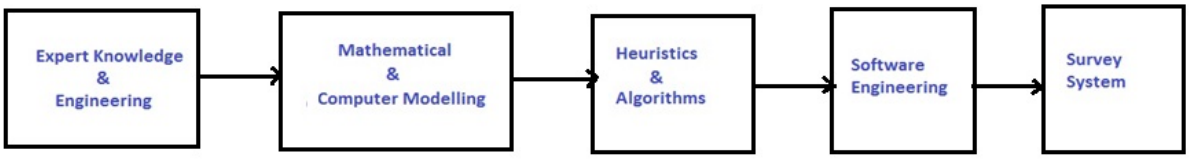
Expert System for Level Monitoring

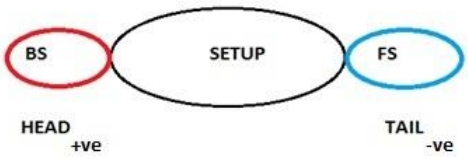
Methodology

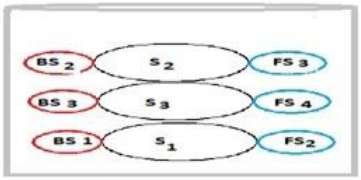
In Computer Science, an Expert System is a software solution that acts the mind of a human expert in a given field and so able to make complex decisions as would a professional. It is usually defined with respect to specific domains, and examples include Wizards/Assistants in many packages and more complex application of robots in industries. Also in the medical field, in the area of diagnosis and surgery, such applications are common. In the case of SMS, it may be described as an expert system for level monitoring.



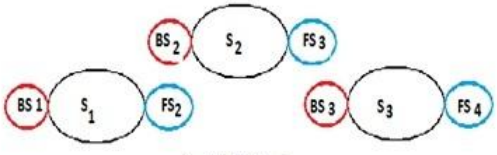
Surveying often involve subjective judgement and decision making, both in the field and office. As a result, a purely algorithmic approach to modelling solutions can lead to inflexible and rigid situations. There have been many a time when surveyors would return from field only to realise that direct input of data into a computer system is not possible. This could occur for a number of reasons, a change in modality for example, and thus inability to follow survey strategy and topology. However, the surveyor would eventually sort out this work manually and arrive at an acceptable result. And if the task can be done manually, it can also be handled by software. That requires introducing heuristics – intuition to survey algorithms, in order to equip survey systems with artificial intelligence.

Against this background, the methodology in SMS development starts with acquisition of survey expertise in order to provide the requisite knowledge engineering. It is followed by mathematical and computer models that represents the expert descriptions. Sound heuristics and algorithm then ensures a working expert system.





Container of raw data



Sorted field book

Data Structures

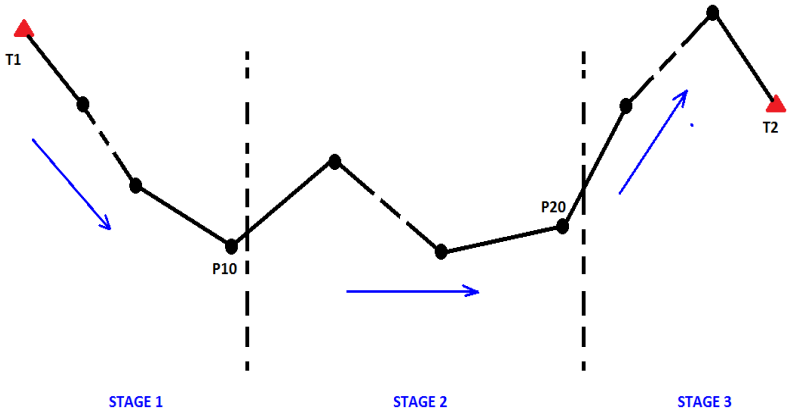
A key component in the design of SMS is object oriented programming. It allows data encapsulation and polymorphism. Survey observations are therefore attributes in object class with member functions. The base class definitions provide foundations for subsequent child objects in the hierarchy. A fundamental data structure is the defined data type, setup_obj. This structure holds all the observations for each level setup. By design, a setup_obj comprises of

core data, a Head and a Tail, with imaginary positive and negative poles respectively. As illustrated in the above diagram, these poles are pointers respectively for the Back Sight and Fore Sight stations. One can then visualize all such observations in a container of raw data file, in observed or random order. However, once the raw data is downloaded into the field book, program run exerts such a field that member functions re-align and sort data into survey topology.

By virtue of these designs, a survey can start from, in any order, and end at any point in a network. What is required is that every station has a unique identity, by unique numbering, and that the network is comprehensively observed to include at least one known and fixed station.

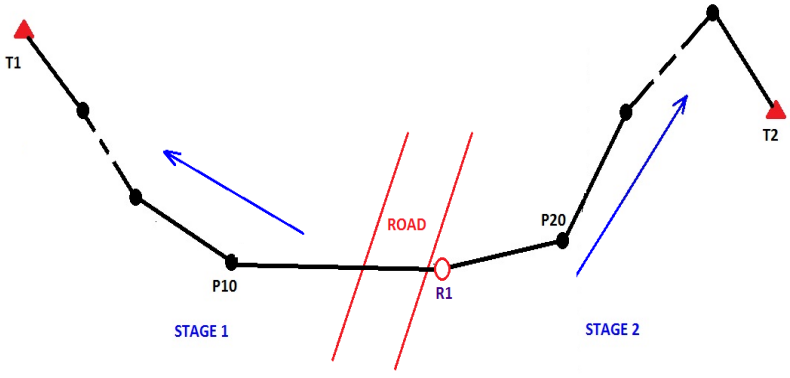
Applications

It is common to divide a survey project into sections, each assigned to a survey party. As illustrated in the diagram below, there may be up to three such stages. So each party may proceed at its own pace, complete work and download to office. The data may arrive in any order such as Stage2, Stage 3 and Stage 1. However, the data once in the field book is sorted into the order of T1-P10-P20-T2. Besides survey parties carrying out tasks on assigned sections, there are instances in a construction environment where a surveyor is not able to follow an ordered pattern of observations because of limited access. He could therefore proceed with Stage 3, Stage2 and later complete with Stage 1.



Resection

Surveyors often employ resection in theodolite work to get out of tight situations. This utility is so valuable that it is a standard function in Total Stations. The same concept could be applied in levelling to assist productivity. Suppose that two survey parties arrive at R1 in the diagram below to carry out a survey, T1-T2. It may be advisable to commence work forthwith, from R1-T1 and R1-T2, in order to complete within the available daylight. Otherwise, by the time the surveyor arrives to take position at T1, bad light or bad weather may have set in. In computation, R1 is



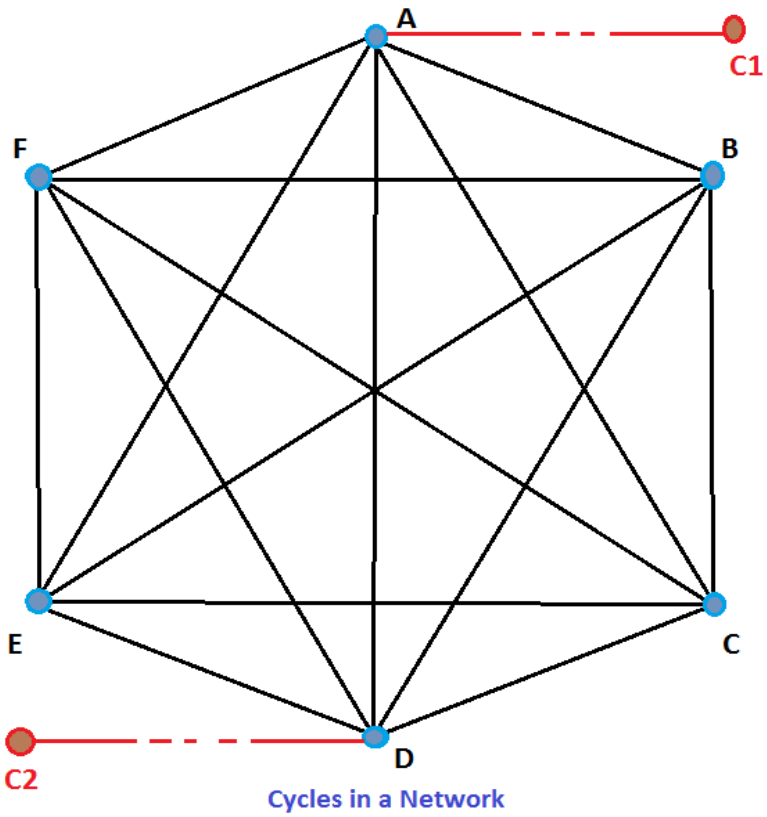
evaluated in a least squares routine so that the two stages can compute as normal. The results would be identical for the same readings as if observed from T1-T2. In other words, the result of a survey is not affected by direction of observations.

Processing

This is a single button action on the data in the field book. It includes collation and merging of field books used in data collection into a single data set. The control points are identified and verified in the observed data set. Next is a numerical description of the observed network, providing such information as the number of nodes, directions and node height differences. Often the actual network observed may be different from a reference network diagram if, the later was not followed strictly in the course of survey. Any confusion is resolved by analysis in numerical description of the network.

An important aspect of any processing is error analysis. This is provided in SMS by closures for every cycle or loop in the network. Actually, these cycles are expressions of Condition Equations. Before now, one needed to have a diagram of the network to be in a position to form such equations. And even with diagrams, it is an exercise that is fraught with difficulties. For instance, it would require an effort to unravel and form condition equations in the diagram, below. Actually, many surveyors do not even contemplate such exercise in a dynamic environment, except for a very small and well defined network.

SMS employs robust algorithms to evaluate all the Condition Equations in a network. This information enables surveyors to isolate any loop or set of observations for re-survey. It is an asset that has proved very useful in a client's work of more than 3000 setups of observations and about 200 loops. Within this large data set, it was possible to isolate errors to a few dataset and determine that they result from station numbering. Note that loops do not include double-levelled setups. These are normally resolved in one direction, as would be done manually.



Cycles in a Network

Overall, the combination of condition and observation equations ensures that error information is available with respect to consistency in the network and also the co-variance of surveyed stations.

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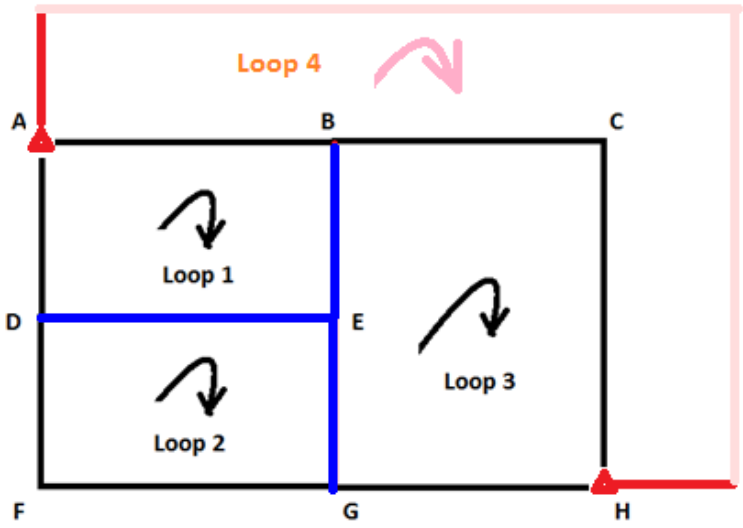
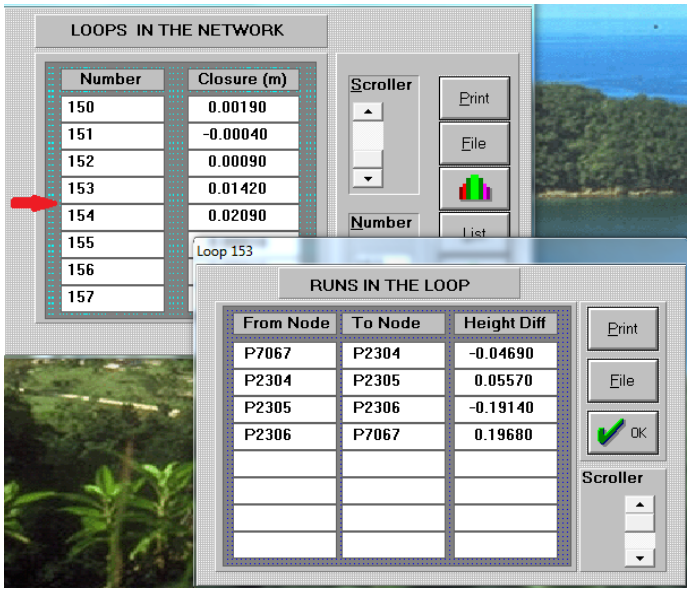
Application

We can illustrate applications further by the diagram below for a simple survey. There are three loops: Loop1, Loop2 and Loop3. There are also three common edges, DE, BE and EG. Suppose Loop3 and Loop2 have satisfactory closures, but not Loop1. Then an inspection would advise a review of observations for lines DA and AB. Similarly, if all the loops are good but not Loop4, then either of the Bench Marks A or H is suspect. Re-surveyed lines take immediate, effect once downloaded in the field book. No editing is required.



Against this background, the surveyor can cope with large level networks such as shown below. As can be seen, loops 153 and 154 are significant. By listing and comparing edges, errors can be detected before computations.



Computation

Users of SMS fondly describe the computations as “Bundle Adjustment”. That’s drawing some analogy with methods of Aero-Triangulation in Photogrammetry. However this description refers to automated nature of level computations. It used to be the case, that nodes are abstracted from the data set based on a network diagram. Then height differences are reduced and the nodes computed by method of Least Squares estimation. It is then followed by inter-node computations and error distribution. The third stage is to compute the height for all intermediate sights from each reference station. On the whole, this is obviously a fractured process that is prone to errors. The result is that in many organisations, survey work involving large level networks are inconclusive, even after weeks of processing and computation.

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These problems are overcome in SMS. In a single click of button, three computations are performed:

- Network adjustment by iterative method of Least Squares
- Inter-node computations
- Intermediate Sight computations

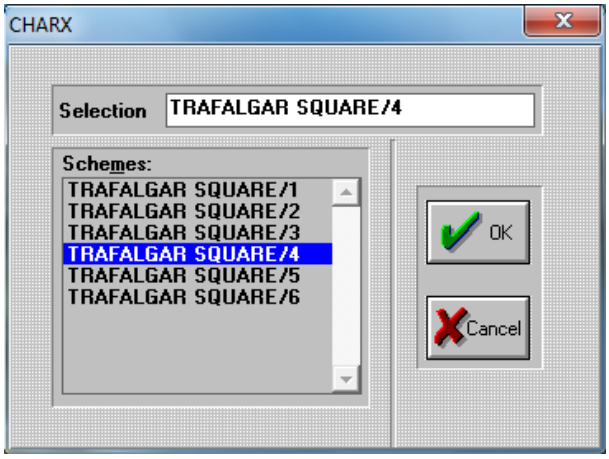
The results are generated with error information, statistics and graphic drawing of profiles for each level run in the network. By these techniques SMS ensures that a surveyor can resolve networks of any complexity, including the confidence to revalue fixed stations. Furthermore, this is achieved with savings in cost and time of up four weeks, in comparison with other methods.

Monitoring

Once data computation is complete, this information is available for application in monitoring, in 1 - 3 dimensions. The registration of each epoch is automatic and also dynamic, meaning that once a date is changed in the header file, it takes effect immediately. It is common in some organisations to rely on spreadsheets and word processors to present reports. This however requires manually creating and managing such database files. It is also inefficient because if the survey is re-computed, the exercise is repeated. Furthermore where stations are lost or new points added, in construction environment, the cumulative changes would also have to be done manually. In other words the elements of automated judgement of likely human decisions are missing. There is also the limitation in charting and graphing of monitoring results. SMS, on the other hand provides customized and optimal options such that the duration of any project is the period of field activity. It is truly a field to finish system.

Application

The first step in monitoring is to select an epoch, and thus the current visit. Hence all comparisons will be based at this point in time. This option allows users to review at random, specific visits. Once a choice has been made, the monitoring icon comes alive. Clicking this option then brings up the main menu. At this point, it is a matter of choice where data source is coming from. It could also be from 3-D Traverse or imports from GPS or other instrument systems.



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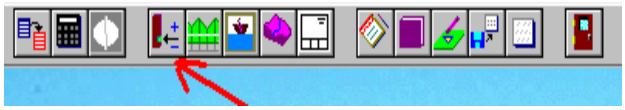
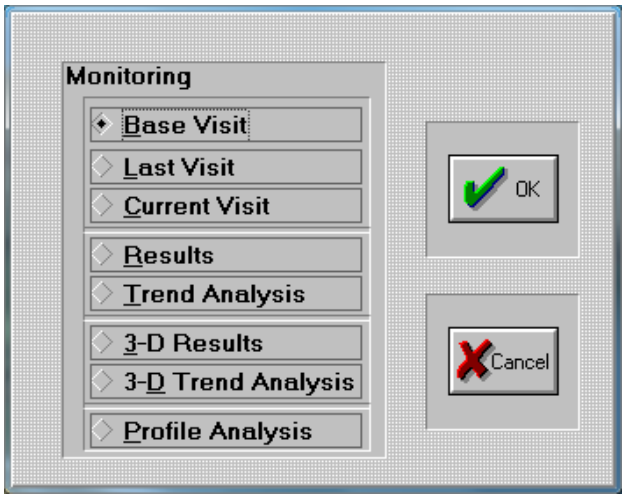
Main Menu
There are three key options:

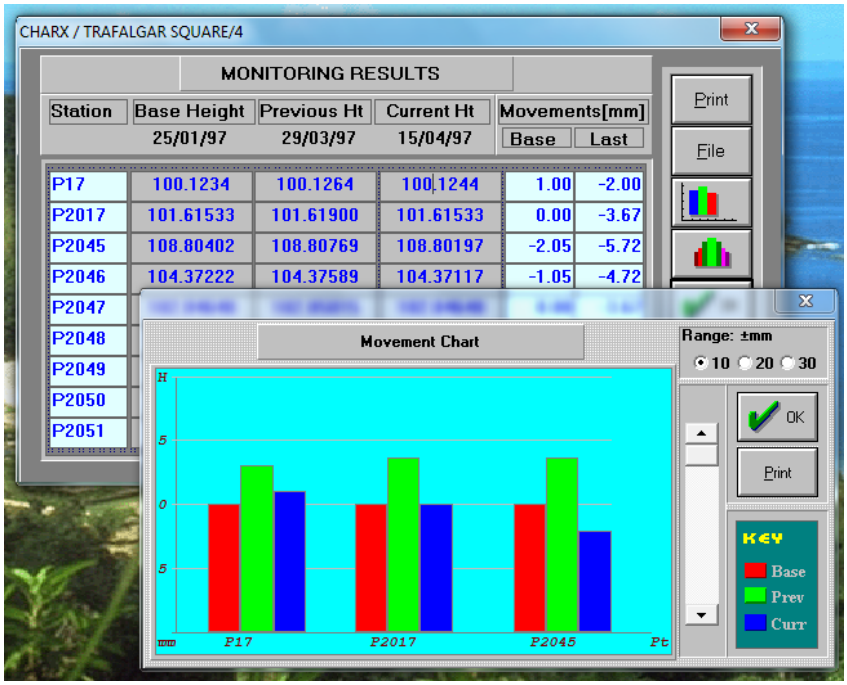


- Results/Trend Analysis for 1-D space
- Results/Trend Analysis for 3-D space
- Profile Analysis



The selection of Base, Last and Current Visits is automated. However, if Overwrite is activated, users can randomly compute comparisons between any cycles. It is advised though, after such evaluation, to retain the normal order and trend of observations in analysis.

Results
Results are important in presenting reports on monitoring exercise. It needs to be comprehensive with precise information. This includes tables, graphic illustration of movements and statistical analysis. Scroll bar allows navigation through the data set. Hardcopies are available for records by direct printing of tables and charts. And where users wish, the option of File allows interface to external packages.



1-D Results

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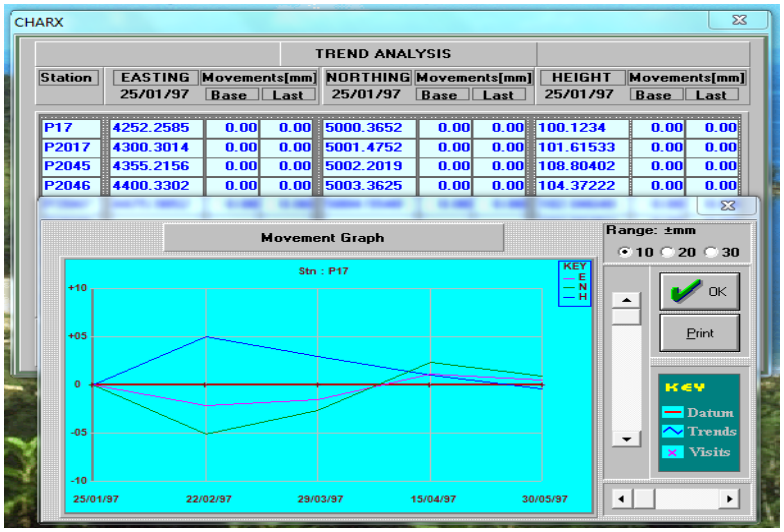
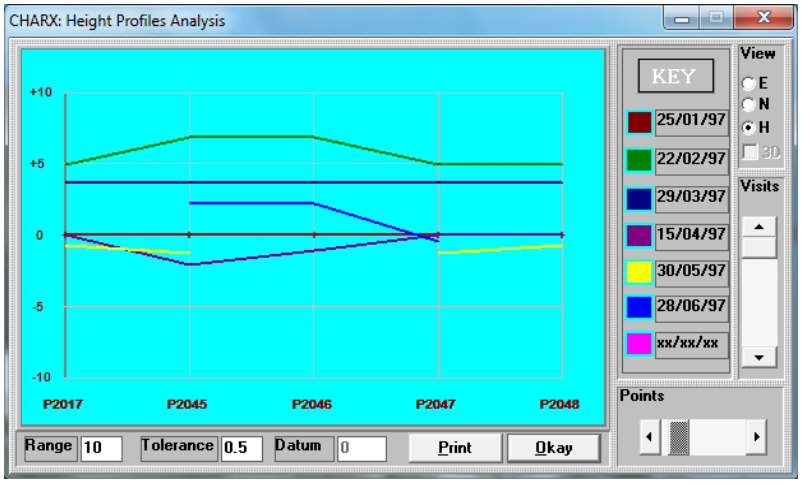
Trend Analysis



Profile Analysis



Profile analysis offers evaluation of movements in a section format at set tolerances. The view Option enables users to select any of three dimensions, Easting, Northing and Height. It is a complement to the format in Trend Analysis. Also referred to as Grid Monitoring, it is much tailored to suit tunnelling and dredging environments.

Conclusion

SMS is a comprehensive package that has been growing in order to attend to requirements in Surveying. On reflection, the success of the package lays a foundation for future software developments. By adopting the technique of domain expertise and knowledge processing, many otherwise intractable problems would have a solution. And this, in line with current trends in technology, would be the way forward. We are pleased to share ideas, offer support and services.