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AUTOMATIC REAL-TIME MONITORING SYSTEM (ARMS) – A ROBOTIC SOLUTION TO SLOPE MONITORING

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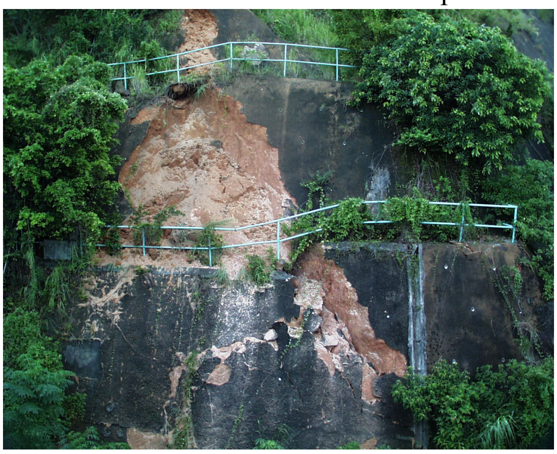
Abstract

In case of natural disasters arising from landslides, the Survey Division (SD) of Civil Engineering Department is responsible for collecting topographic details and monitoring the susceptible slope movement. When carrying out survey in these dangerous areas, staff safety is no doubt the primary concern. Timely and reliable survey results are equally important for engineers to make prompt decisions for mitigation actions. With no doubt, the long and repetitive characteristics of monitoring observations make it a resource demanding exercise to give continuous monitoring results.

To address the problems, SD has developed an **A**utomatic **R**eal-time **M**onitoring **S**ystem (ARMs) to cater for continuous monitoring when severe landslide happens. The system comprises a motorized automatic total station, which is linked up to the office control unit by telephone line or wireless GSM network. With the ARMs, real-time situation of a dangerous slope can be monitored round-the-clock remotely with minimum staff resources.

1. Background

Plate 1: Cracks on failed slope



In August 1999, "SAM" – one of the most powerful typhoons in the past 70 years swept Hong Kong and brought heavy rainfall that caused many severe slope failures. Over seven hundred residents of Shek Kip Mei Estate were threatened by a 50m high 80m wide slow-moving slope (Plate 2) situated just 5m back from their homes. Local residents reported that boulders slipped from the slope knocked down a fence and numerous long cracks (Plate 1) appeared on the slope surface where water and sand debris was coming out. Preliminary inspection revealed that the subject slope was potentially hazardous but more detailed information on the slope movement was required to determine whether to exercise emergency evacuation. SD was called upon to monitor the slope and provide timely results to the engineering counterparts.

Owing to the urgency of the task, SD mobilized itself to deploy three parties, at the peak period, to take observations at daytime and process survey results in roster terms. However, only three epochs a day, at maximum, were taken and the exercise eventually lasted for three months. This arrangement was extremely resource demanding, yet the outcome was less than satisfactory. To monitor the slope movement, officers needed to expose themselves in the hazardous environment for over an hour in field and then another few hours to process the raw data before delivering the results to the engineers. In an emergency situation, a several hours' responding time is absolutely too long that we might have missed the opportunity to take urgent mitigation actions. Moreover, the landslide will also not confine its movement only at daytime when manual observation is possible.

Plate 2: Shek Kip Mei Landslide (August, 1999)

From the experience of the Shek Kip Mei monitoring exercise, SD reckoned the genuine needs to develop a versatile monitoring system which is capable to:

- set up easily
- control remotely
- run automatically
- increase the observation frequency
- operate round-the-clock, and
- deliver the survey results instantly

2. System Overview

To achieve the objectives, SD developed the ARMs to trigger early alarm when the target slope's movement exceeds the threshold magnitude or trend. The system comprises a field unit and an office control unit (Fig. 1) which are both the integrated products of the in-house developed program and readily available software/hardware (Table 1). In the field unit, the Leica TCA 1800/2003 motorized total station with Automatic Target Recognition

(ATR) function takes measurements to the target points and the field notebook perform field data reduction. With the aid of the Win98 Scheduler and PCAnywhere software, the data files are automatically transmitted at pre-defined intervals, via telephone line or wireless GSM network, back to the office control unit for graphical presentation of monitoring results.

Fig. 1: Field and Office Unit

Activity	Major Hardware / Software involved
Field Data Capture	– Leica TCA 1800/2003 – Portable Note-book computer (PIII or above) – In-house developed ARMs program
Field Data Reduction	– ARMs program
Auto wireless data communication	– Nokia Cardphone 2.0 (Transfer rate: 14.4Kbps) – Symantec PCAnywhere version 9.2 – Window 98 Scheduler
Graphical result presentation	– Desktop PIII computer with Win98 or above – Excel 97 or above – AUTO-MOTION Excel file with built-in macro
Instrument Status viewing & remote control of Instrument	– Symantec PCAnywhere – ARMs program

Table 1: ARMs System Overview

3. Functionality Highlights

To cater for the specific requirements in slope monitoring, a number of special functions were developed to allow users to design their own observation schemes. The following paragraphs will briefly describe some of the ARMs functionality:

3.1 User defined monitoring schedule

Once the initial bearing orientation and the ATR target points learning session on the total station are completed, users can proceed to define the monitoring schedule, i.e. to set the start and end date/time; the frequency of the monitoring exercise; the number of measurements taken to each monitoring point per observation cycle and the error handling routines. If a particular target is temporarily blocked by obstacles during observation, there is an available option to re-measure that particular point again after the preset time delay (Fig. 2).

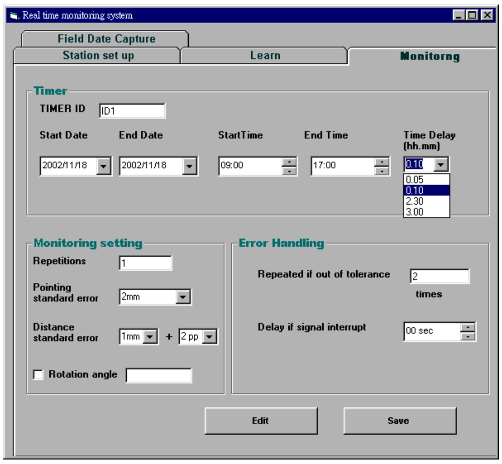


Fig. 2: Monitoring Schedule

3.2 Automatic field data transfer

The field unit is normally placed close to the dangerous landslide area. For safety reasons and to obtain the first hand slope movement information, the field data will be transmitted back to the office control unit immediately. With the aid of Win98 Scheduler and PCAnywhere software, the field data will be synchronized as a back up in the office control unit via the telephone line or wireless GSM communication network automatically at user-defined intervals (Fig. 3).

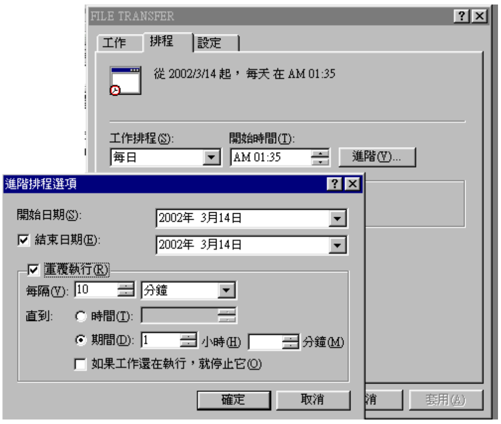


Fig. 3: Field Data Transfer

3.3 User defined target searching range

When taking measurements to two or more prisms which are very closed to each other (e.g. along a crack or joint), the ATR mode of Leica TCA 1800/2003 might not be functioning, as there appear multiple prisms in the field of view (FOV). To tackle the problem, users may select "Small FOV" for that particular pointing by narrowing down the beam width from the default 0.5gon to 0.15gon. As a rough guideline, small FOV should be applied when two prisms are less than 0.8m apart at a distance of 100m from the control station (Fig. 4).

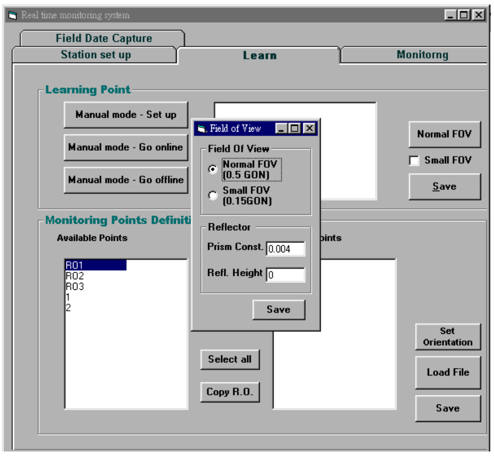


Fig. 4: Field of View

3.4 *Remote operation and Station status check*

ARMs was designed for stand-alone operation in remote area where there is no power supply and telephone service. Once start up, it can be left un-attended in normal circumstance. However, there are information about the field unit like the battery level; inclination data and the error log file which are very useful to help us understanding the current status of the system. The PCAnywhere software enables the host computer (field unit) screen to be emulated on the remote computer (office unit) such that apparent control can be exercised over the field unit (Fig. 5).

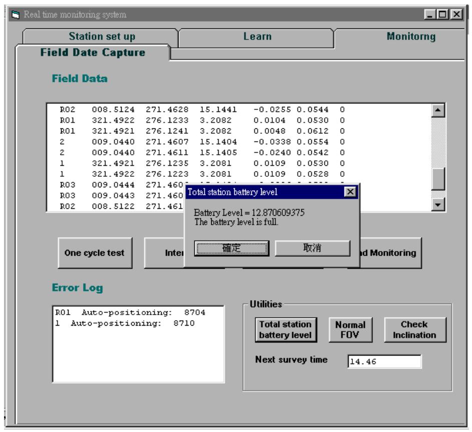


Fig. 5: Remote Operation

3.5 *Alert threshold setting*

Any movement of the slope recorded in each epoch will be automatically transferred back from the field unit to the office unit. The movement, represented by the delta changes as compared to the initial values will then be used to update the settlement graph in dx, dy and dz directions. When the pre-set alert value is exceeded, a message description of the corresponding monitoring points and a continuous beep sound will launch (Fig. 6). The warning message containing the event time; settlement values; and point identity will also be recorded in the error log file for future reference.

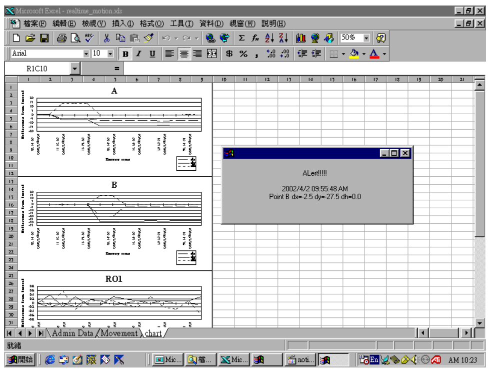


Fig. 6: Alert Threshold

3.6 *Quick installation*

The emergency situation during landslide requires a quick installation and set up procedures. Normally a rigid parapet wall on a building roof can serve as an ideal place for installing the ARMs field unit. The total station clamped on the pillar plate can rest on a force-centering bar permanently fixed on the parapet wall. The tailored design bell-shaped protective shell (Fig. 7) made of stainless steel also provides certain degree of protection to the total station against burglary. An experienced user can set up the whole field unit in an hour's time.

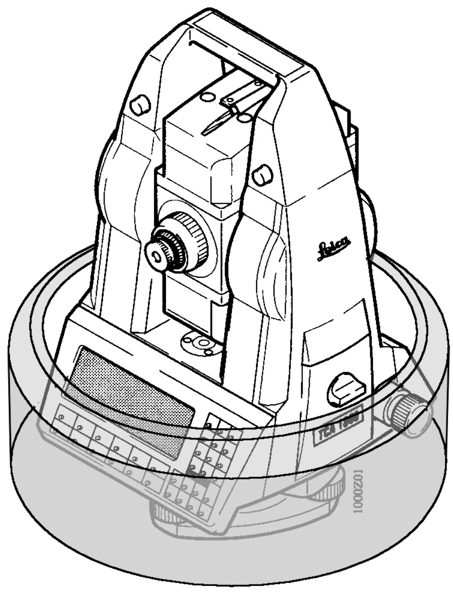


Fig. 7: Protective Shell

4. Conclusions

The whole ARMs set up (Plate 3) is an integration of the in-house developed program, readily available software and hardware. The additional cost to assemble the system is minimal as most the major components come from the existing resources.

In order to critically examine the capability of the system, a 48 hours non-stop rigorous field test was conducted early this year to evaluate the system functions; wireless communication network and the battery life. The test result is encouraging and it proved that the system is reliable in all respects.

Nevertheless, there are areas where further enhancement could be made in future. For instance, to study the feasibility of connecting different sensors such as GPS, geotechnical and meteorological equipment on ARMS to improve the system reliability. Besides, to upgrade the wireless data transmission speed to support better performance of the video camera technology such that the real-time landslide situation could be viewed on screen remotely in conjunction with the monitoring data.

Plate 3 : ARMs in operation

Acknowledgement

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