DEVELOPMENT OF WINDOWS APPLICATION FOR MULTI-EPOCH 3D NETWORK ADJUSTMENT AND DEFORMATION ANALYSIS OF LARGE ENGINEERING STRUCTURES

SUBMITTED BY

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BEING A PROJECT REPORT PRESENTED TO THE DEPARTMENT OF GEOINFORMATICS AND SURVEYING, FACAULTY OF ENVIRONMENTAL STUDIES, UNIVERSITY OF NIGERIA, ENUGU CAMPUS, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MSc IN GEOINFORMATICS AND SURVEYING

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ABSTRACT

- Geodetic measurements for deformation studies whether for monitoring earth movement or for ascertaining structural integrity often involved redundant large amount of observations resulting in redundancy. At the lowest level, analysis involves two-epoch measurements. It becomes more complex in a multi-epoch system with time series observations. Such large amount of data and the rigorous analytical procedures involved raises the need for a computerized system that is not only user-friendly but also has the capability for a comprehensive analysis. This research focused on developing algorithms and computation procedures as well as a computer program for the analysis of 3D structural geodetic deformation network.

ABSTRACT

- Bearing in mind the users' need for effective interaction with the program led to the choice of an object oriented programming language, Visual Basic 6.0 loaded with forms and controls that meet the required standard for Windows application. Thus a highly interactive user interface that guides user along in the use of the application was designed and developed. The computational algorithm designed for different stages of network deformation analysis which include pre-adjustment analysis for detection of outliers, network adjustment and deformation analysis were translated into codes which serves as underlying drive for the desired results. However, due to limited time span for this research, the deformation analysis segment is at the trend analysis stage which analyses movement of the nodal points in a geodetic deformation network. The software on completion was used for the analysis of the new Administrative Building of University of Nigeria, Enugu Campus partly based on real life measurements and simulated data. The results indicated that all the nodal points involved were statistically stable between successive epochs.

TABLE OF CONTENT

1.0 INTRODUCTION

1.1 Background to the Study

- Deformation monitoring essentially is concerned with a systematic measurement and tracking of alteration in the shapes or dimensions of an object as a result of stresses induced by applied loads. That is, the determination of the geometrical status of a deformable body.
- The measuring techniques and instrumentation for geometrical monitoring of structural deformations have traditionally been categorized into two groups according to the two main groups of professionals who use the techniques.

INTRODUCTION CONT'D

- The first is geodetic method, which involves measurement by means of standard geodetic procedure and equipment (such as Terrestrial Positioning Systems-TPS e.g Theodolites, Levels, Total Stations, Scan Stations etc., Global Position System-GPS, close range Photogrammetry, radio astronomy by Very Long Baseline Interferometry (VLBI) and satellite laser ranging) of displacements of portions of the earth or of the structure thereon.
- The second is geotechnical method which is concerned with measurements of local deformations and environmental conditions using piezometers, pressure meters, thermometers, barometers etc.
- Deformation analysis using the geodetic method mainly consists of a two-step analysis via independent adjustment of the network of each epoch, followed by deformation detection between the two epochs (Setan and Singh 2001). Therefore this study is hinged at developing an interactive, user-friendly window application for network adjustment of single epoch observations and deformation analysis of two-epoch and multi-epoch 3D deformation monitoring network of large engineering structures

1.2 STATEMENT OF RESEARCH PROBLEM

- Several cases of building collapses and structural failures have been experienced in Nigeria and other parts of the world. Such failures are either as a result of design errors, construction errors or negligence in providing a good post-construction monitoring system for their early detection.
- Deformation monitoring system requires accurate measurements and observations of object under study as well as an analysis of such measurements to ascertain the degree of deformations.
- Geodetic technique, in particular often requires rigorous computations and analytical procedures that are quite difficult or almost impossible to handle manually, especially in the case of complex network consisting of several monitoring stations
- In the department of Geoinformatics and Surveying, University of Nigeria Enugu Campus, many computer programs bordering on several areas of survey applications have been developed. Examples include a computer program for Horizontal Network Adjustment (HORNA) developed by Dr. Moka E.C. (1998) and University of Nigeria Tidal Analysis and Prediction Program (UNITAPP) by Professor Ojinnaka O. C.

STATEMENT OF RESEARCH PROOBLEM CONT'D

- Reasonable investigations reveals that little or no work has been done in developing a software for a comprehensive monitoring and analysis of deformation monitoring network in University of Nigeria, Enugu Campus.
- This study therefore focuses at developing a software suitable for geodetic network deformation analysis of such structures as the new administrative block in University of Nigeria Enugu Campus (Akpagu, 2016), Central Bank of Nigeria centre of excellence building (2015), New administrative block of Federal School of Surveying, Oyo (Abdullahi and Yelwa, 2016) and many other large engineering structures, whose monitoring network has been established and those that will be subsequently established.

1.3 RESEARCH GOAL AND OBJECTIVES

1.3.1 Aim

The aim of this research is to develop an interactive, user-friendly windows application that can be used for the analysis of a three dimensional (3D) geodetic network comprising of either just a single-epoch network adjustment, two-epoch and/or multi-epoch deformation network adjustment and analysis of any deformation monitoring network established for the monitoring of large engineering structures.

1.3.2 Objectives

The objectives involved in realizing the aim are itemized as follows

- Problem Definition
- Program Planning and Design
- Implementation of designs using visual Basic 6.0
- Program Testing and Debugging
- Analysis of the new administrative building deformation monitoring network
- Deployment and Documentations

1.4 SCOPE OF RESEARCH

This research project involves the development of a windows application for a 3D multi-epoch deformation analysis; it therefore employs the knowledge of pre-adjustment analysis, network adjustment, deformation studies, and computer programming skills in the production of user-friendly object oriented software, installable on any window operating system.

The software on completion was used to carry out deformation analysis of the new administrative building, University of Nigeria, Enugu Campus based on existing data sets.

1.5 JUSTIFICATION/SIGNIFICANCE OF THE STUDY

- It is a notable fact that a number of computer programs have been developed in the department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus. Nevertheless, a reasonable investigation has necessitated the need for this research. The findings are outlined as follows
- No such a single (Compact) program valid for network adjustment and deformation analysis exists in the department.
- In particular; little or no work has been done in developing a suitable software suite for 3D multi-epoch structural deformation analysis
- The commercially available software on deformation analysis are quite expensive
- Most of the available programs are not object oriented; they do not provide users with the liberty of interacting freely with objects on the screen.

2.0 LITERATURE REVIEW

- Some of the related literatures as reviewed in the course of this research are as follows

Author	Year	Title	Publisher
Abdullahi I.M., Yelwa N.A.	2016	*Structural Deformation Monitoring Surveys of New Administrative Building of Federal School of Surveying, Oyo*	Department of Geology, Usman Danfodio University, Sokoto
Ashraf A. B.	2015	*Structural Deformation Monitoring and Analysis of High Way Bridge Using Accurate Geodetic Techniques*	Faculty of Engineering Surveying, Mansoura University, Mansoura City, Egypt
Amiri-Somkooei A. R et'al	2017	Stability Analysis of Deformation Monitoring Network points Using Simultaneous Adustment of Two Epoch	Journal of Surveying Engineering **143**
Axel E.	2014	*Ground-Based Deformation Monitoring*	Department of Geomatic Engineering, University of Calgary
Chen Y.	1983	*Analysis of Deformation Surveys, - A Generalised Method*	Department of Geodesy and Geomatic Engineering, University of New Brunswick
Chrzanowski A., Anna S.	2010	*Deformation Monitoring Survey – Old Problem and Solutions*	Canadian Center for Geodetic Engineering, University of New Brunswick, Canada
Chrzanowski A	1988	*Conference 1988 on Deformation Surveys Executive Summaries*	Department of Surveying Engineering University of New Brunswick, Canada

3.0 RESEARCH METHODOLOGY

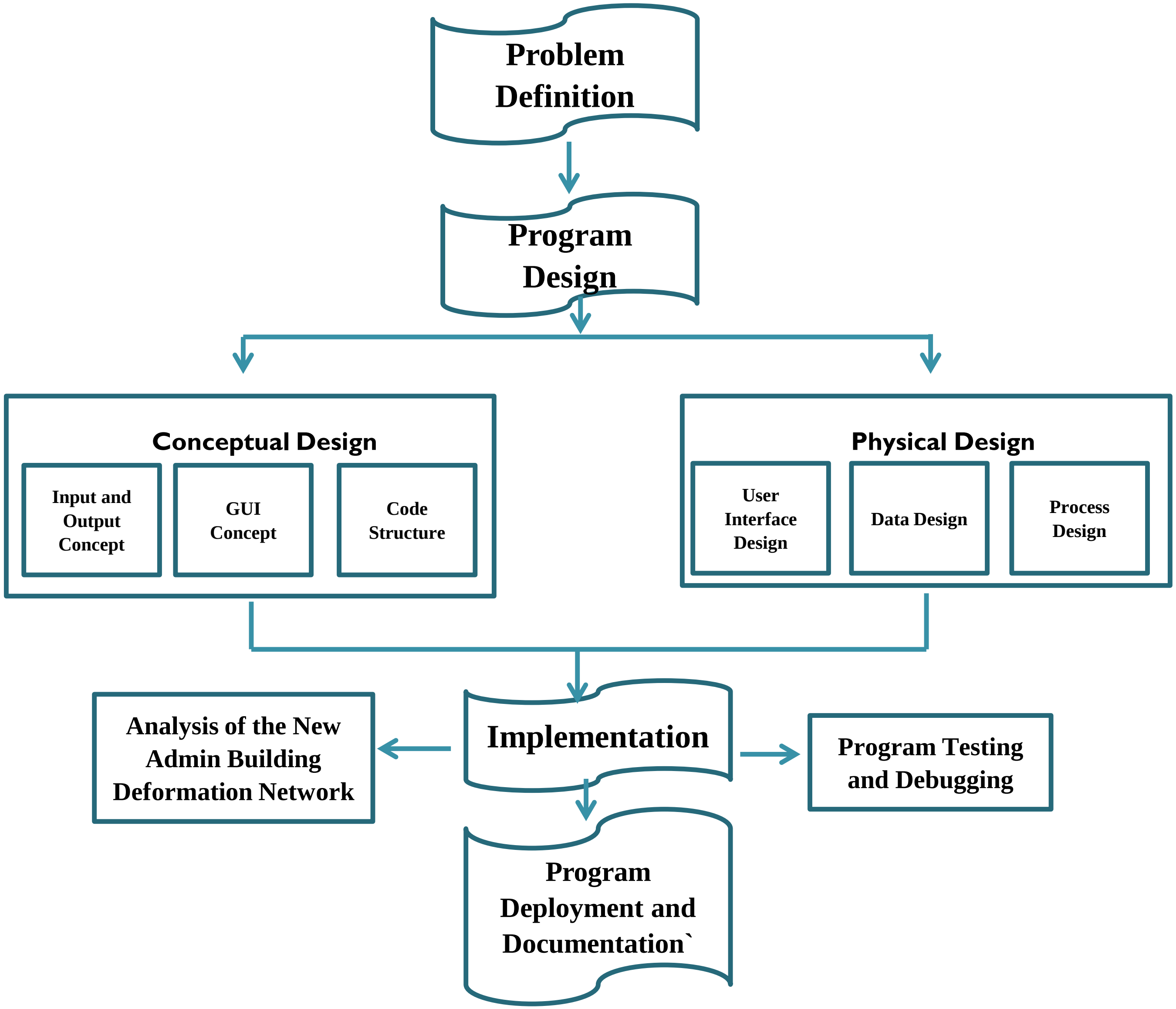


Figure 3.1: Work method flow chart

RESEARCH METHODOLOGY CONT'D

3.1 Program Planning and Design

Writing a computer program to solve a problem is a multistep process encompassing both conceptual and physical design.

3.1.1 Conceptual Design

- The mental perception of how the program will look based on what it seeks to achieve were laid out. This include
  - Conceptual model of the Graphical User Interface (GUI)
  - Conceptual model of the program code
  - Interrelations of the GUI and the program code

RESEARCH METHODOLOGY CONT'D

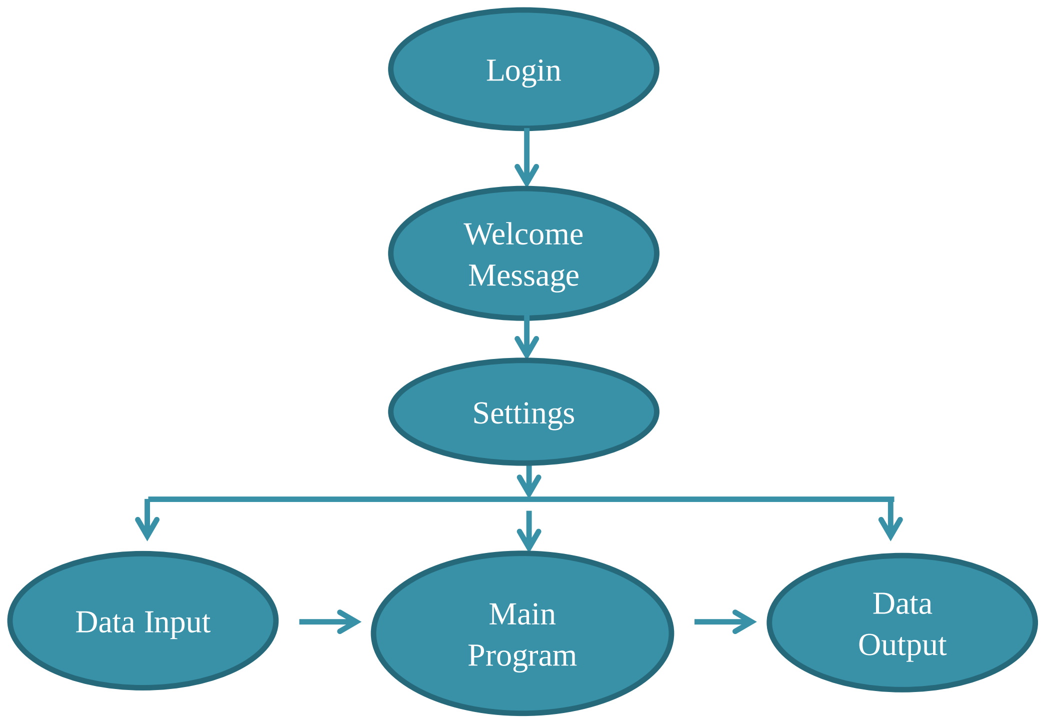


Figure 3.2: Conceptual model of the GUI

RESEARCH METHODOLOGY CONT'D

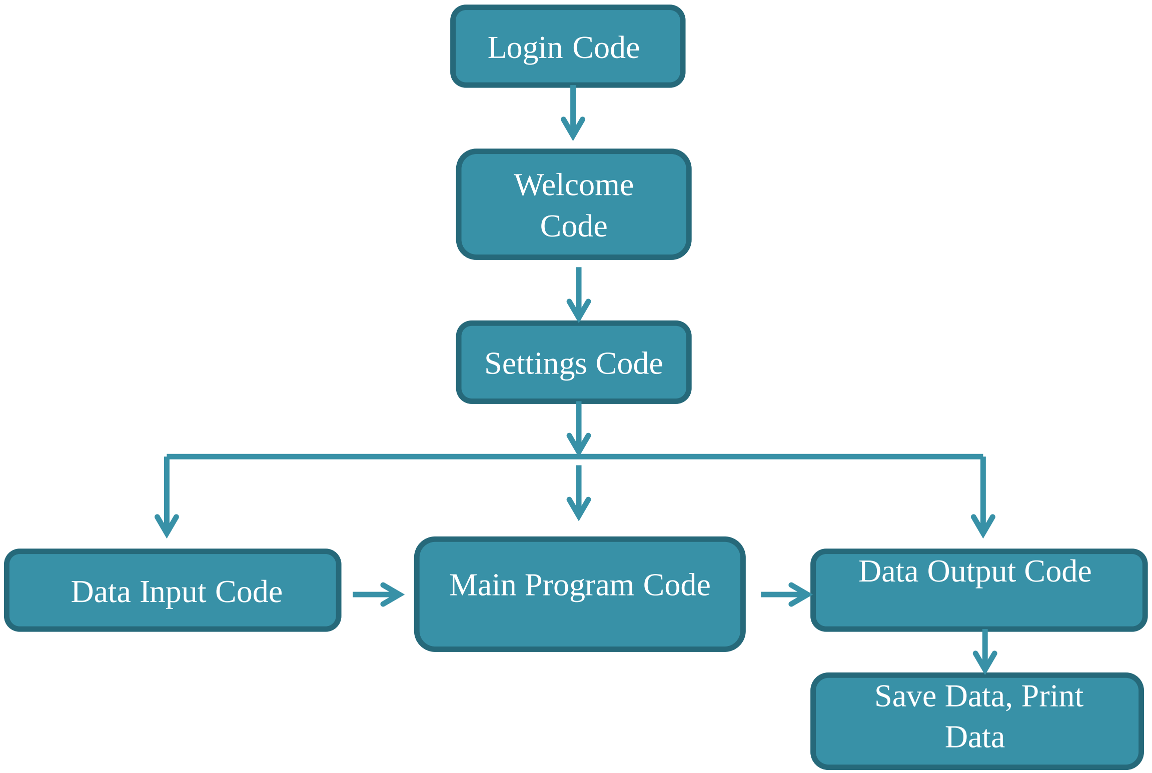


Figure 3.3: Conceptual model of the program code

RESEARCH METHODOLOGY CONT'D

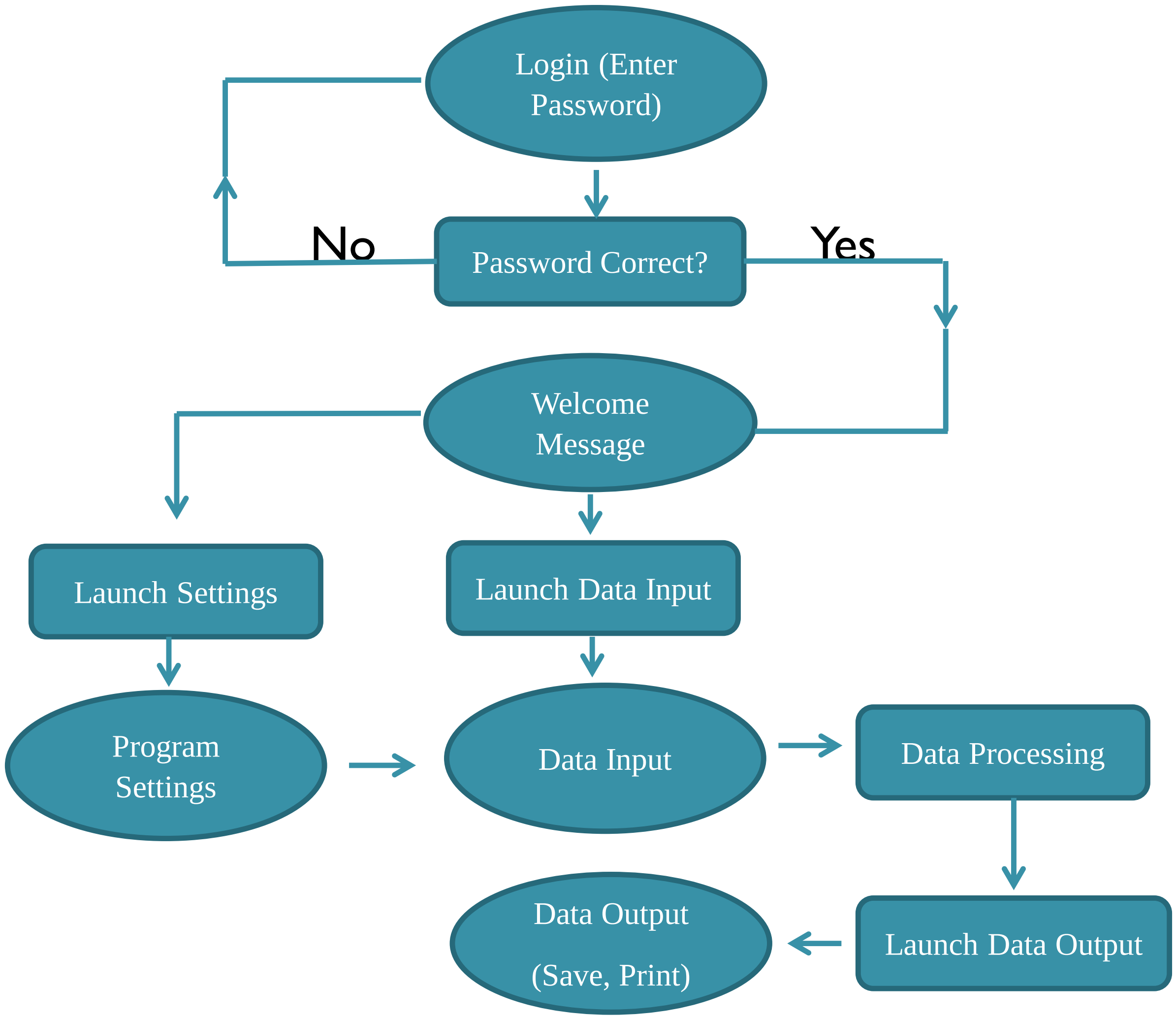


Figure 3.4:Conceptual work flow model (Integration of GUI and program code)

RESEARCH METHODOLOGY CONT'D

3.1.2 Physical Design

- Generally the physical structure of the software shall entail
  - User Interface Design: Physical Layout of the user interface
  - Data Design: Data input and output structures and format
  - Process Design: Underlying computation structures and processes

3.2 Program Implementation

- The implementation of the conceptual and Physical designs was done with Visual Basic 6.0 programming Language

3.2. 1 Installation and setting up of Visual Basic 6.0

- The compiler to be used in the development of the program was installed on a stand alone computer and the Integrated Development Environment configured to reflect the intended use. Part of the set up process involved the naming of the software. Thus the software was named NADA, an acronym for Network Adjustment and Deformation Analysis.

3.2.2 Development of the User Interface

- Generally, the development of the user interface involved three basic operations
  - Adding forms to the Design Interface
  - Adding Objects/controls to the forms
  - Setting the desired properties of the objects

RESEARCH METHODOLOGY CONT'D

3.2.3 Data Design and Format

- **Data Input Design and Format**
- Data input in NADA was designed to be compatible with a simple method of arrangement of survey data in a text file, bearing in mind the conventional geodetic field survey procedure. The key things that the user is expected to bear in mind while trying to upload data into NADA are
- the data type for each epoch (which could be either the observed point x, y, z data, baseline ΔX, ΔY, ΔZ data or even already adjusted data of the nodal points)
- Number of fixed reference stations or datum
- Number of observation stations
- Number of observed target stations per station.
- Number unknown stations
- Once these settings has been effected, the arrangement of data in the input file is expected to follow as outlined in the project report, page 74 to 76 for coordinate data and page 77 for baseline data.

RESEARCH METHODOLOGY CONT'D

- NADA also provides user with three different options for the input of the a priori variance information for the estimation of observation weights
- Assume observation of equal weight
- Estimate weight based on the length of baselines
- Specify weight based on the a priori variance covariance of observations
- **Data Processing Design and Format**
- NADA allow user the flexibility of deciding whether part or all of the processing phases (Pre-Adjustment, Network Adjustment, Deformation Analysis) in NADA is relevant to his intended project. The user must however effect such settings in the settings interface because all the processing phases in NADA are by default disabled.
- **Result Output Design and Format**
- The Output menu on the main program interface gives user the flexibility of selecting a desired output file between any of the three projects (Pre-Adjustment, Adjustment and Deformation Analysis) where each output project in turns also provide user the flexibility of either outputting the result to a Microsoft excel file or Microsoft word document. In case of outputting the results of network adjustment analysis that is often characterized by matrices of large dimensions, while excel output is a preferable option for visualization as it shows the full matrices, word document is preferable for hard copies production as it presents the matrices in a printable format.

RESEARCH METHODOLOGY CONT'D

3.2.4 Development of the Program Kernel

- The code structure of NADA can be broadly divided into two
- User Interface Code (UIC)
- Module Interface Code (MIC)
- There are six modules in NADA with each representing each task or phase of the software development. These include:
- Variable Declaration Module
- Data Input Module
- Pre-Adjustment Analysis Module
- Network Adjustment Module
- Deformation Analysis Module
- Data Output Module

Each module is made up of subroutines or procedure developed based on the applicable mathematical models and computational algorithm as presented on page 47 to 60 of the project report

RESEARCH METHODOLOGY CONT'D

3.3 Program Testing and Debugging

As part of the implementation process, the program was tested and debugged as necessary to ensure that is working correctly.

Testing and debugging was done through the whole stages of implementation. This involved compiling and running the program at intervals as coding progresses. This was done to remove syntax and logic errors from the program

DEFORMATION NETWORK ANALYSIS

- The software on completion was used for the analysis of the new administrative building deformation network based on simulated data set.
- Thirteen baseline data were simulated for a network consisting of three reference points and three object points.
- The adjustment procedure assumed two of the reference points as fixed datum while the third considered as floating point was adjusted simultaneously with the object points in the adjustment of the first observation epoch.

Table 4.2: Fixed Control or Datum points

Description	Easting	Northing	Ellipsoidal Height (m)
MSC04	334657.128	710351.105	233.1458
MSC01	342340.809	720633.558	10911.508

- Subsequent epochs were simulated by either adding or subtracting a small displacement values from some selected baselines in the preceding epoch. Thus a total of five observation epochs were simulated and analysed.
- The trend analysis shows that all the nodal points in the network are statistically stable between successive epochs. That is, based on the simulated data set there is no statistical reason to be concerned about the stability of the structure

DEFORMATION NETWORK ANALYSIS

Simulated Data of the New Administrative Building

SIMULATED BASELINE OBSERVATIONS								
OBSERVATION EPOCH_1								
DATE: 10/01/2018								
From	TO	ΔX	ΔY	ΔZ	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$	$\hat{\sigma}_z^2$	DISPLACEME
MSC04	A013	11644.22320	3601.21650	3399.25500	0.0009	0.0008	0.0013	
MSC04	A005	-5321.71640	3634.07540	3173.66520	0.0009	0.0008	0.0012	
MSC04	A001	1116.68830	4596.45500	4355.30080	0.0009	0.0009	0.0013	
MSC01	A013	3960.54420	-6681.24670	-7279.01480	0.0009	0.0008	0.0013	
MSC01	MSC06	-11167.60760	-394.52040	-907.95930	0.0009	0.0009	0.0012	
MSC01	A001	-6567.23100	-5686.30330	-6322.38070	0.0008	0.0007	0.0011	
MSC06	A013	15128.16470	-6286.70540	-6371.05830	0.00099	0.00089	0.0014	
MSC06	A005	-1837.74590	-6253.85340	-6596.66970	0.00089	0.00088	0.0015	
A001	MSC04	-1116.45230	-4596.16100	-4355.89620	0.0009	0.0009	0.0013	
A001	A013	10527.78520	-994.93770	-956.62460	0.00091	0.00092	0.0011	
A001	A005	-6438.13640	-962.06940	-1182.23050	0.0008	0.0007	0.0012	
A001	MSC06	-4600.37870	5291.77850	5414.43110	0.00087	0.00088	0.0016	
A001	MSC01	6567.23110	5686.29260	6322.39170	0.0008	0.0007	0.0011	
OBSERVATION EPOCH_2								
DATE: 10/04/2018								
MSC04	A013	11644.24820	3601.24150	3399.28000	0.00095	0.00085	0.0014	(+25mm)
MSC04	A005	-5321.71640	3634.07540	3173.66520	0.00095	0.00085	0.0013	

RESULT ANALYSIS

- **Analysis of the new administrative building deformation network based on simulated data**

$$\Delta\overset{a}{X}_{A001\ \text{to}\ MSC06} = \overset{a}{X}_{MSC06} - \overset{a}{X}_{A001} = X^{0}_{MSC06} - X^{0}_{A001} + \hat{X}_{MSC06} - \hat{X}_{A001} = -4600.6399 + \hat{X}M_{SC06} - \hat{X}A_{001}$$

$$\Delta\overset{a}{Y}_{A001\ \text{to}\ MSC06} = \overset{a}{Y}_{MSC06} - \overset{a}{Y}_{A001} = Y^{0}_{MSC06} - Y^{0}_{A001} + \hat{Y}_{MSC06} - \hat{Y}_{A001} = 5291.4526 + \hat{Y}M_{SC06} - \hat{Y}A_{001}$$

$$\Delta\overset{a}{Z}_{A001\ \text{to}\ MSC06} = \overset{a}{Z}_{MSC06} - \overset{a}{Z}_{A001} = Z^{0}_{MSC06} - Z^{0}_{A001} + \hat{Z}_{MSC06} - \hat{Z}_{A001} = 5415.0771 + \hat{Z}M_{SC06} - \hat{Z}A_{001}$$

$$\Delta\overset{a}{X}_{A001\ \text{to}\ MSC01} = \overset{a}{X}_{MSC01} - \overset{a}{X}_{A001} = \overset{a}{X}_{MSC01} - X^{0}_{A001} - \hat{X}_{A001} = 6566.9677 - \hat{X}A_{001}$$

$$\Delta\overset{a}{Y}_{A001\ \text{to}\ MSC01} = \overset{a}{Y}_{MSC01} - \overset{a}{Y}_{A001} = \overset{a}{Y}_{MSC01} - Y^{0}_{A001} - \hat{Y}_{A001} = 5685.973 - \hat{Y}A_{001}$$

$$\Delta\overset{a}{Z}_{A001\ \text{to}\ MSC01} = \overset{a}{Z}_{MSC01} - \overset{a}{Z}_{A001} = \overset{a}{Z}_{MSC01} - Z^{0}_{A001} - \hat{Z}_{A001} = 6323.0364 - \hat{Z}A_{001}$$

Where:

$\Delta\overset{a}{X}$, $\Delta\overset{a}{Y}$ and $\Delta\overset{a}{Z}$ = Ajusted Baseline Components

$\overset{a}{X}$, $\overset{a}{Y}$ and $\overset{a}{Z}$ = Adjusted Parameters

X^{0}, Y^{0} and Z^{0} = Approximate Parameters

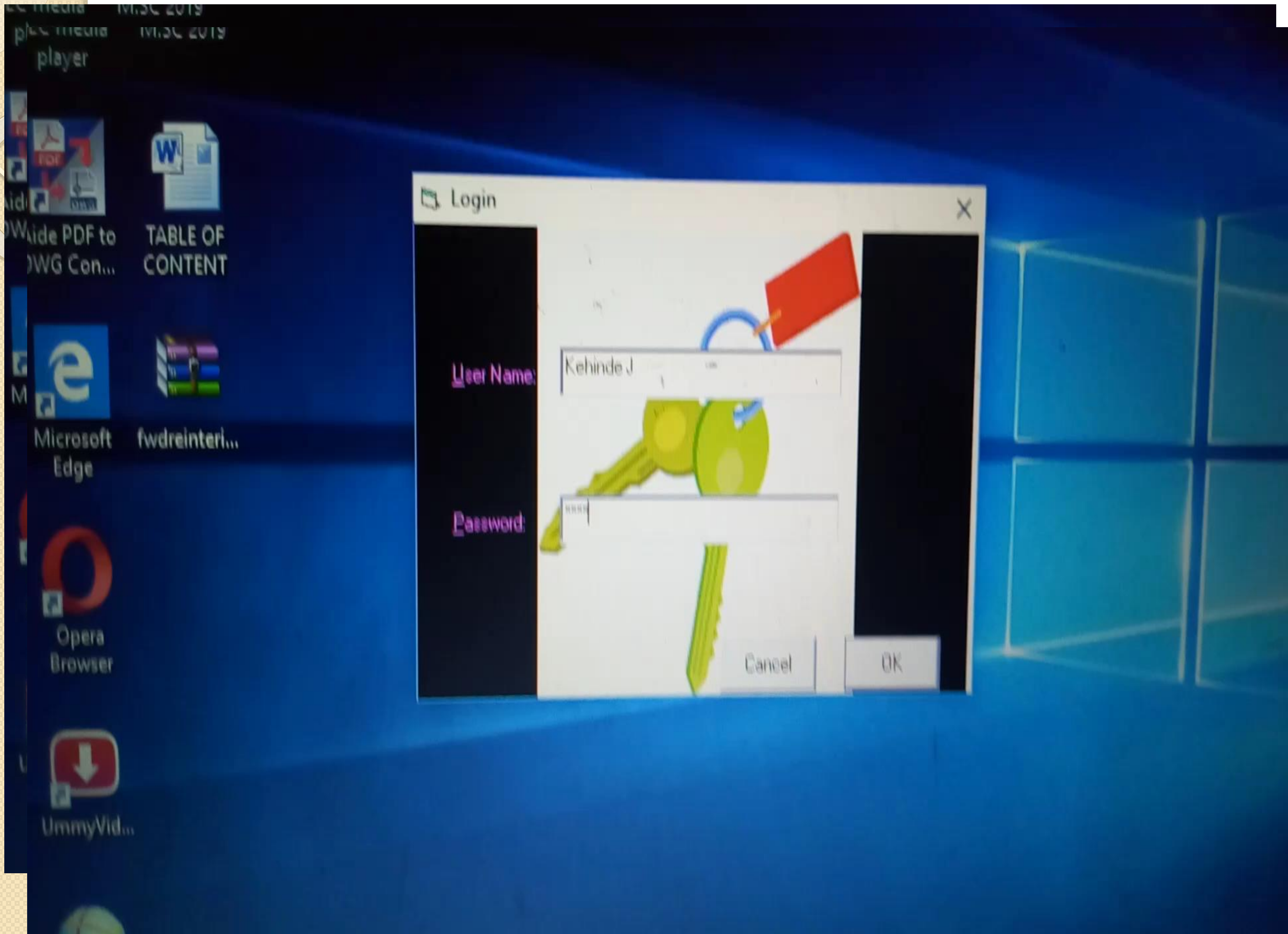
$\hat{X}$, $\hat{Y}$ and $\hat{Z}$ = Correction to Approximate Parameters

Weight Matrix, $W_{(3)}$

1162.79	0	0	0	0	0	0	0	0	0	0	0
0	1315.79	0	0	0	0	0	0	0	0	0	0
0	0	793.651	0	0	0	0	0	0	0	0	0
0	0	0	1162.79	0	0	0	0	0	0	0	0
0	0	0	0	1315.79	0	0	0	0	0	0	0
0	0	0	0	0	862.069	0	0	0	0	0	0
0	0	0	0	0	0	1162.79	0	0	0	0	0

PROGRAM DEPLOYMENT AND DOCUMENTATION

- The executable and other set up files that is needed for installations were compiled to a CD.
- The software can be installed on any windows operating system.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Edge
fwdreinterl...
Opera
Browser
UmmyVid...
Login
User Name:
Kehinde J
Password:
Cancel
OK

CONCLUSION

- The management and analysis of geographic data set is inevitably and integral aspect of surveying and thus the need for such automated systems which will enhance performance and increase productivity within the shortest possible time cannot be overemphasized. This is increasingly pronounced with geodetic procedures that is often characterized by a good number of redundant measurements in which the computational procedures involve are most times impossible to handle manually. This research has thus resulted in the production of a software that can be used to handle the geodetic computation procedures involved in detection of outliers, multi-epoch network adjustment and deformation network analysis. The output results from such analysis are comprehensive and logical, and thus can be used by academic researchers, survey firms and other organizations concerned with geospatial data management.
- It should however be noted that the computational extent at this time covers only pre-adjustment analysis (in the case of input approximate x, y, z coordinates), network adjustment analysis and trend analysis.

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Thanks for Listening