample number, GPS coordinates, and other information related to overall soil conditions (e.g., sample depth and sampling difficulties encountered). Laboratory analysts can then simply scan the tag located in each sample and rapidly obtain the important information. After the analysis is completed, these tags can be sent back to the field and reused. This approach will reduce errors from misinterpreting hand writing, provide consistency with sample data collected in the field, and help expedite the laboratory analysis process.

5 Laser Scanning

Laser scanning is a terrestrial laser-imaging system that quickly creates a highly accurate three-dimensional (3D) image of an object for use in standard computer-aided design (CAD) software packages. The laser's visible green beam is moved across a target in a raster scan. The horizontal and vertical angles of the beam are measured for each point, as well as the time of flight of the pulses. Once an object is encountered, the laser is reflected back to the unit with the time of flight, which generates a measurement of distance. These measurements produce an impact location, which in return displays a cloud of points. Measurements taken from the "cloud" can be used to do interference detection and constructability studies. Each point has embedded x, y, z data,

so it can be directly loaded into a CAD program without any need of digitizing. Less than 6 mm (1/4") accuracy can be obtained using this technology.
Laser scanning is being considered as part of the overall Distributed G-RAD system as a technology that can efficiently collect information about lift thickness, volume of embankments, stockpiles, and borrow pits. This technology will improve the accuracy of determining such quantities, provide an convenient auditable record, and speed up this QA/QC process.

6 Geographic Information Systems (GIS)

Large quantities of data are typically collected during the entire life-cycle process of a roadway, but much of these data (e.g., compaction and material test results, inspection reports, maintenance logs, and accident reports) are not converted into useful information for planners, designers, constructors, and maintenance operators. These data could be useful in the building and operation of new transportation projects. These data are managed by different groups of people using different approaches to storing data– to date, there has not been an efficient method of tying them all together. GIS offers the potential for storing, checking, manipulating, analyzing and displaying data which are spatially referenced to earth.

The GIS is a key part of the distributed G-RAD system since this is the database that will store spatial information related to each project. Information will wirelessly flow from the user in the field to mobile terminals, mobile stations, and finally into a center which will house the GIS. It is envisioned that relevant geotechnical project information such as test results from the DCP, Clegg hammer, Geogauge™, and nuclear density gauge; field inspection reports; and lift thickness—determined using laser scanning will be efficiently processed. This system will also be able to provide field personnel with information residing in the central GIS for more efficient performance of field tasks (e.g., soil boring logs and previous Proctor test data)

7 Conclusions

This paper has presented a vision for using a host of data acquisition technologies for collecting and analyzing geotechnical data using a distributed hierarchical data communication protocol. The system involves the use of G-RAD to collect test data from various geotechnical testing devices (e.g., DCP, Clegg hammer, Geogauge™, and nuclear density gauge), RFID for more efficient sample labeling and identification, and laser scanning for efficient determination of lift thickness and soil volume. These data are transferred to a central GIS using a distributed approach involving handheld PDAs, mobile terminals and stations. To date, the G-RAD software is operational with other aspects of this system being developed.