BIOGRAPHICAL INFORMATION

Carsten Rönsdorf
GI Consultant
Ordnance Survey

Specific Responsibilities

Joined Ordnance Survey in 2002 to become Lead Consultant for Positional Accuracy Improvement of large-scale geodata. This involves consultancy work with customers in government and utilities, software vendors and service providers as well as other mapping agencies worldwide. Responsible for providing customer support for the migration of positionally improved large-scale base maps, analyzing market requirement to enable Ordnance Survey to satisfy customers' needs, maintaining relationships with private-sector companies, and development of technical methodology, case studies and business cases.

Past Experience

Involved in Geographical Information Systems (GIS) since 1995 in various different market sectors and countries. These include planning of worldwide mobile telephone networks with T-Mobile® International, developing a Land Information System for the Indonesian National Land Agency in West Sumatra, Indonesia, as part of a development project managed by the German Technical Cooperation Agency GTZ and being project manager and team leader for a corporate Technical and Geographical Information System implemented in an electricity, gas and water multi-utility company in Germany.

Educational Information

Dipl.-Ing. (comparable to Masters) – Geodesy, University of Bonn, Germany

IMPROVE YOUR BUSINESS POSITION

Carsten Rönsdorf

Ordnance Survey®

Romsey Road
Southampton
SO16 4GU
United Kingdom
Telephone: +44 (23) 8030-5733
Fax: +44 (23) 8079-2039
E-mail: Carsten.Roensdorf@ordnancesurvey.co.uk

ABSTRACT

The paper commences with a short overview about the nature and history of mapping and introduces the geospatial base data currently available in Great Britain. After the formal definition of absolute and relative accuracy, Ordnance Survey's **Positional accuracy improvement (PAI)** program, a four-year initiative that aims to upgrade Great Britain's geospatial map base to an accuracy of about one meter or better in a Global Positioning System (GPS)-defined coordinate system, is described. This will enable data users to integrate GPS captured data and orthorectified imagery with large-scale topographic base maps. The second part of the paper concentrates on the effect an improved base map has for datasets that were originally captured against the unimproved maps. The Migration Triangle, a theory that describes the possible ways of bringing these user datasets back in sympathy with the map data, is described along with the customer impact and the resulting business benefits. Finally, a brief overview of similar initiatives throughout the world is given. This highlights the significance of positional accuracy improvement as an important step to achieve spatially integrated geodata.

INTRODUCTION

Today digital geographic information is used in a wide variety of applications and for a wide variety of purposes. The aim is to display and analyze spatial relationships of phenomena that can be found in the real world. Traditionally, geographic information is often visualized in a form of representation that can be traced back for a few thousand years: a map. A map can be defined as:

> *An abstract, graphic representation of a patch of the Earth at a given point in time.*

Another definition may be that a map is:

A time stamp model of the geographic real-world situation.

Maps present information about the real world in an abstract manner and are subject to interpretation and subjectivity by both the map producer and the map user. In a practical way GIS, in conjunction with digital spatial data, is the high-tech 21st-century equivalent of a paper map: much more powerful, but based on the same fundamental principles, and even downward compatible in a sense that a paper map can be printed off as well. In contrast to a paper map, one of the most powerful features of a GIS is to easily combine spatial data from different sources and allow various independently created datasets to be jointly presented and analyzed. This can be summarized by the ability to *integrate data*, which is the main driver behind this paper.

<u>History of Maps</u>

Mapping as a technology and way of communication has a history that can be traced back to at least 3500 BC (Dorling and Fairbairn, 1997). The quality of a map is directly related to the methods of surveying and cartography available at the time when the map was produced. It is common in surveying and mapping to avoid a complete recollecting of the data every time a new map of a known area is created. It is good practice to use old maps as a basis and enhance them with additional information. This technique is used to create new themes as well as updating a map to a more current time stamp of the real world and hasn't changed with the move to digital maps and the underlying spatial information. This means that today's digital maps or digital geoinformation come with a history as well.

<u>Mapping in Great Britain</u>

In the context of Great Britain, the original surveys are dating as far back as the early 1800s. More importantly, a large amount of the surveys that form the backbone of today's large-scale digital base data was acquired during the first half of the 20th century. At that time it was common practice to use separate, county-specific reference and coordinate systems to survey and display the maps (County Series maps). A fundamental approach to integrate those projections into one common metric coordinate system for Great Britain, the British National Grid, was started in 1935 and finished after the Second World War.

Ordnance Survey is Great Britain's national mapping agency and responsible for the creation and maintenance of digital spatial data and mapping products. Today all large-scale base mapping is available in a consistent, integrated and object-oriented database that currently holds about 440 million real-world features as well as the spatial relations between features. This system, named OS MasterMap®, is updated on a daily basis and allows online orders through the Internet down to the selection of individual features. The following information layers are available with full national coverage: Topography, street network with routing information, and address data for every addressable property. A raster data layer of orthorectified aerial photography is currently available for about 25% of Great Britain and will be extended to full national coverage by 2005. Further layers, such as land use and height, are planned to follow.

Base Data and User Data

Geospatial data within a GIS can usually be divided into two categories: base data that provides the geospatial reference and user data that comprises additional features dependent on the particular application and use. In many cases the user data is generated by the user while the base data is provided by a National Mapping Agency. On a paper map the base map and the user data are usually both drawn or printed onto the same surface and cannot easily be separated from each other—digital maps or datasets maintain both as two or more completely separate layers that are just combined for analysis and publication on the screen or a print.

The next section deals with accuracy definitions that are applicable for both base and user data. The following one deals with the improvement of the base data, while the subsequent chapters describe the effect positional changes have on user data and how this effect can be managed.

ACCURACY OF GEODATA

Up to the 1940s rural mapping in Great Britain was contained within County Series maps, each of which was on a local projection and coordinate system. The roots of Ordnance Survey's PAI program can be traced back to 1938 when the decision was made to integrate all County Series maps into one consistent framework, the British National Grid. With the technology available at the time, the maps were repositioned into the National Grid, but couldn't always be pasted together without discrepancies. It was tried to absorb these into more *flexible* features, such as rivers or open land, rather than built-up areas. In the end the output was a map base that appeared to be quite consistent and was definetely fit for purpose. However, with more and more land to be developed over the following decades, and more and more detail to put on the maps, Ordnance Survey's own surveyors frequently experienced the problem that the mentioned inconsistencies did not give them enough room to fit in new map detail. Subsequently, surrounding map features were moved away to create the necessary space.

Relative Accuracy

The accuracy of maps used to be determined by the measure of the *Relative Positional Accuracy*, which is defined as:

> *The difference of the distance between two defined points in a geospatial dataset and the true distance between these points within the overall reference system.*

Practically, the true distance can be measured using conventional terrestrial surveying techniques, such as a tape or laser distance measure, and can be compared to the calculated length between the two data points.

Ordnance Survey maps were always known for having a very good Relative Positional Accuracy and they are widely used as a reference to match user data to its position in the real world. The position of a street lamp, for example, can be determined as the distance from the nearest house and if one needs to find this particular street lamp in the real word, it is preferable if the description of its position relates to a more easily identifiable feature, such as the mentioned house, which should have an address, and the distance from the house. But within a GIS the position of the street lamp is usually stored as a coordinate along with the house as a sequence of coordinates. In this case the coordinate of the street lamp can be calculated from the known coordinate of a corner of the house and the surveyed distance. This means that in today's GIS the relative relationship between two features (or two points) can be calculated but is not explicitly stored.

Absolute Accuracy

In the 1980s satellite navigation technology, such as GPS, introduced the possibility to obtain a feature's (or actually a point's) coordinate directly without relating to neighboring features. Using appropriate hard and software, surveying techniques and transformations, the true coordinate of a point on the earth within a given reference system (e.g. the National Grid in Great Britain) can be substituted by the GPS measurement. Therefore another accuracy definition is needed.

Absolute Positional Accuracy is defined as:

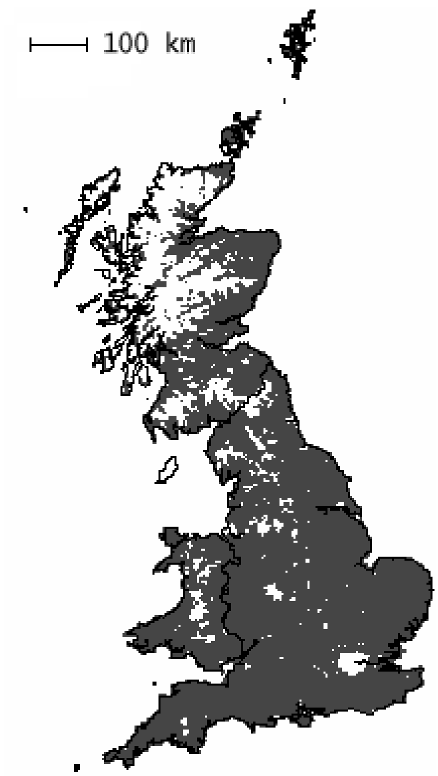
> *The distance between a defined point in a geospatial dataset and its true position in the overall reference system.*
> Practically, the true position within the reference system can be determined to centimeter accuracy using differential GPS (DGPS) surveying.

Both the Absolute and Relative Positional Accuracy of a given dataset can be determined by calculating the differences between the mentioned distances of a significant sample of the dataset and can be expressed as a root mean square error (RMSE) that relates to a confidence level of 67%.

Until recently Relative Accuracy has been more important to most users than Absolute Accuracy. It is anticipated that the widespread use of GPS and aerial photography that is rectified against GPS control points will significantly increase the need for Absolute Accuracy.

ORDNANCE SURVEY'S PAI PROGRAM

Figure 1: Extent of the PAI-affected areas (shaded)



In the late 1990s Ordnance Survey started to plan a national program to improve the Absolute Positional Accuracy of its rural large-scale map base. At the same time the good Relative Accuracy is retained. The aims were to future proof the data for the addition of new building development and other change as well as providing a better relationship between Ordnance Survey rural map data and customers' own GPS-positioned data. Therefore users of spatial data are able to locate and position information far more quickly and precisely than ever before.

Following an extensive consultation process, the PAI program was announced in February 2000. It applies to about two-thirds of the area of Great Britain (see figure 1) and excludes the major urban areas that were already resurveyed to a higher standard in the late 1960s as well as mountain and moorland regions, where a high Positional Accuracy is not economical. The first block of improved data was released in November 2001 and by January 2004 about 30% of the data has been released. The program is scheduled to be completed in March 2006.

In the areas that are part of the PAI program Ordnance Survey currently maintains an absolute Positional Accuracy of ± 2.8m RMSE (before PAI). Through the program this accuracy will be improved to:

- ± 0.4 m RMSE in 212 selected rural towns (about 2 000 km^2); and
- ± 1.1 m RMSE in all other areas (about 150 000 km^2).

Figure 2: Base map with 2.8-m buffer zone (absolute accuracy before PAI)

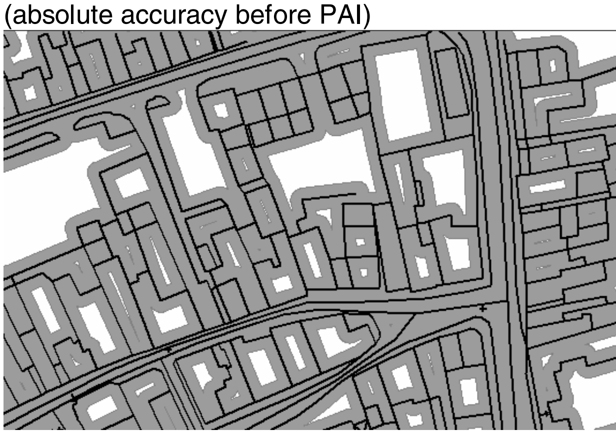
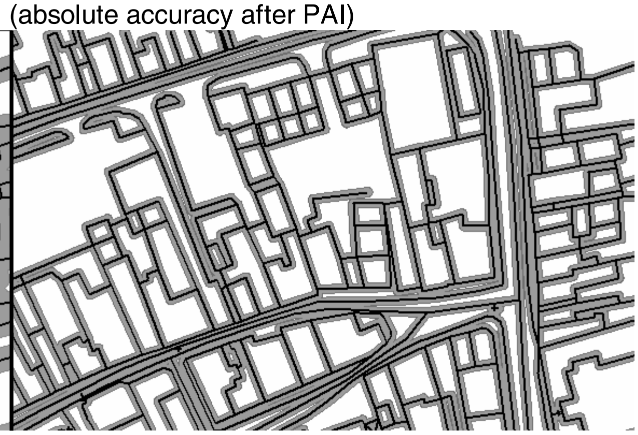
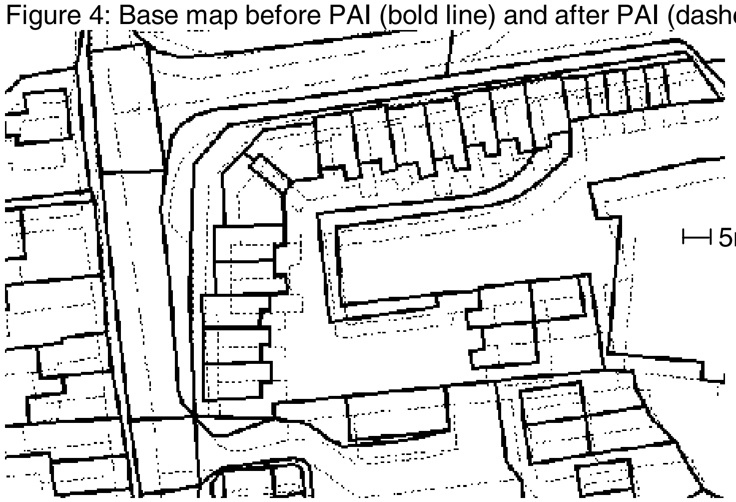


Figure 3: Base map with 1.1-m buffer zone (absolute accuracy after PAI)



These values directly relate to the accuracy that is achievable using two different surveying techniques: photogrammetric mono and stereo plotting. The difference between the accuracy of the data before and after PAI is illustrated in figures 2 and 3, displaying a 2.8-m and a 1.1-m buffer zone respectively.

Figure 4: Base map before PAI (bold line) and after PAI (dashed line)



An analysis of the first 10 000 km^2 showed that the majority of the shifts was less than 2.5 m and that there were areas that did not move at all. The majority of the shifts did not follow a systematic pattern. Therefore the nature of the shift was categorized as pseudo-random. The amount of change that occurred in the PAI process is shown for a sample area in figure 4.

MIGRATION OF USER DATA

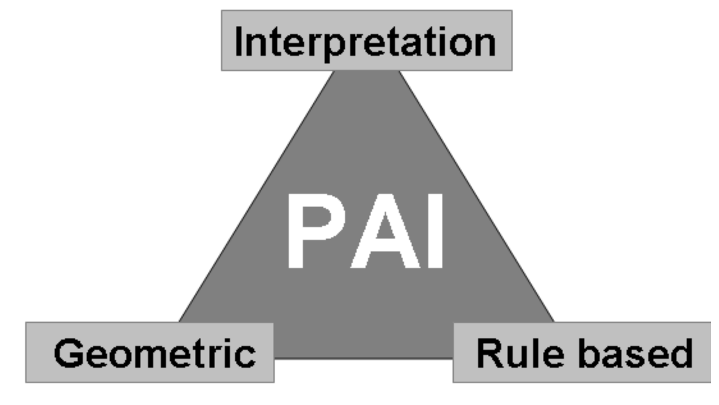
During the planning of the program it became obvious that data users would need to review their data holdings in relation to the positionally-improved Ordnance Survey data and possibly migrate it to the new base map. Recognizing that users need assistance to realign their own data in sympathy with positional changes, Ordnance Survey decided to produce *link files* as an integral part of the PAI program. Each link file contains the coordinate pairs of both the original and new position of identified points. These links form a vector field that can be applied to user datasets in a rubber-sheeting like transformation process and assist users in the migration of their datasets. The link file contains between 500 and 15 000 vectors for an area of 1 km^2, depending on the density of map features.

The problem of moving user data to fit the new base map was underestimated when the PAI program was planned. This process can be characterized as re-establishing the Relative Accuracy between the improved base map and the user data. At the beginning of the program the link file vector field was envisioned to be the solution for all datasets to be migrated. The practical experience has shown that the most efficient methodology to migrate the data is dependent on a number of factors. These include the quality of the original data capture, the structure of the dataset and their current and future use.

The first steps to assess the impact of PAI on a user's data holdings are a data audit and a business impact and risk analysis. The result of that concludes in many cases that just a limited number of datasets (between 5 and 20 for a typical local authority) need to be moved.

The Migration Triangle

Figure 5: Migration Triangle



The three fundamental ways to move data back in sympathy with the base map are illustrated in figure 5, the Migration Triangle. *Interpretation* describes the method of moving features to their improved position by determining this position on an individual, feature-by-feature basis. This could be an application for artificial intelligence but more likely means manually shifting or redrawing a feature. *Geometric* relates to the application of a vector field that describes the difference between the old and the improved base data by means of a geometric transformation. In most cases this means rubber sheeting of the user data with the link file vector field. The *Rule based* method makes use of the specification of the dataset and explicit relationships between features in the base and user datasets.

The Migration Triangle suggests that the most efficient process to migrate user data is likely to be a combination of the three fundamental methods and can be located within the triangle. An often used combination would be to rubber sheet the data first, then snap relevant features back to the improved base map, manually identify the features where this did not work and move these on an individual basis. To date there seems to be no workflow that will migrate 100% of the user data automatically. While in the utility sector an automation factor of 98% could be proved in a trial project (Rönsdorf, 2004), the majority of the market in the U.K. is currently looking at automation rates of not more than 70–90%, leaving the remaining 10–30% to manual editing[*].

Data Management

The process of applying PAI to a user dataset is closely related to applying map updates to a database consisting of base and user data. In both cases the relationship between the base map and the user data may change. In practice most data users take frequent updates of the base map but do not have a process in place that addresses the effect of these changes on the user data, which can result in misinterpretation of combined datasets. In this sense PAI demonstrates the necessity for good data management procedures that maintain the integrity of a geodatabase.

[*] A regularly updated overview of PAI software and services currently available in the UK can be found on the Ordnance Survey PAI website (Ordnance Survey, 2004).

Business Benefits

Despite the costs that are involved in migrating user data, the PAI program has demonstrated a number of business benefits to users:

- Generation of detailed metadata catalogue for corporate data holding through data audit (if this does not already exist)
- Rationalization of data holdings (remove redundant data holdings)
- Introduction of feature-level metadata increases the usability of the data and guaranties defined quality standards
- Support of change-management procedures, which are a crucial factor to enable government users to deliver e-government targets
- Increase of data quality for areas that were not digitized to today's standards (e.g. features were intended to but not completely snapped to the base map)
- Integration with GPS-captured data or GPS-rectified aerial photography
- Support of business case for data maintenance budgets
- Enabling seamless access across a multitude of datasets through consistent Absolute Accuracy

INTERNATIONAL SCOPE

The nature of the described issues is not specific to Great Britain. Today's digital maps contain mapping from historic sources in a lot of countries throughout the world and GPS surveying methods are becoming more and more used throughout the world. A first non-comprehensive survey has identified issues with Absolute Positional Accuracy in Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Ireland, Switzerland, Turkey, and the United States. Since the history of mapping is different in every country, the exact drivers for improving the positional accuracy of spatial data are different as well. On the data user side it does not really matter why the base data was improved, the impact is created by the fact that the base map has moved and that user and base data have lost their synchronization. The task for data users is the same in every country: to re-establish the spatial relation between the user data and the base map. If this is not done, the future use of the user dataset is at risk—along with the possibility to loose the value of the dataset and preceding investments.

While Ordnance Survey's national PAI program has delivered almost a third of the data to be improved, most of the data in other countries hasn't been published yet. Some countries, such as Germany or Australia, have gradually published positionally improved data since the early 1990s. Two examples for successful PAI-type implementations can be found in the utility sector in Germany*. In the U.S. probably the largest PAI-type program is incorporated in the U.S. Bureau of Census's MAF/Tigerline Modernization project, which is predominantly undertaken for the Bureau's own

---

* More information can be found in (Rönsdorf, 2003a) and (Rönsdorf, 2003b).

purpose, but it is expected that improved Tigerline data will be released to the general public at some point[**].

CONCLUSIONS

Current digital geodata is based on historic data as well as new surveys and has a very dynamic character. Present activities in a number of different countries show that Positional Accuracy of geodata is slowly emerging as a global topic. Spatial integration is not an isolated issue in every country and it is also not just an issue for the providers of base data—it will also have massive implications on user data and therefore on the way GIS are used within businesses worldwide. From the experience in Great Britain it is highly recommended to look at Positional Accuracy not just as an issue of base data but to evaluate the effect changes have on user data and seek data user buy-in when starting to plan an improvement process.

The move towards spatially integrated and accurate datasets requires maintenance and additional efforts in dealing with change information and data management in general. Integration comes at a price of investing much effort and money into a consistent framework, but in the long run it will allow seamless access across a multitude of datasets and bring genuine business benefits.

PAI-type scenarios mark the beginning towards spatially integrated geodata, but an even more radical step can be already envisioned: the introduction of new national coordinate systems that are completely defined by GPS.

REFERENCES

Dorling, D. and Fairbairn, D., 1997, Mapping: ways of representing the world, Longman, London

Ordnance Survey, 2004, PAI website: Transforming your data (http://www.ordnancesurvey.co.uk/pai/softwareservices.html)

Rönsdorf, C., 2003a, German experience with PAI: DEW example (http://www.ordnancesurvey.co.uk/pai/pdfs/german_experience_DEW.pdf)

Rönsdorf, C., 2003b, German experience with PAI: E-On Bayern AG example (http://www.ordnancesurvey.co.uk/oswebsite/pai/pdfs/German_experience_E-on_Bayern.pdf)

Rönsdorf, C., 2004, PAI experience: EDF Energy (http://www.ordnancesurvey.co.uk/oswebsite/pai/pdfs/Experience_EDF_Energy.pdf)

U.S. Bureau of Census, 2002, MAF/Tigerline Modernization website (http://www.census.gov/geo/mod/maftiger.html)

[**] More information can be found in (U.S. Bureau of Census, 2002).