Finding out Transformation parameters and Evaluation of New Coordinate system in Sri Lanka

F. L. Karunaratne.
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by

F. L. Karunaratne.

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IFA Assessment Board

Chairman: Prof. Dr. Ir. M.G. Vosselman
Supervisor: Dipl. Ing. K.A. Grabmaier
Second supervisor: Drs. R.A. Knippers

ITC

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS

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Abstract

This task is discussed about Sri Lanka old and new geodetic coordinate systems. After introducing new coordinates system some changes of coordinates are appeared in the old control points. But no way is available to solve this problem.

This study tries to solve this problem considering the coordinates of 32 control points common to the both systems.

MATLAB is used as the programming software and matrix operations are applied to achieve a least square solutions.

In order to evaluate the new coordinate system datum transformation parameters and the process of coordinate transformations from WGS84 to local system, datum transformation parameters of new coordinate system are computed using Bursa wolf datum transformation formula.

Considering old and new coordinate systems as two different datums, datum transformation parameters are computed from old system to new system by Bursa wolf formula. Then coordinates of old control points are transformed to new system by using computed parameters.

Direct transformation of two dimensional coordinates from old system to new system are done using first, second and third order polynomials by computing corresponding coefficient of each polynomial.

As a third method to solve this problem, differences of coordinates of all control points (errors) are plotted as error vectors and try to identify, whether errors of coordinates are random or systematic. Then for direct transformation of two dimensional coordinates are done by computing corresponding parameters of first order for each separate area of the country.

Finally, Comparing the residuals of the computed coordinates, better transformation method is identified as the solution to problem.

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1. General Introduction

1.1. Historical Background

Sri Lanka is an island in Indian Ocean with having about 65610 square kilometres. Systematic triangulation in Sri Lanka commenced at about 1857 with the measurement of the Negombo base. In order to correct some errors observed in the system two base lines (Each base line was about 5.5 miles long and the distance between them was about 127 miles) remeasured with improved techniques (using invar tapes) and recomputation of frame work of principal triangulation was completed at 1930. Old coordinate system (Jackson) referred the Everest ellipsoid (1830) with Kandawala as the datum (Figure 1.2). But this triangulation network was not observed for the Cadastral surveys accuracy.

1.2. Sri Lanka Datum 1999 (SLD99)

In order to facilitate Geographic Information Systems and Cadastral Surveying, a new horizontal control network was established at 1999, using Global Positioning Systems (GPS) technology. Thirty two old points were also included to the new system. Other control points of the old system were not observed in the new system due to non suitability for GPS observation. These old control points were included to new system to compute the transformation parameters to local datum.

This system consist of one base station, 10 secondary base stations and 262 new control stations with including 20 fundamental bench mark points.

Figure 1.1 Sri Lanka Geographical location

(Source: http://geography.about.com/library/cia/blcsrilanka.htm)

1.3. Current Problem Faces with Coordinate Systems.

Since 1999, Sri Lanka datum 1999 (SLD99) coordinate system has been using for all surveying and related purposes. But it appears that the coordinates given by the new system (SLD99) and coordinates of old system (Jackson) of a control point are not taken a same value. The difference between these two values is changed according to the area it refers, and the maximum difference between these two coordinates at a point is close to 5.5 meters (Table 2.1).

Sri Lanka has been doing Cadastre surveying after the introducing of Title registration act at 1998. It has to deal with old map document referring old coordinate system. But there is no proper guidance of methods how to convert old coordinates of map document to the new system.

In addition to that resurveying of forest (Forest project) is also going on in this period. Those surveys have to use control points which are established by GPS technology with new coordinate system. When it deals with old map document, it is necessary to have conversion old coordinates to new system.
In addition to the above surveying work also deal with old document with old coordinates. Therefore, making a coordinate transformation formula has become as an essential task in Sri Lanka.

1.4. Objectives

This study has the following objectives**:**

1. Preparing a quality report for SLD99 coordinate system.
   Considering common points in two systems, evaluate the datum transformation parameters and the SLD 99 coordinates given in the report.

2. Finding out transformation parameters from old to new coordinate system in Sri Lanka using different methodologies.

   i. Datum transformation using Bursa Wolf formula.

   ii. Direct transformation in two dimensional coordinates using first, second and third order polynomials.

1.5. Available Data

Coordinates of 32 common points available in the two coordinate systems in the first order network of Sri Lanka (Table 2.1) are used in this study. In addition to that geographical coordinates of the common points in WGS84 system with global ellipsoidal heights. Orthometric heights of the common points are also available. Some of control points will be taken to compute datum transformation parameters and the rest of the points will be used as check points to evaluate the validity of computed parameters.

1.6. Structure of the Report.

The followings describe the content of the chapters in this report.

Chapter 1 – This is an introduction chapter covers briefly explain, historical back ground of Sri Lanka geodetic coordinate system, old and new coordinate system, current problems faces with coordinate system, objectives of the task and available data to be used.

Chapter 2 – This chapter analyse the problem by considering coordinate systems , technical reasons behind it and datum transformation parameters of each coordinate system. Finally decides how to approach the problem**.**

Chapter 3 – This chapter describes some important theories, equations , various transformation steps between coordinate systems relating to this task and procedure of computing Bursa wolf parameters.

Chapter 4-This chapter mainly evaluate the SLD99 coordinate system. Calculation of datum transformation parameters and coordinates are done. Finally compare those values with SLD99 report values.

Chapter 5– Considering old and new coordinate system as different datums, datum transformation parameters from old to SLD99 system are computed. Using these parameters new system coordinates are computed for the check points. Then compare with SLD99 values with the help of residuals.

Chapter 6– First, second and third order polynomials are used to identify better polynomial for direct transformation of two dimensional coordinates by considering residuals.

Chapter7–Differences of coordinates of common control points are plotted as error vectors. Then points are clustered considering the vector direction and first order polynomials are separately applied to each area. Then compare the computed coordinates by polynomial with SLD99 values.

Chapter8– This chapter is reserved for Conclusion and Recommendation to make clear the objectives in relation to the results for the purpose of implementation.

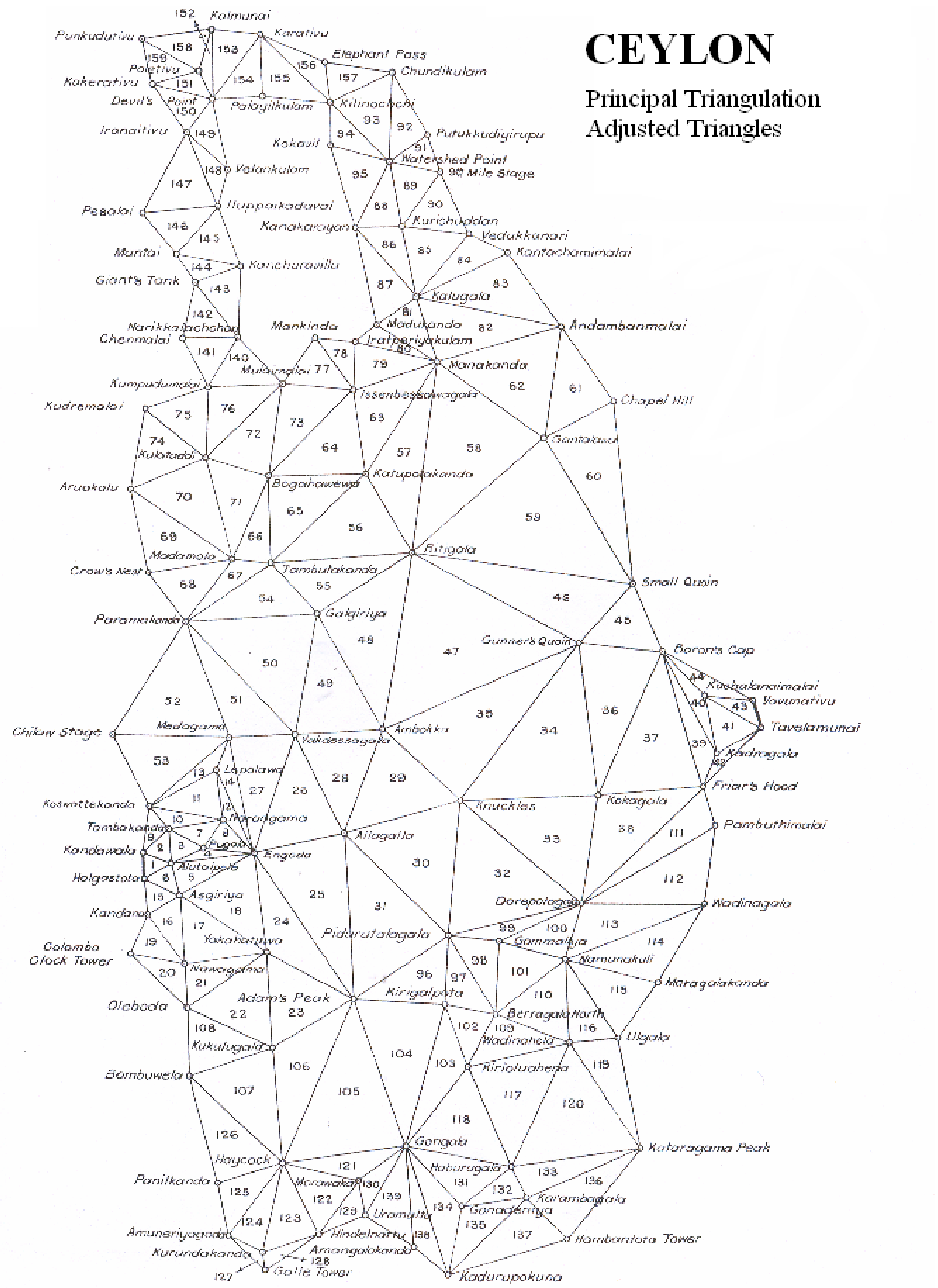


Figure 1.2 Triangulation network of Sri Lanka in 1930 (old coordinate system)

(Source: Principal Triangulation, Survey Department, Sri Lanka)

2. Identifying and Analysis of Problem

2.1. Introduction

In this chapter try to identify technical or theoretical reasons behind this problem. For this purpose , more attention is drawn to study about projection parameters of the map projection and datum transformation parameters of both old and new coordinate systems. By analysing above mentioned things, path of solution is identified to suit the available data.

2.2. Technical Reasons Behind the Problem

Sri Lanka use Transverse Mercator projection as the map projection. The projection parameters for the old system as follows.

Central meridian	80^0 $46^{'}$ $18.160000^{''}$ E
Latitude of origin	07^0 $00^{'}$ $01.729000^{''}$ N
Scale Factor at Central Meridian	0.9999238418
False Northing	200000 m
False Easting	200000 m

Here, Pidurutalagala station has been used as the latitude of origin and the central meridian of the old system.

Projection parameters of the new (SLD 99) system are given bellow.

Central meridian	80^0 $46^{'}$ $18.16710^{''}$ E
Latitude of origin	07^0 $00^{'}$ $01.69750^{''}$ N
Scale Factor at Central Meridian	0.9999238418
False Northing	500000 m
False Easting	500000 m

Coordinates of the Pidurutalagala station in new system is differed from old system due to introducing of new value to that point. SLD99 report says, due to new adjustment of the network, it has been changed. Therefore, to identify distinctly the new system from the old system , false Easting and Northing values of new system were used as 500000 m N and 500000 m E.

Due to above mentioned slight change in the angle coordinate, old and new coordinates are changed 0.21m in Easting and 0.945m in Northing. This will effect to coordinates of other areas also. But quantity of contribution of this change will depend on the area.

Coordinates given to the common control points in the new and old system are different and it is shown in Table 2.1

In cadastre surveying control traverses are used to maintain the necessary accuracy. When it deals with old map document, it is very difficult to decide how to use old coordinates with the new control points. According to the SLD99 report this error implies bad adjustment of the old network .

Station	Easting	Northing	Old East.	Old North.	ΔE	ΔN
TO034	468187.016	688677.883	168187.111	388681.544	-0.095	-3.661
TO037	440581.294	646092.298	140580.098	346094.244	1.196	-1.946
TO038	471880.084	646870.629	171879.964	346872.589	0.120	-1.961
TO039	441500.931	618988.808	141499.911	318990.588	1.020	-1.780
TO040	487091.332	622603.187	187091.240	322604.701	0.093	-1.514
TO047	429238.952	619904.877	129237.897	319906.615	1.055	-1.738
TO049	415004.553	600229.771	115003.078	300230.858	1.475	-1.088
TO053	424310.158	552633.931	124309.053	252633.471	1.106	0.460
TO056	427264.572	536575.157	127263.807	236574.792	0.766	0.365
TO057	436960.322	525982.897	136960.005	225982.441	0.317	0.456
TO058	466516.179	532730.457	166515.883	232730.570	0.296	-0.113
TO060	450146.938	564416.259	150146.388	264417.124	0.550	-0.865
TO061	456733.219	603275.619	156732.899	303276.628	0.320	-1.008
TO073	542853.912	510971.294	242854.445	210971.249	-0.533	0.045
TO074	503967.375	543742.345	203967.213	243742.777	0.162	-0.432
TO078	555044.360	467569.618	255044.801	167569.305	-0.441	0.312
TO080	515533.461	474921.436	215534.001	174921.075	-0.541	0.360
TO082	506758.772	458073.537	206759.830	158073.635	-1.058	-0.098
TO083	486755.509	431999.709	186758.022	131998.979	-2.513	0.730
TO089	539090.362	402841.564	239092.796	102843.969	-2.434	-2.405
TO090	489543.520	399273.962	189548.035	99274.280	-4.515	-0.319
TO091	472808.754	407953.771	172813.205	107952.552	-4.450	1.218
TO092	471274.718	420805.379	171278.367	120804.344	-3.649	1.034
TO093	458791.431	403225.834	158795.977	103223.615	-4.546	2.220
TO096	429543.022	402358.136	129546.570	102354.436	-3.548	3.700
TO097	426058.826	419251.519	126061.269	119248.347	-2.443	3.172
TO098	447548.558	426080.178	147551.215	126077.858	-2.657	2.320
TO099	416680.405	453574.474	116681.425	153572.806	-1.020	1.668
TO100	443670.910	462775.939	143671.946	162774.955	-1.035	0.984
TO103	416116.064	475581.848	116116.186	175580.092	-0.123	1.756
TO108	410504.573	522689.213	110504.251	222688.555	0.321	0.659
TO110	420675.415	527792.994	120674.847	227792.465	0.568	0.529

Table 2.1Coordinates of common control points

(Source: Report on Sri Lanka datum 1999, Survey Department, Sri Lanka)

2.3. Datum Transformation Parameters of Coordinate Systems

To establish SLD 99 coordinate system, it has been used GPS technology. It refers World global Reference system WGS 84. But this global datum is not suitable for Sri Lanka due to higher undulation value available with the geoid.

Old system refers Everest ellipsoid with Kandawala datum; Sld99 system refers same Everest ellipsoid. Transformation parameters of both systems from WGS84 to respective datums are given in table 2.2

Table 2.2: Transformation parameters of Sri Lanka old system and SLD99

Parameter	Sri Lanka old system	SLD99 system	
Rotation origin X_o	0.000m	0.000m	
Rotation origin Y_o	0.000m	0.000m	
Rotation origin Z_o	0.000m	0.000m	
Shift Dx :	97.000m	0.2933	± 10.7765 m
Shift Dy	-787.0000 m	-766.9499	± 5.3273 m
Shift Dz	-86.0000 m	-87.7131	± 6.0293 m
Rotation about x-axis	0.000000”	0.1957040”	±0.1930251”
Rotation about y-axis	0.000000”	1.6950677”	±0.1735736”
Rotation about z-axis	0.000000”	3.4730161”	±0.3490028”
Scale factor	1.0000000000	1.0000000393	±0.0000008051

(Source: Report on Sri Lanka datum 1999, Survey Department, Sri Lanka)

2.4. Analytical Approach.

Different methods are employed to achieve the objectives. All calculations are done in MATLAB soft ware using matrix operations.

(A.) In order to evaluate SLD99 coordinate system, the seven parameter Bursa wolf formula is used in following to ways.

- WGS84 coordinates and Sri Lanka old system coordinates are used to compute the datum transformation parameters from WGS84 to Sri Lanka old datum. Comparison of those values with the SLD99 report values.

- Coordinates of SLD99 system are computed using datum transformation parameters given in the SLD99 report. Computed coordinates are compared with values given in the report to evaluate the SLD99 coordinate system.

(B) To find a relationship between two coordinate systems three, different methods are used as follows.

- Bursa wolf formula is used to compute datum transformation parameters from old system to SLD99 system, using common points in the both system. Some of the control points are used to compute transformation parameters, the rest of the control points are used as check points for independent checks.

- Different order (first, second and third) polynomials are used to transform old two dimensional coordinates to new system, without considering heights. Some of the control points are used to compute polynomial parameters and other points are used as independent check points.

- By plotting coordinate differences of common points in a vector form, study the direction of error vectors and try to identify areas having approximately same direction of vectors in errors (clusters). Then transformation parameters are computed from one system to other. This is done separately for every local area.

2.5. Conclusion

According to the above study, it is clear that one of the reason is for availability of differences in coordinates due to application of different coordinates for central meridian and to latitude of origin in projection parameters. Other reason is low accuracy or bad adjustment of old coordinate system.

3. Datum Transformation

3.1. Introduction

In this chapter it describes some basic definitions and basic theories necessary for some calculations available in the next chapters. However, more details and equations relevant to those theories are given in appendix.

3.2. Coordinate Systems on the Earth.

Some important basic definitions are given below relating to coordinate systems.
Projection coordinates: Curved surface of the earth is represented as the plane within this plane, a simple set of XY or east and north axes is defined.

Orthometric heights: Heights defined above the irregular surface, the geoid that closely approximates mean sea level.

Geodetic coordinates: Latitude and longitude defined with respect to an ellipsoid.

Ellipsoidal heights: Heights defined above an ellipsoid which has been established as the datum for particular country or region, or on a global basis**.**

Cartesian coordinates: Three dimensional coordinates defined with respect to a set of axes with their origin at the centre of the spheroid used in the datum

3.3. Coordinate Transformation

Consider the two datums, these may be such as WGS84 and ITRF global datums or any locally defined datums used by a country or region.

Two rows of the below figure represent two different datums (A and B). Within each row, each vertically arranged box represents a different method of expressing coordinates.

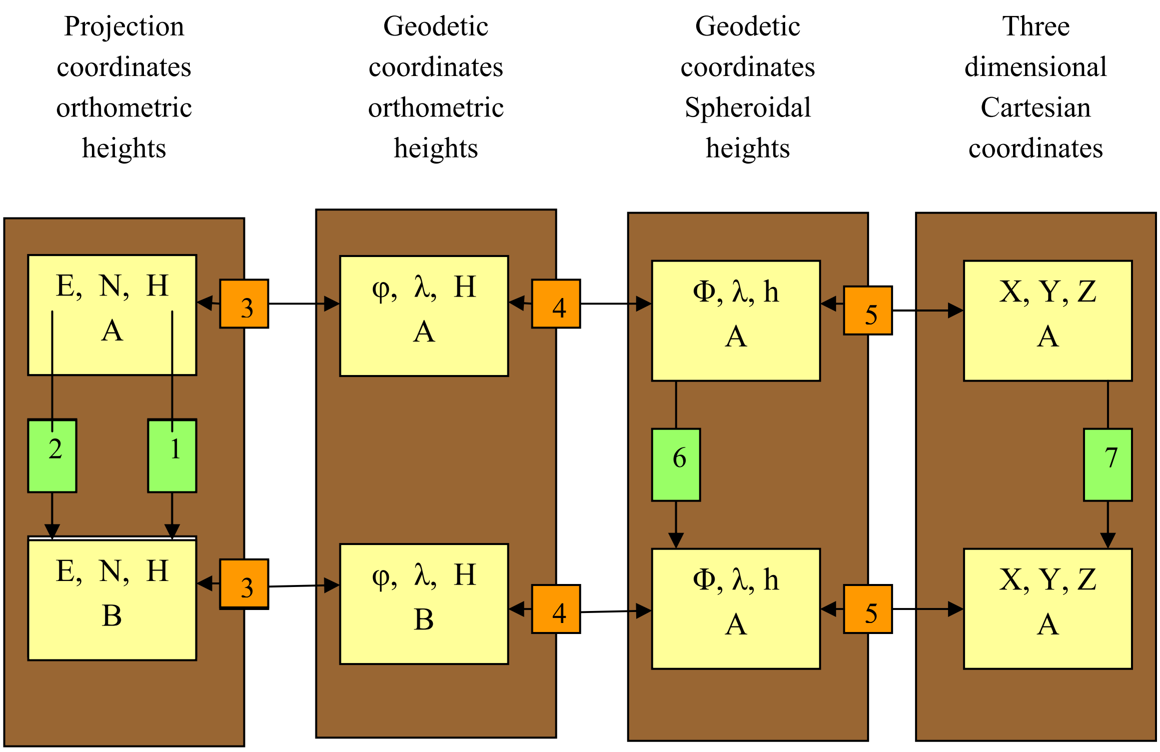


Figure 3.1 Complete procedure for transformations between different datums and projections.

For data conversion from one datum to another datum, one or more steps have to be applied as labelled in figure3.1 and described in below.

1) Two dimensional datums, coordinate can be described as eastings and northings or X and Y coordinates. The vertical datums used for orthometric heights are not actually related to the two dimensional datums.

2) Direct conversion from one map coordinates to another is possible for low level of accuracy provided that common points can be identified in both systems.

3) Conversion formulae from projection coordinate to geodetic coordinates or vice versa always depend on the type of projection.

4) Conversion of orthometric heights to ellipsoidal heights or vice versa requires knowledge about the geodetic undulation. (Separation between the geoid and considering ellipsoid.)

5) A straight forward method can be used for conversion from geodetic to Cartesian coordinates. It requires only knowledge about the parameters of the ellipsoid in the datum used.

6) Direct conversion from geodetic coordinates on one datum to geodetic coordinates on another datum is possible by using Molodensky's formulae. It gives the shift of origin from one another. This method gives comparatively low accuracy values relative to the seven or ten parameter transformations describes to next.

7) Actual datum transformation is represented by this step. This process involves at least a three-dimensional shift, and possibly rotation and scale change.
This will use in this task to transform coordinates from one datum to another.

3.4. Seven Parameter Transformation (Bursa Wolf Formula)

A coordinate transformation is a conversion from one system to another, to describe the same space. Transformation of one geocentric coordinates to another geocentric coordinate system (step 7 in chapter 3.3), can be done with Bursa wolf seven parameters formula given below.

$$\begin{pmatrix} X_T \\ Y_T \\ Z_T \end{pmatrix} = (S)\begin{pmatrix} 1 & \gamma & -\beta \\ -\gamma & +1 & \alpha \\ \beta & -\alpha & 1 \end{pmatrix} \times \begin{pmatrix} X_S \\ Y_S \\ Z_S \end{pmatrix} + \begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix}$$

Here, X_T, Y_T, Z_T and X_S, Y_S, Z_S are coordinates of in target coordinate system and source coordinate system respectively. α, β, γ are rotation angles about the X, Y and Z axes respectively and those are considered as very small. dX, dY and dZ are the translation of the origin. S is scale change from source to target datum. Change in scale δ is introduced as ppm value,
Then $S = (1 + \delta * 10^{-6})$ and above equation can be written as below.

$$\begin{pmatrix} X_T - X_S \\ Y_T - Y_S \\ Z_T - Z_S \end{pmatrix} = \begin{pmatrix} \delta & \gamma & -\beta \\ -\gamma & +\delta & \alpha \\ \beta & -\alpha & \delta \end{pmatrix} \times \begin{pmatrix} X_S \\ Y_S \\ Z_S \end{pmatrix} + \begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix}$$

δ, α, β, γ, dX, dY and dZ are seven unknown parameters. These parameters are computed using common known points in both systems. If the number of common points is more than three, least square solutions can be obtained for the 7 unknown parameters using matrix operation.

3.5. Procedure

Following procedure is used to compute the datum transformation parameters

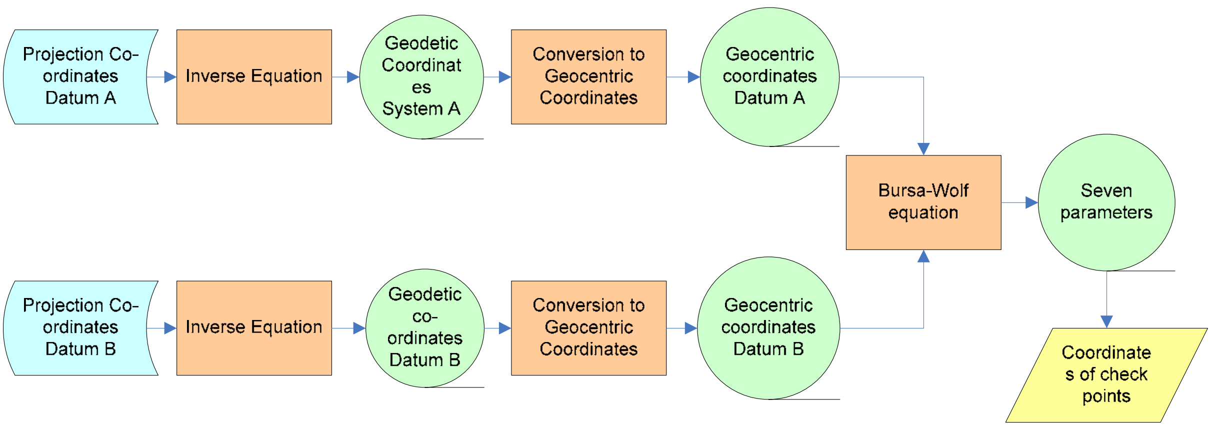


Figure 3.2: Computation procedure of transformation parameters

4. Evaluation of SLD99 Coordinate System

4.1. Introduction

The main objective of this chapter is evaluation of the SLD99 coordinate system. In order to evaluate SLD99 coordinate system, it is expected to compute datum transformation parameters from WGS84 to old coordinate system using Bursa Wolf seven parameters formula and those parameters are compared with corresponding parameters in the SLD99 report.

Secondly, SLD99 coordinates are computed by datum transformation parameters given in the report and compare with corresponding report values.

MATLAB soft ware is used for all calculations and coordinates are used in matrix form in order to obtain least square solution for the datum transformation parameters.

4.2. Why Select MATLAB?

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. As a programming language, it is faster than with traditional programming languages, such as C, C++, and FORTRAN. Another attractive features of MATLAB are easy to debug and more user friend in mathematical calculations. In this task, it is necessary to do more calculations, to compute datum transformation parameters and parameters of various polynomial. Those calculations can easily be done in MATLAB with the help of matrix operation. Other important thing is that it can easily compute least square solution for the parameters.

4.3. Computation of Datum Transformation Parameters (WGS 84 to Old System).

The main objective of this calculation is evaluating the quality of transformation parameters given in SLD99 report. Thirty two common points are used. Procedure of computation is very close as described in figure 3.2. WGS84 coordinates are available as geodetic coordinates in SLD99 report. Therefore first two steps in one of the branches are not necessary for in the computation work. The program written according to the steps shown in the figure 3.2 is used to compute datum transformation parameters and it is given in Appendix C (Para_WGS84_To_SLD99.m). No ellipsoidal heights are available for the Sri Lanka old datum. Therefore, orthometric heights are used for height values.

4.4. Comparison of Datum Transformation Parameters

Computed parameters and corresponding values in the report are shown in Table 4.1. Differences of dX, dY and dZ are very small. According to difference of rotation angles, it will produce maximum of 3 mm in each direction. This is same as change in shift parameters. Difference in ppm will give maximum of 10mm change in coordinates considering width (maximum 200 km) of Sri Lanka. This is also not comparatively large value considering the other errors.

Table 4.1: Datum Transformation parameters computed and corresponding report values.

Parameter	Report value	Computed value	difference
Shift dX (m)	18.072	18.070	0.002
Shift dY (m)	-859.123	-859.125	0.002
Shift dZ (m)	-92.271	-92.274	0.003
Rotation about X-axis arc second	-0.163409	-0.163508	9.9E-05
Rotation about Y-axis arc second	-1.485284	-1.485207	-7.7E-05
Rotation about z-axis arc second	1.986825	1.986911	-8.6E-05
scale (ppm)	13.794405	13.794828	-0.000423

4.5. Computing of SLD99 Coordinates Using Parameters in SLD99 Report.

Objective of this computation is to evaluate the coordinate transformation process part in SLD99 report.
According to SLD99 report, it has not been used parameters given in table 4.1. Because of ppm value of the scale change is not close to zero. Accepted 7 parameter set by the SLD99 report is given in table 2.1 in chapter 2.2.

Accepted 7 parameters are used to transform WGS84 geodetic coordinates of 32 common control points to SLD99 system. Program is designed according to the steps shown in figure 4.1. Used program is given in Appendix C (WGS84_To_SLD99_Report.m) and the computed coordinates are given in table 4.2 with comparing SLD99 report values.

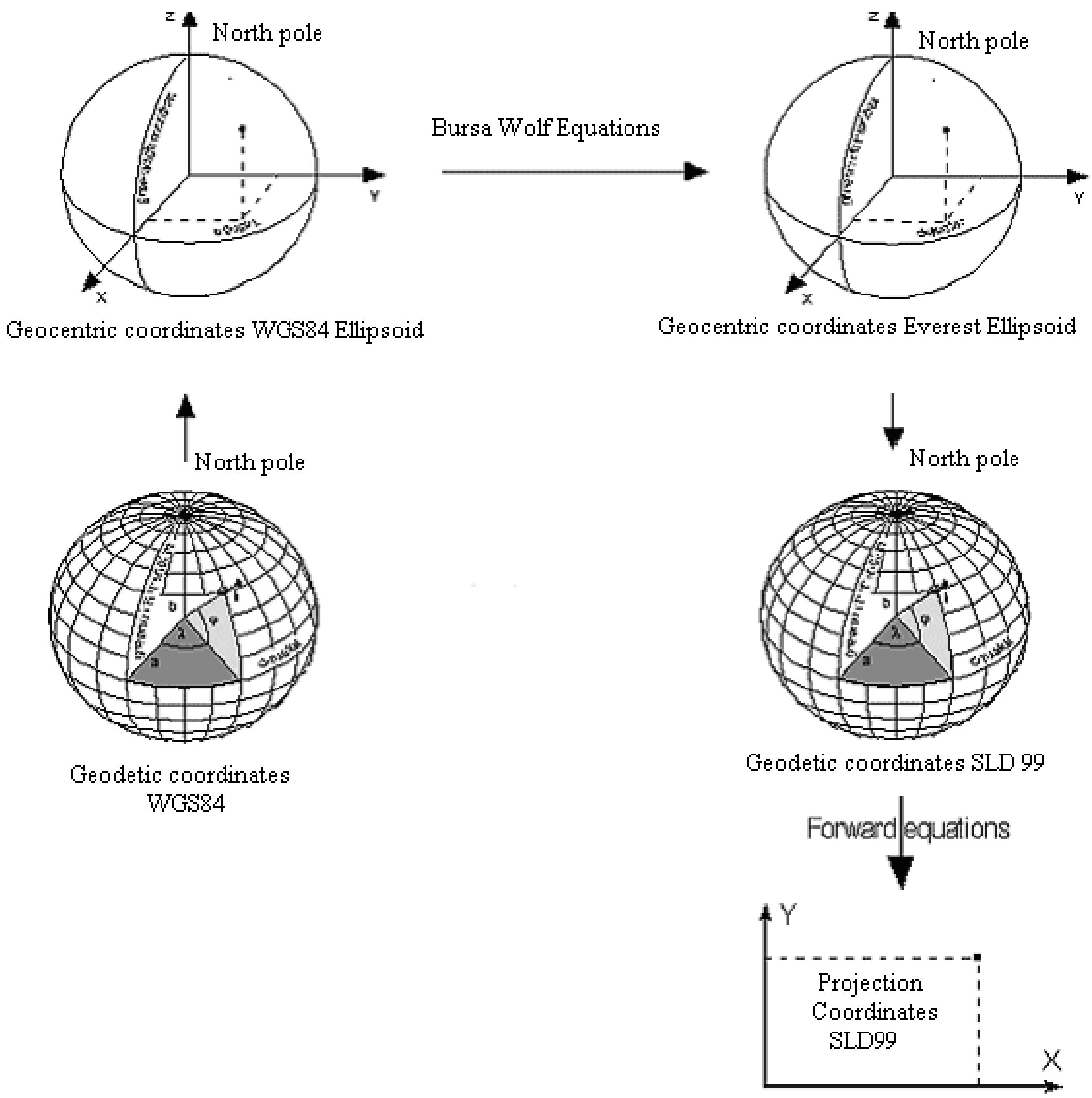


Figure 4.1: Coordinate transformation from WGS84 to SLD99

Table 4.2:Differences of computed and SLD99 report coordinates of the common 32 points.

Point ID	Easting m	Computed m	Diff. ΔE	Northing	Computed	Diff. ΔN	Heightsm	computed	Diff Δh
TO034	468187.02	468187.017	-0.001	688677.883	688677.882	0.001	132.942	132.943	-0.001
TO037	440581.29	440581.295	-0.001	646092.298	646092.297	0.001	102.492	102.492	-0.001
TO038	471880.08	471880.085	-0.001	646870.629	646870.628	0.001	401.647	401.648	-0.001
TO39	441500.93	441500.932	-0.001	618988.808	618988.807	0.001	280.479	280.479	-0.001
TO040	487091.33	487091.333	-0.001	622603.187	622603.187	0.000	766.016	766.017	-0.001
TO047	429238.95	429238.953	-0.001	619904.877	619904.876	0.001	260.755	260.756	-0.001
TO049	415004.55	415004.554	-0.001	600229.771	600229.770	0.001	160.547	160.547	-0.001
TO053	424310.16	424310.160	0.000	552633.931	552633.931	0.000	142.996	142.997	-0.001
TO056	427264.57	427264.574	0.000	536575.157	536575.156	0.001	197.195	197.196	-0.001
TO057	436960.32	436960.323	-0.001	525982.897	525982.896	0.001	308.823	308.824	-0.001
TO058	466516.18	466516.180	-0.001	532730.457	532730.457	0.000	1032.27	1032.274	-0.001
TO060	450146.94	450146.939	-0.001	564416.259	564416.258	0.001	522.65	522.650	-0.001
TO061	456733.22	456733.220	-0.001	603275.619	603275.619	0.000	570.973	570.973	-0.001
TO073	542853.91	542853.913	-0.001	510971.294	510971.293	0.001	1513.66	1513.664	-0.001
TO074	503967.38	503967.377	0.000	543742.345	543742.344	0.001	1861.69	1861.686	-0.001
TO078	555044.36	555044.361	-0.001	467569.618	467569.617	0.001	574.048	574.049	-0.001
TO080	515533.46	515533.462	-0.001	474921.436	474921.435	0.001	1777.56	1777.558	-0.001
TO082	506758.77	506758.773	-0.001	458073.537	458073.536	0.001	732.358	732.359	-0.001
TO083	486755.51	486755.510	-0.001	431999.709	431999.708	0.001	1358.88	1358.876	-0.001
TO089	539090.36	539090.364	0.000	402841.564	402841.563	0.001	30.0633	30.064	-0.001
TO090	489543.52	489543.521	-0.001	399273.962	399273.961	0.001	224.439	224.439	-0.001
TO091	472808.75	472808.755	-0.001	407953.771	407953.770	0.001	430.41	430.411	-0.001
TO092	471274.72	471274.719	-0.001	420805.379	420805.378	0.001	724.243	724.244	-0.001
TO093	458791.43	458791.432	-0.001	403225.834	403225.834	0.000	408.225	408.226	-0.001
TO096	429543.02	429543.024	-0.002	402358.136	402358.136	0.000	35.3103	35.311	-0.001
TO097	426058.83	426058.827	-0.001	419251.519	419251.518	0.001	53.2919	53.293	-0.001
TO098	447548.56	447548.559	-0.001	426080.178	426080.177	0.001	659.694	659.695	-0.001
TO099	416680.41	416680.407	0.000	453574.474	453574.473	0.001	157.181	157.182	-0.001
TO100	443670.91	443670.911	-0.001	462775.939	462775.938	0.001	701.902	701.903	-0.001
TO103	416116.06	416116.065	-0.001	475581.848	475581.848	0.000	112.833	112.834	-0.001
TO108	410504.57	410504.574	-0.001	522689.213	522689.213	0.000	54.2421	54.243	-0.001
TO110	420675.42	420675.416	-0.001	527792.994	527792.993	0.001	167.723	167.724	-0.001
Max .Diff.			**.002**			**0.001**			**0.001**

4.6. Conclusion

Computed datum transformation parameters here for WGS84 to old coordinate system is similar to the corresponding values in the report. Further, computed coordinates of SLD99 and corresponding values in the report are very similar with maximum difference of 2 mm. It implies that coordinate transformation procedure is almost correct in SLD99 report. Therefore this calculation evaluate the SLD99 coordinate system

5. Datum Transformation Method

5.1. Introduction

In this chapter datum transformation parameters are computed from Old coordinate system to SLD99 using Bursa Wolf formula and SLD99 coordinates of some check points are computed from the computed parameters. Then those coordinates are compared with corresponding SLD99 coordinates in the report.

5.2. Procedure in MATLAB

The procedure of computation of parameters from Sri Lanka old system to SLD99 is done same as in chapter 4.3. SLD99 coordinates of the control points are converted to the geodetic coordinates using inverse formula in Mercater projection. Used program is given appendix C (Mercater_InverseSLD99.m).

First, coordinates of twenty control points are used to compute the parameters and other twelve points are used as the check points to evaluate the computed parameters. In order to validation of computing parameters to all area of the country, twenty control points are selected in such away that those points to be spread all over the country. Twelve check points are also selected in the same way as before. Used program and text file are given in Appendix C (Para_SLold_To_SLD99.m)

Secondly, Used all 32 points to compute transformation parameters from old system to SLD99 and then SLD99 coordinates are computed using computed datum parameters.
Finally, compare both set of coordinates computed for SLD99.

5.3. Computed Parameters from Old System to SLD99

Computed parameters are given in Table 3.3. and coordinates are given in Table 3.4.

Table 5.1:Computed datum transformation parameters from old system to SLD99 system

Parameter	Computed value (20 points)	Computed value (32 points)
Shift dX (m)	-11.130	-17.772
Shift dY (m)	83.059	92.163
Shift dZ (m)	7.095	4.558
Rotation about X-axis	0.414196	0.359218
Rotation about Y-axis	2.818424	3.180139
Rotation about Z-axis	1.175512	1.486160
scale (ppm)	-12.590872	-13.755267

5.4. Comparison of Computed Coordinates

Table 5.2:Computed SLD 99 coordinates from computed coordinates (check points are bolded)

Point ID	Diff. ΔE (20 used)	Diff. ΔE (32 used)	Diff. ΔN (20 used)	Diff. ΔN (32 points)
T0034	-1.898	-2.076	-1.379	-1.211
TO037	-0.341	-0.471	-0.600	-0.533
TO040	-0.515	-0.545	0.214	0.340
TO047	-0.242	-0.335	-0.884	-0.869
TO049	0.285	0.212	-0.689	-0.723
TO053	0.720	0.747	0.396	0.323
TO058	0.734	0.848	0.183	0.166
TO061	-0.390	-0.419	0.034	0.081
TO073	1.183	1.429	1.167	1.266
TO074	0.910	1.049	0.542	0.607
TO078	2.048	2.388	1.062	1.132
TO082	0.958	1.258	-0.163	-0.194
TO083	-0.375	-0.049	0.045	-0.054
TO089	0.782	1.223	-2.706	-2.743
TO090	-1.874	-1.486	-1.374	-1.506
TO096	-1.707	-1.396	1.820	1.581
TO097	-0.889	-0.613	1.455	1.229
TO099	-0.077	0.125	0.252	0.050
TO103	0.495	0.656	0.607	0.429
TO108	0.193	0.259	0.017	-0.116
TO038	**-1.028**	-1.122	**-0.150**	-0.024
TO039	**-0.111**	-0.188	**-0.762**	-0.725
TO056	**0.648**	0.708	**0.142**	0.056
TO057	**0.476**	0.567	**0.238**	0.158
TO060	**0.320**	0.356	**-0.405**	-0.415
TO080	**1.347**	1.628	**0.632**	0.637
TO091	**-2.143**	-1.791	**0.035**	-0.118
TO092	**-1.545**	-1.218	**-0.013**	-0.154
TO093	**-2.351**	-2.007	**0.773**	0.589
TO098	**-0.926**	-0.637	**0.998**	0.820
TO100	**0.116**	0.333	**0.068**	-0.074
TO110	**0.495**	0.564	**0.100**	-0.008
max	2.048	2.388	2.706	2.743

5.5. Conclusion

According to results, obtained residuals are large values in both type of points. But actual situation is represented by differences of check points. Because they are independent checks. Though, obtained highest value for residuals is smaller than to original maximum difference in coordinates (4.515m for Eastings and 3.700 m for Northings), these residual values implies that this transformation is not sufficient for achieve cadastre survey accuracy.

6. Polynomial Method

6.1. Introduction

Generally, people have only Northing and Easting as coordinates in old document in the field. Therefore in this chapter no attention is drawn to consider the height values in coordinates. In other wards direct two dimensional coordinate transformations is considered. First, second and third order polynomials are used to identify mathematically more correct relationship between old system and new system of coordinates. Finally, comparing the residuals in each case most ftted polynomial is identified.

Difference in false northing and false easting in both systems is 300,000m. Therefore, when the coordinates values are substituted to the polynomials, above difference is deducted from the SLD99 coordinate values to increase the precision of the parameters.

Coordinates of twenty control points are used to compute the polynomial parameters. Other twelve points are used as check points to evaluate the computed parameters in each case.

6.2. Method of Solution in MATLAB

According to algebra, coefficients of a polynomial can be computed as follows.
If the n^{th} order polynomial Y is given as $Y= a_0X^n+a_1X^{n-1}+ \text{-----}+a_n$, with a_o, a_1 …a_n unknown coefficients,

Then Y = CX will be the matrix form of this equation. If the number of available equations are more than unknowns (coefficients), the least square solution of those coefficients are given by matrix P, and

$P = (C^I Y)^{-1}(C^IY)$

Where C^I is the transpose matrix of matrix C.

In order to find least square solution for the coefficients of the polynomials, above theory is used and all coordinates values are used in matrix form. Then, P column matrix will be given the values of coefficients of the corresponding polynomial.

6.3. Transformation Parameters Using First Order Polynomial

6.3.1. Problem

Calculation of transformation parameters between Sri Lanka old coordinate system and SLD99.Here it is assumed that coordinates of one system is a linear relation ship of coordinates of other system. It can represents in mathematically as follows.

$X_n = a_1Xo + a_2Yo + a_3$
$Y_n = a_4 X_o + a_5Y_o + a_6$

X_o – Eastings of old coordinate system
Y_o – Northings of old coordinate system
X_n – Eastings of new coordinate system
Y_n – Northings of new coordinate system

a_1, a_2, a_3, a_4, a_5 and a_6 are unknown parameters.
.
.

6.4. Methodology

In order to compute unknown parameters least square method is used with matrix operation. Twenty common points out of 32 are used to compute unknown parameters and balance12 points are used as check points to check the accuracy of the computed parameters. Used program and text files are given in Appendix C(Poly1_20.m).

6.5. Computed Parameters and Coordinates

Table 6.1: Computed parameters for the first order polynomial.

Parameter	Approximated value	Parameter	Approximated value
a1	0.99999671	a4	-0.00001886
a2	0.00001461	a5	0.99998442
a3	-3.270	a6	6.422

6.6. Transformation Parameters Using First Order Polynomial (Centre of Gravity Method)

6.6.1. Problem

Calculation of transformation parameters between Sri Lanka old coordinate system and SLD99. Here it is assumed that coordinates of one system is a linear relation ship of coordinates of others system. It can represent in mathematically as follows.

$X_n = m_1Xo + m_2Yo + m_3$-----------------------------A, $Y_n = m_4 X_o + m_5Y_o + m_6$-------------------------------B

Consider the centre of gravity of the control points.

$\overline{X}_n = X_n - X_{nm}$, $\overline{Y}_n = Y_n - Y_{nm}$, $\overline{X}_o = X_o - X_{om}$, $\overline{Y}_o = Y_o - Y_{om}$,

Here,

X_{om} – Centre of gravity of eastings in old system, X_{nm} – Centre of gravity of eastings in new system
Y_{om}– Centre of gravity of northings in old system, Y_{nm} – Centre of gravity of northings in new system

m_1, m_2, m_3, m_4, m_5 and m_6 are unknown parameters.
By substituting,
$(\overline{X}_n + X_{nm}) = m_1(\overline{X}_o + X_{om}) + m_2(\overline{Y}_o + Y_{om}) + m_3$, $(\overline{Y}_n + Y_{nm}) = m_4(\overline{X}_o + X_{om}) + m_5(\overline{Y}_o + Y_{om}) + m_6$

$\overline{X}_n = m_1 \overline{X}_o + m_2 \overline{Y}_o + (m_1X_{om} - X_{nm} + m_2Y_{om} + m_3)$, $(m_1X_{om} - X_{nm} + m_2Y_{om} + m_3) = q$ (constant)

Then, $\overline{X}_n = m_1 \overline{X}_o + m_2 \overline{Y}_o + q$ -------(1), $m_3 = q - m_1X_{om} + X_{nm} - m_2Y_{om}$-------------(1a)

Similarly, $\overline{Y}_n = m_4 \overline{X}_o + m_5 \overline{Y}_o + r$,------(2) , $m_4X_{om} - Y_{nm} + m_5Y_{om} + m_6 = r$ (constant),

$m_6 = r - m_4X_{om} + Y_{nm} - m_5Y_{om}$---------------------------(2a)

Equations (1) and (2) are same as previous case (chapter 4.3). Therefore same method is used to compute parameters.

Then equations 1a and 2a are used to find the values of m_3 and m_6. Finally, m_3 and m_6 are substituted in above equations A and B to compute X_n and Y_n for check points.

6.6.2. Input

In order to calculate unknown parameters, $\overline{X}_n$, $\overline{Y}_n$, $\overline{X}_o$ and $\overline{Y}_o$ are computed by deducting relevant mean values of each coordinate. Twenty control points are used to compute the unknown parameters.

6.6.3. Methodology

Procedure is same as described in chapter 4.3.4. Used program and text files are given Appendix C (Poly1_Mean20.m).

6.6.4. Computed Parameters and Coordinates.

Table 6.2: Computed parameters by the first order polynomial (centre of gravity method)

Parameter	Approximated value	Parameter	Approximated value
m1	0.99999671	m4	-0.00001886
m2	0.00001461	m5	0.99998442
m3	299996.730	m6	300006.422

6.7. Transformation Parameters Using Second Order Polynomial

6.7.1. Problem

Calculation of transformation parameters between Sri Lanka old coordinate system and SLD99. Here it is assumed that the relationship between two coordinates systems can be represent by second order polynomial in mathematically as follows.

$X_n = b_1X_o^2 + b_2Y_o^2 + b_3 X_oY_o + b_4X_o + b_5Y_o + b_6$

$Y_n = b_7X_o^2 + b_8Y_o^2 + b_9 X_oY_o + b_{10}X_o + b_{11}Y_o + b_{12}$

b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_8, b_9, b_{10}, b_{11} and b_{12} are parameters**.** Other notations are same as in chapter 4.3.1

6.7.2. Methodology

Procedure is same as described in chapter 4.3.4. Used program and text files are given Appendix C (Poly2_20.m)

6.7.3. Computed Parameters and Coordinates

Parameter	Approximated value	Parameter	Approximated value
b1	0.00000000016050	b7	0.00000000014212
b2	-0.00000000010229	b8	-0.00000000004827
b3	-0.00000000006699	b9	0.00000000027378
b4	0.99995310	b10	-0.00011946
b5	0.00007329	b11	0.99996348
b6	-5.566	b12	16.473

6.8. Transformation Parameters using Third Order polynomial

6.8.1. Problem

Calculation of transformation parameters between Sri Lanka old coordinate system and SLD99. Here it is assumed that the relationship between two coordinates systems can be represent by third order polynomial in mathematically as follows.

$X_n = c_1X_o^3 + c_2Y_o^3 + c_3 X_o^2Y_o + c_4X_o Y_o^2 + c_5 X_o^2 + c_6 Y_o^2 + c_7 X_oY_o + c_8X_o + c_9Y_o + c_{10}$

$X_n = c_{11}X_o^3 + c_{12}Yo3 + c_{13} X_o^2Y_o + c_{14}X_o Y_o^2 + c_{15} X_o^2 + c_{16} Y_o^2 + c_{17} X_oY_o + c_{18}X_o + c_{19}Y_o + c_{20}$

c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_8, c_9, c_{10}, c_{11}, c_{12}, c_{13}, c_{14}, c_{15}, c_{16}, c_{17}, c_{18}, c_{19} and c_{20} are parameters**.** Other notations are same as in 4.3.1

.

6.8.2. Methodology

Procedure is same as described in chapter 4.3.4. Used program and text files are given in Appendix C (Poly3_20.m).

6.8.3. Computed Parameters and Coordinates

Table 6.3: Computed parameters for the third order polynomial

Parameter	Approximated value	Parameter	Approximated value
c1	-0.00000000000000	c11	0.00000000000001
c2	0.00000000000000	c12	-0.00000000000000
c3	-0.00000000000000	c13	0.00000000000000
c4	-0.00000000000000	c14	-0.00000000000000
c5	0.00000000231209	c15	-0.00000000288701
c6	-0.00000000010287	c16	0.00000000016220
c7	0.00000000171523	c17	0.00000000029272
c8	0.99942818	c18	0.00041721
c9	-0.00005981	c19	0.99991668
c10	30.264	c20	-10.823

6.9. Transformation Parameters Using Third Order Polynomial (Modified Type)

6.9.1. Problem

Since Sri Lanka is close to 400 km in length, the third order polynomial calculations are dealing with maximum of $(2*10^5)^3$m values in first three terms of the polynomial. As a result of this high values, first three parameters of the third order polynomial will be very small values. Therefore those parameters are not significant in calculation. In addition to that when the matrix operations are applied to the coefficient matrix in MATLAB the corresponding matrix will become close to singular one. Because of this reason computed parameters may be inaccurate.

As a solution for this, old system coordinates are substituted to the polynomial after deducting 200,000m from each and dividing by 10^{-5}. Main objective of this preparation is to away from becoming to a singular matrix ,when matrix operations are applied to the corresponding coefficient matrix and facilitate to take more accurate values for the polynomial parameters.

Here, dX and dY are defined as

$dX = X_{new}$ -300000_X_{old}, $dY = Y_{new}$ -300000_Y_{old},

$X_{om} = (Xo-200000)1*10^{-5}$, $Y_{om} = (Yo-200000)1*10^{-5}$

If dX and dY are polynomials of X_{om} and Y_{om}

$dX = p(X_{om}, Y_{om})$, $dY = q(X_{om}, Y_{om})$

Then coordinates of new system (SLD99) will be given as

$X_{new} = X_{old} +300000 +dX$, $Y_{new} = Y_{old} +300000 +dY$,

Procedure is same as described in chapter 4.3.4. Used program and text files are given in Appendix C (Poly3_20_modified.m).

6.9.2. Parameters and Computed Coordinates.

: Computed parameters for the third order polynomial (modified type)

Param -eter	value	Param -eter	value	Param -eter	value	Param -eter	value
c1	-2.725	c6	-2.007	c11	5.049	c16	-0.807
c2	0.249	c7	-3.489	c12	-0.046	c17	3.521
c3	-3.923	c8	0.572	c13	1.227	c18	-1.821
c4	-1.237	c9	1.611	c14	-1.078	c19	-0.254
c5	-1.075	c10	-0.171	c15	3.875	c20	-0.115

6.10. Comparision of Coordinate differences with Polynomial Order

Now residuals obtained by different orders in polynomials are tabulated below in table 5.2

Though MATLAB software is given warnings about coefficient matrix as close to singular matrix, when the matrix operations are done. The same result are produced, in Centre of gravity method and normal method in first order polynomial. The same thing is occurred normal and modified type in third order polynomial.

Therefore only three cases available to be considered. When the order of polynomial is increased

Table 6.4: Residuals of Northings and Eastings of points used to parameter computation

	Residual in Eastings			Residual in Northings		
Point ID	First polynomial	Second polynomial	Third polynomial	First polynomial	Second polynomial	Third polynomial
T0034	-1.949	0.167	-0.037	-0.856	-0.474	-0.036
TO037	-0.127	0.332	0.093	-0.325	0.666	0.072
TO040	-0.734	-0.138	0.219	0.618	-0.332	0.244
TO047	0.078	-0.205	-0.136	-0.739	0.157	-0.364

TO049	0.738	-0.157	0.198	-0.663	0.161	0.084
TO053	1.094	0.139	0.349	0.318	0.349	0.337
TO058	0.715	0.302	0.073	0.231	-0.131	-0.379
TO061	-0.324	-0.339	-0.450	0.249	0.251	0.014
TO073	0.455	-0.519	-0.099	1.489	0.027	-0.316
TO074	0.543	0.162	0.043	0.789	-0.294	-0.036
TO078	1.221	0.101	0.000	1.311	0.837	0.226
TO082	0.584	0.505	0.035	-0.159	0.083	0.268
TO083	-0.556	-0.026	0.040	-0.114	0.522	0.365
TO089	0.121	0.363	0.077	-2.717	-0.907	-0.081
TO090	-2.071	-0.832	-0.169	-1.619	-0.305	-0.385
TO096	-1.347	-0.141	-0.006	1.315	0.930	0.302
TO097	-0.500	0.207	0.133	0.985	0.425	0.080
TO099	0.391	0.191	-0.133	-0.161	-0.961	-0.613
TO103	0.965	0.377	0.173	0.259	-0.444	0.018
TO108	0.703	-0.488	-0.404	-0.211	-0.561	0.201
				2.717		
Max abs Res.	**2.071**	**0.832**	**0.450**		**0.961**	**0.613**

Table 6.5: Residuals of Northings and Eastings in check points

	Residual in Eastings			Residual in Northings		
Point ID	First polynomial	Second polynomial	Third polynomial	First polynomial	Second polynomial	Third polynomial
TO038	-1.111	-0.113	-0.086	0.263	0.053	0.366
TO039	0.096	0.064	-0.003	-0.564	0.008	-0.465
TO056	0.998	0.105	0.25	0.028	-0.109	-0.154
TO057	0.737	0.032	0.087	0.137	-0.078	-0.327
TO060	0.452	-0.027	-0.084	-0.336	-0.444	-0.773
TO080	0.885	0.515	-0.035	0.728	0.576	0.788
TO091	-2.189	-1.043	-0.401	-0.263	0.543	0.023
TO092	-1.58	-0.733	-0.316	-0.275	0.304	-0.206
TO093	-2.261	-0.956	-0.213	0.399	0.928	0.129
TO098	-0.743	-0.033	0.306	0.644	0.657	-0.047
TO100	0.329	0.303	0.374	-0.193	-0.439	-0.917
TO110	0.908	-0.088	0.052	-0.069	-0.301	-0.089
Max abs Res.	**2.261**	**1.043**	**0.401**	**0.728**	**0.928**	**0.917**

6.11. Conclusion

According to the obtained results maximum (absolute) residuals are decreased in Easting as well as Northings when the polynomial order is increased. Theoretically it must be occurred because higher order polynomials are fitted in better way than the lower order.

But, if residuals are considered in check points they have no same behaviour met like in the first 20 points. Here residuals of Eastings are decreased with order of the polynomial and residuals of Northings have no regular pattern in behaviour like previous case.

First four parameters obtained for third order polynomial are not significant up to 13^{th} decimal place. Reason for this may be those terms are considered third power of the coordinates. Then result for that multiplication will be close to $(2*10^5)^3$, when considered the extent of Sri Lanka.

Fifth, sixth and seventh parameters of the third order polynomial and first three parameters of the second order polynomial are also significant after the eighth decimal place. Reason for this also justify by the same argument like in previous case.

Considering above facts, it conclude that logically and practically most convenient polynomial as the first order polynomial. But if the facility is available for more accurate calculations second order poly nomial can be used to obtain comparatively better results.

7. Graphical Representation

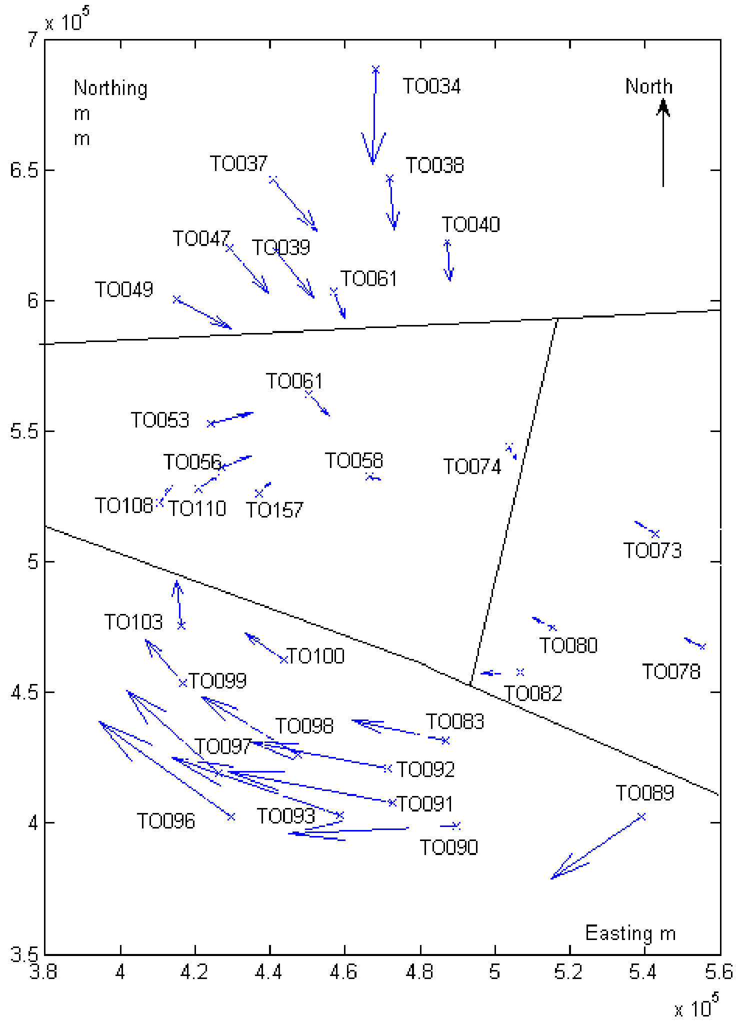
7.1. Introduction

In this chapter coordinate differences (Eastings and Northings) are plotted as error vectors. From this it is expected to identify the errors are systematic or random in area vice. By considering the direction of vectors points are divided to different areas. Then, parameters of the first order polynomial are computed for each area separately.

7.2. Analysis of Errors by Vector Plotting

Quiver function in MATLAB is used to plot the errors. Coordinate differences are plotted with respect to SLD99 (new) coordinates. The relevant data is given in Table 2.1and the program is given in Appendix C (Error_Vector_plot.m) ,Obtained results are shown in figure 4.1.

In order to understand easily, resultant error vectors are plotted comparatively very high scale than the coordinates.



According to the graph, differences of coordinates of control points are clustered to the four separate areas, when the directions of error are considered. Those errors appear to be systematic, if it is considered area vice.

Therefore it may be more logical, if polynomials are applied for each area separately.

Main four areas are defined as Eastern, Western, Northern and Southern as shown in the figure 7.2 considering the error vector direction

Figure 7.1: Graphical representation of Coordinate differences

7.3. Computed Parameters and Coordinates

The programme used in chapter 4.3 is used for computation of parameters and coordinates, Computed parameters in each case considering first order polynomial are given in Used program and text files are given in appendix C(Poly1_Northern8.m). The corresponding computed coordinates and residuals are given in appendix B

Table 7.1: Computed parameters of polynomial in area vice.

Parameter	Northern	Eastern	Southern	Western
a1	0.99997832	1.00000845	1.00000393	0.99999254
a2	-0.00000284	0.00000237	0.00005430	0.00001394
a3	4.868	-3.010	-10.180	-1.749
a4	0.00000398	0.00000460	-0.00004997	-0.00000999
a5	0.99997134	0.99999753	0.99996888	0.99997928
a6	7.044	-0.465	13.148	6.495

Figure 7.2: Coordinates of SLD99 by First order polynomial for Northern area.

Point ID	Easting m	Computed	ΔE m	Northing m	Computed	ΔN m

		m			m	
T0034	468187.016	468187.228	-0.212	688677.883	688678.116	-0.233
TO037	440581.294	440580.934	0.360	646092.298	646091.927	0.371
TO038	471880.084	471880.120	-0.036	646870.629	646870.374	0.255
TO039	441500.931	441500.804	0.127	618988.808	618989.052	-0.244
TO040	487091.332	487091.135	0.197	622603.187	622603.242	-0.055
TO047	429238.952	429239.054	-0.102	619904.877	619905.004	-0.127
TO049	415004.553	415004.599	-0.046	600229.771	600229.754	0.017
TO061	456733.219	456733.507	-0.288	603275.619	603275.603	0.016
Max abs diff			0.360			0.371

Table 7.2: Coordinates of SLD99 by First order polynomial for Eastern area.

Point ID	Easting m	Computed m	ΔE m	Northing m	Computed m	ΔN m
TO073	542853.912	542853.989	-0.077	510971.294	510971.382	-0.088
TO078	555044.360	555044.345	0.015	467569.618	467569.601	0.017
TO080	515533.461	515533.228	0.233	474921.436	474921.171	0.265
TO082	506758.772	506758.943	-0.171	458073.537	458073.732	-0.195
Max abs diff			0.233			0.265

Table 7.3: Coordinates of SLD99 by First order polynomial for Southern area.

Point ID	Easting m	Computed m	ΔE m	Northing m	Computed m	ΔN m
TO083	486755.509	486755.744	-0.235	431999.709	431998.687	1.022
TO089	539090.362	539089.141	1.221	402841.564	402841.969	-0.405
TO090	489543.52	489543.991	-0.471	399273.962	399274.867	-0.905

TO091	472808.754	472809.567	-0.813	407953.771	407953.705	0.066
TO092	471274.718	471275.420	-0.702	420805.379	420805.174	0.205
TO093	458791.431	458792.027	-0.596	403225.834	403225.616	0.218
TO096	429543.022	429542.457	0.565	402358.136	402357.925	0.211
TO097	426058.826	426058.060	0.766	419251.519	419251.485	0.034
TO098	447548.558	447548.461	0.097	426080.178	426079.709	0.469
TO099	416680.405	416680.043	0.362	453574.474	453575.344	-0.870
TO100	443670.91	443671.170	-0.260	462775.939	462775.858	0.081
TO103	416116.064	416115.997	0.067	475581.848	475581.974	-0.126
Max abs diff			1.221			1.022

Table 7.4: Coordinates of SLD99 by First order polynomial for Western area

Point ID	Easting m	Computed m	ΔE m	Northing m	Computed m	ΔN m
TO053	424310.158	424309.899	0.259	552633.931	552633.489	0.442
TO056	427264.572	427264.407	0.165	536575.157	536575.113	0.044
TO057	436960.322	436960.385	-0.063	525982.897	525982.885	0.012
TO058	466516.179	466516.137	0.042	532730.457	532730.579	-0.122
TO060	450146.938	450147.206	-0.268	564416.259	564416.639	-0.380
TO074	503967.375	503967.341	0.034	543742.345	543742.183	0.162
TO108	410504.573	410504.783	-0.210	522689.213	522689.331	-0.118
TO110	420675.415	420675.374	0.041	527792.994	527793.034	-0.040
Max abs diff			0.268			0.442

7.4. Conclusion

Plotted errors indicates that coordinate differences can be considered as systematic errors available in area vice. Differences between computed coordinates and SLD99 report values are very close. One of the reason for this may be the availability of low number of points in each case relative the earlier cases.

Errors are more systematic when those are considered in area vice. This is the other reason to reduce difference.
However , though this path is more effective to find the better polynomial for each area it is more difficult in practical implementation. Because, Sri Lanka has no natural permanent boundaries match with these boundaries. There is no principal is available to decide which polynomial is used for the boundary. Therefore this result is impossible to implement as a solution.

8. Conclusion and Recommendations

8.1. Conclusion

- In this study what ever the method is used to compute transformation parameters in each case, control pints were selected in such way that those are scattered all over the country except far northern area. The check points were also selected to cover the most of the area. Therefore computed parameters should have the validity for all area except northern part of the country.

- The least square principal was used to compute parameters in all cases of this task. Number of control points used were also higher value than the minimum necessary for computation of parameters. Those facts will result to up grade the validation of computed parameters.

- Computed 7 datum transformation parameters from WGS84 to SLD99 using Bursa wolf formula were almost same to the values given in the SLD99 report. Difference of computed and given values are not significant, when it is considered the corresponding changes will have to be occurred in coordinates. This result implies that SLD99 report are correct. Computed coordinates and given coordinates in SLD99 report are similar up to to maximum of 2 mm. It implies that coordinate transformation process is correct in SLD99 report. These two results have been given quality of the SLD99 system. This was the first objective of this task.

- One of another main objective of this task was computing of datum transformation parameters between Sri Lanka old and SLD99 coordinate system. It was successful in MATLAB programs. But the scale change was close to 13ppm. This is comparatively high value. Because it must be close to zero for better transformation. In this method,Maximum residual obtained in coordinates was 2.351m. However, this is smaller than original maximum difference (4.546m). Therefore those parameters are able to use to transform Sri Lank old coordinates to SLD99. But this residual implies that this accuracy will not sufficient for Cadastre surveys.

Other objective of this study to identify the better polynomial for direct transformation of two dimensional coordinates.

- When obtained residuals are analysed, it implies that residuals are decreasing when the polynomial order is increasing. The third order polynomial have produced the least values among the considered other polynomial types. However first four coefficients or parameters of third polynomial are only significant after the 13 th decimal place. Because of this reason it will not useful in practical situations.
- Even the First three parameters of the second order polynomial are also significant after the 8 th decimal place. Therefore for normal usages for the field calculation more convenient polynomial type is first order one. However, if the facilities are available for the accurate calculations second order polynomial is also possible to use.

- When the first order polynomial is applied separately for four areas, obtained residuals are comparatively smaller than those obtained to the same order polynomial for whole country (table 5.2). It means transformation parameters obtained considering the error vector graph is more effective. It means that errors are more systematically distributed in area vice.

Table 8.1: Maximum residuals for control points according to the area.

Area	No of points	Maximum residual obtained	
		Easting m	Nothings m
Northern	08	0.360	0.371
Eastern	04	0.233	0.265
Southern	12	1.221	1.022
Western	08	0.268	0.442

- Though this method is offered better result, implementation of this results faces practical difficulties when it is defined the area boundaries. No way method is avilabe to propose how to choose a polynomial from the both sides polynomials, for the boundary points. When it is considered topography of my country, No natural boundaries are present to fit with this method. Therefore, This solution can not be implemented in practically.

8.2. Recommendations

One important fact is that the parameters derived will be applicable only in the area of known control points and extrapolation beyond this area is likely to cause problems. When it is considered situation in Sri Lanka no common control points are available to both coordinate system in far northern area. Common points available to eastern are also few. Therefore, computed parameters for polynomials may not be given good results for those areas. It is better to add more points from mentioned areas by observing old control points using GPS and recomputation of parameters of the polynomials are needed.

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Appendices

Appendix A

Cartesian Coordinates

Three dimensional earth centered coordinates system simply can represent as given in figure3.3. The origin of the coordinate system is at centre of the ellipsoid and the z axis is parallel to the minor axis of the ellipsoid or to the polar axis of the earth. Axis X is aligned with the Greenwich prime meridian; the Y axis forms a right handed system.

Geodetic coordinates can be transformed to Cartesian coordinates by the set of formulae given bellow. For this conversion, it needs knowledge about the parameters of the reference ellipsoid.

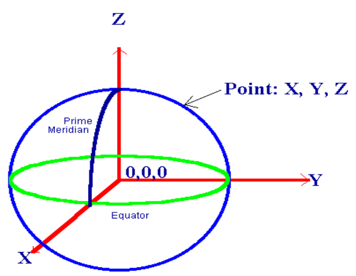


Figure appA 1: Catesian Coordinates

$$X = (v + h)\cos\phi\cos\lambda \qquad Y = (v + h)\cos\phi\sin\lambda,$$

$$Z = \{(1 - e^2)v + h\}\sin\phi$$

Where, $v = \dfrac{a}{\sqrt{(1 - e^2\sin^2\phi)}}$, ϕ is latitude, positive north; λ is longitudes positive east and h is the ellipsoidal height.

Following equations can be used for reverse computation.

$$\tan\lambda = \frac{Y}{X}, \qquad \lambda = \tan^{-1}\left(\frac{X}{Y}\right),$$

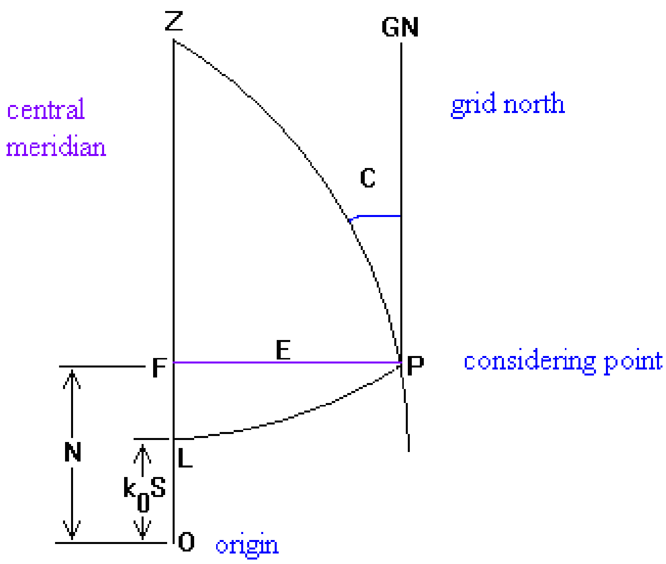
$$\tan\phi = \frac{Z + e'^2 b\sin^3 u}{p - e^2 a\cos^3 u}, \qquad \phi = \tan^{-1}\left(\frac{Z + e'^2 b\sin^3 u}{p - e^2 a\cos^3 u}\right)$$

Where,

$$p = \sqrt{(X^2 + Y^2)}, \qquad \tan u = \frac{Za}{pb}, \quad e'^2 = \frac{e^2}{1 - e^2}$$

Equation in Transverse Marketer Projection.

Figure app.B 1 shows the necessary points and lines to understand the equations used in transverse Mercater projection.



F = foot of perpendicular from P to the central meridian.
LP = parallel of latitude of P
ZP = meridian of P
OL = k_0S = meridional arc from equator
LF = ordinate of curvature
OF = N = grid northing
FP = E = grid distance from central meridian
C = convergence of meridians

φ = latitude of point

λ =longitude of point, λ_0 = central meridian

k_0 = scale along λ_0

Figure app.B 2 Transverse Mercater projection

This is the radius of curvature of the earth perpendicular to the meridian plane. It is also the distance from the point in question to the polar axis, measured perpendicular to the earth's surface.

Converting atitudes and Longitudes to XY Coordinates. (Forward equation)

$$x = koN\left\{A + \frac{(1-T+C)A^3}{6} + \frac{(5-18T+T^2+72C-58e'^2)A^5}{120}\right\}$$

$$y = ko\left\{M - Mo + N\tan\phi[\frac{A^2}{2} + (5-T+9C+4C^2)\frac{A^4}{24} + (61-58T+T^2+600C-330e'^2)\frac{A^6}{720}]\right\}$$

$$k = ko[1 + (1+C)\frac{A^2}{2} + (5-4T+42C+13C^2-28e'^2)\frac{A^4}{24} + (61-148T+16T^2)\frac{A^6}{720}]$$

Where,

$$e = \sqrt{\frac{a^2-b^2}{a^2}},\ e'^2 = \frac{e^2}{1-e^2},\ 1 \quad (1-e\ \sin\ \varphi) \quad \frac{M}{a(1-\frac{e^2}{4}-\frac{3e^4}{64}-\frac{5e^6}{256})}$$

$$N = \frac{a}{(1-e^2\sin^2\phi)^{1\frac{1}{2}}}, C = e'^2\cos^2\phi, A = (\lambda - \lambda_o)\cos\phi,$$ λ and Φ in radians,

$$M = a[(1-\frac{e^2}{4}-\frac{3e^4}{64}-\frac{5e^6}{256}-\cdot\cdot)\phi - (\frac{3e^2}{8}+\frac{3e^4}{32}+\frac{45e^6}{1024}+\cdot\cdot)\sin 2\phi + (\frac{15e^4}{256}+\frac{45e^6}{1024}+\cdot\cdot)\sin 4\phi - (\frac{35e^6}{3072}+\cdot\cdot)\sin 6\phi]$$

$$L = L_o + (\frac{Q_5 - Q_6 + Q_7}{\cos\phi_1})$$

Where, $Q_5 = D$

$$Q_6 = (1+2T_1+C_1)\frac{D^3}{6},\ Q_7 = (5-2C_1+28T_1-3C_1{}^2+8e'^2+24T_1{}^2)\frac{D^5}{120}$$

Converting Latitude and Longitude to XY coordinates (Inverse equation)

$$e_1 = \frac{1-\sqrt{(1-e^2)}}{1+\sqrt{(1-e^2)}}\quad ,M = M_o + \frac{y}{k_o}$$

$$\phi_1 = \mu + J_1\sin(2\mu) + J_2\sin(4\mu) + J_3\sin(6\mu) + J_4\sin(8\mu)$$

Where,

$$J_1 = (\frac{3e_1}{2} - \frac{27e_1{}^3}{32}\cdots), J_2 = (\frac{21e_1{}^2}{16} - \frac{55e_1{}^4}{32} + \cdot\cdot), J_3 = (\frac{151e_1{}^3}{96} + \cdot\cdot), J_4 = (\frac{1097e_e{}^4}{512} + \cdot\cdot)$$

$$\phi = \phi_1 - Q_1(Q_2 - Q_3 + Q_4),$$

Where

$$Q_1 = \frac{N_1\tan\phi_1}{R_1}\text{Q}, Q_2 = \frac{D^2}{2}\ Q_3 = (5+3T_1+10C_1-4C_1{}^2-9e'^2)\frac{D^4}{24}$$

$$Q4 = (61-90T_1+298C_1+45T_1{}^2-3C_1{}^2-252e'^2)\frac{D^6}{720}$$

$$R = \frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2\phi)}}, v = \frac{a}{\sqrt{(1-e^2\sin^2\phi)}}, D = \frac{x}{N_1k_o}, C_1 = e'^2\cos^2\phi$$

Both system projected coordinates are converted to geographic coordinates of respective datums.

Appendix B (Computed Coordinates and Residuals)

Coordinates of SLD99 by First order polynomial

Table apB. 1: Coordinates of SLD99 by First order polynomial

Point ID	1st order Easting m	2st order Easting m	3rdt order Easting m	1st order Northing m	2st order Easting m	3rd order Northing m
T0034	468188.965	468186.849	468187.053	688678.739	688678.357	688677.919
TO037	440581.421	440580.962	440581.201	646092.623	646091.632	646092.226
TO040	487092.066	487091.470	487091.113	622602.569	622603.519	622602.943
TO047	429238.874	429239.157	429239.088	619905.616	619904.720	619905.241
TO049	415003.815	415004.710	415004.355	600230.434	600229.610	600229.687
TO053	424309.064	424310.019	424309.809	552633.613	552633.582	552633.594
TO058	466515.464	466515.877	466516.106	532730.226	532730.588	532730.836
TO061	456733.543	456733.558	456733.669	603275.370	603275.368	603275.605
TO073	542853.457	542854.431	542854.011	510969.805	510971.267	510971.610
TO074	503966.832	503967.213	503967.332	543741.556	543742.639	543742.381
TO078	555043.139	555044.259	555044.360	467568.307	467568.781	467569.392
TO082	506758.188	506758.267	506758.737	458073.696	458073.454	458073.269
TO083	486756.065	486755.535	486755.469	431999.823	431999.187	431999.344
TO089	539090.241	539089.999	539090.285	402844.281	402842.471	402841.645
TO090	489545.591	489544.352	489543.689	399275.581	399274.267	399274.347
TO096	429544.369	429543.163	429543.028	402356.821	402357.206	402357.834
TO097	426059.326	426058.619	426058.693	419250.534	419251.094	419251.439
TO099	416680.014	416680.214	416680.538	453574.635	453575.435	453575.087
TO103	416115.099	416115.687	416115.891	475581.589	475582.292	475581.830
TO108	410503.870	410505.061	410504.977	522689.424	522689.774	522689.012

Table apB. 2: Coordinates of check points by First order polynomial

Point ID	1st order Easting m	2st order Easting m	3rdt order Easting m	1st order Northing m	2st order Northing m	3rd order Northing m
TO038	471881.195	471880.197	471880.170	646870.366	646870.576	646870.263
TO039	441500.835	441500.867	441500.934	618989.372	618988.800	618989.273
TO056	427263.574	427264.467	427264.322	536575.129	536575.266	536575.311
TO057	436959.585	436960.290	436960.235	525982.760	525982.975	525983.224
TO060	450146.486	450146.965	450147.022	564416.595	564416.703	564417.032
TO080	515532.576	515532.946	515533.496	474920.708	474920.860	474920.648
TO091	472810.943	472809.797	472809.155	407954.034	407953.228	407953.748
TO092	471276.298	471275.451	471275.034	420805.654	420805.075	420805.585
TO093	458793.692	458792.387	458791.644	403225.435	403224.906	403225.705
TO098	447549.301	447548.591	447548.252	426079.534	426079.521	426080.225
TO100	443670.581	443670.607	443670.536	462776.132	462776.378	462776.856
TO110	420674.507	420675.503	420675.363	527793.063	527793.295	527793.083

Coordinates of SLD99 by Second order polynomial(32 Points)

Table apB. 3: Coordinates of SLD99 by Second order polynomial (32 Points)

Point ID	Easting m	computed Easting m	Difference m	Northing m	computed Northing m	Difference m
T0034	468187.016	468186.721	0.295	688677.883	688678.463	-0.580
To037	440581.294	440580.924	0.370	646092.298	646091.601	0.697
TO038	471880.084	471880.164	-0.080	646870.629	646870.609	0.020
TO039	441500.931	441500.868	0.063	618988.808	618988.744	0.064
TO040	487091.332	487091.500	-0.168	622603.187	622603.534	-0.347
TO047	429238.952	429239.177	-0.225	619904.877	619904.625	0.252
TO049	415004.553	415004.793	-0.240	600229.771	600229.449	0.322
TO053	424310.158	424310.085	0.073	552633.931	552633.466	0.465
TO056	427264.572	427264.517	0.055	536575.157	536575.174	-0.017
TO057	436960.322	436960.305	0.017	525982.897	525982.926	-0.029
TO058	466516.179	466515.869	0.310	532730.457	532730.593	-0.136

TO060	450146.938	450146.983	-0.045	564416.259	564416.658	-0.399
TO061	456733.219	456733.564	-0.345	603275.619	603275.338	0.281
TO073	542853.912	542854.648	-0.736	510971.294	510971.218	0.076
TO074	503967.375	503967.288	0.087	543742.345	543742.639	-0.294
TO078	555044.360	555044.442	-0.082	467569.618	467568.764	0.854
TO080	515533.461	515532.930	0.531	474921.436	474920.941	0.495
TO082	506758.772	506758.169	0.603	458073.537	458073.587	-0.050
TO083	486755.509	486755.305	0.204	431999.709	431999.408	0.301
TO089	539090.362	539089.822	0.540	402841.564	402842.700	-1.136
TO090	489543.520	489543.993	-0.473	399273.962	399274.599	-0.637
TO091	472808.754	472809.465	-0.711	407953.771	407953.527	0.244
TO092	471274.718	471275.170	-0.452	420805.379	420805.327	0.052
TO093	458791.431	458792.046	-0.615	403225.834	403225.208	0.626
TO096	429543.022	429542.892	0.130	402358.136	402357.444	0.692
TO097	426058.826	426058.425	0.401	419251.519	419251.260	0.259
TO098	447548.558	447548.356	0.202	426080.178	426079.722	0.456
TO099	416680.405	416680.164	0.241	453574.474	453575.459	-0.985
TO100	443670.910	443670.492	0.418	462775.939	462776.464	-0.525
TO103	416116.064	416115.691	0.373	475581.848	475582.258	-0.410
TO108	410504.573	410505.162	-0.589	522689.213	522689.631	-0.418
TO110	420675.415	420675.567	-0.152	527792.994	527793.188	-0.194
Max abs diff			0.736			1.136

Coordinates of SLD99 by Third order polynomial (modified-32 Points)

Table apB. 4: Coordinates of SLD99 by Third order polynomial (modified-32 Points)

Point ID	Easting m	computed E m	Difference m	Northing m	computed Northing m	Difference m
T0034	468187.016	468187.064	-0.048	688677.883	688678.010	-0.127
To037	440581.294	440581.186	0.108	646092.298	646092.198	0.100
TO038	471880.084	471880.137	-0.053	646870.629	646870.278	0.351
TO039	441500.931	441500.936	-0.005	618988.808	618989.114	-0.306
TO040	487091.332	487091.037	0.295	622603.187	622603.038	0.149
TO047	429238.952	429239.063	-0.111	619904.877	619905.182	-0.305
TO049	415004.553	415004.295	0.258	600229.771	600229.797	-0.026
TO053	424310.158	424309.866	0.292	552633.931	552633.352	0.579
TO056	427264.572	427264.406	0.166	536575.157	536575.003	0.154
TO057	436960.322	436960.339	-0.017	525982.897	525982.827	0.070
TO058	466516.179	466516.169	0.010	532730.457	532730.593	-0.136
TO060	450146.938	450147.083	-0.145	564416.259	564416.703	-0.444
TO061	456733.219	456733.683	-0.464	603275.619	603275.413	0.206
TO073	542853.912	542853.978	-0.066	510971.294	510971.767	-0.473

TO074	503967.375	503967.283	0.092	543742.345	543742.607	-0.262
TO078	555044.360	555044.441	-0.081	467569.618	467569.260	0.358
TO080	515533.461	515533.477	-0.016	474921.436	474920.936	0.500
TO082	506758.772	506758.712	0.060	458073.537	458073.490	0.047
TO083	486755.509	486755.417	0.092	431999.709	431999.362	0.347
TO089	539090.362	539090.223	0.139	402841.564	402841.762	-0.198
TO090	489543.520	489543.513	0.007	399273.962	399274.440	-0.478
TO091	472808.754	472809.041	-0.287	407953.771	407953.675	0.096
TO092	471274.718	471274.974	-0.256	420805.379	420805.463	-0.084
TO093	458791.431	458791.536	-0.105	403225.834	403225.572	0.262
TO096	429543.022	429542.965	0.057	402358.136	402357.912	0.224
TO097	426058.826	426058.700	0.126	419251.519	419251.459	0.060
TO098	447548.558	447548.257	0.301	426080.178	426079.984	0.194
TO099	416680.405	416680.622	-0.217	453574.474	453575.123	-0.649
TO100	443670.910	443670.629	0.281	462775.939	462776.495	-0.556
TO103	416116.064	416115.991	0.073	475581.848	475581.788	0.060
TO108	410504.573	410505.032	-0.459	522689.213	522689.050	0.163
TO110	420675.415	420675.444	-0.029	527792.994	527792.870	0.124
Max abs diff			0.464			0.649

Appendix C (List Programs & Text Files)

Para_WGS84_To_SLD99.m

```
%Program to compute transformation parameters from WGS84 to Sri Lanka old
%system.Bursa wolf  7 Parameters are computed.
% 32 control points with WGS 84 latitudes, longitudes, and ellipsoidal
heights
% 32 control point with SLD old Easting, Northings and Everest ellipsoidal
% heights.
clc
clear
format long
% Projected coordinates of SL old given in reportSLD99 are converted to
latitudes and  longitudes values by
% using inverse equations of the Transverse Mercater projection..
NPoints=32;
a=6377276.345;

e=0.08147298125167;
% Projection Parameters given in SLD99 report for SL old system  are used.
Lo=(80+(46/60)+(18.16/3600))*pi/180;
Po=(7+(1.729/3600))*pi/180;
e1=(1-realsqrt(1-e^2))/(1+realsqrt(1-e^2));
[PN, Xo, Yo, Hv]=textread('SL_old_32.txt','%s %f %f %f');
```

```
X=Xo-200000;
Y=Yo-200000;


ed=realsqrt((e^2)/(1-e^2));
Mo=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*Po-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*Po)+(15*(e^4)/256+45*(e^6)/1024)
*sin(4*Po)-(35*(e^6)/3072)*sin(6*Po));
ko=0.9999238418;

for i=1:NPoints;
M(i,1)=Mo+Y(i,1)/ko;
mu(i,1)=M(i,1)/(a*(1-(e^2/4)-3*(e^4)/64-5*(e^6)/256));

J1(i,1)=(3*e1/2-27*(e1^3)/32);
J2(i,1)=(21*(e1^2)/16-55*(e1^4)/32);
J3(i,1)=(151*(e1^3)/96);
J4(i,1)=(1097*(e1^4)/512);
P1(i,1)=mu(i,1)+J1(i,1)*sin(2*mu(i,1))+J2(i,1)*sin(4*mu(i,1))+J3(i,1)*sin(6
*mu(i,1))+J4(i,1)*sin(8*mu(i,1));

C1(i,1)=(ed^2)*(cos(P1(i,1)))^2;
T1(i,1)=(tan(P1(i,1)))^2;

R1(i,1)=a*(1-e^2)/(1-(e^2)*(sin(P1(i,1)))^2)^1.5;

N1(i,1)=a/realsqrt(1-(e^2)*(sin(P1(i,1)))^2);
D(i,1)=X(i,1)/(N1(i,1)*ko);

Q1(i,1)=(N1(i,1)*tan(P1(i,1)))/R1(i,1);
Q2(i,1)=((D(i,1)^2)/2);
Q3(i,1)=(5+3*T1(i,1)+10*C1(i,1)-4*C1(i,1)^2-9*e1^2)*((D(i,1)^4)/24);
Q4(i,1)=(61+90*T1(i,1)+298*C1(i,1)+45*T1(i,1)^2-3*C1(i,1)^2-
252*ed^2)*((D(i,1)^6)/720);
P(i,1)=P1(i,1)-Q1(i,1)*(Q2(i,1)-Q3(i,1)+Q4(i,1));

Q5(i,1)=D(i,1);
Q6(i,1)=(1+2*T1(i,1)+C1(i,1))*(D(i,1)^3)/6;
Q7(i,1)=(5-2*C1(i,1)+28*T1(i,1)-
3*C1(i,1)^2+8*ed^2+24*T1(i,1)^2)*(D(i,1)^5)/120;
L(i,1)=Lo+((Q5(i,1)-Q6(i,1)+Q7(i,1))/cos(P1(i,1)));
end
Pv=P*180/pi;
Lv=L*180/pi;

[PW, PM, PS, LI, LM, LS, HI]=textread('wgsLP.txt','%f %f %f %f %f %f %f');
PD=(PW+(PM/60)+(PS/3600));
LD=(LI+(LM/60)+(LS/3600));

% Computing of Geocentric coordinates with respect to global Ellipsoid
% (WGS84)
ag=6378137.0;
eg=0.081819190842622;
bg=6356752.3142;
for i=1:NPoints;
ng(i,1)=(eg*sind(PD(i)))^2;
vg(i,1)=ag/(realsqrt(1-ng(i)));

XI(i,1)=(vg(i)+HI(i))*cosd(PD(i))*cosd(LD(i));
YI(i,1)=(vg(i)+HI(i))*cosd(PD(i))*sind(LD(i));
ZI(i,1)=(vg(i)*(1-(eg^2))+HI(i))*sind(PD(i));
end
```

```
av=6377276.345;
bv=6356075.413;

ev=realsqrt(((av^2)-(bv^2))/(av^2));

for i=1:NPoints
Nv=av/(realsqrt(1-(ev*sind(Pv(i)))^2));

Xv(i,1)=(Nv+Hv(i))*cosd(Pv(i))*cosd(Lv(i));
Yv(i,1)=(Nv+Hv(i))*cosd(Pv(i))*sind(Lv(i));
Zv(i,1)=(Nv*(1-(ev^2))+Hv(i))*sind(Pv(i));
end
C=zeros(NPoints*3,7);

for i=1:NPoints
    C(i*3-2,1)=XI(i);
    C(i*3-2,3)=-ZI(i);
    C(i*3-2,4)=YI(i);
    C(i*3-2,5)=1;
    C(i*3-1,1)=YI(i);
    C(i*3-1,2)=ZI(i);
    C(i*3-1,4)=-XI(i);
    C(i*3-1,6)=1;
    C(i*3,1)=ZI(i);
    C(i*3,2)=-YI(i);
    C(i*3,3)=XI(i);
    C(i*3,7)=1;
end

y=zeros(NPoints*3,1);

for i=1:NPoints
    y(i*3-2,1)=Xv(i)-XI(i);
    y(i*3-1,1)=Yv(i)-YI(i);
    y(i*3,1)=Zv(i)-ZI(i);
end
% Computing of Bursa Wolf 7 parametrs using least square Principle.
S=(inv(C'*C))*(C'*y);

Rx=((180/pi)*3600)*S(2)
Ry=((180/pi)*3600)*S(3)
Rz=((180/pi)*3600)*S(4)
Dx=S(5)
Dy=S(6)
Dz=S(7)
Sf=1000000*S(1)
```

SL_old_32.txt

```
T0034   168187.111      388681.544      133.115
T0037   140580.098      346094.244      102.912
T0038   171879.964      346872.589      402.234
T0039   141499.911      318990.588      281.47
T0040   187091.24       322604.701      766.148
T0047   129237.897      319906.615      261.525
T0049   115003.078      300230.858      160.776
T0053   124309.053      252633.471      143.172
T0056   127263.807      236574.792      197.083
T0057   136960.005      225982.441      308.254
T0058   166515.883      232730.57       1031.098
T0060   150146.388      264417.124      521.935
T0061   156732.899      303276.628      571.35
T0073   242854.445      210971.249      1512.569
T0074   203967.213      243742.777      1860.392
T0078   255044.801      167569.305      574.683
```

```
T0080   215534.001      174921.075      1775.206
T0082   206759.83       158073.635      732.176
T0083   186758.022      131998.979      1358.242
T0089   239092.796      102843.969      31.63
T0090   189548.035      99274.28 221.872
T0091   172813.205      107952.552      430.38
T0092   171278.367      120804.344      724.155
T0093   158795.977      103223.615      408.65
T0096   129546.57       102354.436      36.472
T0097   126061.269      119248.347      53.991
T0098   147551.215      126077.858      659.813
T0099   116681.425      153572.806      157.146
T0100   143671.946      162774.955      701.362
T0103   116116.186      175580.092      112.879
T0108   110504.251      222688.555      54.452
T0110   120674.847      227792.465      167.777
```

```
'wgsLP.txt'
8 42 24.73729 80 29 4.59747 37.138
8 19 17.51703 80 14 3.39951 5.94
8 19 43.88237 80 31 6.33166 305.730
8 4  35.27890 80 14 34.63082 183.815
8 6  34.12756 80 39 23.74082 670.283
8 05 04.52238 80 07 54.07772 163.844
7 54 23.27206 80 00 10.35601 63.240
7 28 34.46053 80 05 16.66339 45.627
7 19 51.85172 80 06 53.80212 99.795
7 14 07.47172 80 12 10.37219 211.561
7 17 48.06560 80 28 13.72064 935.649
7 34 59.10931 80 19 18.95958 425.876
7 56 04.32896 80 22 52.65648 474.539
7 05 59.49015 81 09 42.06765 1418.379
7 23 46.92492 80 48 34.82289 1765.860
6 42 26.20190 81 16 17.88052 478.716
6 46 26.37419 80 54 51.34830 1681.535
6 37 17.93503 80 50 05.50911 636.058
6 23 09.03267 80 39 14.44798 1262.012
6 07 19.39127 81 07 36.93572 -66.005
6 05 23.62075 80 40 45.37583 127.400
6 10 06.02779 80 31 40.95515 333.104
6 17 04.40196 80 30 50.84617 626.997
6 07 31.83857 80 24 05.09502 310.605
6 07 02.69069 80 08 13.81031 -62.912
6 16 12.50375 80 06 19.79490 -44.883
6 19 55.57809 80 17 58.73851 562.008
6 34 49.41570 80 01 13.03548 59.045
6 39 50.08093 80 15 51.35763 604.384
6 46 45.79356 80 00 53.55672 14.829
7 12 18.94385 79 57 48.16561 -43.589
7 15 05.64070 80 03 19.42180 70.135
```

WGS84_To_SLD99_ReportPara.m

```
%Program to compute SLD99 values from accepted parameters of SLD99 report.
%Coordinate Transformation From WGS84 To SLD99 system;
%Entered Latitudes and Longitudes value in degrees, Minutes, Seconds format
in
%a text file
clc
clear
%Reading the text file
format long
NPoints = 32;
[PI,PM,PS,LI,LM,LS,HI]=textread('wgsLP.txt','%f %f %f %f %f %f %f');
PD=(PI+(PM/60)+(PS/3600));
LD=(LI+(LM/60)+(LS/3600));

% Computing of Geocentric coordinates with respect to global Ellipsoid
% (WGS84)
ag=6378137.0;
eg=0.081819190842622;
bg=6356752.3142;
for i=1:NPoints;
```

```
ng(i,1)=(eg*sind(PD(i)))^2;
vg(i,1)=ag/(realsqrt(1-ng(i)));

XI(i,1)=(vg(i)+HI(i))*cosd(PD(i))*cosd(LD(i));
YI(i,1)=(vg(i)+HI(i))*cosd(PD(i))*sind(LD(i));
ZI(i,1)=(vg(i)*(1-(eg^2))+HI(i))*sind(PD(i));
end
% matrix C is prepared using WGS84 geocentric coordinates
C=zeros(NPoints*3,7);

for i=1:NPoints
    C(i*3-2,1)=XI(i);
    C(i*3-2,3)=-ZI(i);
    C(i*3-2,4)=YI(i);
    C(i*3-2,5)=1;
    C(i*3-1,1)=YI(i);
    C(i*3-1,2)=ZI(i);
    C(i*3-1,4)=-XI(i);
    C(i*3-1,6)=1;
    C(i*3,1)=ZI(i);
    C(i*3,2)=-YI(i);
    C(i*3,3)=XI(i);
    C(i*3,7)=1;
end
%Use the 7 transformation parameters as the column matrix
S=[0.000000039338
  0.195704*pi/3600/180
  1.695068*pi/3600/180
   3.473016*pi/3600/180
   0.2933
  -766.95
  -87.7131];
%Computing of Geocentric coordinates respect to Everest Ellipsoid.
yI=C*S;

for i=1:NPoints
    X(i,1)=yI(i*3-2,1)+XI(i);
    Y(i,1)=yI(i*3-1,1)+YI(i);
    Z(i,1)=yI(i*3,1)+ZI(i);
end
%Calculation of Latitudes, Longitude and heights values respect to Everest
%Ellipsoid.

for i=1:NPoints;
a=6377276.345;
b=6356075.413;

e=realsqrt(((a^2)-(b^2))/(a^2));


er=(e^2)/(1-e^2);
Pe(i,1)=realsqrt(X(i)^2+Y(i)^2);
u=atan(Z(i)*a/(Pe(i,1)*b));

L(i,1)=atan(Y(i)/X(i));
P(i,1)=atan((Z(i)+er*b*((sin(u))^3))/(Pe(i,1)-(e^2)*a*((cos(u))^3)));
n(i,1)=(e*sin(P(i)))^2;
v(i,1)=a/(realsqrt(1-n(i)));


h(i,1)=realsqrt(X(i)^2+Y(i)^2);
H(i,1)=((h(i,1))*sec(P(i,1))-v(i));
end
```

```
%Direct Formula Transverse Mercater Projection

a=6377276.345;
e=0.08147298125167;
Lo=(80+(46/60)+(18.1671/3600))*pi/180;
Po=(7+(1.6975/3600))*pi/180;
e1=(1-(1-e^2)^(1/2))/(1+(1-e^2)^(1/2));
%[P22, L22]=textread('Computed99_20.txt', '%f %f');
P22=P;
L22=L;
Mo=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*Po-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*Po)+(15*(e^4)/256+45*(e^6)/1024)
*sin(4*Po)-(35*(e^6)/3072)*sin(6*Po));
ko=0.9999238418;

ed=realsqrt((e^2)/(1-e^2));

for i=1:NPoints;
N(i,1)=a/realsqrt(1-(e^2)*((sin(P22(i,1))^2)));
T(i,1)=(tan(P22(i,1))^2);
C(i,1)=(ed^2)*((cos(P22(i,1))^2));
A(i,1)=(L22(i,1)-Lo)*cos(P22(i,1)); %L and P are in radians
M(i,1)=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*P22(i,1)-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*P22(i,1))+(15*(e^4)/256+45*(e^6)
/1024)*sin(4*P22(i,1))-(35*(e^6)/3072)*sin(6*P22(i,1)));

k(i,1)=ko*(1+(1+C(i,1))*(A(i,1)^2)/2+(5-4*T(i,1)+42*C(i,1)+13*C(i,1)^2-
28*(ed^2))*(A(i,1)^4)/24+(61-148*T(i,1)+16*(T(i,1)^2))*(A(i,1)^6)/720);

x(i,1)=ko*N(i,1)*(A(i,1)+(1-T(i,1)+C(i,1))*(A(i,1)^3)/6+(5-
18*T(i,1)+T(i,1)^2+72*C(i,1)-58*(ed^2))*(A(i,1)^5)/120);

y(i,1)=ko*(M(i,1)-Mo+N(i,1)*(tan(P22(i,1)))*((A(i,1)^2)/2+(5-
T(i,1)+9*C(i,1)+4*(C(i,1)^2))*(A(i,1)^4)/24+(61-
58*T(i,1)+T(i,1)^2+600*C(i,1)-330*(ed^2))*(A(i,1)^6)/720));
end;
%computing of SLD99 projected coordinates
Xe=x+500000;
Ye=y+500000;
```

SLD99_To_LL.m

```
%Program to compute latitudes and longitudes correspod to SLD 99 Projected
%coordinates.Coordinates of 32 cmmon points given in SLD99 repot are used

clear
clc

format long;
NPoints=32;
% projection parameters are given in the SLD99 report for the SLD99 system
% are used in inverse equations of the Transverse Mercater projection.
a=6377276.345;

e=0.08147298125167;
Lo=(80+(46/60)+(18.1671/3600))*pi/180;
Po=(7+(1.6975/3600))*pi/180;
e1=(1-realsqrt(1-e^2))/(1+realsqrt(1-e^2));
[PN, Xn, Yn]=textread('SLD99_Coord32.txt','%s %f %f');
```

```
X=Xn-500000;
Y=Yn-500000;


ed=realsqrt((e^2)/(1-e^2));
Mo=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*Po-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*Po)+(15*(e^4)/256+45*(e^6)/1024)
*sin(4*Po)-(35*(e^6)/3072)*sin(6*Po));
ko=0.9999238418;

for i=1:NPoints;
M(i,1)=Mo+Y(i,1)/ko;
mu(i,1)=M(i,1)/(a*(1-(e^2/4)-3*(e^4)/64-5*(e^6)/256));

J1(i,1)=(3*e1/2-27*(e1^3)/32);
J2(i,1)=(21*(e1^2)/16-55*(e1^4)/32);
J3(i,1)=(151*(e1^3)/96);
J4(i,1)=(1097*(e1^4)/512);
P1(i,1)=mu(i,1)+J1(i,1)*sin(2*mu(i,1))+J2(i,1)*sin(4*mu(i,1))+J3(i,1)*sin(6
*mu(i,1))+J4(i,1)*sin(8*mu(i,1));

C1(i,1)=(ed^2)*(cos(P1(i,1)))^2;
T1(i,1)=(tan(P1(i,1)))^2;

R1(i,1)=a*(1-e^2)/(1-(e^2)*(sin(P1(i,1)))^2)^1.5;

N1(i,1)=a/realsqrt(1-(e^2)*(sin(P1(i,1)))^2);
D(i,1)=X(i,1)/(N1(i,1)*ko);

Q1(i,1)=(N1(i,1)*tan(P1(i,1)))/R1(i,1);
Q2(i,1)=((D(i,1)^2)/2);
Q3(i,1)=(5+3*T1(i,1)+10*C1(i,1)-4*C1(i,1)^2-9*e1^2)*((D(i,1)^4)/24);
Q4(i,1)=(61+90*T1(i,1)+298*C1(i,1)+45*T1(i,1)^2-3*C1(i,1)^2-
252*ed^2)*((D(i,1)^6)/720);
P(i,1)=P1(i,1)-Q1(i,1)*(Q2(i,1)-Q3(i,1)+Q4(i,1));

Q5(i,1)=D(i,1);
Q6(i,1)=(1+2*T1(i,1)+C1(i,1))*(D(i,1)^3)/6;
Q7(i,1)=(5-2*C1(i,1)+28*T1(i,1)-
3*C1(i,1)^2+8*ed^2+24*T1(i,1)^2)*(D(i,1)^5)/120;
L(i,1)=Lo+((Q5(i,1)-Q6(i,1)+Q7(i,1))/cos(P1(i,1)));
end
Pdd=P*180/pi;
Ldd=L*180/pi;
```

Para_SLold_To_SLD99_20points.m

```
%program to compute Transformation parameters from SL old to SLD99
%Coordinates of  20 control points are used
clc
clear
format long
% Computed Latitudes and longitudes values from earlier programes are used
% with orthometric heights of the points
NPoints = 20;

[PI, PR, LR, HI]=textread('SL_old_LL20_heights.txt','%s %f %f %f');
% Computing of Geocentric coordinates with respect to SL old datum
ag=6377276.345;
bg=6356075.413;
eg=realsqrt(((ag^2)-(bg^2))/(ag^2));
```

```
for i=1:NPoints;
ng(i,1)=(eg*sin(PR(i)))^2;
vg(i,1)=ag/(realsqrt(1-ng(i)));

XI(i,1)=(vg(i)+HI(i))*cos(PR(i))*cos(LR(i));
YI(i,1)=(vg(i)+HI(i))*cos(PR(i))*sin(LR(i));
ZI(i,1)=(vg(i)*(1-(eg^2))+HI(i))*sin(PR(i));
end

[PII, PRR, LRR, Hv]=textread('SLD99_LLcomputed20.txt','%s %f %f %f');

%Conversion of(Everest) Lat, lon and ellipsoidal heights to
Geocentric(X,Y,Z) coordinates

av=6377276.345;

bv=6356075.413;

ev=realsqrt(((av^2)-(bv^2))/(av^2));

for i=1:NPoints
Nv=av/(realsqrt(1-(ev*sin(PRR(i)))^2));

Xv(i,1)=(Nv+Hv(i))*cos(PRR(i))*cos(LRR(i));
Yv(i,1)=(Nv+Hv(i))*cos(PRR(i))*sin(LRR(i));
Zv(i,1)=(Nv*(1-(ev^2))+Hv(i))*sin(PRR(i));
end

C=zeros(NPoints*3,7);

for i=1:NPoints
    C(i*3-2,1)=XI(i);
    C(i*3-2,3)=-ZI(i);
    C(i*3-2,4)=YI(i);
    C(i*3-2,5)=1;
    C(i*3-1,1)=YI(i);
    C(i*3-1,2)=ZI(i);
    C(i*3-1,4)=-XI(i);
    C(i*3-1,6)=1;
    C(i*3,1)=ZI(i);
    C(i*3,2)=-YI(i);
    C(i*3,3)=XI(i);
    C(i*3,7)=1;
end

y=zeros(NPoints*3,1);

for i=1:NPoints
    y(i*3-2,1)=Xv(i)-XI(i);
    y(i*3-1,1)=Yv(i)-YI(i);
    y(i*3,1)=Zv(i)-ZI(i);
end
% Bursa wolf 7 parameters are computed using least suare principal.
S=(inv(C'*C))*(C'*y);

Rx=((180/pi)*3600)*S(2)
Ry=((180/pi)*3600)*S(3)
Rz=((180/pi)*3600)*S(4)
Dx=S(5)
Dy=S(6)
Dz=S(7)
```

```
Sf=1000000*S(1)
```

```
'SL_old_LL20_heights.txt
T0034  0.151960466   1.404685689   133.115
T0037  0.145234349   1.400315794   102.912
T0040  0.141532985   1.407687657   766.148
T0047  0.141098624   1.398525057   261.525
T0049  0.137989464   1.396276518   160.776
T0053  0.130479879   1.397761733   143.172
T0058  0.12734592    1.404438806   1031.098
T0061  0.138479385   1.402882115   571.35
T0073  0.123910333   1.416504209   1512.569
T0074  0.129085848   1.41035962    1860.392
T0078  0.117058023   1.418423335   574.683
T0082  0.115563519   1.41079944    732.176
T0083  0.111447551   1.407642836   1358.242
T0089  0.106843707   1.41589767    31.63
T0090  0.10628212    1.408083999   221.872
T0096  0.10676188    1.398621264   36.472
T0097  0.109427705   1.398068278   53.991
T0099  0.114843237   1.396580697   157.146
T0103  0.118316543   1.396486129   112.879
T0108  0.125750119   1.395587192   54.452
```

```
'SLD99_LLcomputed20.txt'
T0034  0.151959735   1.404685709     132.9419
T0037  0.145233889   1.400316018   102.4917
T0040  0.141532594   1.407687706   766.0164
T0047  0.141098197   1.398525259   260.7551
T0049  0.13798914    1.396276787   160.5467
T0053  0.130479799   1.397761943   142.9963
T0058  0.12734575    1.404438888   1032.273
T0061  0.138479073   1.4028822     570.9726
T0073  0.123910188   1.416504159   1513.6631
T0074  0.129085627   1.41035968    1861.6857
T0078  0.11705792    1.4184233     574.0482
T0082  0.115563351   1.410799307   732.3578
T0083  0.111447513   1.407642474   1358.8753
T0089  0.106843175   1.41589732    30.0633
T0090  0.106281917   1.408083321   224.4385
T0096  0.10676231    1.398620738   35.3103
T0097  0.109428052   1.398067927   53.2919
T0099  0.114843348   1.39658057    157.1813
T0103  0.118316667   1.396486144   112.8334
T0108  0.12575007    1.395587277   54.2421
```

SLold_To_SLD99_Com20_check12.m

```
%Program to compute  SLd99 coordinates  from computed 7 parameters
%Coordinate Transformation from SL old  To SLD99 system .
clc
clear
%Reading the text file
format long
NPoints = 32;
[PI, PR, LR, HI]=textread('SLold_LL_com20_check12.txt','%s %f %f %f');
```

```
% Computing of Geocentric coordinates with respect to old Sri Lanka datum.
ag=6377276.345;
bg=6356075.413;
eg=realsqrt(((ag^2)-(bg^2))/(ag^2));

for i=1:NPoints;
ng(i,1)=(eg*sin(PR(i)))^2;
vg(i,1)=ag/(realsqrt(1-ng(i)));

XI(i,1)=(vg(i)+HI(i))*cos(PR(i))*cos(LR(i));
YI(i,1)=(vg(i)+HI(i))*cos(PR(i))*sin(LR(i));
ZI(i,1)=(vg(i)*(1-(eg^2))+HI(i))*sin(PR(i));
end
% matrix C is prepared using WGS84 geocentric coordinates
C=zeros(NPoints*3,7);

for i=1:NPoints
    C(i*3-2,1)=XI(i);
    C(i*3-2,3)=-ZI(i);
    C(i*3-2,4)=YI(i);
    C(i*3-2,5)=1;
    C(i*3-1,1)=YI(i);
    C(i*3-1,2)=ZI(i);
    C(i*3-1,4)=-XI(i);
    C(i*3-1,6)=1;
    C(i*3,1)=ZI(i);
    C(i*3,2)=-YI(i);
    C(i*3,3)=XI(i);
    C(i*3,7)=1;
end
%Use computed 7 transformation parameters as the column matrix
S=[-0.00001259087238
   0.00000200807989
   0.00001366410386
   0.00000569904513
 -11.13019760200177
  83.05851246067198
   7.09547691177431];
%Computing of Geocentric coordinates respect to Everest Ellipsoid.
yI=C*S;

for i=1:NPoints
    X(i,1)=yI(i*3-2,1)+XI(i);
    Y(i,1)=yI(i*3-1,1)+YI(i);
    Z(i,1)=yI(i*3,1)+ZI(i);
end
%Calculation of Latitude Longitude values respect to Everest Ellipsoid and
%Ellipsoidal heights
for i=1:NPoints;
a=6377276.345;
b=6356075.413;

e=realsqrt(((a^2)-(b^2))/(a^2));


er=(e^2)/(1-e^2);
Pe(i,1)=realsqrt(X(i)^2+Y(i)^2);
u=atan(Z(i)*a/(Pe(i,1)*b));

L(i,1)=atan(Y(i)/X(i));
P(i,1)=atan((Z(i)+er*b*((sin(u))^3))/(Pe(i,1)-(e^2)*a*((cos(u))^3)));
n(i,1)=(e*sin(P(i)))^2;
v(i,1)=a/(realsqrt(1-n(i)));
```

```
h(i,1)=realsqrt(X(i)^2+Y(i)^2);
H(i,1)=((h(i,1))*sec(P(i,1))-v(i));
end
%Direct Formula Transverse Mercater Projection
%Use projection parameters given for SLD99 system in the SLD99 report.
Lo=(80+(46/60)+(18.1671/3600))*pi/180;
Po=(7+(1.6975/3600))*pi/180;
ko=0.9999238418;

ed=realsqrt((e^2)/(1-e^2));

Mo=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*Po-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*Po)+(15*(e^4)/256+45*(e^6)/1024)
*sin(4*Po)-(35*(e^6)/3072)*sin(6*Po));


for i=1:NPoints;

N(i,1)=a/realsqrt(1-(e^2)*((sin(P(i,1))^2)));
T(i,1)=(tan(P(i,1))^2);
C(i,1)=(ed^2)*((cos(P(i,1))^2));
A(i,1)=(L(i,1)-Lo)*cos(P(i,1)); %L and P are in radians
M(i,1)=a*((1-(e^2)/4-3*(e^4)/64-5*(e^6)/256)*P(i,1)-
(3*(e^2)/8+3*(e^4)/32+45*(e^6)/1024)*sin(2*P(i,1))+(15*(e^4)/256+45*(e^6)/1
024)*sin(4*P(i,1))-(35*(e^6)/3072)*sin(6*P(i,1)));


k(i,1)=ko*(1+(1+C(i,1))*(A(i,1)^2)/2+(5-4*T(i,1)+42*C(i,1)+13*C(i,1)^2-
28*(ed^2))*(A(i,1)^4)/24+(61-148*T(i,1)+16*(T(i,1)^2))*(A(i,1)^6)/720);

x(i,1)=ko*N(i,1)*(A(i,1)+(1-T(i,1)+C(i,1))*(A(i,1)^3)/6+(5-
18*T(i,1)+T(i,1)^2+72*C(i,1)-58*(ed^2))*(A(i,1)^5)/120);

y(i,1)=ko*(M(i,1)-Mo+N(i,1)*(tan(P(i,1)))*((A(i,1)^2)/2+(5-
T(i,1)+9*C(i,1)+4*(C(i,1)^2))*(A(i,1)^4)/24+(61-
58*T(i,1)+T(i,1)^2+600*C(i,1)-330*(ed^2))*(A(i,1)^6)/720));
end;
%Use the false nothing and false Easting of the projection to help the
%comparison
Xp=x+500000;
Yp=y+500000;

'SLold_LL_com20_check12.txt'
```

T0034	0.151960466	1.404685689	133.115
TO037	0.145234349	1.400315794	102.912
TO040	0.141532985	1.407687657	766.148
TO047	0.141098624	1.398525057	261.525
TO049	0.137989464	1.396276518	160.776
TO053	0.130479879	1.397761733	143.172
TO058	0.12734592	1.404438806	1031.098
TO061	0.138479385	1.402882115	571.35
TO073	0.123910333	1.416504209	1512.569
TO074	0.129085848	1.41035962	1860.392
TO078	0.117058023	1.418423335	574.683
TO082	0.115563519	1.41079944	732.176
TO083	0.111447551	1.407642836	1358.242

TO089	0.106843707	1.41589767	31.63
TO090	0.10628212	1.408083999	221.872
TO096	0.10676188	1.398621264	36.472
TO097	0.109427705	1.398068278	53.991
TO099	0.114843237	1.396580697	157.146
TO103	0.118316543	1.396486129	112.879
TO108	0.125750119	1.395587192	54.452
TO038	0.145362156	1.405275875	402.234
TO039	0.140956835	1.400467231	281.47
TO056	0.12794605	1.398232771	197.083
TO057	0.126276319	1.399767791	308.254
TO060	0.132345015	1.401845888	521.935
TO080	0.118222518	1.412185331	1775.206
TO091	0.107651129	1.405444257	430.38
TO092	0.109679625	1.40520118	724.155
TO093	0.106903407	1.403233932	408.65
TO098	0.110509383	1.401457298	659.813
TO100	0.11630108	1.400839444	701.362
TO110	0.126558351	1.397193325	167.777

Poly1_20.m

```
%Program to compute parameters of the first order polynomial.
%Xn =  a1Xo + b1Yo +c1
%Yn =  d1Xo+ e1Yo +f1
%a1,b1,c1,d1,e1 and f1 are parameters.
%Used 20 points of 32 points to compute the parameters. Other 12 points
%used as check points.
clc
clear
NPoints=20;
format long
%Reading coordinates of 20 control points of 32 points
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('con20.txt','%s %f %f %f %f');

C=zeros(NPoints*2,6);

for i=1:NPoints %Populating coefficients matrix(old system coordinates)
     C(i*2-1,1)=Xo(i);
     C(i*2-1,2)=Yo(i);
     C(i*2-1,3)=1;
     C(i*2,4)=Xo(i);
     C(i*2,5)=Yo(i);
     C(i*2,6)=1;
end

y=zeros(NPoints*2,1);

for i=1:NPoints %Populating y matrix(new system coordinates).
    y(i*2-1,1)=Xn(i);
    y(i*2,1)=Yn(i);
end
P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.
M=C*P;  %computing new coordinates of the used control points using
computed parameters.
```

```
for i=1:NPoints % computing the residuals  of the computed new coordinates
of  points.
    Er(i,1)=M(i*2-1)+300000;
    Nr(i,1)=M(i*2)+300000;
    Rx(i,1)=Xn(i)-M(i*2-1);
    Ry(i,1)=Yn(i)-M(i*2);

end
%rounding up the residuals to last millimeter.
Rx1=round((Rx)*1000);
Ry1=round((Ry)*1000);
Rx2=Rx1/1000;
Ry2=Ry1/1000;


% no. of check points = 12.
BPoints=12;
%Reading coordinates of the 12 check points.
%Old easting, Northing and New Easting, Northing

[pI, xo, yo, xn, yn]=textread('restcon_12.txt','%s %f %f %f %f');
Cb=zeros(BPoints*2,6);
%Populating coefficient matrix with the check points (old system)
coordinates.
for i=1:BPoints
     Cb(i*2-1,1)=xo(i);
     Cb(i*2-1,2)=yo(i);
     Cb(i*2-1,3)=1;
     Cb(i*2,4)=xo(i);
     Cb(i*2,5)=yo(i);
     Cb(i*2,6)=1;
end
L=(Cb*P);%computing coordinates of the new system using computed
parameters.

for i=1:BPoints
    Ec(i,1)=L(i*2-1)+300000;
    Nc(i,1)=L(i*2)+300000;
    Cx(i,1)=xn(i)-L(i*2-1);%difference in Easting between issued and
computed values in new system.
    Cy(i,1)=yn(i)-L(i*2);%difference in Northing between issued and
computed values in new system.

    Dx(i,1)=xo(i,1)-xn(i,1);%difference in Easting between new and old.
    Dy(i,1)=yo(i,1)-yn(i,1);%difference in Northing between new and old.
end
%rounding up the differences( computed value -  report value ) to last
millimeter.
Cx1=round((Cx)*1000);
Cy1=round((Cy)*1000);
Cx2=Cx1/1000;
Cy2=Cy1/1000;
```

'con20.txt'

T0034	168187.111	388681.544	168187.016	388677.883
TO037	140580.098	346094.244	140581.294	346092.298
TO040	187091.240	322604.701	187091.332	322603.187
TO047	129237.897	319906.615	129238.952	319904.877

TO049	115003.078	300230.858	115004.553	300229.771
TO053	124309.053	252633.471	124310.158	252633.931
TO058	166515.883	232730.570	166516.179	232730.457
TO061	156732.899	303276.628	156733.219	303275.619
TO073	242854.445	210971.249	242853.912	210971.294
TO074	203967.213	243742.777	203967.375	243742.345
TO078	255044.801	167569.305	255044.360	167569.618
TO082	206759.830	158073.635	206758.772	158073.537
TO083	186758.022	131998.979	186755.509	131999.709
TO089	239092.796	102843.969	239090.362	102841.564
TO090	189548.035	99274.280	189543.520	99273.962
TO096	129546.570	102354.436	129543.022	102358.136
TO097	126061.269	119248.347	126058.826	119251.519
TO099	116681.425	153572.806	116680.405	153574.474
TO103	116116.186	175580.092	116116.064	175581.848
TO108	110504.251	222688.555	110504.573	222689.213

'restcon_12.txt'

```
TO038 171879.964   346872.589   171880.084   346870.629
TO039 141499.911   318990.588   141500.931   318988.808
TO056 127263.807   236574.792   127264.572   236575.157
TO057 136960.005   225982.441   136960.322   225982.897
TO060 150146.388   264417.124   150146.938   264416.259
TO080 215534.001   174921.075   215533.461   174921.436
TO091 172813.205   107952.552   172808.754   107953.771
TO092 171278.367   120804.344   171274.718   120805.379
TO093 158795.977   103223.615   158791.431   103225.834
TO098 147551.215   126077.858   147548.558   126080.178
TO100 143671.946   162774.955   143670.910   162775.939
TO110 120674.847   227792.465   120675.415   227792.994
```

Poly1_Mean20.m

```
%Duduct the mean of the coordinate from each value.
%Program to compute parameters of the first order polynomial.
%
%Xn =  m1Xo + m2Yo +m3
%Yn =  m4Xo+ m5Yo +m6
%m1,m2,m3,m4,m5 and m6 are parameters.
%Used 20 points of 32 points to compute the parameters. Other 12 points
%used as check points.
clc
clear
NPoints=20;
format long
%Reading coordinates of 20 control points of 32 points
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('Coord_20.txt','%s %f %f %f %f');

%Duducting the mean of the coordinate from each value.
Xom=mean(Xo);
Yom=mean(Yo);
Xnm=mean(Xn);
Ynm=mean(Yn);
```

```
C=zeros(NPoints*2,6);
%Populating coefficients matrix(old system coordinates)
for i=1:NPoints
     C(i*2-1,1)=Xo(i)-Xom;
     C(i*2-1,2)=Yo(i)-Yom;
     C(i*2-1,3)=1;
     C(i*2,4)=Xo(i)-Xom;
     C(i*2,5)=Yo(i)-Yom;
     C(i*2,6)=1;
end

y=zeros(NPoints*2,1);
%Populating y matrix(new system coordinates).
for i=1:NPoints
    y(i*2-1,1)=Xn(i)-Xnm;
    y(i*2,1)=Yn(i)-Ynm;
end

P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.
L=C*P;%computing new coordinates of the used control points using computed
parameters.

for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
Ec(i,1)=L(i*2-1)+Xnm;
Nc(i,1)=L(i*2)+Ynm;
Rx(i,1)=Xn(i)-(L(i*2-1)+Xnm);
Ry(i,1)=Yn(i)-(L(i*2)+Ynm);
end
%rounding up the residuals to last millimeter.
Rx1=round((Rx)*1000);
Ry1=round((Ry)*1000);
Rx2=Rx1/1000;
Ry2=Ry1/1000;

BPoints=12;

[pI, xo, yo,  xn, yn]=textread('Coord_12.txt','%s %f %f %f %f');
%computing of original parameters for original polynomial shown below.
%Xn =  a1Xo + a2Yo +a3.
%Yn =  a4Xo+ a5Yo +a6.

m3=P(3)+Xnm-P(1)*Xom-P(2)*Yom;
m6=P(6)+Ynm-P(4)*Xom-P(5)*Yom;

for i=1:BPoints
%computing coordinates of the new system using computed parameters.

xnc(i,1)=P(1)*xo(i)+P(2)*yo(i,1)+m3;
ync(i,1)=P(4)*xo(i)+P(5)*yo(i,1)+m6;

Cx(i,1)=xn(i)-xnc(i);%difference in Easting between issued and computed
values in new system.
Cy(i,1)=yn(i)-ync(i);%difference in Northing between issued and computed
values in new system.
dE(i,1)=xn(i)-xo(i)-300000;%difference in Easting between new and old.
dN(i,1)=yn(i)-yo(i)-300000;%difference in Northing between new and old.
end
%rounding up the differences( computed value -  report value ) to last
millimeter.
Cx1=round((Cx)*1000);
Cy1=round((Cy)*1000);
```

```
Cx2=Cx1/1000;
Cy2=Cy1/1000;
'Coord_20.txt'
```

T0034	168187.111	388681.544	468187.016	688677.883
TO037	140580.098	346094.244	440581.294	646092.298
TO040	187091.240	322604.701	487091.332	622603.187
TO047	129237.897	319906.615	429238.952	619904.877
TO049	115003.078	300230.858	415004.553	600229.771
TO053	124309.053	252633.471	424310.158	552633.931
TO058	166515.883	232730.570	466516.179	532730.457
TO061	156732.899	303276.628	456733.219	603275.619
TO073	242854.445	210971.249	542853.912	510971.294
TO074	203967.213	243742.777	503967.375	543742.345
TO078	255044.801	167569.305	555044.360	467569.618
TO082	206759.830	158073.635	506758.772	458073.537
TO083	186758.022	131998.979	486755.509	431999.709
TO089	239092.796	102843.969	539090.362	402841.564
TO090	189548.035	99274.280	489543.520	399273.962
TO096	129546.570	102354.436	429543.022	402358.136
TO097	126061.269	119248.347	426058.826	419251.519
TO099	116681.425	153572.806	416680.405	453574.474
TO103	116116.186	175580.092	416116.064	475581.848
TO108	110504.251	222688.555	410504.573	522689.213

```
'Coord_12.txt'
```

TO038	171879.964	346872.589	471880.084	646870.629
TO039	141499.911	318990.588	441500.931	618988.808
TO056	127263.807	236574.792	427264.572	536575.157
TO057	136960.005	225982.441	436960.322	525982.897
TO060	150146.388	264417.124	450146.938	564416.259
TO080	215534.001	174921.075	515533.461	474921.436
TO091	172813.205	107952.552	472808.754	407953.771
TO092	171278.367	120804.344	471274.718	420805.379
TO093	158795.977	103223.615	458791.431	403225.834
TO098	147551.215	126077.858	447548.558	426080.178
TO100	143671.946	162774.955	443670.910	462775.939
TO110	120674.847	227792.465	420675.415	527792.994

Poly2_20.m

```
%Program to compute parameters of the second order polynomial.
%Xn = a2Xo^2 + b2Yo^2 +c2 XoYo+ d2Xo + e2Yo+ f2
%Yn = a3Xo^2 + b3Yo^2 +c3 XoYo+ d3Xo + e3Yo+ f3
%a2, b2, c2, d2, e2 , f2 ,a3, b3, c3, d3, e3 and f3 are parameters

%Used 20 points of 32 points to compute the parameters. Other 12 points
%used as check points.
```

```
clc
clear
NPoints=20;
format long
%Reading coordinates of 20 control points of 32 points
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('con20.txt','%s %f %f %f %f');


C=zeros(NPoints*2,12);
%Populating coefficients matrix(old system coordinates)
for i=1:NPoints
     C(i*2-1,1)=Xo(i)^2;
     C(i*2-1,2)=Yo(i)^2;
     C(i*2-1,3)=Xo(i)*Yo(i);
     C(i*2-1,4)=Xo(i);
     C(i*2-1,5)=Yo(i);
     C(i*2-1,6)=1;
     C(i*2,7)=Xo(i)^2;
     C(i*2,8)=Yo(i)^2;
     C(i*2,9)=Xo(i)*Yo(i);
     C(i*2,10)=Xo(i);
     C(i*2,11)=Yo(i);
     C(i*2,12)=1;
end

y=zeros(NPoints*2,1);

for i=1:NPoints%Populating y matrix(new system coordinates).
    y(i*2-1,1)=Xn(i);
    y(i*2,1)=Yn(i);
end
P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.
M=C*P;%computing new coordinates of the used control points using computed
parameters.

for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
    Er(i,1)=M(i*2-1)+300000;
    Nr(i,1)=M(i*2)+300000;
    Rx(i,1)=Xn(i)-M(i*2-1);
    Ry(i,1)=Yn(i)-M(i*2);
end
%rounding up the residuals to last millimeter.
Rx1=round((Rx)*1000);
Ry1=round((Ry)*1000);
Rx2=Rx1/1000;
Ry2=Ry1/1000;

% no. of check points = 12.
BPoints=12;
%Reading coordinates of the 12 check points.
%Old easting, Northing and New Easting, Northing
[pI, xo, yo, xn, yn]=textread('restcon_12.txt','%s %f %f %f %f');
Cb=zeros(BPoints*2,12);
%Populating coefficient matrix with the check points (old system)
coordinates.
for i=1:BPoints
     Cb(i*2-1,1)=xo(i)^2;
     Cb(i*2-1,2)=yo(i)^2;
     Cb(i*2-1,3)=xo(i)*yo(i);
     Cb(i*2-1,4)=xo(i);
```

```
     Cb(i*2-1,5)=yo(i);
     Cb(i*2-1,6)=1;
     Cb(i*2,7)=xo(i)^2;
     Cb(i*2,8)=yo(i)^2;
     Cb(i*2,9)=xo(i)*yo(i);
     Cb(i*2,10)=xo(i);
     Cb(i*2,11)=yo(i);
     Cb(i*2,12)=1;
end
L=(Cb*P);%computing coordinates of the new system using computed
parameters.

for i=1:BPoints
    Ec(i,1)=L(i*2-1)+300000;
    Nc(i,1)=L(i*2)+300000;
    Cx(i,1)=xn(i)-L(i*2-1);%difference in Easting between issued and
computed values in new system.
    Cy(i,1)=yn(i)-L(i*2);%difference in Northing between issued and
computed values in new system.

    dE=xo-xn;%difference in Easting between new and old.
    dN=yo-yn;%difference in Northing between new and old.
end
%rounding up the differences( computed value -  report value ) to last
millimeter.
Cx1=round((Cx)*1000);
Cy1=round((Cy)*1000);
Cx2=Cx1/1000;
Cy2=Cy1/1000;
```

Poly3_20.m

```
%Program to compute parameters of the third order polynomial.
%Xn = c1Xo^3 + c2Yo^3+c3Xo^2Yo+c4XoYo^2+c5Xo^2+c6Yo^2+c7XoYo+c8Xo+c9Yo+c10
%
%Yn = c11Xo^3 +
c12Yo^3+c13Xo^2Yo+c14XoYo^2+c15Xo^2+c16Yo^2+c17XoYo+c18Xo+c19Yo+c20
%c1,c2,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14,c15,c16,c17,c18,c19 and c20
% are parameters

%Used 20 points of 32 points to compute the parameters. Other 12 points
%used as check points.

clc
clear
NPoints=20;
format long
%Reading coordinates of 20 control points of 32 points
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('con20.txt','%s %f %f %f %f');


C=zeros(NPoints*2,20);
%Populating coefficients matrix(old system coordinates)
for i=1:NPoints
     C(i*2-1,1)=Xo(i)^3;
     C(i*2-1,2)=Yo(i)^3;
     C(i*2-1,3)=(Xo(i)^2)*Yo(i);
     C(i*2-1,4)=Xo(i)*(Yo(i)^2);
     C(i*2-1,5)=Xo(i)^2;
     C(i*2-1,6)=Yo(i)^2;
     C(i*2-1,7)=Xo(i)*Yo(i);
     C(i*2-1,8)=Xo(i);
```

```
     C(i*2-1,9)=Yo(i);
     C(i*2-1,10)=1;
     C(i*2,11)=Xo(i)^3;
     C(i*2,12)=Yo(i)^3;
     C(i*2,13)=(Xo(i)^2)*Yo(i);
     C(i*2,14)=Xo(i)*(Yo(i)^2);
     C(i*2,15)=Xo(i)^2;
     C(i*2,16)=Yo(i)^2;
     C(i*2,17)=Xo(i)*Yo(i);
     C(i*2,18)=Xo(i);
     C(i*2,19)=Yo(i);
     C(i*2,20)=1;
end

y=zeros(NPoints*2,1);
%Populating y matrix(new system coordinates).
for i=1:NPoints
    y(i*2-1,1)=Xn(i);
    y(i*2,1)=Yn(i);
end
P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.
M=C*P;%computing new coordinates of the used control points using computed
parameters.

for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
    Er(i,1)=M(i*2-1)+300000;
    Nr(i,1)=M(i*2)+300000;
    Rx(i,1)=Xn(i)-M(i*2-1);
    Ry(i,1)=Yn(i)-M(i*2);
end
%rounding up the residuals to last millimeter.
Rx1=round((Rx)*1000);
Ry1=round((Ry)*1000);
Rx2=Rx1/1000;
Ry2=Ry1/1000;

% no. of check points = 12.

BPoints=12;
%Reading coordinates of the 12 check points.
%Old easting, Northing and New Easting, Northing
[pI, xo, yo, xn, yn]=textread('restcon_12.txt','%s %f %f %f %f');
Cb=zeros(BPoints*2,20);
%Populating coefficient matrix with the check points (old system)
coordinates.
for i=1:BPoints
     Cb(i*2-1,1)=xo(i)^3;
     Cb(i*2-1,2)=yo(i)^3;
     Cb(i*2-1,3)=(xo(i)^2)*yo(i);
     Cb(i*2-1,4)=xo(i)*(yo(i)^2);
     Cb(i*2-1,5)=xo(i)^2;
     Cb(i*2-1,6)=yo(i)^2;
     Cb(i*2-1,7)=xo(i)*yo(i);
     Cb(i*2-1,8)=xo(i);
     Cb(i*2-1,9)=yo(i);
     Cb(i*2-1,10)=1;
     Cb(i*2,11)=xo(i)^3;
     Cb(i*2,12)=yo(i)^3;
     Cb(i*2,13)=(xo(i)^2)*yo(i);
     Cb(i*2,14)=xo(i)*(yo(i)^2);
     Cb(i*2,15)=xo(i)^2;
     Cb(i*2,16)=yo(i)^2;
```

```
     Cb(i*2,17)=xo(i)*yo(i);
     Cb(i*2,18)=xo(i);
     Cb(i*2,19)=yo(i);
     Cb(i*2,20)=1;
end
L=(Cb*P);%computing coordinates of the new system using computed
parameters.

for i=1:BPoints
    Ec(i,1)=L(i*2-1)+300000;
    Nc(i,1)=L(i*2)+300000;
    Cx(i,1)=xn(i)-L(i*2-1);%difference in Easting between issued and
computed values in new system.
    Cy(i,1)=yn(i)-L(i*2);%difference in Northing between issued and
computed values in new system.

end
%rounding up the differences( computed value -  report value ) to last
%millimeter.
Cx1=round((Cx)*1000);
Cy1=round((Cy)*1000);
Cx2=Cx1/1000;
Cy2=Cy1/1000;

dE=xo-xn;%difference in Easting between new and old.
dN=yo-yn;%difference in Northing between new and old.
```

Poly3_20_modified.m

```
%Program to compute parameters of the third order polynomial(modfied Type).
%Xn = c1Xo^3 + c2Yo^3+c3Xo^2Yo+c4XoYo^2+c5Xo^2+c6Yo^2+c7XoYo+c8Xo+c9Yo+c10
%
%Yn = c11Xo^3 +
c12Yo^3+c13Xo^2Yo+c14XoYo^2+c15Xo^2+c16Yo^2+c17XoYo+c18Xo+c19Yo+c20
%c1,c2,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14,c15,c16,c17,c18,c19 and c20
% are parameters

%Used 20 points of 32 points to compute the parameters. Other 12 points
%used as check points.

clc
clear
NPoints=20;
format long
%Reading coordinates of 20 control points of 32 points
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('Coord_20.txt','%s %f %f %f %f');
Xom=(Xo-200000)/100000;
Yom=(Yo-200000)/100000;
DXn=(Xn-Xo-300000);
DYn=(Yn-Yo-300000);

C=zeros(NPoints*2,20);
%Populating coefficients matrix(old system coordinates)
for i=1:NPoints
     C(i*2-1,1)=Xom(i)^3;
     C(i*2-1,2)=Yom(i)^3;
     C(i*2-1,3)=(Xom(i)^2)*Yom(i);
```

```
     C(i*2-1,4)=Xom(i)*(Yom(i)^2);
     C(i*2-1,5)=Xom(i)^2;
     C(i*2-1,6)=Yom(i)^2;
     C(i*2-1,7)=Xom(i)*Yom(i);
     C(i*2-1,8)=Xom(i);
     C(i*2-1,9)=Yom(i);
     C(i*2-1,10)=1;
     C(i*2,11)=Xom(i)^3;
     C(i*2,12)=Yom(i)^3;
     C(i*2,13)=(Xom(i)^2)*Yom(i);
     C(i*2,14)=Xom(i)*(Yom(i)^2);
     C(i*2,15)=Xom(i)^2;
     C(i*2,16)=Yom(i)^2;
     C(i*2,17)=Xom(i)*Yom(i);
     C(i*2,18)=Xom(i);
     C(i*2,19)=Yom(i);
     C(i*2,20)=1;
end

y=zeros(NPoints*2,1);
%Populating y matrix(new system coordinates).
for i=1:NPoints
    y(i*2-1,1)=Xn(i)-300000-Xo(i);
    y(i*2,1)=Yn(i)-300000-Yo(i);
end
P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.
DM=C*P;%computing new coordinates of the used control points using computed
parameters.

for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
    Er(i,1)=DM(i*2-1)+Xo(i)+300000;
    Nr(i,1)=DM(i*2)+Yo(i)+300000;
    Rx(i,1)=Xn(i)-(DM(i*2-1)+Xo(i)+300000);
    Ry(i,1)=Yn(i)-(DM(i*2)+Yo(i)+300000);
end
%rounding up the residuals to last millimeter.
Rx1=round((Rx)*1000);
Ry1=round((Ry)*1000);
Rx2=Rx1/1000;
Ry2=Ry1/1000;
% no. of check points = 12.

BPoints=12;
%Reading coordinates of the 12 check points.
%Old easting, Northing and New Easting, Northing
[pI, xo, yo, xn, yn]=textread('Coord_12.txt','%s %f %f %f %f');

xom=(xo-200000)/100000;
yom=(yo-200000)/100000;



Cb=zeros(BPoints*2,20);
%Populating coefficient matrix with the check points (old system)
coordinates.
for i=1:BPoints
     Cb(i*2-1,1)=xom(i)^3;
     Cb(i*2-1,2)=yom(i)^3;
     Cb(i*2-1,3)=(xom(i)^2)*yom(i);
     Cb(i*2-1,4)=xom(i)*(yom(i)^2);
     Cb(i*2-1,5)=xom(i)^2;
```

```
     Cb(i*2-1,6)=yom(i)^2;
     Cb(i*2-1,7)=xom(i)*yom(i);
     Cb(i*2-1,8)=xom(i);
     Cb(i*2-1,9)=yom(i);
     Cb(i*2-1,10)=1;
     Cb(i*2,11)=xom(i)^3;
     Cb(i*2,12)=yom(i)^3;
     Cb(i*2,13)=(xom(i)^2)*yom(i);
     Cb(i*2,14)=xom(i)*(yom(i)^2);
     Cb(i*2,15)=xom(i)^2;
     Cb(i*2,16)=yom(i)^2;
     Cb(i*2,17)=xom(i)*yom(i);
     Cb(i*2,18)=xom(i);
     Cb(i*2,19)=yom(i);
     Cb(i*2,20)=1;
end
dm=(Cb*P);%computing coordinates of the new system using computed
parameters.

for i=1:BPoints
    Ec(i,1)=dm(i*2-1)+xo(i)+300000;
    Nc(i,1)=dm(i*2)+yo(i)+300000;
    Cx(i,1)=xn(i)-(dm(i*2-1)+xo(i)+300000);%difference in Easting between
issued and computed values in new system.
    Cy(i,1)=yn(i)-(dm(i*2)+yo(i)+300000);%difference in Northing between
issued and computed values in new system.

end
%rounding up the differences( computed value -  report value ) to last
millimeter.
Cx1=round((Cx)*1000);
Cy1=round((Cy)*1000);
Cx2=Cx1/1000;
Cy2=Cy1/1000;


dE=xn-xo-300000;%difference in Easting between new and old.
dN=yn-yo-300000;%difference in Northing between new and old.
```

Error_Vector_plot.m

```
%Program to plot the Differences of SL old and SLD99 coordinates.
%differences of coordinates are  used as error vector component of the
corresponding points and to plot the resultant  vector

clc
clear
x=[468187.016,440581.294,471880.084,441500.931,487091.332,429238.952,415004
.553,424310.158,427264.572,436960.322,466516.179,450146.938,456733.219,5428
53.912,503967.375,555044.360,515533.461,506758.772,486755.509,539090.362,48
9543.520,472808.754,471274.718,458791.431,429543.022,426058.826,447548.558,
416680.405,443670.910,416116.064,410504.573,420675.415];
y=[688677.883,646092.298,646870.629,618988.808,622603.187,619904.877,600229
.771,552633.931,536575.157,525982.897,532730.457,564416.259,603275.619,5109
71.294,543742.345,467569.618,474921.436,458073.537,431999.709,
402841.564,399273.962,407953.771,420805.379,403225.834,402358.136,419251.51
9,426080.178,453574.474,462775.939,475581.848,522689.213,527792.994];
u=[-
0.095,1.196,0.12,1.02,0.093,1.055,1.475,1.106,0.766,0.317,0.296,0.55,0.32,-
0.533,0.162,-0.441,-0.541,-1.058,-2.513,-2.434,-4.515,-4.45,-3.649,-4.546,-
3.548,-2.443,-2.657,-1.02,-1.035,-0.123,0.321,0.568];
```

```
v=[-3.661,-1.946,-1.961,-1.78,-1.514,-1.738,-1.088,0.46,0.365,0.456,-
0.113,-0.865,-1.008,0.45,-0.432,0.312,0.36,-0.098,0.73,-2.405,-
0.319,1.218,1.034,2.22,3.7,3.172,2.32,1.668,0.984,1.756,0.659,0.529];
quiver(x,y,u,v);
```

Poly1_Northern8_final.m

```
%Consider the control points in Northern area.
%Program to compute parameters of the first order polynomial.
%Xn =  a1Xo + a2Yo +a3.
%Yn =  a4Xo+ a5Yo +a6.
%a1,a2,a3,a4,a5 and a6 are parameters.
%Used 10 points to compute the parameters.

clc
clear
NPoints=8;
format long
%Reading coordinates of 8 control points.
%Old easting, Northing and New Easting, Northing
[PI, Xo, Yo,  Xn, Yn]=textread('Poly1_8Northern.txt','%s %f %f %f %f');


C=zeros(NPoints*2,6);
%Populating coefficients matrix(old system coordinates)
for i=1:NPoints
     C(i*2-1,1)=Xo(i);
     C(i*2-1,2)=Yo(i);
     C(i*2-1,3)=1;
     C(i*2,4)=Xo(i);
     C(i*2,5)=Yo(i);
     C(i*2,6)=1;
end

y=zeros(NPoints*2,1);
%Populating y matrix(new system coordinates).
for i=1:NPoints
    y(i*2-1,1)=Xn(i);
    y(i*2,1)=Yn(i);
end
P=(inv(C'*C))*(C'*y);%computing coefficients of the polynomial using least
square method.

L=(C*P); %computing new coordinates of the used control points using
computed parameters.

for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
    Er(i,1)=L(i*2-1)+300000;
    Nr(i,1)=L(i*2)+300000;
    Rx(i,1)=Xn(i)-L(i*2-1);
    Ry(i,1)=Yn(i)-L(i*2);
    dE(i,1)=Xn(i)-Xo(i);
    dN(i,1)=Yn(i)-Yo(i);
end




for i=1:NPoints% computing the residuals  of the computed new coordinates
of  points.
```

```
    Er(i,1)=L(i*2-1)+300000;
    Nr(i,1)=L(i*2)+300000;
    Rx(i,1)=Xn(i)-L(i*2-1);
    Ry(i,1)=Yn(i)-L(i*2);
    dE(i,1)=Xn(i)-Xo(i);
    dN(i,1)=Yn(i)-Yo(i);
end

'Poly1_8Northern.txt'
```

T0034	168187.111	388681.544	168187.016	388677.883
TO037	140580.098	346094.244	140581.294	346092.298
TO038	171879.964	346872.589	171880.084	346870.629
TO039	141499.911	318990.588	141500.931	318988.808
TO040	187091.240	322604.701	187091.332	322603.187
TO047	129237.897	319906.615	129238.952	319904.877
TO049	115003.078	300230.858	115004.553	300229.771
TO061	156732.899	303276.628	156733.219	303275.619

Poly1_4eastern.txt

TO073	242854.445	210971.249	242853.912	210971.294
TO078	255044.801	167569.305	255044.360	167569.618
TO080	215534.001	174921.075	215533.461	174921.436
TO082	206759.830	158073.635	206758.772	158073.537

TO083	186758.022	131998.979	186755.509	131999.709
TO089	239092.796	102843.969	239090.362	102841.564
TO090	189548.035	99274.280	189543.520	99273.962
TO091	172813.205	107952.552	172808.754	107953.771
TO092	171278.367	120804.344	171274.718	120805.379
TO093	158795.977	103223.615	158791.431	103225.834
TO096	129546.570	102354.436	129543.022	102358.136
TO097	126061.269	119248.347	126058.826	119251.519
TO098	147551.215	126077.858	147548.558	126080.178
TO099	116681.425	153572.806	116680.405	153574.474
TO100	143671.946	162774.955	143670.910	162775.939
TO103	116116.186	175580.092	116116.064	175581.848

Poly1_8western.txt

TO053	124309.053	252633.471	124310.158	252633.931
TO056	127263.807	236574.792	127264.572	236575.157
TO057	136960.005	225982.441	136960.322	225982.897
TO058	166515.883	232730.570	166516.179	232730.457
TO060	150146.388	264417.124	150146.938	264416.259
TO074	203967.213	243742.777	203967.375	243742.345
TO108	110504.251	222688.555	110504.573	222689.213
TO110	120674.847	227792.465	120675.415	227792.994