THE DEVELOPMENT OF A SIMPLE AND NEAR REAL TIME DEFORMATION MONITORING SYSTEM

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Abstract

Numerous accidents or disasters associated with large construction projects (e.g. dams, tunnels, bridges, etc.) and natural events (earthquakes, tsunami, landslides, mass movement areas, etc) in the past have called for the need of monitoring surveys with continuous observations and instant results to serve as an early-warning or alarm system. To perform such task, an automated system is required. Automated system can reduce human errors and substitute for tough manual fieldwork (where observations may need to be carried out round-the-clock). However, automated systems in market nowadays may be too expensive, while other common deformation monitoring software would not be that practical as they post-processed the data. This research focuses on the development of a simple and low-cost system which is suitable to be used in the cases mentioned above. The survey approach chosen is the GPS RTK method with a single reference station. Basically, this system consists of a reference station, several monitored stations and a control centre. The communication devices involved are radio links and internet. This system is almost fully automated, beginning from data collection to result presentation (inclusive of graphical presentation). The results will be presented in near real time due to a lag caused by signal and data transferring as well as outliers filtering. Since the results could be obtained instantly, extensional functions like siren wailing, auto-dialling, etc. can be activated to notify the persons-in-charge whenever the deformation is detected.

1.0 INTRODUCTION

Deformation monitoring survey can be categorised based on the condition (or health status) of the monitored object and the required safety level around the site, i.e. normal or urgent. If the monitored object is considered healthy, then the observation may not need to be carried out so frequently and results can be presented off-line via post-processing. Therefore this case is considered as normal deformation monitoring survey. However in a large construction project (where excavations will be definitely involved) carried out around a tunnel (or LRT/MRT track), to make sure the safety of the commuters, the observation must be carried out continuously round-the-clock and the results are required instantly (or near real time), and this is one of the cases of urgent deformation monitoring survey. This research focuses on the later case, i.e. near real time monitoring survey.

Geodetic approach of deformation monitoring survey can basically be brought out in two different methods. They are terrestrial positioning system (TPS) and global positioning system (GPS). This research concentrates on real-time kinematics (RTK) GPS method with single reference (master) station.

Next, this research also applies the concept of automation and field-to-finish to complete the survey method. In other words, the RTK data will be collected and sent for computation and presentation simultaneously.

In addition, to make the final result presentation more user-friendly, the presentation will be in both numerical as well as graphical format. Morever, to make it more easily-accessible, the presentation is also able to be accessed via internet.

2.0 PROBLEM STATEMENT

A complete deformation monitoring system basically consists of data collection, computation and presentation. To achieve the survey purpose for urgent cases, which is to make sure the safety around the site, silly human errors are strictly not allowed. However, to do such rigorous observation which is non-stop and round-the-clock, the most ideal solution is to computerise the observation. As a result, an automatic, field-to-finish and "real-time" system is thus required in urgent cases of deformation monitoring survey.

In fact, the accuracy and precision of RTK data are very much depending on baseline length and activities of ionosphere and troposphere around. Therefore, the accuracy and precision of RTK data have to be first clarified so that the reliability of the results can be determined. Based on the reliability, the practicality of RTK method in deformation monitoring survey can then be classified to different cases more specifically. Unquestionably, the deformation tolerance must be reasonable too.

In fact, there is already some commercial monitoring software which is quite complete (e.g. GeoMoS of Leica Geosystems, Condor Monitoring System). Nevertheless, they are too costly. Other common software is however not so practical because they need to post-process the data. Therefore, this research focuses on a low-cost system to meet the 'real time' requirement.

3.0 METHOD

The main objectives of the research are to study the practicality of GPS RTK method in urgent deformation monitoring survey, and to unify the essential functions in single urgent deformation monitoring system. The research consists of 5 main activities:

1. To determine reliable data and reasonable deformation tolerance

   This is the major part of this research, because without convincing data, deformation tolerance and final results, the system will be very much degraded no matter how outstanding the functions it has. To gain good results, the deformation tolerance must be very reasonable. Therefore, the accuracy and precision of data must be well verified and understood first, so that the reasonable deformation tolerance will be opted or decided properly.

   The RTK data is not as accurate as the data collected from static method or other methods by TPS equipment (Figure 1). This is mainly due to the changing of ionosphere and troposphere activities, which are not taken into account in producing RTK data. Therefore the results of RTK data keep on shifting from one period to another period gradually. Yet it is quite precise periodically (and this certainly depends on the baseline length as well).

   In this research, it is proposed to adopt a method called 3-σ precision detection (Figure 2). This method is not only able to produce a more reasonable deformation tolerance, but also to achieve zero outlier level. It is actually to formulate an <u>adaptable average value</u>, according to the shifting trend and precision of the data. The basic idea is explained below.

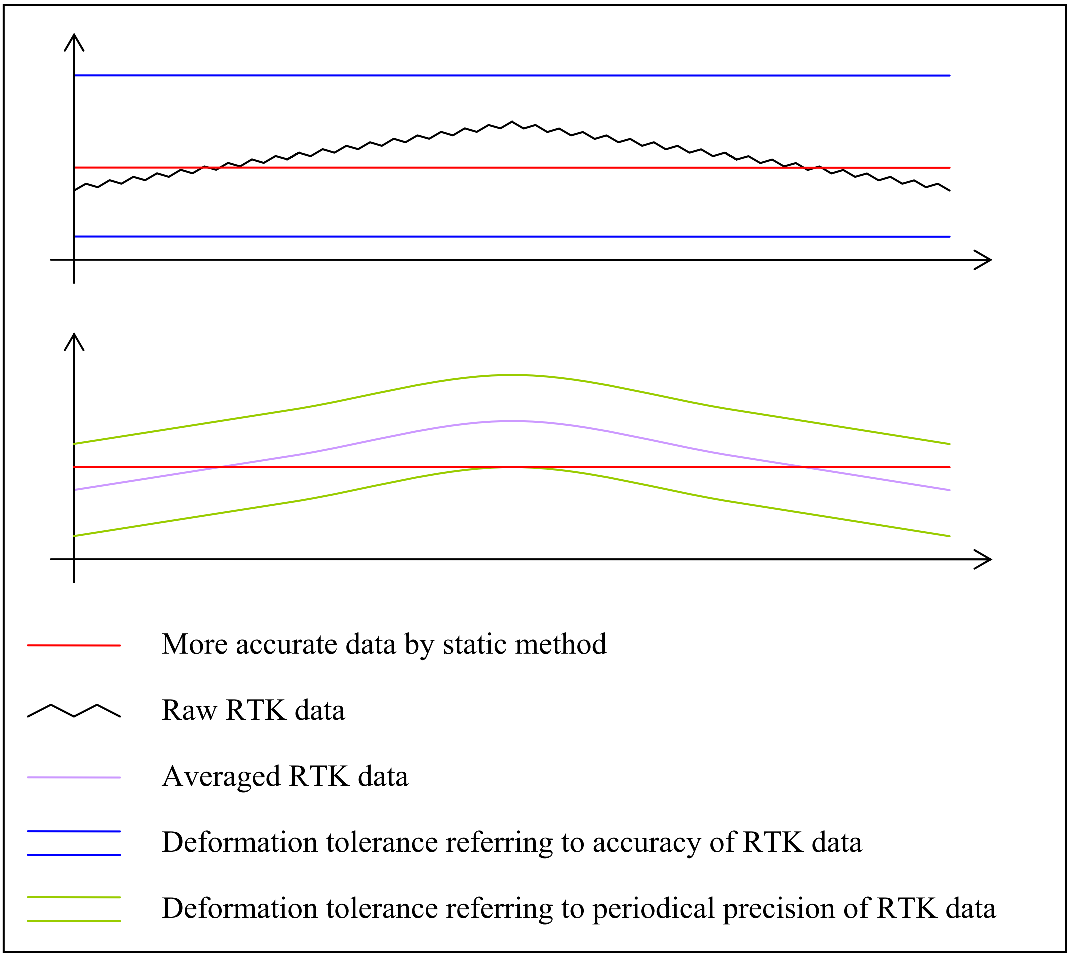

Figure 1. RTK data and deformation tolerance

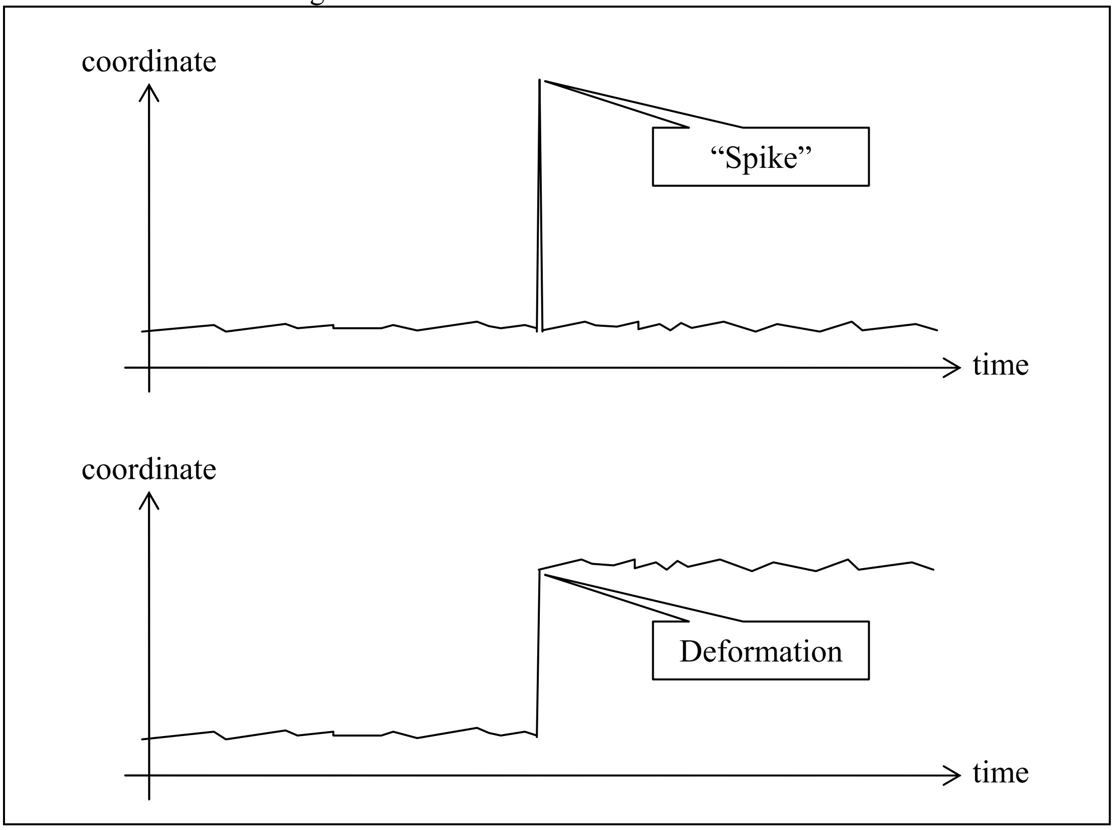

Figure 2. Spike and deformation in RTK data

Sometimes because of some interference like multi-path, there will be “spike” in the data collected (Figure 2). Usually, the spike will be very strange from others and this may cause the system to interpret it as deformation. Therefore, once the data collected is greater than the tolerance (3σ) allowed, the system will stop the averaging, and check with the next incoming data to differentiate whether spike or deformation. If the incoming data had shifted back to normal value, then it was recognised as spike and would be drawn out from formulating averaged RTK data. However, if the incoming data kept continuing greater and stability of reference station was proved stable, then it was recognised as deformation. Yet this will cause a lag to produce real-time result as few seconds are needed to recognise whether spike or deformation.

$$\sigma = \sqrt{\left(\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right)}$$

Sometimes misunderstand or accident may happen when the only reference station is disturbed or deformed while the target stations are in good condition. Therefore, an automatic checking of the stability of reference station at all time will be carried out to check the distances among the target stations (Figure 3). This is because the distances among the target stations would remain the same if it was only the reference station being disturbed. Certainly, the reference station should have been set at some platforms that considered as very stable and safe.

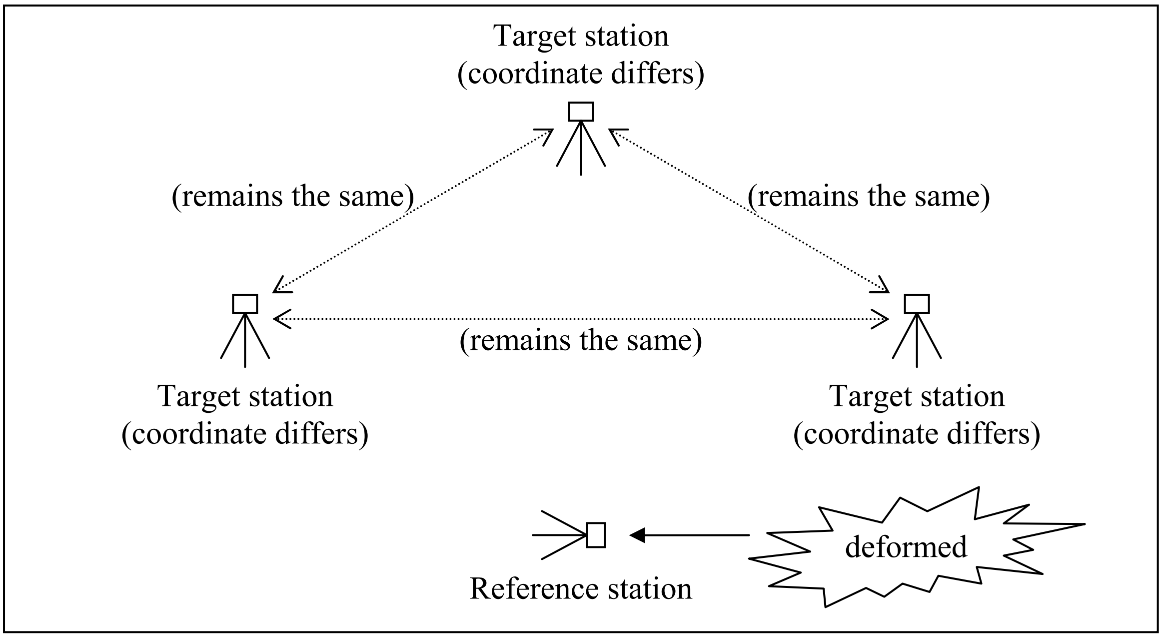

Figure 3. Automatic checking of reference station stability

Though the modified deformation tolerance (mode), which is referring to the periodical precision of data, is applied to gain more reasonable tolerance and better deformation detection, the dumb deformation tolerance (dude) should not be taken dispensable. This is because when the deformation occurs very slowly or the velocity of deformation varies slightly, then the mode will become unworkable.

The selection of mode will depends on factors such as baseline length, type of monitored objects, healthiness of monitored objects and others. Certainly it must not greater than 3σ. In addition, to launch this system, a pre-launch observation must be carried out at least 24 hours. This is actually to roughly read the trend of RTK data to get some pilot idea of deformation tolerance so that they will be decided more properly. This is important because deformation tolerance will directly influence the outcome of deformation monitoring system.

2. To computerise data collection and result finalisation

   This is actually the key part of developing fully automatic and field-to-finish system. To make the system automatic in order to substitute the manual labour, data collection must be first computerised, so that data collected will then be sent to the control centre for further computation and presentation.

   Normally the RTK data are only available in the receivers and post-processing needs to be carried out to obtain the output manually. Nevertheless, several existing software are able to extract data from hardware and send to computer automatically and in "real-time". One of them is Microsoft Hyperterminal.

   The output format of raw RTK data is in National Marine Electronics Association 0183 (NMEA-0183).

   Once the data collection is computerised, the following step is to transfer the data from target station to control centre (Figure 4). After that, the data computation (outliers filtering, reference station stability checking and deformation detection) and result presentation could be performed.

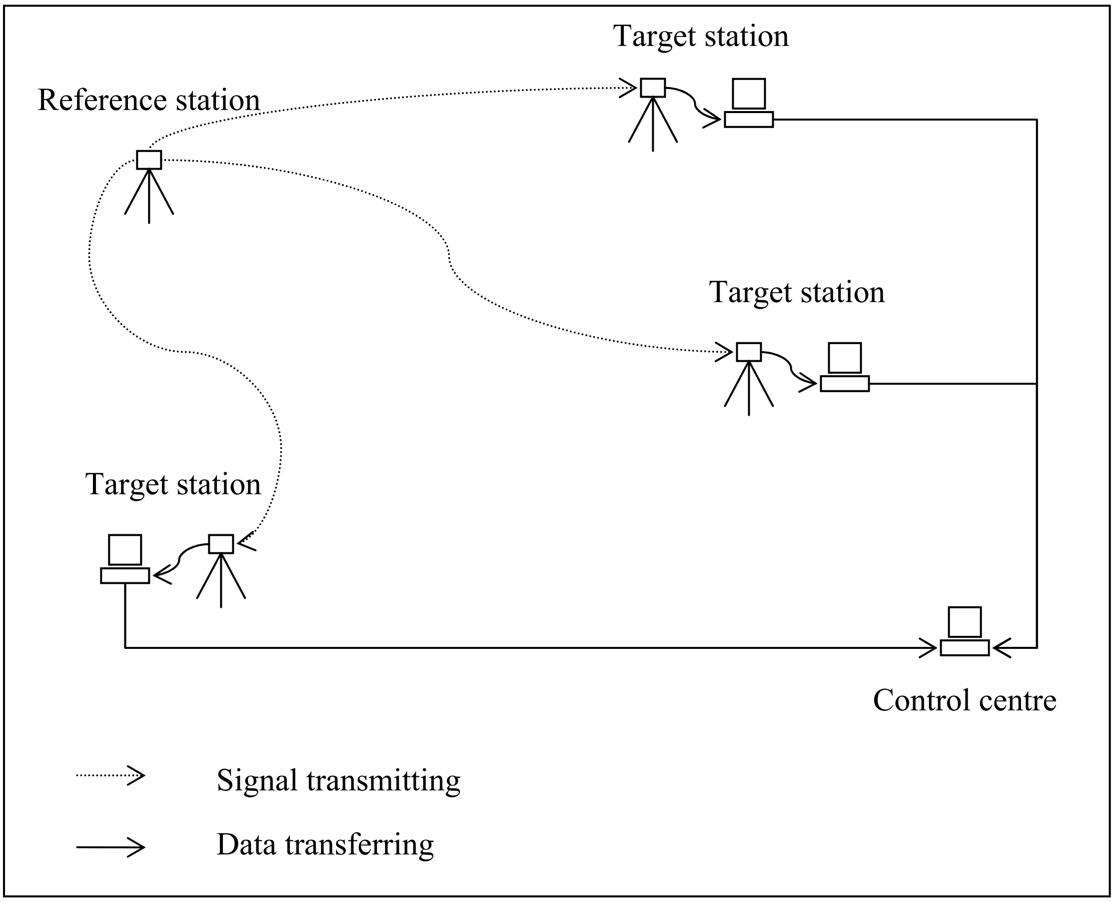

Figure 4. Data transfer to control centre

3. "Real-time" lag

   One of the objectives of this research is to produce the final result in real-time so that safety around the site and monitored object will be more secured, yet there will be lag in between data collection and result finalisation. Basically the lags can be divided into:

~ Mechanism lag

Mechanism lag is the lag occurred in the process of sending signal or data among equipments, computers or hardware themselves.

~ Formulation lag

Formulation lag is the lag we use to recognise whether spike or deformation as discussed earlier. It will take about 4 seconds.

Therefore this system will take about 6 seconds to produce final result when the deformation occurs.

4. Result presentation

Users of this deformation monitoring system are no doubt the surveyor, yet the end users may be the contractors, developers or many others who do not have surveying background. Therefore the user-friendliness of the system is quite important sometimes. To present the user-friendly output, the presentation is proposed to be in both numerical as well as graphical format. The basic concept of the presentation is shown in Figure 5.

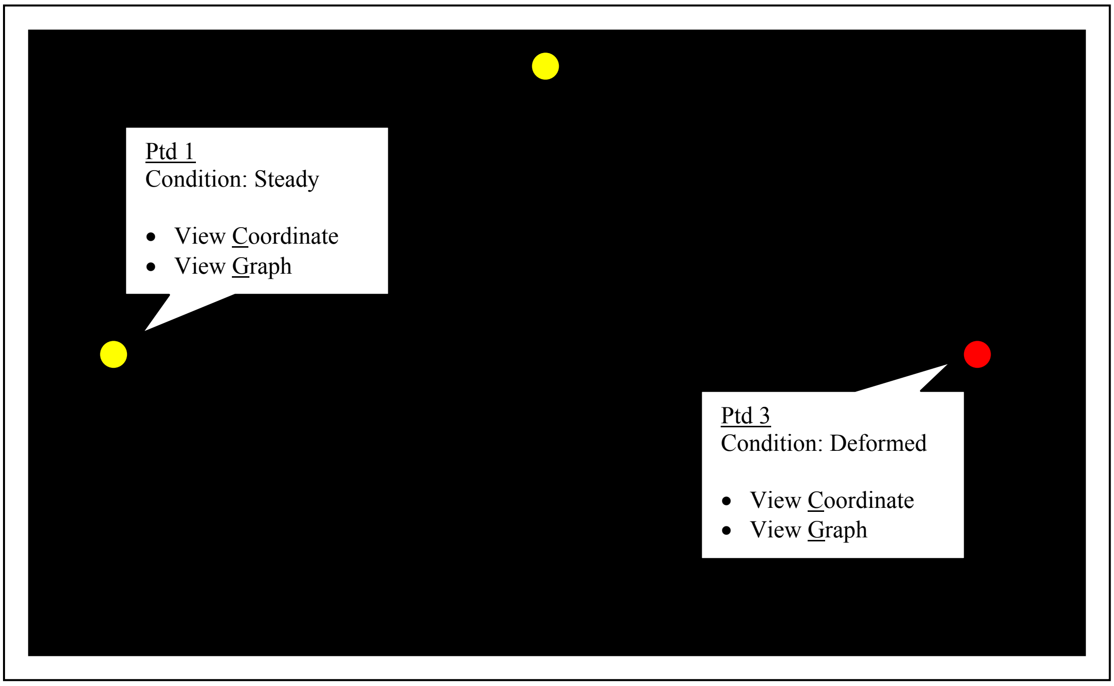

Figure 5. Result presentation

All the target stations will be first showed (fitted) in one window with the colours indicating their stabilities. From the main presentation window, user can then go to view the coordinates station by station in more detail in either text format (through View Coordinate) or chart format (through View Graph). Besides, this output presentation can be accessed through internet as well.

5. Extensional function

Once the final results are obtained instantly and automatically, then a lot of applicable functions could be then extended. For example, it is proposed to extend to:

~ siren wailing to inform the public around the danger signal, and

~ auto-dialling to call to the responsible party.

To extend to these extra functions is actually to complete a so-called early-warning system or alarm system.

4.0 EXPECTED RESULTS

After these studies and testing have been tried out, the best of the deformation tolerance and the lag in producing instant result will be more clearly summarised. As a result, the practicality of GPS RTK method in urgent deformation monitoring survey will be summarised as well.

5.0 CONCLUSION AND RECOMMENDATION

The idea of this research mainly came from numerous accidents or disasters happened in the past like tragedies of Highlands Tower (1993) and tsunami (2004). Throughout this research, it is hoped that the effort would provide some help to those in need and bring up the public awareness of the danger around us as humans' live are always so fragile. Sometimes because of knowledge/technology leftover and financial problems, people may have to give up implementing this kind of safety measure.

Therefore, this research is trying to develop a simple system but sufficient to match the requirements needed in urgent deformation monitoring survey. If the system was successful to be developed, it would have the advantages like low-cost, reliable result, user-friendly, easy-accessible and able to serve as an early-warning system.

It is recommended that a proper classification of deformation survey should be done according to its specification such as epoch of observation, accuracy of data, urgency level of result, etc.

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