Change Detection and Scenarios for Maintaining a National Road Database

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Abstract

In order to maintain a high quality road database a well organized data revision process has to be secured. The paper demonstrates a pilot project using high resolution satellite data for the updating process of the National Road Database (National WegenBestand, NWB) of The Netherlands. NWB contains in total 145.000 km of roads and has an up-to-dateness better than one year. The pilot project has proven, that high res satellite data can be one of several data sources to overcome efficiently and economically the updating process.

Zusammenfassung

Erfassung von Veränderungen und Szenarien zur Laufendhaltung der Nationalen Straßen-Datenbank in den Niederlanden
Um die Qualität von Straßen-Datenbanken sicherzustellen, ist ein gut durchorganisierter Datenfortführungsprozess notwendig. Der vorliegende Beitrag stellt Erfahrungen aus einem Pilotprojekt vor, bei dem hochaufgelöste Satellitendaten zur Fortführung der Nationalen Straßen-Datenbank (National WegenBestand, NWB) der Niederlande verwendet worden sind.
NWB enthält insgesamt 145.000 km Straßen und hat eine Datenfortführungsrate von besser als einem Jahr. Das Pilotprojekt hat gezeigt, dass hochaufgelöste Satellitendaten eine von mehreren Datenquellen sein können, um das Fortführungsproblem effizient und ökonomisch zu lösen.

1. Introduction

The Transport Research Centre AVV is a special department of Rijkswaterstaat (the Ministry of Transport, Public Works and Water Management). One of the products of AVV is the National Road Database (Nationaal WegenBestand NWB). The NWB is regarded as the de-facto digital road database and used by the public sector as a geographical integrator for traffic and transport studies.

The NWB is a digital geographical network containing the centerlines of public roads in the Netherlands. At this moment the NWB contains in total 145.000 kilometer of roads, which are build up of 850.000 centreline segments. AVV estimates that the database contains 98% of the public roads in the Netherlands, that 95% of the centerlines are within an accuracy of 10 meters (scale 1:10.000), and that the up-to-dateness is better than 1 year.

A crucial aspect in maintaining a high quality road database is a well organized updating process. In case of the NWB, information about geometrical road changes is provided by the same road administrator who causes the changes. Consequently AVV receives changes, in a wide variety of quality, from 9 directorates and 26 districts (concerning state roads), 465 municipalities, 12 provinces and 26 water boards, leading to a diffuse and non-transparent updating process and to an inconsistent product quality. This is enhanced by the fact that up-to-dateness is considered more important than accuracy, which makes an operator process a specific 'real infrastructure' change several times within the NWB network. Each time a more accurate data source is available, it will be used for newly digitizing the same road change.

Prior to 2002, the AVV used a spatial reference (the vectorized centreline database "Top10wegen" from the Dutch Ordnance Survey) to periodically match (e.g. upgrade the NWB quality to the reference's quality level) the NWB in order to unify all the different NWB sources. After matching the NWB quality meets its customer requirements as stated before.

In 2002, the AVV decided to cancel its contract for the Top10wegen of the Ordnance Survey, citing cost and quality reasons. The accuracy of the delivered data was high, but the up-to-dateness of the reference was as much as 4 years; too long considering the growing customer demand for up-to-dateness of better than 1 year.

Soon after, AVV noticed a slowly decreasing geometrical quality of the NWB, because the geometrical information on the road changes as delivered by the road administrators possesses a lower overall quality. A detailed analysis revealed a growing part of low quality sources being used to update the NWB, meaning that over a certain period the quality of the NWB will be lower than the customer's demand and previous investments would be wasted.

In summary: the NWB has a diffuse and inefficient updating process, and the quality of the NWB is not assured over time.

Given today's available technological tools the AVV started looking for alternatives for updating the NWB in an efficient way. The ideal situation would be to detect a road change as soon as it has become a reality and to digitize each road change just once.

In view of this perspective, a pilot was carried out during 2004 to investigate whether High Resolution satellite images (HI-RES) can improve the efficiency of the updating process and assure the NWB product quality. Included was a cost-benefit analysis for several implementation scenarios.

2. Change detection for maintaining the road database NWB.

2.1. Background

The principle of Change detection is rather simple. Take two pictures (e.g. high resolution satellite images) of the same area but from a different date. Position both pictures exactly on each other (e.g. geo-reference) and look what has changed. When dealing with digital images the process of change detection is a computation of the differences between two coinciding pixels (e.g. similar spots on the earth surface). A computer can perform this computation automatically. But more important, the outcome still has no meaning besides the information about position and a numerical value of differences between pixels in two images.

This is the starting point of the scenario, or the implementation of change detection within the updating process of the NWB.

The changes on pixel-level must first be clustered, interpreted and ordered into different object types, such as roads. The isolated roads must be validated upon by

Fig. 2. IKONOS satellite image of the study area (100 km2)

an operator and classified into correct changes (road segments in accordance with the definition of the NWB such as new roads, changed geometry or disappeared roads) and incorrect (road segments not in accordance with the definition of the NWB such as cycle paths).

The final decision whether to accept the road changes into the NWB is up to the operator. At AVV this is done in a GIS by manual digitalization of the change. The merging of the changes and the actual NWB is done manually.

The implementation of the human-machine interface on change detection heavily relies on human interpretation. Up to now it is not feasible to have a (semi)-automated interface for the updating of a large road database. The extraction, validation and merging of the roads must still be performed manually.

2.2. Pilot

Now the pilot will be discussed in more detail. The project area consists of 100 km2 around Delft as shown in Figure 2. Clearly, both rural and urban (very dense road network) areas can be identified in the image.

The scenario implemented during the pilot is shown in Table 1.

The first procedural step is a complete matching between the manually extracted road centrelines from the 2002 satellite images and the NWB. All the differences between the extracted roads of the 2002 image and the 2002 NWB should be validated, accepted and merged into the NWB. After this complete and laborious matching only incremental matching is needed because the unchanged part in the incremental steps has already been matched and ▶

evaluated before during the complete matching. This complete matching performs a complete quality update of the NWB onto the quality level of the satellite images.

The quality level of the satellites images outstands the customer's demand by far (accuracy is better than 5 meter, up to dateness is dependent on the processing time but within 1 month, completeness is almost 100% except roads that can not be identified from the image such as underpasses or roads through woods)

The matching of the 2002 image an the 2002 NWB showed that the quality of the NWB within the study area is lower than expected by AVV and lower than demanded by customers. About 80% of the differences between the extracted roads and the NWB are accepted by the operator as new roads, changed geometry or disappeared roads.

The next step is an incremental matching, based on the change detection between the satellite images of 2002 and 2003, between the images changes and the 2003 NWB. This resulted in a change rate of roads of a few percent. AVV found the delivered change information useful with regard to completeness and accuracy. The operator accepted 80 % of the delivered change information as being relevant to the NWB.

The same findings were reported for the third step e.g. the change detection between satellite images of 2003 and 2004.

Comparing the results of the change detection with the actual NWB changes showed that the NWB updating is running behind to the actual situation. Some cases of road changes, which already have been identified on the 2002 satellite image, are not updated before the version of the NWB in the year 2004. These cases are very rare but it shows the strength and quality of the use of satellite images and change detection.

Further analysis of the inaccuracies of the NWB revealed that 20% to 60% of these inaccurate road segments result from the use of low quality sources. The priority of up-to-dateness is shown to have a negative effect on the geometrical quality. In the current process these errors will gradually be eliminated when new and better sources are available but it is a very inefficient way of updating.

Up to now the discussion of the pilot has restricted itself to product quality and quality assurance. A very time consuming and expensive part of the updating process is the work spent communication with the road administrator. The pilot also shows that change detection can improve the effectiveness of the communication with the road administrator. Simply, because a image is an area full of changes. Changes within a large jurisdiction of the road administrator can be detected and missing attribute information about these changed road segments can be communicated with the road administrator in one time (a copy of the satellite image with the markings of the changes or a web-based application). Besides, construction works can be seen on the images, which inform you about road changes to come. A pro-active way of updating the NWB is possible.

Satellite images		PROCEDURE	NWB	
15 September 2002 (IKONOS)		►Complete matching◄	01 November 2002	
15 September 2002 (IKONOS)	Image changes 2002-2003	►Incremental matching◄	NWB changes 2003	01 November 2002
22 April 2003 (Quickbird)				01 May 2003
22 April 2003 (Quickbird)	Image changes 2003-2004	►Incremental matching◄	NWB changes 2004	01 May 2003
02 September 2004 (Quickbird)				01 October 2004

Table 1: The procedure steps of the scenario.

2.3. Conclusion.

The conclusions from the pilot are:

- AVV can save time and money on the updating of the NWB by using a yearly change detection from high resolution satellite images.
- Efficiency is gained by improved communication with the road maintainers and by a decreased amount of digitalisation work (collect and digitize once).
- Yearly change detection also prevents the deterioration in quality of the NWB. As a result no more expensive matching procedures will be needed in the future.
- The use of a yearly change detection is estimated to be cost-neutral in five years compared to the actual updating process.

3. Future developments

As a further development of the pilot AVV will start a project in 2006 in which the concept of change detection will be implemented on a larger scale (an area of 10.000 km2) and in a more automated way.

The practical implementation of change detection faces several challenges:

- (semi)-automatic road extraction from HR satellite images;
- (semi)automatic change detection on road objects;
- (semi)automatic verification of extracted roads;
- (semi)automatic map merge between newly extracted roads and current road database;
- optimizing the human-machine interface within the updating process ;
- decision support on the acquisition of new series of HR images;
- implementation of a quality management system.

Universities or companies who are able to facilitate AVV in facing these challenges are kindly invited to contact the author.

4. References

AVV, AGI and NEO, "Hoge Resolutie satellietbeelden t.b.v. het NWB (Deel2 AGI-Nummer 28275)", 2004, The Netherlands.

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