DEVELOPMENT OF GEODETIC DEFORMATION ANALYSIS SOFTWARE BASED ON ITERATIVE WEIGHTED SIMILARITY TRANSFORMATION TECHNIQUE

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To my beloved mother and father

To My wife

To My sons Seraj and Esraa

To my brothers and sisters

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ABSTRACT

Deformation analysis is one of the most challenging tasks in engineering survey. The analysis of deformation is essential to monitor the movement of established network or of object under study for many purposes such as tectonic movement or monitoring of large engineering structures (e.g. dams, bridges and etc). This study will concentrate on the development of computational software for the purpose of 2D geodetic network deformation analysis. The tasks in the study are divided into two parts – the least squares adjustment (LSA) computation and the analysis of deformation. The LSA is initially done by employing minimum constraint technique. The analysis of deformation is been performed using robust technique known as Iterative Weighted Similarity Transformation (IWST). The software developed in this study was implemented for deformation analysis by utilizing two epochs of measurement data performed on a deformation network. Results obtained from this computation show a very good agreement with results of a previous exercise computed using the same data set.

ABSTRAK

Analisa deformasi merupakan salah satu tugas yang mencabar dalam ukur kejuruteraan. Analisa deformasi adalah penting bagi pemantauan pergerakan jaringan yang ditubuhkan atau objek kajian untuk pelbagai kegunaan seperti pergerakan tektonik atau pemantauan strukutur kejuruteraan yang besar (contohnya empangan, jambatan dan sebagainya). Kajian ini akan bertumpu kepada pembangunan sebuah perisian untuk kegunaan menghitung analisa deformasi bagi jaringan geodetik 2D. Tugas dalam kajian ini dibahagikan kepada dua bahagian – hitungan pelarasan kuasa dua terdikit dan analisa deformasi. Hitungan pelarasan kuasa dua terdikit diselesaikan dengan teknik kekangan minima. Analisa deformasi pula dilakukan dengan teknik robust yang dikenali sebagai *Iterative Weighted Similarity Transformation*. Perisian yang dibangunkan dalam kajian ini telah diimplemen untuk analisa deformasi menggunakan data pengukuran dua epok sebuah jaringan deformasi. Keputusan hitungan yang telah diperolehi menunjukkan kesamaan dengan keputusan hitungan yang dilakukan dalam sebuah kajian sebelum ini menggunakan set data yang sama.

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LIST OF ABBREVIATIONS

Abbreviation	Full Name
LSA	Least Squares Adjustment
GDA	Geodetic Deformation Analysis
IWST	Iterative Weighted Similarity Transformation
GPS	Global Positioning System
MSR	Mean Success Rate
OKF	Optimized Kalman Filter
1-D	One Dimension
2-D	Two Dimension
3-D	Three Dimension
LEV	STAR*NET-LEV edition
PLUS	STAR*NET- PLUS edition
PRO	STAR*NET- PRO edition
UTM	University Technology Malaysia
CDA	Conventional Deformation Analysis
HCNs	horizontal control networks
RD	Random deformations (RD)
ID	influential deformations (ID)

CHAPTER ONE

INTRODUCTION

1.1Background

Deformation analysis can be described as the study of the changes in shape of an arbitrary body in time. The process involves in the analysis of deformation include the measurement and analysis phases. The measurement phase is for the purpose of acquiring observational data and it can be done by techniques like conventional geodetic using Total Station, close range photogrammetry, terrestrial laser scanning system, global position system (GPS) and remote sensing. Performing the least square adjustment (LSA) of observational data obtained from repeated measurements is the first computational step which should be done in geodetic deformation analysis for before applying deformation monitoring and analysis of the object two or many time (e.g. epoch1 and epoch2) and obtains estimate coordinates to each epoch is the first step before applying deformation monitoring and analysis.

Geodetic deformation is typically related to changes of the position or the point coordinates of the object under study obtained from two or more epoch of measurements. Therefore, analysis of deformation requires determining the spatial coordinates of all measurement points over two epochs, comparing them and evaluating their differences in order to identify any deformation occurrence.

Deformation analyses for any kind of a deformable body include geometrical analysis and physical interpretation. Geometrical analysis described the change in shape and dimensions of the monitored object. Therefore, the main goal of the geometrical analysis is to define the displacement of all deformable object and its strain fields in space and time domains (Chrzanowski, 1986).

Generally, in geodetic deformation analysis, there are two basic types of measurement network, i.e., the absolute and the relative deformation network. In the case of absolute network we initially assume that network reference points are located on stable ground outside the deformation area. Measurements then were made to object points which might be subject of deformation. For the case of relative network we assume all the points involve in the measurement are subject to deformation. In other words in relative network all the measurement points are considered unstable i.e., even the 'reference points (Halim and Singh, 2001).

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1.2 Problem Statement

The analysis of geodetic deformation requires several computational procedures to be fulfilled. In the first step, coordinates for all points of the network are computed by a separate LSA for each epoch respectively. The computational procedure dedicated for geodetic deformation analysis GDA will takes place after the completion of LSA computation. The tasks of determining the deformation is based on the evaluation of the displacement vector field against the error committed in that process. The displacement vector of deformation for any point i (Δdi) is generally determine from the difference of coordinate computed in both epoch ($\Delta di^2 = [Ni,_2\text{-}Ni,_1]^2 + [Ei,_2\text{-}Ei,_1]^2$). The displacement vector Δdi is then compared with its error ellipse to determine whether deformation has occurred or not. Hence, the task of deformation detection is thoroughly challenging and requires detailed analysis especially so if the expected deformation is small in magnitude compared with the precision of which can be achieved.

One of the problematic tasks in Geodetic Deformation Analysis (GDA) is regarding the datum point selection used in LSA computation. The datum point selection is needed in the case where LSA is done using minimum constraint technique. In principle the datum chosen must be represented by reference point which should be stable. But in practice the datum point is initially been choose without any knowledge about its stability. Therefore the procedure of determining the reference point stability should be incorporated in GDA computational routine. The search for a correct datum point can be furnished by having such a procedure through pillar stability segregation analysis performance.

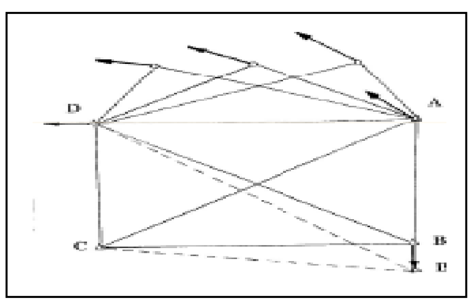

Figure 1.1: Biased deformation resulted from the effect of wrong datum point selection (Chen et.al, 1990)

The problem resulted from choosing wrong datum point in GDA computation was highlighted by Chen et.al (1990) using an illustration as shown in Figure 1.1. A deformation monitoring network consists of four reference points (i.e., A, B, C and D) was established to monitor object points located above them. Point B was chosen as datum point in the adjustment. Point B was not a stable reference point. It has actually moved but was nevertheless adopted as datum in the adjustment done using minimum constraint technique. As a result deformations were detected at points A and D and also at the three target points as all of them having moved significantly. The deformations detected were a biased finding since they were falsely created by wrong selection of datum point.

The example above clearly indicated the need of having a re-examination on the selection of datum point. Therefore a GDA procedure of determining the reference point stability should be incorporated in GDA computational routine. The search for a correct datum point can be furnished by having such a procedure through pillar stability segregation analysis performance. One such procedure available is the methodology known as the Iterative weighted Similarity Transformation (IWST) introduced by Chen (1983).

In this study the method of IWST will be pursued and incorporated in a LSA computational routine for the purpose of GDA. The method of IWST is chosen because its concept is simple and easy to understand.

1.3 Objectives of the Study

The goals of this project are arranged as following.

i. To study the concept and applications of Iterative Weighted Similarity Transformation (IWST) and applying it for deformation analysis.

ii. To develop a computational program package using MATLAB for geodetic least square adjustment followed by analysis of deformation using IWST technique.

1.4 Significance of the Study

The significances of this study are:

i. The research work described here hopefully could benefit the geomatic students in local universities and the practicing surveyors with aspiration of attracting them to explore the works in geodetic deformation analysis.
ii. This work is also furnished to serve as a case study in the implementation of the deformation analysis in practical uses.
iii. This research also highlighted the facts that the analysis of pillar stability is very crucial in geodetic deformation analysis. Result from this analysis provides answer to the problem of selecting the right datum in LSA computation.
iv. Therefore the computational software developed from this study is very useful in the sense that it will solved two major computational procedures in GDA namely the LSA and the geodetic deformation analysis in an integrated manner.

1.5 Research Scope

The scope of this study can be defined as follows – the 2D geometrical deformation analysis using data obtained by the geodetic method of measurement involving angular observation (i.e., angle and bearing or azimuth) and distance measurement. The network least squares adjustment will be done initially by minimal constraint technique while the methodology of IWST will be used in the implementation of analysis of deformation.

This project was implemented using the survey data taken from two measurement of geodetic deformation networks. The first network is a deformation network consists of twelve points. The measurement data were taken from the work of Khairulnizam (2004) of a geodetic monitoring scheme for civil engineering application. The second geodetic deformation network used is a simulated network established within UTM campus (i.e, at a location near Block C02, Faculty of Geoinformation and Real Estate). The network is consists of four reference stations and four object points.

All the required computations were performed using a program developed using MATLAB which enable the LSA and computation of deformation analysis using distances, angles, and azimuth.

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