Understanding Positional and Local Uncertainty

Paper by

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Abstract

This paper explains the meaning of positional and local uncertainty and how it will affect the way spatial information professionals will express positional quality. The paper also explains the reasons for introducing positional uncertainty. It also outlines how the Department of Lands is preparing itself and the users of spatial information for the implementation of statements of positional and local uncertainty.

Positional and Local Uncertainty

What is it?

Positional and Local Uncertainty is the "New Way" of expressing the accuracy of spatial data. Positional and Local Uncertainty enables users to determine the suitability for purpose of any particular information.

Definitions

Positional Uncertainty: The uncertainty of the coordinates or height of a point, in metres, at the 95% confidence level, with respect to the defined reference frame. Positional Uncertainty is expressed in absolute terms.

Local Uncertainty: The average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates, or height, of a point(s), with respect to adjacent points in the defined frame.

Local Uncertainty is approximately equivalent to the way spatial accuracy is expressed now (see Class and Order below). Local Uncertainty, being a relative measure, gives an indication of how a point in a network fits with surrounding points.

Who decided?

In 2000, Intergovernmental Committee on Surveying and Mapping (ICSM) adopted POSITIONAL UNCERTAINTY and LOCAL UNCERTAINTY as new, easily understood method of classifying the accuracy of coordinates.

ICSM Publications - Standards & Practices for Control Surveys (SP1) Version 1.5 - May 2002 had a major addition by the inclusion of the concept of Positional and Local Uncertainty.

Where is the idea from?

POSITIONAL & LOCAL UNCERTAINTY are based on the concepts of Network Accuracy and Local Accuracy published by the United States Federal Geographic Data Committee as part of the National Spatial Data Infrastructure ("Geospatial Positioning Accuracy Standards Part2: Standards for Geodetic Networks").

What is it like?

- **"Class"** stays as is, it results from the analysis of relative standard ellipses of a minimally constrained data validation run of an adjustment and is really expressed as a ppm function, when we say "A" or "B", etc.

- **"Order"**, currently also expressed as a ppm function, results from the analysis of the relative standard ellipses of a constrained run of an adjustment. It expresses the external fit to established coordinates. A substantial and increasing cross section of our users prefers to see this value expressed in millimetres rather than ppm, to make it more GIS friendly. By averaging patches of the millimetre column of the (95%) relative standard ellipses list of the constrained adjustment, with respect to adjacent stations, a value is obtained which we call **"local uncertainty".**

- **Positional Uncertainty**. Quite a few users prefer to get a handle, not on the relative accuracy, which expresses the local correlation length of the coordinates, but on the millimetre value of the (95%) point standard ellipses as related back to the Australian Fiducial Network. This is called the **"Positional Uncertainty"** of the points, expressed in millimetres. This helps relate people, who use modes of AusPos, WADS, Omnistar, VRS, RTK and so on, to the established control survey values.

Why Change?

The statistics world has changed. We now speak of uncertainties rather than standard deviations, the full error budget is now to be considered. A lot of the standards around the world will move with the new General Uncertainties of Measurements (GUM 1993 standards).

The new positional technologies are very productive and demand a place in the survey database, where they can be acknowledged as having some positional relationship relative to the traditional coordinate data.

Positional Uncertainty is

- A numeric value measure of absolute accuracy (uncertainty) of position with respect to the GDA geodetic datum.
- Compatible with International Standards
- Easily understood - even by non-specialists.
- Allows modern measurement techniques to contribute to the survey data base.

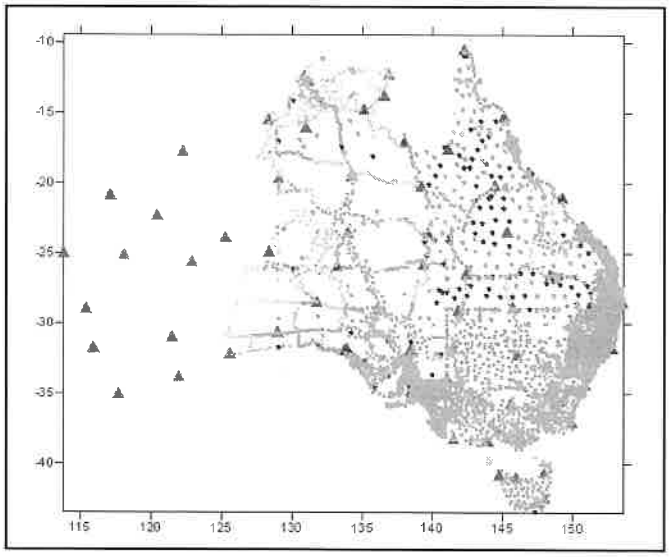
Implementation Issues

What is proposed?

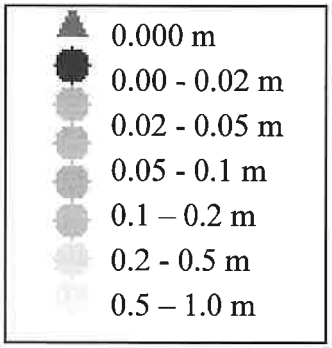
Currently, all accuracies published by the Department of Lands are expressed as Class and Order. Prior to Order being introduced in SCIMS 2000 accuracies were only expressed as a form of Class (eg: H1 or H9). The 1966 National Adjustment incorporated the concept of Network Order. The Geodetic Control Register (GCR) which was administered by the Central Mapping Authority, had a form of Order statements since the mid 1970's.

The Department of Lands is responsible for the management of the Survey Control Information Management System (SCIMS). SCIMS is populated with almost 200000 control survey marks that have their accuracies expressed as Class and Order.

Geosciences Australia as the national agency for geoscience research and geospatial information, has produced a data set that is the basis for the Department of Lands to evaluate positional uncertainties for all the information held in SCIMS (see diagram below).



Distribution of Positional Uncertainty (95%) for the original GDA94 geodetic adjustment.



How to populate the rest of the data quality tables?

To determine the Positional Uncertainty of any mark, it is necessary to determine the error ellipses for all the computed positions. This can only be done by computing the full variance covariance (VCV) matrix of all positions. This is a rigorous way of determining these values.

Several methods have been developed to process the very large numbers of marks that need to be handled.

The Challenge

The challenge facing jurisdictions that are responsible for survey control data, is how to propagate the Positional Uncertainty down through the hierarchy of adjustments, to all levels of positions. There appear to be several options, each with varying degrees of difficulty:

1. Rigorously include all networks in an "all in one" adjustment.
2. Constrain supplementary control with the output VCV from the higher level adjustment.
3. Make a sensible allocation of Positional Uncertainty, based on the known Order and the Positional Uncertainty of the fixed stations.

Rigorous "all in one" Adjustment Method

- This would be a conceptual future aim
- It would need a fast and robust software package (DNA?)
- It will allow for future dynamic coordinates
    - Clients will need things like real time data base access and contribute to a national input file

F. J. Leahy for his PhD developed a program called **Dynamic Network Adjustment** that is a tool for network geodetic adjustment, extension & maintenance. He envisages, in this scenario, that all adjustments be put through this centralised processing engine. This process allows for the automated segmenting and sequential phased adjustment of large geodetic networks and produces a rigorous variance matrix for all blocks.

The operational reality of such a system would require an ongoing daily maintenance regime across the nation. Then one adjustment would be run per day, nationally. This would be an enormous bottleneck in design and create a fragile system where individuals or individual jurisdictions would not have control over their own business processes.

Another option would be a once a month national run, where all States' files of updates are periodically tackled and a new whole-of-government VCV is created.

Constrained Hierarchical Adjustments Method

- Run a "fixed" adjustment for publishable coordinates, **and**
- Run a "constrained" adjustment to give Positional Uncertainty, with either:
  (a) Position Equation sets with VCV (full inter-station correlation) or
  (b) Individual Position Equations with VCV (station elements correlation) or
  (c) Constrained Positions (no correlation)
- When you progress down the adjustment hierarchy:
  - The positional uncertainty grows
  - The station spacing tends to decrease at the same time
  - This means the use of inter-station correlation is more necessary.

The coordinates have to stay stable and will be seeded out with constrained positions in the traditional hierarchical way. The **stats** are the issue and in order to be able to propagate positional uncertainties in a manner that acknowledges the inter-station connectivities, we need to work quite rigorously with the full covariance matrix as in (a). This is the more practical approach: obtain the SPINE national VCV, use this full matrix that includes inter-station correlative information and run the densification adjustments after this, for stats propagation purposes only.

This would mean we have to run with an adjustment engine that can handle full VCVs.

Sensible Estimate Method

It is our view that this is a minimal fall-back position, useful as a first-pass of the implementation in preparation for the full treatment

- This would need a consistent network because it involves generalisation of results
- We would need good knowledge of data quality to derive an educated estimate
- We would need good knowledge of higher level Positional Uncertainty as the starting point for the propagation estimates.

What could be done would entail judging all 2A/0 (Class 2A/Order 0) stations say having a 95% positional uncertainty of 50mm, all A/1stations say having 150* mm positional uncertainty in rural areas (where say there is 25 km control density) while having say 75* mm positional uncertainty for all A/1stations in urban or metropolitan areas (where say there is about 10km density here). In urban or metropolitan areas traversing would produce B/2 control, with a noise of at most a centimetre per traverse leg but with a regular tie off to "a 75mm point" in order to limit the variance propagation.

**These values are able to be kept this small through the contribution of GPS lines to the SPINE network which without GPS observations otherwise basically is the old 1966 EDM and triangulation network..*

Other implementation Issues

Computational needs for the creation of these new statistical classifiers involve:

- Deciding what to database: coordinates? adjustment input? adjustment output? raw observations? full VCV?
- Selection of an adjustment engine?
- Mechanisms need to be developed for producing positional uncertainty statements on accuracy for all survey data.

- Issues regarding how to archive the data and VCV for real time national access, in one of the implementation scenarios.

Educational issues will arise regarding the why, what for and how in their specific situation, to a target audience of Surveyors, users (casual or professional), the public, Departments, Authorities, Local government, GIS Industry and technical and legal professionals.

Conclusion

The ICSM implementation date for Positional Uncertainty is 2005. The Department of Lands is ready to embrace this challenge and to prepare the users of spatial data to this way of expressing position.

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