Geotechnical
Instrumentation
NEWS

Geotechnical Instrumentation News

John Dunnicliff

Introduction

This is the sixty-sixth episode of GIN. Two articles this time, and three more one-pagers about web-based data management software.

> **New Website for GIN**
>
> The new website is www.geotechnicalnews.com/instrumentation_news.php. It has an index of GIN articles that are on the web, 83 downloadable articles, and guidelines on how to submit articles to me for future GINs.

On My Soapbox

I'm returning to a favorite topic—who should be responsible for monitoring and instrumentation during construction? By this I mean the tasks of buying and installing instruments, and collecting and interpreting data. As I've claimed many times, if significant decisions are to be based on the monitoring data, it is imperative that data quality is maximized. I contend that these four tasks should **NOT** be assigned to general construction contractors on a low-bid basis because they may not have the greatest interest in ensuring maximum quality. My following article gives four specific reasons for assigning responsibility for these tasks to personnel selected by the project owner or designer and under direct contract with the project owner.

I appreciate that, when considering most readers of GIN, I'm preaching to the converted. But we need to do all we can to get this message to owners (and project managers in design firms, who supposedly have the owner's interests at heart) that it's in their interest to adopt the recommendations in the article.

Displacement Monitoring by Terrestrial SAR Interferometry

New techniques are being developed for monitoring displacement without use of traditional geotechnical instrumentation. One of these is terrestrial synthetic aperture radar interferometry. Here's an article by a colleague from Italy.

The companies listed in Table 1 provide terrestrial SAR interferometry services. If you know of others, please tell me.

Table 1. Companies providing terrestrial SAR interferometry services

Company Name and Country	Website
Aresys S.r.l., Italy	www.aresys.it
IMG S.r.l., Italy	www.img-srl.com
NHAZCA S.r.l., Italy	www.nhazca.com

I hope to have other articles about new remote techniques in future GINs, such as:

- Satellite synthetic aperture radar interferometry
- Robotic total station able to monitor surfaces such as asphalt and concrete, using a reflectorless distancemeter.
- Airborne laser scanning by Lidar (Light Detection and Ranging)

Web-based Data Management Software

David Cook's article "Fundamentals of Instrumentation Geotechnical Database Management – Things to Consider" was in December 2010 GIN, pp 25-28. March 2011 GIN, pp 34-40, included seven one-page articles by suppliers of the software. Here are three more, by Durham Geo Slope Indicator, Roctest and Soldata.

Rick Monroe of Durham Geo Slope Indicator, whose article about their Atlas web-based data management software is on page 31, has sent me the following additional valuable recommendation, about response time:

> *David Cook defined response time as the delay between data collection and data presentation. Suppose we collect a reading, send it to the Internet via our cell phone, and then see a graph about five seconds later. That would be a response time of five seconds. Granted, David Cook was thinking about software, but that definition misses an important parameter: frequency of reading. Suppose we visit the site just once a week. Is five-seconds a still a relevant measure of response time? Let's change the definition to "Response time is the delay between the occurrence of an event and the monitoring system's first report of the event".*
>
> *Now take a common scenario: in-place inclinometers are connected*

to a data logger. The data logger takes readings every twenty minutes. Then, once an hour, a PC retrieves readings from the data logger and forwards a data file to the monitoring system. The monitoring software checks the readings and, seconds later, issues an alarm. In this scenario, response time could be as long as one hour. Is that good enough?

If the intent of monitoring is evaluating performance, then a response time of minutes or even hours is probably acceptable. Alarms, in this case, are meant to focus attention on disturbing trends so that corrective actions can be taken. However, if intent of monitoring is to warn of a sudden event, such as a mudslide or a rockfall, then a response time of just a few seconds is required. This is the domain of dedicated, real-time monitoring systems with rapid reading rates, in-logger processing, and on-site alarms.

Fiber-Optic Sensing Systems

In December 2010 GIN, page 32, I tabulated eight commercial sources of fiber-optic sensing systems. Table 2 gives three more:

Table 2. More commercial sources of fiber-optic sensing systems

Company Name and Country	Website
Fibersensing, Portugal	www.fibersensing.com
Laser Solutions, Russia	www.lscom.ru
Marmota, Switzerland	www.marmota.com

Instrumentation Courses in Florida

There appears to be ongoing interest in these courses—for the April 2011 course there were 76 registrants from 14 different countries. The next course is planned for March or April 2013. Information will be on http://conferences.dce.ufl.edu/geotech in late summer next year.

Next International Symposium on Field Measurements in Geomechanics (FMGM)

As many of you will know, FMGM symposia are organized every four years, the previous one being in Boston in September 2007. They are "the places to be" for folks in our club. The next FMGM will be in Berlin, Germany on September 12-16, 2011. Information is on www.fmgm2011.org. I've just seen the detailed program which, at the time of writing, is not yet on the web. LOTS of papers and presentations about new and emerging technologies! Worthwhile to join us.

Corporate Changes

There have recently been three of these:

Applied Geomechanics

Founded in 1982 by Dr. Gary Holzhausen, Applied Geomechanics Inc. (AGI) began as a tiltmeter manufacturing company in Santa Cruz, California. After 25 years in the manufacturing industry, AGI was purchased by Pinnacle Technologies, a wholly owned subsidiary of Carbo Ceramics (NYSE:CRR). In the summer of 2007 AGI moved its headquarters from Santa Cruz to San Francisco, California, joining Pinnacle's base of operations. Pinnacle, a service company working in the oil and gas sector, purchased AGI to expand its instrumentation services into the civil engineering and mining markets. As a result of the merger, AGI added a variety of cutting-edge technologies, such as precision GPS and fiber optics, to its instrument and service product lines. In the fall of 2008, Carbo Ceramics sold Pinnacle Technologies to Halliburton, but retained AGI to further its growth.

Today AGI continues to sell precision equipment and services to a range of markets including volcanology, mining, heavy construction, bridges, and astronomy. AGI is currently headquartered in San Francisco, California with satellite offices in Denver, Chicago and Boston. Current management comprises: Gary Holzhausen, General Manager; Jeff Keller, Sales Manager; Jeff Crook, Engineering Manager; Tom Weinmann, Manager of Structural Health Monitoring; Alan Jones, Manager of Special Projects. For more information, please visit our website at www.geomechanics.com.

Durham Geo Slope Indicator

Durham Geo Slope Indicator is a leading manufacturer of geotechnical instruments, materials testing equipment, and environmental pumps. The company has ISO-certified manufacturing and R&D operations in Georgia and Washington states in the USA, and its products are used worldwide by consulting engineers and scientists, universities, government agencies, research laboratories, and civil and environmental construction companies.

In September 2009, DGSI became part of Nova Metrix LLC further strengthening the brand and significantly expanding the company's reach. For more information on Nova Metrix and Durham Geo Slope Indicator, please visit the company's websites at www.nova-metrix.com and www.slopeindicator.com.

Roctest

On December 10th 2010, Nova Metrix LLC, through a wholly owned subsidiary ("Nova Metrix"), completed the acquisition of Roctest Ltd. and its subsidiaries, Smartec SA, Telemac SAS, FISO Technologies Inc. and EnOmFra SAS ("Roctest").

Nova Metrix is a privately held company based in Woburn, Massachusetts, USA. Nova Metrix, through its subsidiaries and affiliates, designs, manufactures and markets test and measurement instrumentation solutions.

Nova Metrix, which also owns Durham Geo Slope Indicator, represents one of the largest producers and suppliers of instrumentation solutions for geotechnical and structural health monitoring. Nova Metrix has combined the extensive experience and expertise in traditional sensing techniques, fiber optic sensing, system integration, and data analysis.

For more information on Nova Metrix and Roctest, please visit our websites at www.nova-metrix.com and www.roctest-group.com.

Closure

Please send contributions to this column, or an abstract of an article for GIN, to me as an e-mail attachment in MSWord, to john@dunnicliff.eclipse.co.uk, or by mail: Little Leat, Whisselwell, Bovey Tracey, Devon TQ13 9LA, England. Tel. +44-1626-832919.

Na zdravie (Slovakia)

Who Should be Responsible for Monitoring and Instrumentation During Construction?

John Dunnicliff

Introduction

We all know that geotechnical construction of is not an exact science, and that therefore monitoring often plays a crucial role in ensuring that the project site and surrounding properties are safe, and meet the designer's intent. Monitoring often includes the use of geotechnical instrumentation. If significant decisions are to be based on the monitoring data, it's imperative that data quality is maximized.

If instrumentation is used, the tasks include:

1. Buying instruments
2. Installing instruments
3. Collecting data
4. Interpreting data

How can we ensure that these tasks are assigned to the people who are most likely to maximize quality?

The Golden Rule

The golden rule is: **The people who have the greatest interest in the monitoring and instrumentation data should be given direct responsibility for obtaining the data.** Or put another way, who has the motivation to do these nit-picking tasks with enough care?

Who has the motivation to do these tasks with enough care?

Who are the Candidates for Task Assignment?

They are the staff of:

- The project owner
- The project designer
- The construction manager
- The general construction contractor
- Possibly a design/build contractor
- Often a specialist geotechnical subcontractor.

The selection depends on the specifics of each project, on who has "the greatest interest".

The selection depends on who has the greatest interest

If general construction contractors, design/build contractors or specialist geotechnical subcontractors (with the agreement of the general construction contractor) have initiated the monitoring program, clearly they have the greatest interest, and all's well. But if the program has been initiated by the designer of the project, personnel in these three organizations may not have enough motivation to ensure quality. Let's look at the options for this situation.

Options for Assignment of Tasks 1, 2 and 3 when the Monitoring Program has been Initiated by the Designer of the Project.

Let's call these three tasks of buying and installing instruments and collecting data "field instrumentation services". Use of the conventional low-bid procedure, whereby these tasks are included as items in the construction bid schedule, has often led to poor quality data. Is there an alternative? Yes, there is.

There are four specific reasons for assigning responsibility for field instrumentation services to personnel selected by the project owner or designer and under direct contract with the project owner.

There are four reasons for assigning responsibility to personnel under direct contract with the project owner.

First Reason – Quality of Data

General construction contractors may not have enough motivation to ensure quality. A few years ago a UK colleague and I put together some ideas about how to maximize quality when the monitoring program has been initiated by the designer of the project. We made a strong plea for using a qualifications-based selection procedure for field instrumentation services. If you have any interest, you can download these ideas from (www.geotechnicalnews.com/instrumentation_news.php and scroll down to the only entry for 2001). Our preferred option is that the people responsible for field instrumentation services should be selected by the project owner or designer and under direct contract with the project owner. Our publication includes many comments from the technical literature in support of a qualifications-based selection procedure, which can be useful when trying to convince decision-makers to accept this method.

Second Reason - Cost

Colleagues at Mueser Rutledge Consulting Engineers in New York discuss the issue from the viewpoint of an instrumentation subcontractor to the general construction contractor (see www.geotechnicalnews.com/instrumentation_news.php and scroll to *Geotechnical Instrumentation News, Sept. 2009*). They warn:

> *The award of instrumentation work based on the 'bottom line' includes little consideration for quality, if any at all … After the contract is awarded to a construction contractor, potential instrumentation subcontractors are invited to re-bid, so that the construction contractor can compare line item breakdowns. Instrumentation bidders revisit their costs and strip contingencies. The firm ultimately awarded the work is likely to have assumed that the more stringent specification requirements will not be enforced.*

In my own experience as an instrumentation subcontractor in USA, this "stripping" can be up to 20%. Let's look at whether owners get a fair deal if this happens. As an example, if the amount assigned for field instrumentation services in the construction contractor's bid is $800,000 the project owner pays that amount, but only receives work that costs $640,000. There's a strong message for owners there.

Third Reason – Adequacy of Baseline Data

If construction work is likely to impact on neighboring structures, and monitoring with instrumentation is required to mitigate the impact, there's another important reason for favoring a contract directly with the project owner. If field instrumentation services are included in the general construction contract, monitoring can't start until the award of that contract. In that case there's rarely sufficient time to establish adequate records of pre-construction behavior (baseline data). Structures move and groundwater regimes often change from season to season, and monitoring data cannot be interpreted correctly if adequate baseline data are not obtained.

Fourth Reason – Greater Cost and also Lack of Conformance on Multi-general Contract Projects

For multi-general contract projects, there would be one monitoring subcontractor for each construction contract, hence greater cost when compared with a single assignment.

For multi-general contract projects, the various monitoring subcontractors would probably make different selections of web-based data management software, so that contract-to-contract comparisons would be difficult. This also places a heavier burden on a construction manager needing to become simultaneously proficient in more than one system.

Recommendations for Assignment of Tasks 1, 2 and 3 (Buying and Installing Instruments and Collecting Data) when the Monitoring Program has been Initiated by the Designer of the Project.

My recommendations are given in Table 1.

Table 1. Recommendations for assignment of tasks 1, 2 and 3 when the monitoring program has been initiated by the designer of the project

Type of Monitored Data	Recommendations for Assignment of Tasks 1, 2 and 3
Pre-construction baseline data	Specialist firm under contract with the project owner
Data during construction, outside general construction contractor's work area	Specialist firm under contract with the project owner
Data during construction, within general construction contractor's work area	Either: • Construction manager, with assistance from general construction contractor for access as necessary, or • Specialist firm as assigned subcontractor, instrument suppliers as assigned suppliers (see box on next page), or • General construction contractor, with partnering and rigorous and **enforced** specifications.

Options for Assignment of Task 4 (Interpreting Data) when the Monitoring Program has been initiated by the Designer of the Project.

Clearly the people who initiated the monitoring program should have a role in interpreting the data. However, the general construction contractor MUST pursue a parallel effort, and construction documents must specify that the general construction contractor has the **primary** responsibility for interpretations and must stay on top of the data flow at all times.

Closing Comments

I know very well that it isn't easy to convince owners (and project managers in design firms, who supposedly have the owner's interests at heart) that it's in their interest to adopt the above recommendations, **but it is!** Join the campaign to ensure that the people who have the greatest interest in the monitoring and instrumentation data should be given direct responsibility for obtaining the data.

Join the campaign!

John Dunnicliff

Assigned Subcontractor and Assigned Supplier

When the *assigned subcontract* method is used for installing instruments and collecting data, the project owner or designer negotiates with specialist firms, selects one firm using a qualifications-based selection procedure, and assigns the contract to the construction contractor for administration. Payment is made on the basis of actual work done, and the cost is included in the total bid price. A line item in the bid schedule is designated as an *allowance item* and *Provide Services of Specialist Field Instrumentation Personnel* is entered in the description column. The cost estimate is included in the bid schedule. An explanation of this procedure is included in the contract documents. After contract award, the construction contractor is instructed to enter into a subcontract with the assigned subcontractor, and payment is made to the subcontractor via the construction contractor under the allowance item. The construction contractor's monthly payment requests to the owner are supported by including copies of subcontractor invoices. The cost estimate should not be regarded as a not-to-exceed figure, and the contract price should be increased by change order if needed.

Opposition to this procedure sometimes includes the concern that the subcontractor, who has been selected by the project owner or designer, is under contract with the construction contractor, hence is there uncertainty about contractual commitment? In my experience, with appropriate people-communication, this has never been a problem in the field.

When the *assigned supplier* method is used for buying instruments a similar procedure is used with another allowance item, *Furnish Instruments*. The specification states that, after contract award, the owner's representative will determine instrument descriptions, sources, quantities, and prices and will provide this information to the construction contractor. The contractor is then required to place orders, within a specified time period, and the instrument suppliers become assigned suppliers.

Displacement Monitoring by Terrestrial SAR Interferometry for Geotechnical Purposes

Paolo Mazzanti

Acronyms Used in this Article

- GPS: Global Positioning System
- RTS: Robotic total stations
- SAR: Synthetic Aperture Radar.
- SInSAR: Satellite SAR Interferometry
- TInSAR: Terrestrial SAR Interferometry
- TLS: Terrestrial Laser Scanner
- DTM: Digital Terrain Model

Introduction

The geotechnical community is looking with increasing interest at emerging technologies. Innovative techniques able to solve problems that have been unsolved for decades are now available. However, geotechnical engineers and engineering geologists must be confident on their effectiveness before applying them, and especially on the reliability of collected data. Remote sensing techniques are one of the main innovations in the field of geotechnical monitoring, since they are changing the philosophy from "contact" to "non-contact" monitoring. In other words, by remote sensing techniques, some geotechnical parameters are collected by equipment located away from the investigated area. However, ground-based remote sensing instruments such as manual or robotic total stations and GPS (Global Positioning Systems) cannot be defined as fully "non-contact" instruments since they need targets or sensors installed on the monitored ground or structure. Among the ground-based techniques, only Terrestrial Laser Scanner (TLS) and the Terrestrial SAR Interferometry (TInSAR) can be considered completely "non-contact" remote sensing techniques.

The first prototypes of TInSAR were developed at the end of the 1990s, and the first commercial equipment dates back to 4-5 years ago. Seven years experience with TInSAR has allowed me to follow this technique from its first steps to the first long-term and successful applications for complex geotechnical problems.

In what follows, the basic principles of this technique, together with a detailed description of its performance, main advantages and limitations and lessons learned from real cases will be discussed.

Theoretical Basis and Performance

The Terrestrial SAR Interferometry (Bozzano et al. 2010; Luzi 2010) is a displacement monitoring technique based on the same operational principles of Satellite SAR Interferometry (Massonet & Fiegl 1998). The SAR principle consists of a combination of several radar images collected while the emitting and receiving antennas move along a predefined trajectory (an orbit for a satellite, a route for an airplane or a rail in the case of terrestrial equipment) (Figure1). The

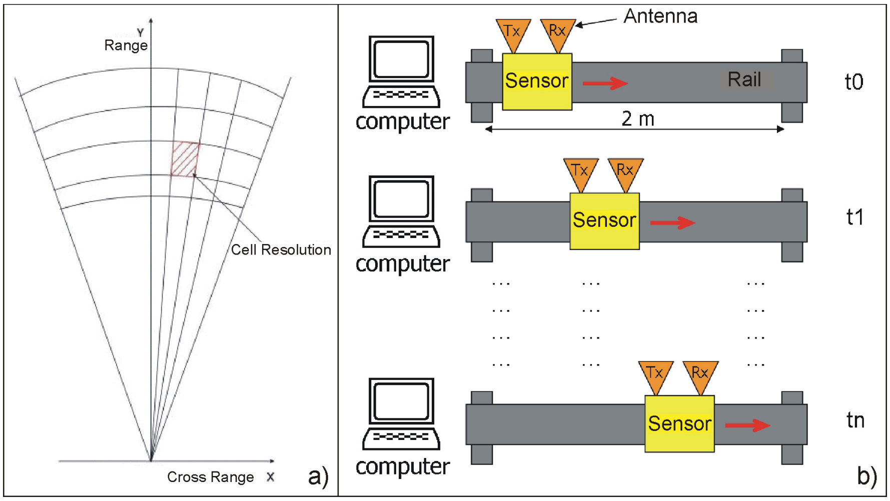

Figure 1. a) Resolution cell of RADAR maps; b) Synthetic aperture obtained by an antenna moving along a rail.

combination by the focusing technique of radar images that are acquired during the movement of the antennas allows 2D SAR images to be obtained. These images are characterized by range (instrument-scenario joining direction) and cross-range (direction normal to the range direction in the horizontal plane) resolution (Figure 1). The final SAR image consists of several pixels whose size strongly depends on the equipment features and on the radar-scenario distance.

By comparing the phase difference, i.e interferometric technique, of each pixel of two or more SAR images collected at different times, the displacement along the instrument line of sight can be estimated by using the following equation:

$$d = \frac{\lambda}{4\pi}\Delta\phi$$

where *d* is the displacement, λ is the wavelength of the radar signal and Δϕ is the phase difference between the two acquisitions. However, additional processing aiming at remove the atmospheric noise is required. The final output of TInSAR monitoring is 2D color images where the magnitude of displacements along the instrumental line of sight, in the computed elapse of time, can be quickly identified (Figure 2). In addition, displacement time histories of each pixel of the image can be achieved.

The pixel resolution of a SAR image ranges from few decimeters to several meters (depending on the equipment and on the monitoring distance) and the displacement accuracy ranges from few tenths of millimeters to a few millimeters, depending on the operational distance and the atmospheric conditions. For example, at a distance of 1 km, commercial equipment has a range resolution of about 0.5 m and a cross-range resolution of 4 m; as regards the accuracy values ranging from 0.5 to 3 mm are reasonable at a distance of 1 km. This equipment has a maximum range capability of few kilometers and a maximum temporal frequency of images collection of few minutes. However, future TInSAR equipment is expected to be faster in data collection and smaller in size.

Advantages and Limitations

As already stated, TInSAR is one of the two "real" remote monitoring sensing techniques, since it does not require the installation of sensors or targets in the monitored area. This is probably one of the main advantages of TInSAR as the access to the monitored areas is often dangerous (e.g. active landslides), difficult (e.g. cliffs) or prohibited by local authorities, such as heritage situations. Sometimes, we are faced with movements so rapid, e.g. rapid landslides, that sensors are quickly destroyed or made unusable. In these cases remote TInSAR monitoring can be an efficient solution. An additional advantage is related to the control of an area (i.e. pixel) instead of single points identified by sensors, reflectors etc. This feature can reduce the misinterpretation, which is a frequent problem in the case of points-based monitoring. On the other hand, the analysis of an area instead of a point can also be a limitation if this area behaves in a heterogeneous way, or if the monitoring of a specific point is required. In these cases passive corner reflectors for TInSAR can be installed, thus allowing the increase of the signal to noise ratio of the pixel and also the precise identification of the monitored point.

A further advantage of TInSAR is the full operability under all lighting (day and night) and weather conditions (rainfalls, clouds, fog etc).

A significant advantage is the ability for "spatial" monitoring. This means that TInSAR can be used to simultaneously monitor the displacement of

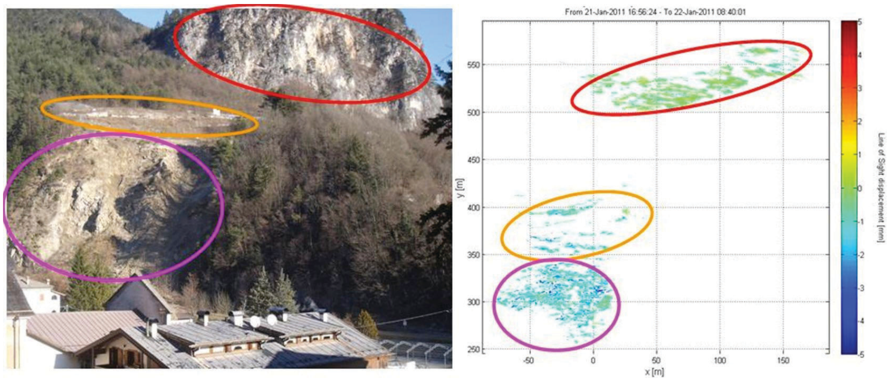

Figure 2. Picture of a slope (on the left) and TInSAR displacement image (on the right). Color ellipses enclose corresponding parts of the investigated slope.

several adjacent pixels over large areas. In other words, TInSAR images can be seen as a very dense network of adjacent sensors (i.e. pixels) collecting data simultaneously over a large area. The main practical advantages of this feature are:

- increasing the statistical reliability of monitored displacements because data are collected in several adjacent pixels
- monitoring of large areas, thus avoiding the risk of underestimating the size of the displacement area
- identification of spatial distribution and gradient of displacement.

Additional features such as the high data sampling rate (few minutes), long range efficacy (up to some kilometers) and the high accuracy in the displacement measurement make this technique a valuable monitoring solution for appropriate geotechnical problems.

However, in spite of its advantages, this technique is characterized by some limitations which must be taken into account. The difficulties in the management, processing and interpretation of data are probably the main limitations. Mistakes can be made if the technique is not used in the appropriate way and if data are not analyzed carefully. Some additional limitations related to technical features are:

- the large size of commercial equipment, having a rail of at least a couple of meters long
- the cone of view is limited to a few tenths of degrees (depending on antennas) in the horizontal and vertical planes
- the displacement can be measured only along the line-of-sight direction, i.e., the displacement monitored by TInSAR is only a component of the real displacement
- phase ambiguity, i.e. the displacement between two subsequent images can be measured without ambiguity only if the phase difference is lower than π/2 (about 4.5 mm for the typical signal frequency used by the Terrestrial SAR Interferometers).

However, the above mentioned limitations can be reduced by a careful monitoring planning (in terms of the installation site and the monitoring plan). For example, in order to optimize the displacement detection capabilities the equipment can be installed as parallel as possible to the real displacement direction. The phase ambiguity can be solved (up to a threshold velocity on the order of meters/day) by a high data sampling rate.

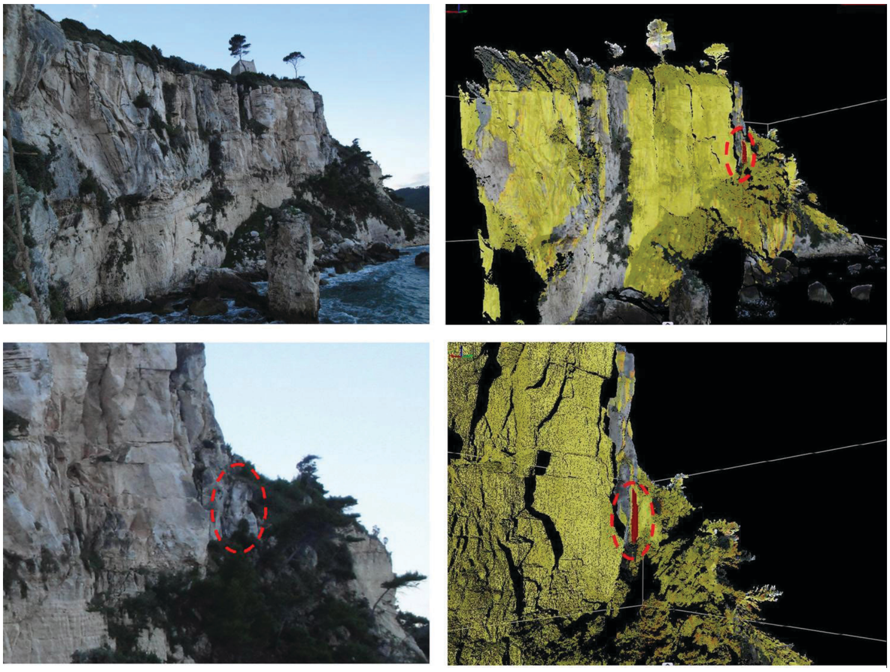

Figure 3. Picture of a costal rock cliff in the southern part of Italy (on the left). On the right, 3D displacement images achieved by the combination of TInSAR image and TLS DTM (Digital Terrain Model); yellow-green color identifies stability while red color identifies sectors affected by displacements.

Comparison with Conventional Techniques

The first comparison of TInSAR should be with Satellite SAR Interferometry (SInSAR), since they are based on the same operational principle. However, due to the different platforms (ground-based and satellite-based respectively) there are several differences between them, especially in terms of achievable results. SInSAR is a suitable technique for monitoring large areas characterized by slow movement (e.g. subsidence, volcanic structures, unstable regions etc.), while TInSAR is more suitable for the detailed and continuous monitoring of small areas, up to few square kms, that are characterized by both slow and rapid movement (e.g. single unstable slopes and cliffs, volcanic flanks etc). Also, due to the low data sampling rate (about one image per month), SInSAR is not suitable for control and continuous emergency monitoring, but is more appropriate as an investigation tool (especially if the historical database of satellite images available from 1992 is considered). In contrast, TInSAR images can be collected only after the installation of equipment.

The comparison of TInSAR with robotic total stations (RTS) is probably more appropriate because these techniques are often used for similar applications, even though they are based on different operating principles. In what follows a brief comparison between these two techniques is given. First of all, RTS is based on Laser technology, while TInSAR is based on Radar technology; i.e. RTS uses Light or Infra-Red waves while TInSAR uses Microwaves. From the practical point of view the main difference is related to the monitoring effectiveness of TInSAR with the presence of fog and clouds (not acceptable for RTS). Furthermore, RTS requires the installation of targets in the monitored area while

TInSAR is a completely remote monitoring technique. This is an important feature when faced with heritage situations and unsafe areas such as landslides.

On the other hand TInSAR can only measure line-of-sight displacements while RTS can be used for measuring the 3D displacement field.

The accuracy of displacement monitoring of the two techniques is difficult to compare, since it strongly depends on processing solutions and specific site conditions. However, experiments under ideal conditions have demonstrated that similar accuracies can be achieved.

Successful Applications and Lessons Learned

In recent years successful applications of TInSAR have demonstrated that such a technique is a very powerful and versatile solution for the monitoring of different types of geotechnical and structural engineering problems, and especially for the continuous monitoring in emergency conditions, e.g. landslides and volcano flanks. The recent application at an unstable slope overlooking an artificial lake in a mountainous region (up to 3000 m above sea level), frequently affected by fog, demonstrated the effectiveness of TInSAR under any weather conditions: a basic requirement for 24/7 emergency monitoring.

But in the author's experience, the most complex application of TInSAR has been the monitoring of a slope affected by construction of a tunnel. Because of the presence of a large and deep active landslide in rock material, continuous monitoring of the slope stability was required. Displacement monitoring by conventional on-site techniques (e.g. inclinometers, total stations, GPS) was difficult due to the geomorphology of the area and the ongoing construction work at the tunnel entrance (gabions, anchored bulkheads etc). Furthermore, a technique with minimum intervention of personnel on the slope for installing instruments or targets was necessary for 24/7 emergency monitoring. The continuous monitoring of this slope by TInSAR, from a distance of about 1 km, allowed monitoring of every type of displacement that affected the slope: excavated debris, gabions, bulkheads etc. This allowed engineering decisions to be made efficiently, such as stopping tunnel excavation as a consequence of sudden increases of slope displacement such as an increase of one order of magnitude of the velocity in a few hours. 3½ years of continuous monitoring by TInSAR, continuing to this date, demonstrated the long-term reliability of this technique and its effectiveness in monitoring both rapid and slow movements. This feature, together with the capability of monitoring without any targets on the slope, makes TInSAR particularly suitable for the monitoring of ground movements that are characterized by a high and non-homogeneous velocity field and little vegetation cover. In addition to the project just described, several cases of ground movement have been monitored by TInSAR in recent years, both for emergency and investigation purposes.

Further suitable applications of TInSAR for geotechnical problems are the monitoring of dams and mines.

But the new frontier of TInSAR is probably monitoring for investigation purposes. For example, displacement monitoring of several points over large areas by TInSAR has recently been proven for susceptibility analyses of cliffs. In this application TInSAR has been used for determining and mapping the most susceptible sectors of cliffs, slopes and man-made structures.

The monitoring of buildings and heritage situations in urban areas is a new challenge for TInSAR. On one hand there is the great advantage of having highly accurate displacement images by a non-contacting technique, but on the other hand there must be separate monitoring for vertical movements. At present, combining with conventional techniques is considered a basic requirement in such applications.

Conclusion and Outlook

Terrestrial SAR Interferometry is an emerging technique for geotechnical monitoring. Although not yet extensively used in common practice, TInSAR has been successfully proven for monitoring some geotechnical problems such as landslides and dams, and is a promising method for some others, such as cliffs and buildings. The high price of equipment and the complexity of data processing and interpretation of results can be considered the main limitations for extensive use of this technique. However, TInSAR can be more efficient than conventional monitoring, and in some cases also less expensive if rational monitoring plans are made. Private companies specializing on TInSAR already exist. Furthermore, the combination of TInSAR with other techniques such as Terrestrial Laser Scanner and robotic total stations may further strengthen its effectiveness and simplify the interpretation of results—see an example in Figure 3.

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Geoscope Web-based Data Management Software

Martin Beth, Soldata

Introduction

This is not a product presentation but rather a general paper about web-based data management software. In this short one-pager I shall first list the typical level of expectation nowadays, based on my understanding of technical specifications from all size projects in US, Europe and Asia, and then indicate some important issues and lessons learned from our experience.

The Standard Expectations

All clients nowadays expect the following:

- Data to be displayed on the Internet as soon as collected.
- Full Internet access, password protected, available on PC, tablets or mobile phones.
- Graphical site views, helping the users to understand the large flow of data coming towards them. These views should combine flexibility and simplicity, different graphs types, etc…
- Ability to integrate all types of automatic or manual data, for any type of sensor.
- Ability to carry out various calculations of the data.
- Alarms by mail and SMS.

First Important Issue: Scalability

The software should be simple and easy to use and be applicable for small sites. But it should also have the capacity to handle mega-sites such as for example Barcelona Linea 9 Metro Line, where we currently have 1.5 billion data from over 50,000 measurements points, inside a 130 Gb database.

The risk of too much data should be overcome. The system should help the user to remain in control of the data flow; it should include tools to simplify, to filter and to sort the data. This is neither easy nor obvious.

Second Important Issue: Security

What happens if something goes wrong with the monitoring system itself? The following two main features should be available:

- There should be a watchdog computer somewhere, separate from the site and from the database, checking that the monitoring system and the module in charge of sending the alarms are working properly, have operational internet access, etc….
- It must be remembered that SMS are not considered as a certified and secured system. Have you never received an SMS a few hours or even a few days after it was written? The software should include an automatic repeat mode or even an automatic escalation process until the alarm has been acknowledged.

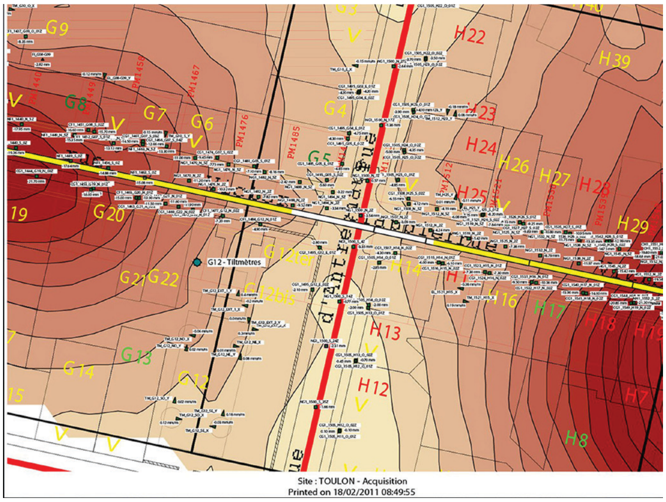

Figure 1. An isolign plot of road surface and buildings settlement, and the tunnel advance (yellow line), both updated automatically in "real time".

Security against data loss is crucial. Storage of intermediate data at different steps along the data flow line should also be implemented. Furthermore the system should have the capability to process past data when restarted.

Third Important Issue: Data Presentation and Data Analysis

From our experience:

- 3D interactive "computer game" type site views are very nice and sexy and will add a strong positive feeling about the software. But in reality let's face it; they are not a lot of use to the engineer. Over the past 10 years and say 500 monitoring sites, we have probably used this functionality a dozen times.
- On the contrary it is of the utmost importance for the software to be able to integrate external information of parameters affecting the data, like tunnel face position, comments by the users about the data, geological log reports, grouting data, and other external event likely to influence the results. The system should include a log book, for users to enter any type of information, and it should be possible to view this information on the graphs.
- Isolign plots are also useful in grasping rapidly a global idea of the site behaviour. See Figure 1.

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SHMLive Web-based Data Management Software

Daniele Inaudi, Roctest / SMARTEC

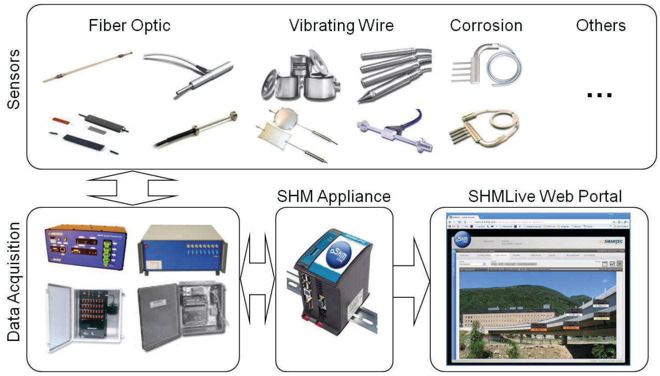
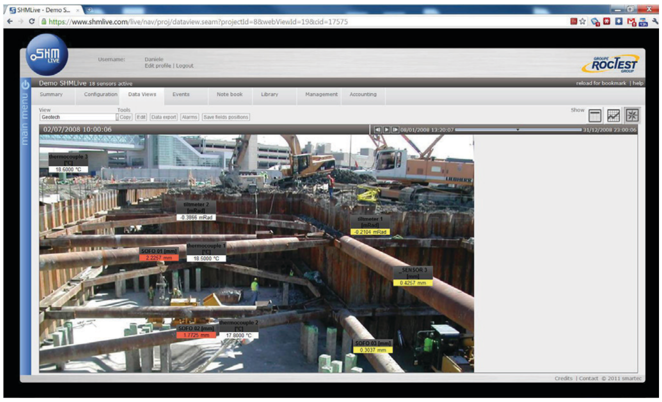


Figure 1. SHMLive System Architecture.



Username: Daniele
Edit profile | Logout

Demo SHMLive 18 sensors active

View: Geotech

02/07/2008 10:00:06

08/01/2008 13:20:07 – 31/12/2008 23:00:06

thermocouple 3 [°C] 18.6000 °C

tiltmeter 2 [mRad] -0.3866 mRad

tiltmeter 1 [mRad] -0.2104 mRad

SOFO 01 [mm] 2.2257 mm

thermocouple 1 [°C] 18.5000 °C

_SENSOR 3 [mm] 0.4257 mm

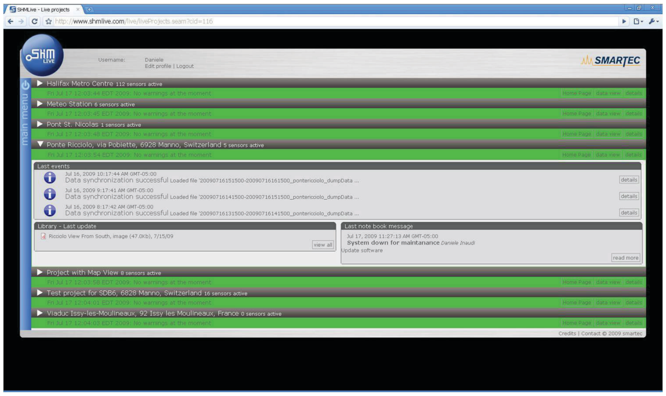
SOFO 02 [mm] 1.7725 mm

thermocouple 2 [°C] 17.8000 °C

SOFO 03 [mm] 0.3037 mm

Credits | Contact © 2011 smartec

Figure 2. Map data representation example.



Username: Daniele
Edit profile | Logout

Halifax Metro Centre 112 sensors active
Fri Jul 17 12:03:44 EDT 2009: No warnings at the moment

Meteo Station 6 sensors active
Fri Jul 17 12:03:45 EDT 2009: No warnings at the moment

Pont St. Nicolas 1 sensors active
Fri Jul 17 12:03:48 EDT 2009: No warnings at the moment

Ponte Ricciolo, via Pobiette, 6928 Manno, Switzerland 5 sensors active
Fri Jul 17 12:03:54 EDT 2009: No warnings at the moment

Last events
Jul 16, 2009 10:17:44 AM GMT-05:00
Data synchronization successful Loaded file '20090716151500-20090716161500_ponterricciolo_dumpData ...
Jul 16, 2009 9:17:41 AM GMT-05:00
Data synchronization successful Loaded file '20090716141500-20090716151500_ponterricciolo_dumpData ...
Jul 16, 2009 8:17:42 AM GMT-05:00
Data synchronization successful Loaded file '20090716131500-20090716141500_ponterricciolo_dumpData ...

Library - Last update
Ricciolo View From South, image (47.0Kb), 7/15/09

Last note book message
Jul 17, 2009 11:27:13 AM GMT-05:00
System down for maintanance *Daniele Inaudi*
Update software

Project with Map View 8 sensors active
Fri Jul 17 12:03:58 EDT 2009: No warnings at the moment

Test project for SDB6, 6828 Manno, Switzerland 16 sensors active
Fri Jul 17 12:04:01 EDT 2009: No warnings at the moment

Viaduc Issy-les-Moulineaux, 92 Issy les Moulineaux, France 0 sensors active
Fri Jul 17 12:04:03 EDT 2009: No warnings at the moment

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Figure 3. SHMLive project summary page.

Web-based services are becoming the new standard in reliable and cost effective mission-critical business applications, such as email, customer relationship management tools or document exchange. In the same way that it makes sense to operate your own power generation station in house, the management and publication of monitoring data is more efficiently managed by instrumentation and IT professionals, rather than civil or geotechnical engineers or owners.

The SHMLive web portal is a secure hosted website coupled with an online database that manages and displays monitoring data in real-time anywhere in the world. SHMLive web portal is a part of Roctest's complete SHMLive offering, which can also include full monitoring services, such as design, installation and all hardware, provided for a fixed monthly fee.

The SHMLive database can receive data from a large variety of measurement systems and sensors such as vibrating wire instruments, fiber optic sensors, laser sensors, concrete corrosion sensors, and any type of electrical sensors. As depicted in Figure 1, data is automatically pushed to the SHMLive database from our SHM Appliance, which collects the data directly from all installed data acquisition systems, without the use of text files or other intermediate data formats. All data is stored in our secure and redundant database system, located in a data center with the highest standards of reliability and security.

Authorized users gain access to their data through an easy to use online web portal where data is available 24/7 for display and downloading to Excel and other formats. The web interface allows different levels of authorization for data access and users can easily log on with any web browser or smart phone. The SHMLive web portal allows real-time alerting and advanced data representation, enabling an unlimited number of data views in table, graph or map plots (Figure 2) with associated options such as thresholds plots, X-Y plots and color coding. It is also possible to define warnings and alerts, based on individual sensors or free mathematical formulas, combining the values of multiple sensors. Alert levels, language of the user interface and delivery methods, such as email or text messaging, can be tailored to individual user preferences.

The Web portal also serves as an information hub, allowing the storage of complementary documents, reports, alert histories and log book entries, facilitating communication among all stakeholders within the monitoring project. A summary page (Figure 3) allows a quick overview of the status of all projects to which the user has access. The web-interface can be rebranded with the user logo, with links to any external websites containing complementary data, such as webcams or meteorological data.

The SHMLive portal is accessible at www.shmlive.com.

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Atlas Web-Based Data Management Software for Instrumentation

Rick Monroe, Durham Geo Slope Indicator

Atlas - the Project Web Site

Think of Atlas as a web site that is dedicated to a project. The pages of the web site include plan views and photographs of the project and contain links to data, graphs, and reports. Users log into Atlas with their web browsers.

Atlas provides three levels of access. "Administrators" can create new projects, authorize users, and set up sensors, graphs, plan views, alarms, and reports. "Users" can see graphs and plan views, enter manually-collected readings, and add notes and photos to the logbook. "Guests" can see only selected plan views and plots.

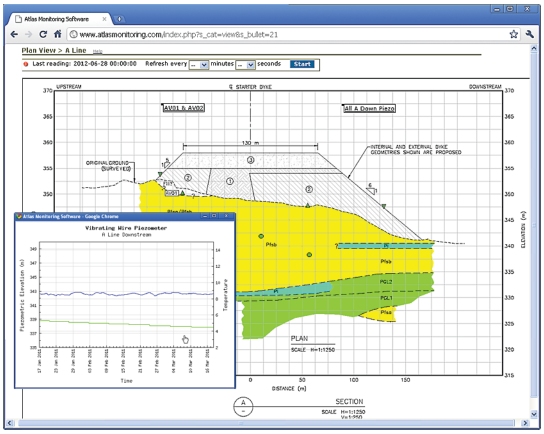
Data Collection

Atlas provides web forms to receive manually-collected readings, a logbook to receive notes and photos, and an input folder to receive data files forwarded from data loggers.

Atlas processes incoming data to check for alarm conditions, but it stores only the original, unprocessed readings in its database. Thus readings in the database remain directly traceable to readings collected at the site.

Data Processing

When Atlas generates a graph or serves data, it always processes the original readings on the fly. This makes calculations easy to verify, and it ensures that changes or corrections to calculations take effect immediately, with no need to purge and rebuild the database with corrected readings.



Plan View > A Line

Last reading: 2012-06-28 00:00:00 Refresh every -- minutes -- seconds Start

The core of the Atlas processing engine is the sensor table. It lists every sensor along with its calibration factors, unit conversions and labels, alarm limits, and processing instructions. Processing instructions accept most math functions and can reference earlier readings and other sensors. This makes it possible to calculate changes, correct for temperature and barometric pressure, and perform cumulative calculations for in-place inclinometers and beam sensors.

Data Presentation

Plan views are site drawings or photographs that show the location, current reading, and alarm status of all the sensors at a site. Sensors are represented as icons that change color to indicate their alarm status: green for normal, yellow or red for alarms. Mousing over an icon displays the current reading, and clicking on a reading calls up a trend plot. A quick look at the trend plot can reveal whether the alarm condition is the result of a trend or a transient event.

Plots present data graphically and automatically include the most recent readings. Atlas provides trend plots, profile plots, and correlation plots. Multiple Y scales allow different types of sensors to be shown on the same plot. Clicking the plot displays a table of the values used in the plot.

Reports present a daily, weekly, or monthly compilation of selected plots, data, log book entries, and photographs. Reports can be distributed automatically by email as PDF attachments.

Alarms and Notifications

When Atlas detects an alarm condition, it records the alarm in a logbook, displays an on-screen warning, and generates an alarm notification. An alarm notification is an email or sms message that identifies a sensor, the time and value of the reading, and the level of the alarm.

Atlas provides filters that help validate alarms, consolidate notifications, and delay or escalate notifications. This filtering improves user confidence in the alarm system and also prevents alarm notifications from flooding email boxes and cell phones.

Data Downloads and Archiving

Readings can be downloaded for analysis in other programs. After the user specifies sensors, a date range, and a data format, Atlas generates a text file that can be saved on a local PC and opened in a spreadsheet.

Data can be archived two ways. Archiving processed readings makes data available for historical investigations after completion of the project. Archiving the original readings provides a way to control the size of the database, though this function is rarely needed.

Software Response Time

The overall response time of a monitoring system is likely to be controlled by the rate of data collection rather than by the responsiveness of the software. That said, Atlas can serve graphs within one or two seconds, refresh plan views every few seconds, and send out alarm notifications seconds after the arrival of new readings.

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