Testing piles* with virtual instruments

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SYNOPSIS

Since its introduction to the piling community, pile-testing equipment has developed through three generations:

1. Purely analog (Oscilloscope) equipment,
2. Digital systems based on purpose-built computers and proprietary operating systems,
3. Systems based on ruggedized laptop PC computers with DOS based software.

Today, practically all testing systems in use are digital, belonging to either second or third generation.

This paper describes the principles of fourth-generation testing equipment that has recently become available. Consisting of existing off-the-shelf resources, such as notebook computers and WINDOWS operating system, it utilizes the accelerated progress made in computing power, peripherals and software capabilities.

As an illustration, the paper describes two fourth-generation systems for the integrity testing of piles: The Pile Echo Tester (PET) and the Cross Hole Ultrasonic Monitor (CHUM).

HISTORY

The first-generation of pile-testing equipment consisted of purely analog components. With its debut in the early seventies it consisted of makeshift equipment (1,2), then evolving to commercially available systems (3). The early eighties saw the transition to the second-generation: Digital systems based on purpose-built computers and proprietary operating systems (4). It is noteworthy that current cross-hole equipment mostly belongs to this generation. With the availability of ruggedized laptop personal computers, third-generation pile-testing equipment based on DOS was a natural consequence (5). Today, practically all sonic testing systems in use are computerized, belonging to either second or third generation.

THE COMPUTER GAP

In the course of a few years, a large gap has opened between the systems used by testing firms on site and those they use in the office (Word processors, worksheets, Internet browsers, etc.). Office computers are constantly becoming more powerful and, at the same time, more affordable. They use an operating system (Windows 95/NT) which has practically become a global standard, enjoying many advantages:

- All applications have a similar appearance, thus the learning curve is very short
- Data can be easily transferred between various applications using methods such as cut and paste, Object Linking (OLE) and Dynamic Data Exchange (DDE)
- Any peripheral equipment may be easily, or even automatically (Plug & Play), installed and upgraded
- Communication with other computers, either within a local office network, or anywhere in the world, is straightforward.

Although it is theoretically possible to enjoy all these benefits from a DOS based program, the efforts involved are, at best, not worthwhile.

As a result, existing pile-testing instruments look very outdated and by contemporary standards, quite slow. Their user-interface is rather awkward, forcing the operator to remember a long list of acronyms. Moreover, updating such instruments to include modern computing power at a reasonable cost is practically impossible. Thus, the ability of these systems to perform serious, real-time analysis on-site, is severely limited.

Fourth-generation pile testing equipment, which has recently become available, does abolish this dichotomy. It is based on the recognition that, on a world scale, the market for pile testing equipment is tiny. Therefore, to produce a cost-effective instrument, developers must dedicate their efforts to the job-specific part of the system. Using standard software and hardware components, of which a large choice is now universally available, frees the developers to concentrate on the real heart of the system - software. Instead of designing and constructing displays, pointing devices, printer drivers, file storage, communication, operating system etc., these are readily picked from specialized manufactures at attractive prices.

VIRTUAL INSTRUMENTATION

Principles

Ideally, the virtual instrument would consist of software only. This may be illustrated by two examples:

1. Most modern notebook computers are usually equipped with a built-in microphone and audio card. It takes only the necessary software to turn such a computer into an instrument capable of measuring acoustic noise (including intensity and frequency) or into a so-called "lie-detector."
2. Analog-to-digital (A/D) devices are available in the form of PC cards. Once inserted into a notebook computer with the right software, the computer becomes a powerful digital oscilloscope, able to measure electric current of any voltage, frequency and wave shape.

* In this paper, wherever the word "Pile" is used, it also applies to other forms of deep foundations: Drilled shafts, caissons, barrettes, slurry wall elements etc.

With pile-testing equipment, the situation is not as simple as that: In the sonic test, for instance, one measures the velocity (or acceleration) at the pile top. In addition, certain systems also monitor the force in the hammer. Pile testing, therefore, cannot be done without some specific hardware.
The situation with cross-hole ultrasonic testing is more complicated: In the sonic test the input is provided by a plastic hammer, and the electronic component is purely passive. The cross-hole system, in comparison, must also have an electronic component to produce the ultrasonic pulses. It is evident, therefore, that pile-testing is not a good candidate for purely virtual instrumentation. How close, though, can one get to this ideal?

Design

The common combination of a word processor and a printer is a good example for joining specific hardware to a virtual DTP (Desk Top Publishing) system. It is only natural to want the system to work with all kinds of printers, including those that were developed *after* the software was released. This task is done by using a device driver as a "middleman" between the purely virtual part of the system and the specific hardware. The device driver, which is a relatively small software fragment, is considered a part of the hardware.
Following this example, The unavoidable specific hardware involved in the pile testing system must be linked to the all-virtual heart of the system via a device driver. This design simplifies things in several ways:

- The software and hardware can be upgraded separately.
- The same software can be linked to several hardware variants, each with it's own device driver.
- The same hardware can be linked to several software packages, simplifying their design.
- An office version (which needs no hardware) of the test equipment can be made easily using a "do-nothing" driver.
- A device driver which simulates the hardware using synthetic or pre-recorded signals looks identical to the virtual software and can serve as an educational tutor or evaluation version of the system.

Examples

The PET (pile echo tester) is an instrument for sonic testing of piles in the time domain. Its' hardware consists of:

1. Sensor (accelerometer)
2. Constant voltage supply to the sensor
3. A/D converter

Items 2 and 3 are packaged in compact D-type plug which may be inserted in the parallel port of any computer. A pen notebook computer (tablet) is the preferred configuration.
On site, the operator enters Identification of the project, subsite and pile designation into the computer. PET software then calculates the wave velocity appropriate to the concrete grade and age. The operator then presses the sensor against the pile and hits it (lightly and repeatedly) with a plastic hammer. PET software then carries on with all the rest, specifically:

- Sampling and analysis of the incoming waves, disregarding random noise and movement of the operator's hand. Once the beginning of a regular hammer blow is identified, however, the whole blow is recorded.

The acceleration history is integrated over time to obtain the velocity which then undergoes the following treatment: low-pass filtering, sharpening, exponential amplification, rotation and normalization.

- Each resulting reflectogram is displayed on the screen together with the accumulated average. There is no limit to the number of blows (Figure 1).
- Once a satisfactory average has been obtained, the operator stops the sampling operation. Blows that are evidently irregular may be deleted and the effect on the average examined.
- Based on the quality of the results, the operator may save only the average or the whole set of blows, for further analysis in the office.
- For each pile, the operator may add his on-site comments regarding the pile preparation and integrity. The comments may be chosen from a standard list, or hand-written using the pen.
- The analysis may be completed in the office by a senior engineer, and the report produced in standard word processor format. The report may be either daily, monthly (for invoicing purposes) or final, in any language supported by Windows 95/NT. The form of the report may be designed according to the preferences of the testing firm and may be edited on the user's own word processor.
- Even a modest-sized disk can store the whole annual output of a large testing firm.

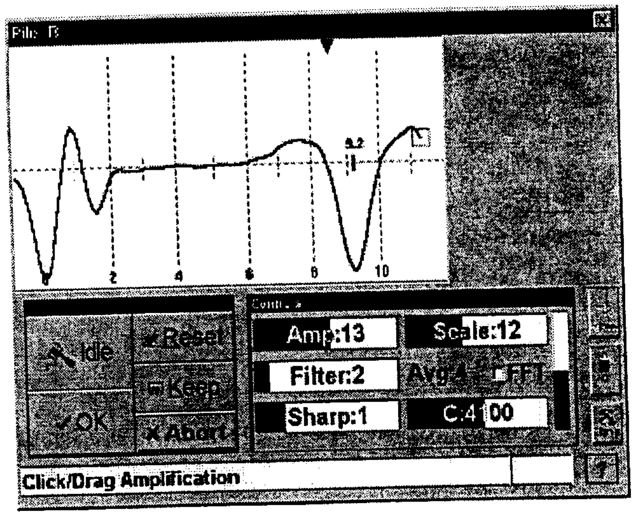

Figure 1: The PET Screen

The CHUM (Cross Hole Ultrasonic Monitor) is an instrument for cross-hole ultrasonic testing of piles. Its' hardware (second) is by necessity more elaborate than that of the sonic instrument, including:

1. 100 kHz probes (transmitter and receiver)
2. Two depth encoders (US patent application)
3. Pulse generator & Signal processor
4. A/D converter & counter
5. Notebook computer.

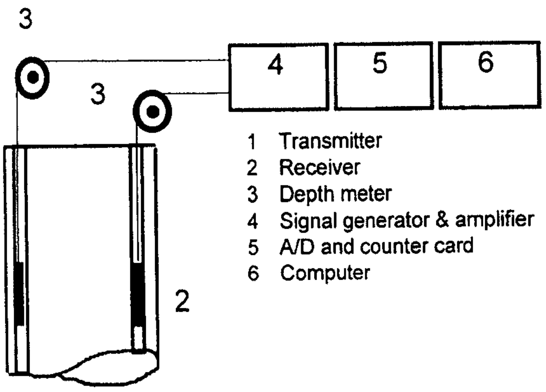

Figure 2: The CHUM Hardware

The hardware performs the following tasks:

- Monitors the current position of both probes
- Triggered by the software, it transmits an ultrasonic pulse
- It sends the received pulse to the computer via a standard A/D card.

The CHUM software does the following:

- Keeps track of the project Identification, subsite and pile designation, including the site plan.
- Leads the user through the various test stages using a test "wizard" (Figure 3).
- Triggers the hardware at fixed depth intervals to transmit a pulse.
- Picks up the received pulse and analyzes it "on the fly", enabling real-time, high resolution tomography.
- Post processes the whole log and plots 1-D log or 2-D tomography using several calculation methods and presentation options (Figure 4).

<u>The PISA (Pile Integrated Sonic Analyzer)</u> is basically a CHUM instrument, to which one may attach other peripherals according to the mission. By attaching an accelerometer, for instance, the PISA can be turned into a full-capability sonic tester.

ADVANTAGES

Users of virtual pile-testing instruments enjoy the following advantages:

- Standardization: All instruments have a very similar user interface, and come naturally to the operator familiar with current office applications.
- User-friendliness: Short learning period and convenient on-line help is always available. Desktop may be customized by operators according to their preferences.
- Modularity: All hardware components of the equipment can be replaced separately at low cost. Certain elements may be obtained from a variety of vendors.
- Upgradability: Virtual instruments have naturally an unlimited room for further development. Software can be serviced or upgraded in a few minutes either by e-mail or by downloading from a dedicated WWW site.
- Completeness: Data collection, analysis and reporting are incorporated in one package.
- Reporting: Fully customizable report format with multilingual capabilities and compatibility with current word processors and worksheets. Hard copy is easily obtained by any available resource.

Communications: Testing instruments are easily connected, by standard peripherals, to LAN or to the WWW.

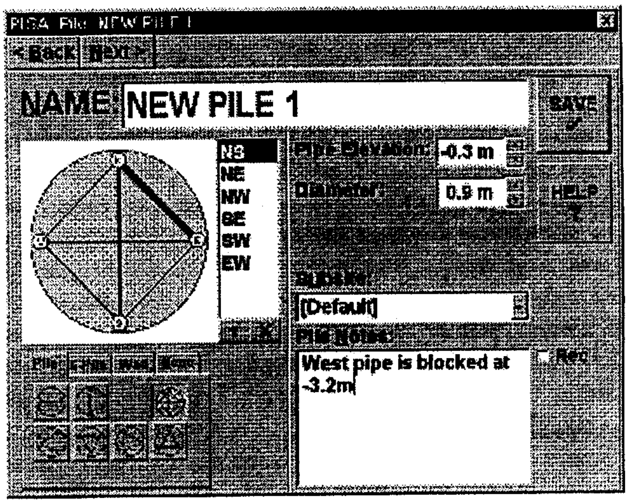

Figure 3: The CHUM Test Wizard

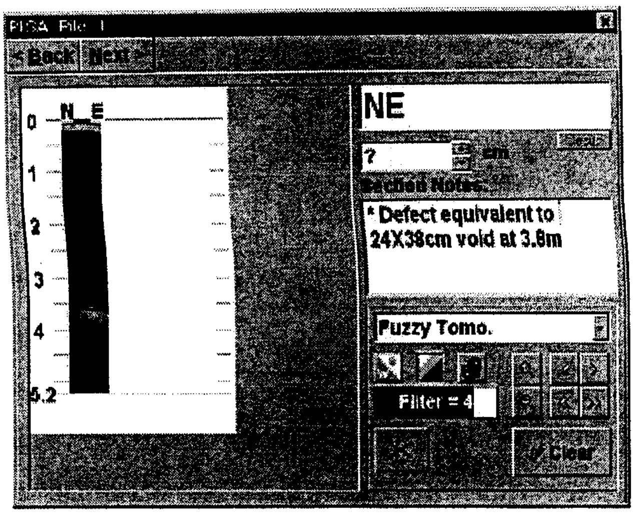

Figure 4: CHUM Tomography

SUMMARY

After more than two decades in which pile testing equipment has evolved, the industry is now ripe to switch over to virtual, or fourth-generation, instrumentation. Such instruments help developers eliminate duplicated effort, freeing them to concentrate on the heart of the system - the software.

The examples given demonstrate the advantages offered the users by the use of virtual instrumentation

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