QUALITY MANAGEMENT OF ATKIS DATA

Andreas Busch (1), Felicitas Willrich (2)

(1) Federal Agency for Cartography and Geodesy
Richard-Strauss-Allee 11, D-60598 Frankfurt, Germany
Phone ++ 49 69 6333 312, Fax ++ 49 69 6333 441, busch@ifag.de

(2) Institute for Photogrammetry and GeoInformation, University of Hannover
Nienburger Str. 1, D-30167 Hannover, Germany
Phone ++ 49 511 762 4922, Fax ++ 49 511 762 2483, willrich@ipi.uni-hannover.de

Abstract

Describing the quality of digital geodata in a geodatabase is required for many applications. As well customers as users want to know how good the data are and if the data are up to date. We present a concept and our developments for automated quality control of the area-wide available topographic vector data set ATKIS® in Germany using images. The automation comprises automatic cartographic feature extraction and comparison with ATKIS, which both are triggered by additional knowledge derived from the existing scene description. To reach an operational solution the system is designed as an automated system, which admits user interaction to perform a final check of the fully automatically derived quality description of the data.

Keywords: quality control, road extraction, semi-automatic procedure, user interaction, integration of image processing and GIS

1. INTRODUCTION

Describing the quality of digital geodata in a geodatabase is required for many applications because tasks like environmental planning, documentation and analysis highly depend on the quality of the input data used for it. Additionally a quality description in terms of geometric and thematic accuracy and completeness is a prerequisite for identifying areas of interest where an updating has to be performed.

For checking the quality of existing geodata and for updating the data an efficient quality management system is required to ensure that a production process of geodata delivers the desired quality. Such a system has to cover a chain of processes for quality control that guaranty to keep the specified quality. Each step in quality control checks one aspect of quality specifications defined for the underlying data model. Thus, quality management should be the first step in data processing, data analysis, maintenance or homogenisation of different data sets to ensure a well-defined result in any of these processing tasks.

A major task of the Bundesamt für Kartographie und Geodäsie (BKG, Federal Agency for Cartography and Geodesy) consists in providing the geodata of the ATKIS project on the territory of the Federal Republic of Germany. The acronym ATKIS® stands for the Authoritative Topographic-Cartographic Information System for Germany. ATKIS is a trademark of the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV). Components (Fig. 1) of ATKIS are object-based digital landscape models (DLM), digital topographic maps (DTK) in vector and raster formats and standardised orthophotos (DOP). The object-based digital landscape models encompass several resolutions and the digital topographic maps of different scales are derived by a transformation to map geometry and symbol add-ons.

The ATKIS DLMBasis, i.e. the ATKIS data of the highest resolution or of the largest scale (cf. Fig. 1), are produced by the federal states (Länder) of Germany based on different data for the acquisition and are delivered to the BKG, where they are stored in a database at the Geodata Centre (GDC) of the BKG (Endrulis 2000). Since these data that are supplied by 16 surveying authorities are delivered to customers on the one hand and are used to derive data of smaller scales within the BKG on the other hand, a system for quality management of the ATKIS data is essential.

This paper presents the concept of quality management of the ATKIS DLMBasis as it is proposed at the BKG. Parts of it already are performed in an operational way within the daily production process. To solve the complete process chain in an efficient way BKG has initiated a common project with the University of Hannover to develop a system for automated quality control of ATKIS DLMBasis using digital orthoimages which is also described in this paper.

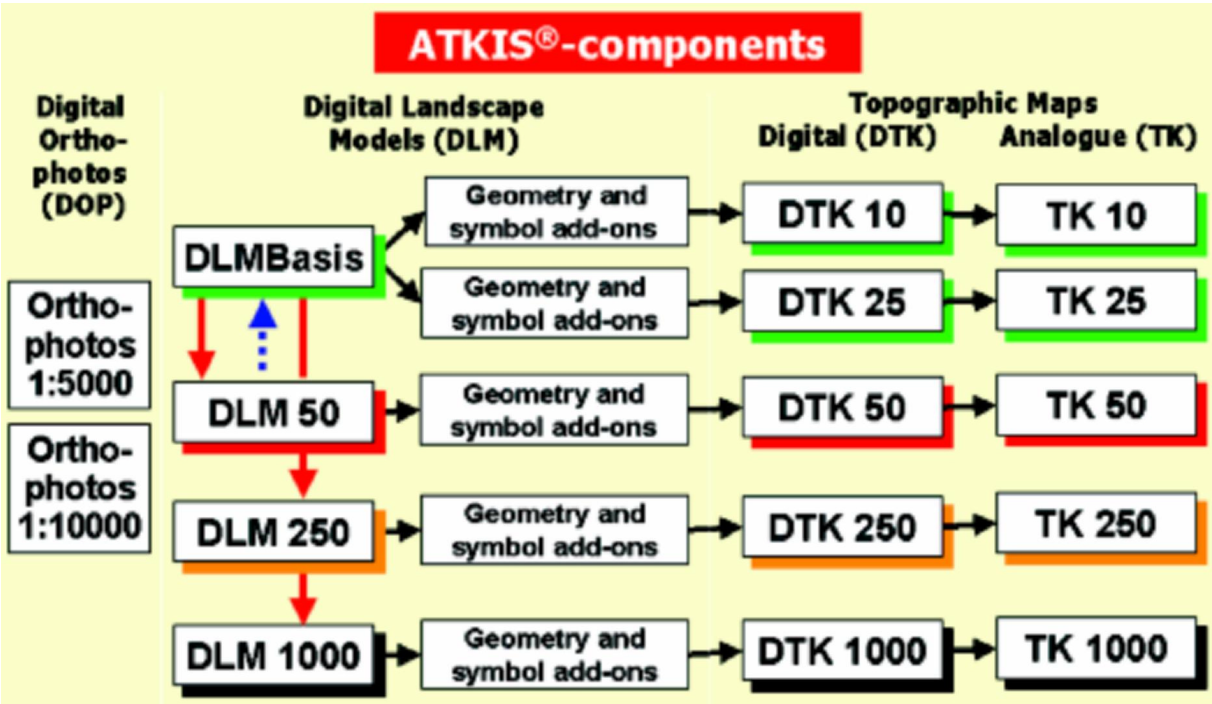

Figure 1. The components of ATKIS (cf. AdV 2000)

2. QUALITY OF GEOTOPOGRAPHIC DATA

2.1 Quality Measures

For rating the quality of geodata we need a certain set of measures, which give us expressive, comprehensive and useful criteria. That is the reason why quality measures are part of norms or specifications from e.g. ISO, CEN or the OpenGIS Consortium. We want to start with a coarse subdivision of quality measures into two categories, which due to the following arguments are important for practical applications:

1. Quality measures that concern consistency with the data model,
2. Quality measures that concern consistency of data and reality within the scope of the model.

A complete check of the first category can be performed automatically using solely the ATKIS vector data and functionality and routines within a database or GIS without any additional data. This inspection can be done exhaustively, i.e. the whole area covered by the data can be checked. On the other hand the comparison of data and reality is much more expensive. Performing it for the whole area requires nearly the same order of effort as the initial acquisition of the data.

Joos (2000) suggests a system of four criteria, which are conceptually independent or orthogonal, namely completeness, correctness, consistency, and accuracy.
The quality elements of ISO 19113

- completeness
- logical consistency
- positional accuracy
- temporal accuracy
- thematic accuracy

are strongly related to the criteria above. The ISO elements are refined by so-called subelements. So completeness comprises missing objects, i.e. omissions, and the complementary event, where a data object does not exist in reality, i.e. commission. Within ISO 19113 correctness is defined as a subelement of thematic accuracy. Temporal accuracy measures whether a dataset is up-to-date. Some quality elements of ISO differentiate between features and attributes. The quality elements of ISO are listed in Table 1 together with additional information.

2.2 Concept of Quality Management of the ATKIS DLMBasis at the BKG

Since the data of the ATKIS DLMBasis are delivered by 16 federal states, it is the task of the BKG to join them to one homogeneous set of data. This includes establishing logical and geometrical consistency at the borders of the different data sets. All incoming data sets and update files from the surveying authorities of the federal states have to undergo the quality control. Table 1 shows the current status of quality control at the BKG within the framework of the quality elements of ISO 19113. Automatic routines that test conformity of the data sets with the model, have been implemented at the Geodata Centre (GDC). These routines perform an exhaustive check, which includes the data quality element logical consistency and some other subelements of ISO 19113. Because spatial omissions concern the question, whether the whole area is covered by ATKIS objects without any gaps, they are revealed without any comparison of the data to the real world. In case of attribute completeness both commissions and omissions can be checked, because the model defines which attributes must be present for a given type of object and which not. Additionally for temporal consistency some plausibility checks are applied. All these tests concern quality measures belonging to the first category, i.e. quality measures that concern consistency with the data model. If once implemented, they perform on the full coverage of the data requiring computation power and time only. Unlike these automatic tests the comparison of the data to the real world will always require manpower. In Table 1 this is indicated by the term automated. Automated procedures consist of automatic steps that are started by an operator and give back a result that requires further processing by the operator.

Any error that is detected during the quality control is reported to the respective federal state. Since the federal states are producers of the data of the ATKIS DLMBasis, they are responsible for the appropriate amendment of the data. When the errors have been corrected, the updated datasets from the surveying authorities of the federal states are delivered to the BKG again where they are stored in the database at the GDC. This procedure guarantees that there exists one unique dataset of the ATKIS DLMBasis only.

Quality element	Quality subelement	Coverage	Status
Completeness	Omission (Feature completeness)	sample	automated
	Commission (Feature completeness)	sample	automated
	Omission (Attribute completeness)	full	automatic
	Commission (Attribute completeness)	full	automatic
	Omission (Spatial completeness)	full	automatic
	Commission (Spatial completeness)	—	no
Logical consistency	Conceptual consistency	full	automatic
	Domain consistency	full	automatic
	Format consistency	full	automatic
	Topological consistency	full	automatic
Positional accuracy	Absolute or external accuracy	sample	automated
	Relative or internal accuracy	sample	automated
	Gridded data position accuracy	—	no
Temporal accuracy	Accuracy of time measurement	—	no
	Temporal consistency	full	automatic, checked partially
	Temporal validity	sample	automated
Thematic accuracy	Classification correctness	sample	automated
	Non-quantitative attribute correctness	sample	automated
	Quantitative attribute accuracy	sample	automated

Table 1. Quality elements from ISO and their current status for the quality control at the BKG

2.3 Conformity of Data and Reality

A complete comparison of data and reality requires a lot of effort and cost, but it furnishes all the update information for the data. Update processes of digital geotopographic databases have changed in comparison to the periodic update cycles of analog maps. There is no technical problem in altering a specific feature or attribute as soon as the information about its change is available. As a consequence revision of geoinformation turns from periodic to continuous procedures. This requires that the information about changes in the real world has to be available continuously, too, if it is of relevance to the geotopographic data. Since nearly all of the changes in the real world are man-made, information concerning the changes is available very early, usually already during the phase of planning. Therefore the surveying authorities of Germany are forcing topographical information management to gather information about changes and make it available in time for the update of ATKIS. The flow of information from the authorities that cause the changes plays an important role in topographical information management.

This paper focuses on a method for quality control of the ATKIS DLMBasis that compares the data with reality using sensor data from an independent source. Thus, we look at quality control as an independent procedure to rate the quality of geodata by sample and to detect deficiencies within the chain of production. It depends on the type of sensor which features and attributes can be verified. Our main interest concerns objects where most changes arise and that are important, namely the road network and built-up area. Currently we are using only digital orthophotos as sensor data. If the orthophoto is of recent date, it is an up-to-date reference of reality and can be used to assess temporal accuracy, too. Orthophotos and photogrammetry are very suitable tools to determine the positional accuracy of features and geometric attributes like the width of a road. Nevertheless, there will be always features and attributes that are not detectable by the sensor data. In these cases quality control has to be based on the topographic information management.

Figure 2. How to check conformity between data and reality is performed

3. SYSTEM OVERVIEW & COMPONENTS

In chapter 2.2 we gave an overview over the quality management of the ATKIS DLMBasis at the BKG. The data quality concerning consistency with the data model is already checked fully automatically in an operational way. For efficiently checking the consistency of data and reality within the scope of the model, BKG has initiated a pilot R&D project together with the University of Hannover to develop a system for automated quality control by comparing ATKIS to imagery covering the scene.

The main idea followed with the developments is to check the quality of the ATKIS DLMBasis by extracting features from black and white orthoimages and comparing the extracted information to the DLM. To increase the efficiency of the quality control, extraction and comparison should be performed fully automatically.

3.1 System Overview

Automatic feature extraction from aerial images has been a major activity of international research in photogrammetry and computer vision during the last decades (e.g. Förstner et al. 1999, Baltsavias et al. 2001). Although there is many success in cartographic feature extraction experiences have shown that algorithms particularly give good results if applied to well-defined application areas. The reason is that all approaches need additional knowledge to be involved by using appropriate models, which can more easily be formulated for restricted situations. Walter (1999) for instance developed a system that supports the operator in quality control of area and line objects in ATKIS by automatically extracting land cover classes by multi-spectral classification from satellite imagery and comparing it to the corresponding ATKIS objects. He uses knowledge derived from the existing GIS for defining training sets for a supervised classification. Those ATKIS objects that show a high probability of differences between the extracted object classes are indicated to be presumed changes and can be visualized for further interactive analysis by the operator.

Knowledge based systems have proven to be suitable framework for representing knowledge about the objects and exploiting it during the recognition process. Liedtke et al. (2001) present a system for knowledge-based image interpretation which models structural dependencies by semantic networks with concept nodes and edges describing the relations between the nodes by steering the top-down and bottom-up analysis. The system is designed to use holistic methods for feature primitive extraction attached to nodes on different semantic levels. Examples for land use interpretation are given using ortho images, laser DEM and an initial segmentation derived from vector data given by a GIS.

We present an automated system prototype for knowledge-based quality control, which is designed to combine fully-automatic analysis with interactive pre-processing by an operator to reach an optimal workflow. We admit a final user interaction to transfer the knowledge based image interpretation techniques to an operational solution for practical applications as in general one can not expect any automatic image analysis tool to lead to 100% reliability which however is needed for operational systems (cf. Lang and Förstner 1996, Gülch 2000). The fully automatic part attains to focus the interaction and thus reduces the amount of interaction by an operator, which is the time consuming part in the quality control process chain.

The knowledge we use is partially derived from the existing geodata that is from ATKIS and coded in rules. In future it will be implemented in the knowledge-based system presented in Liedtke et al (2001). Although in general the system is designed to handle all object types of ATKIS we presently are focussing on those objects for which the highest up-to-dateness is required, and test it for roads.

The system development is embedded in a broader concept of a knowledge-based workstation, which provides functionality from photogrammetry, GIS, and cartography for the acquisition, and maintenance of geoinformation. A major goal of this concept is to integrate several components performing different tasks within the framework of a knowledge-based system.

3.2 System Components

The system is designed as a knowledge-based photogrammetric-cartographic workstation, which provides functionality from knowledge-based photogrammetric image analysis and cartography for the production of geoinformation. It consists of three major parts: a. the GIS component, b. the photogrammetric component and c. the knowledge-based component:

a. *The GIS component:* The GIS component of the system is based on the GIS ArcInfo 8 and runs with the desktop version under Windows. It is used for automatic pre-processing of the ATKIS data, as an interface to the database and to the image processing system, for interactive post-processing of automatically derived results and generally spoken as an user interface and for the overlay of aerial images and ATKIS data.

b. *The photogrammetric component:* The photogrammetric component running under Linux comprises the automatic cartographic feature extraction modules and the comparison with the original vector data leading to quality measures. Both tasks are triggered by the GIS data being a valuable source of additional knowledge. The underlying result of the feature extraction steps as well as the automatically derived quality of the ATKIS objects are stored in exchange files. They are transferred to the GIS component and are used to support the operator during the interactive final check and during geometric corrections.

c. *The knowledge-based component:* This part of the system is responsible for making pre-knowledge from the GIS available and transfer it in a suitable way to the photogrammetric component, that is to the object extraction, comparison and evaluation algorithms. As the link to the photogrammetric component is very close it is also running under Linux. Pre-knowledge especially is used for defining regions of interest, for selecting the appropriate algorithms, for parameter control of the road extraction and evaluation of deviations between ATKIS and extracted features. Additionally it is helpful for steering the complete automatic workflow.

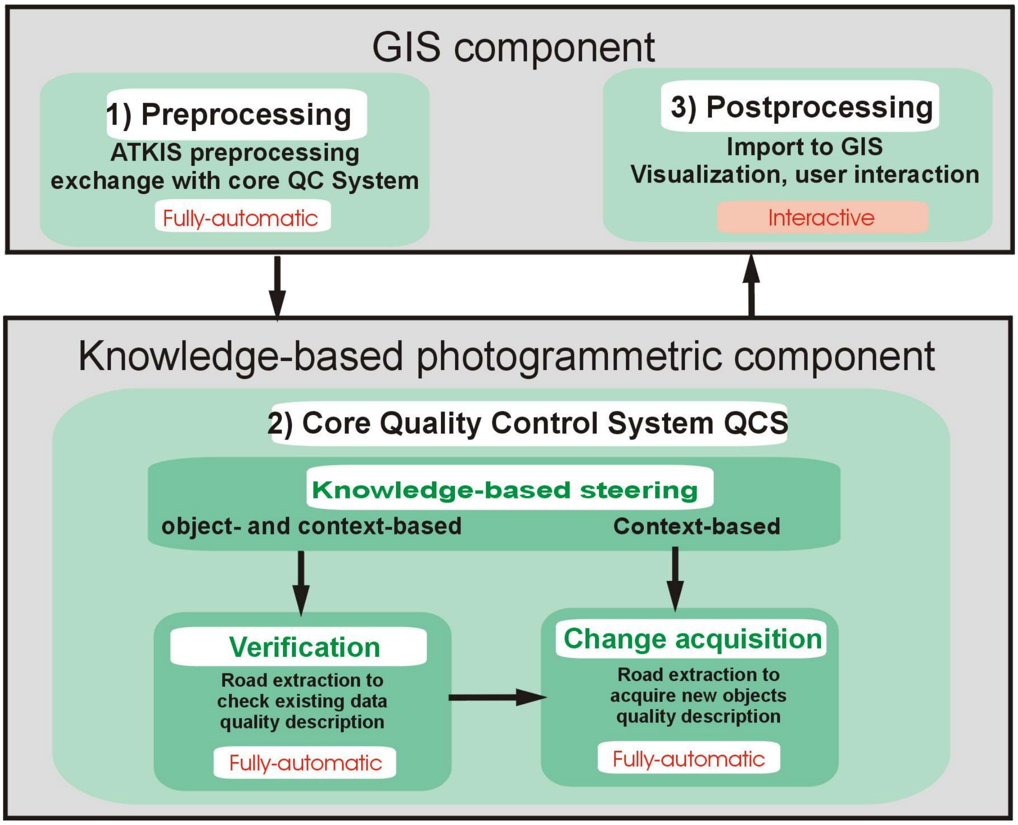

Figure 3. The components of the system for quality control

The result of the automatic knowledge-based reasoning is imported to the GIS component so that it is available to the operator. Quality measures are delivered as attributes and are used for an appropriate visualisation. During the final interactive check of the results the operator focuses on roads that were indicated as not verified and roads where the photogrammetric component indicated an uncertain situation. Thus he only has to handle a reduced number of objects contained in the GIS. Missing objects, geometric differences that exceed the tolerances given by the ATKIS data model and wrong values of attributes are recorded and forwarded for the correction of the database.

4. PROCEDURE FOR AUTOMATIC QUALITY CONTROL

4.1 Overview

The complete automated system for quality control, checking the consistency of data and reality is subdivided into the three steps: 1) fully-automatic pre-processing, 2) fully-automatic quality control and 3) interactive post-processing (cf. Fig. 3) . In the following we describe the fully automatic part in detail. It is to be regarded as being a black box for the operator delivering a preliminary quality check for focussing the interactive intervention by the user.

The procedure starts with automatically pre-processing and preparing the GIS data so that it is appropriate as well for the automatic processes as for the interactive analysis by the operator. This pre-processing is performed by the GIS component and compounds e.g. the selection of test area for quality control, establishing the link between object geometry and thematic attributes and supplying an appropriate interface to the knowledge-based photogrammetric component. Due to practical reasons the working units are image tiles of a size of e.g. 2 km × 2 km or interactively selected image areas defined for the quality control. For each tile all types of ATKIS objects and their attributes, that are relevant for quality control are requested from the database and are transferred to the photogrammetric component. Actually these ATKIS objects are exported to interchange formats, that can be read by the knowledge-based photogrammetric component but in future the transfer will be performed by database queries.

The second step, the core of the system for automatic quality control (QCS), which combines the knowledge-based, and the photogrammetric component is running under Linux. It comprises automatic road extraction adapted for the quality check and the comparison of its result to the original data. The quality description is delivered to the GIS component, the ArcInfo 8 system, where the operator performs the well directed pre-editing of those parts of the scene description, which could not be reliably analysed by the automatic process.

4.2 Core Quality Control System QCS

4.2.1 Automatic Road Extraction

International research has produced many different algorithms for road extraction (e.g. Förstner et al. 1999, Baltsavias et al. 2001) each of them being suitable for well-defined extraction tasks. Our concept for checking the quality of roads in general is designed to use different algorithms whereas the selection of the algorithm is performed by the knowledge-based component. We actually apply software developed by C. Wiedemann (cf. Wiedemann et al. 1998a, Wiedemann 2001) at the Chair for Photogrammetry and Remote Sensing at the Technical University Munich. We adapted it to our specific tasks especially by exploiting the GIS scene description and embedded it into the knowledge-based framework for steering and deriving quality statements. The underlying road model partly can be steered by parameters, which are automatically defined or even adapted to the image content by the knowledge-based component.

4.2.2 The use of pre-knowledge for quality control

GIS data in general can provide a valuable source of additional knowledge (cf. Vosselman 1996) and can be used to stabilize the image interpretation tasks. Examples are given in e.g. Quint and Sties (1995) or Wallace et al. (2001). In contrast to cartographic feature extraction solely based on imagery the starting position for quality control of existing data is different, as an initial scene description already is available. In this case algorithms for object extraction can benefit from the information contained in the GIS. This however requires a close and well-defined interaction between image analysis and GIS.

The knowledge we use for road extraction and for evaluation of the differences between extracted roads and objects in the database can be distinguished into object-specific properties and context-specific properties:

- Object-specific properties e.g. are the road type (highway, single/multi track, road, path), road widths or road constitution (asphalt, concrete). These kinds of properties usually are partially represented in the underlying road model of each algorithm and thus characterize the application domain of the algorithm.
- Context-specific properties can be subdivided into global and local context dependencies (cf. Baumgartner et al. 1997).
    - The global context, e.g. the environment through which a linear feature passes or is contained in influences the appearance of the road in the images e.g. by probabilities for having disturbances like shadow, fragmentation or low contrast. The expected appearance of the road is also partially represented in the underlying road model of

each algorithm, but in many cases it can be adapted to the scene by parameter steering. Actually we use three types of context regions given by the GIS for extraction and evaluation: rural, forestry and urban. The appropriate parameters are defined by empirical studies.

- The local context, e.g. the local neighbourhood relations between different objects also influences the appearance of the road in the images by interrelationships like occlusion and shadow, connectivity and parallelism conditions (e.g. buildings cast shadows on roads and buildings in general are connected to roads). It is difficult to model the influence of local context and therefore is not considered in our approach.

The main idea of our procedure is to exploit the initial scene description in the geodatabase to guide and constrain the road extraction by a knowledge-based procedure in the following way:

- by definition of region of interest
- by selection of the appropriate algorithm
- by parameter control of the road extraction
- by parameter control for evaluating the results

4.2.3 Verification of Road Data and Acquisition of Changes

For quality control we distinguish two different functionalities, namely verification and acquisition of changes. The partitioning mainly is motivated by the different amount of knowledge, which can be exploited:

- *Verification:* The verification focuses on those objects, which are described in the database. It is able to check the positional and the thematic accuracy as well as the completeness subelement commission, but not the completeness subelement omission (cf. Table 1). Beneath general context information object specific knowledge defined by the object instances in the database is used during the road extraction.
- *Acquisition of changes*: The acquisition of changes cannot use any specific knowledge defined by the object instances as it aims at checking the completeness subelement omission (cf. Table 1) that is registering additional objects, which are not contained in the database. The knowledge, which is used, is about the scene, about the global context and in general about the objects of interest. The acquisition of changes is executed subsequently to the verification to introduce verified ATKIS objects as reliable pre-information.

Verification: The verification is performed object by object by comparing the existing road data with roads extracted from the images. The geometric and thematic description of each object is transferred to constraints for defining regions of interest, the appropriate algorithm and its parameters used for automatic road extraction for verification of the respective ATKIS object. The differences between extracted roads and the original data are analysed and evaluated. The evaluation result leads to simplified quality measures described by different quality classes. For road elements which could not be initially verified the reason for rejecting the data is analysed by refined verification in a feed-back-loop following the hypotheses and verify paradigm. The generation of new hypotheses is performed by analysing the specific geometric and radiometric situation given by the raster data.

Acquisition of changes: After having verified the existing data the acquisition of changes can be performed. This task is even more difficult as it can be compared to object extraction from scratch, where no constraints are given by the GIS. The only pre-knowledge that can be introduced in this case is given on the one hand by the verified road data which can be used as reliable road parts during the road network generation. On the other hand the context regions can be used for steering the extraction as well as for self-diagnosis of the extraction result. The reliability of the extraction result especially depends on the extraction context and on the underlying low-level extraction used for road network generation. A self-diagnosis is used to derive a traffic-light-solution describing the quality of the data by a qualitative description as it is done during the verification of the existing data.

4.2.4 Quality evaluation

After the road extraction either for verification or for change acquisition, the extraction result has to be compared to the existing geodata to derive a quality measure. The quality measure has to distinguish road verification and acquisition. The quality description is simplified to a so-called traffic-light solution indicating three types of quality attributes: verified, rejected, and ambiguous. Details and a refinement of the decision may be analysed by a feedback loop to denote if the error is caused by wrong attributes or wrong geometry.

- *Quality description in road verification:* For verification we check if and how good an extracted road matches the corresponding ATKIS object. If no road matches the ATKIS object the object is denoted rejected. Otherwise the RMS is derived to further classify into verified and ambiguous objects.
- *Quality description in acquisition of changes:* In acquisition of changes we actually compare the extracted roads to the verified roads using the evaluation scheme proposed by (Wiedemann et al. 1998b). We especially are interested in new objects which are not contained in the verified dataset and which are denoted as changes and are delivered to the operator. As there still are extracted many false road elements a further classification of these changes is required, e.g. using the internal accuracy of the extracted roads. Thus the user interaction can further be reduced to very probable changes.

Fig. 4 shows an example of the automatically derived quality measure and the underlying road extraction used for road verification.

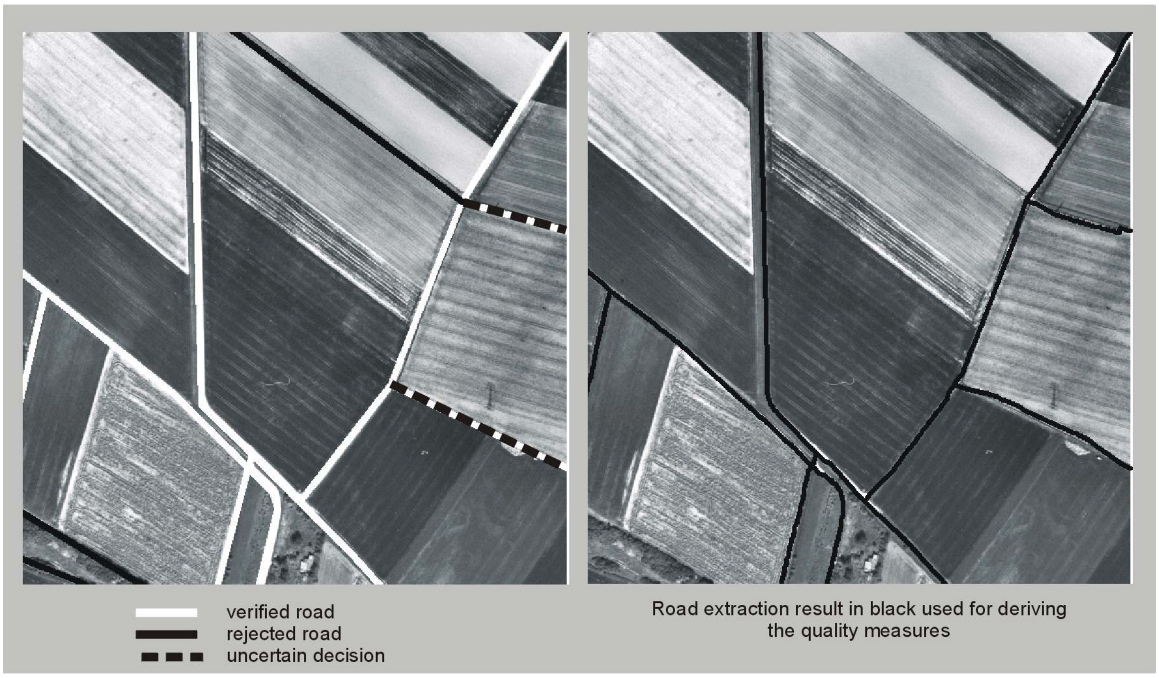

Figure 4: The result of the fully automatic quality control of the verification step as it is transferred to the interactive quality control by an operator.

5. INTERACTIVE QUALITY CONTROL

5.1 Tasks of the Operator

An efficient interlocking of the interactive steps of the operator and the automatic verification procedure as described in Section 4 is essential to guarantee an optimal workflow and a significant increase in productivity. Therefore the operator needs a graphical user interface (GUI) that allows fast and simple access to

- the image data,
- the relevant data from the ATKIS DLMBasis,
- the automatic verification procedure from Section 4,
- the tools to convert the ATKIS data to formats that can be read by the automatic verification procedure,
- the results of the automatic verification procedure,
- the tools for the final editing of the results.

After the automatic verification procedure has run as a batch process in the background, the results are imported and visualized together with the orthoimages on the screen. The quality measures are delivered as attributes of each inspected ATKIS object. They are used for an appropriate visualization to guide the operator to those objects that require his intervention. Of most importance are situations where the knowledge-based system indicates an uncertain decision. In these cases the final decision is made by the operator who classifies it as verified or not verified. All ATKIS objects that could not be verified by the automatic verification procedure have to be checked by the operator, too. Here the decision of the system has to be corrected, if necessary. To ensure that all objects that are classified as uncertain or not verified are processed, they can be stored in a queue that has to be worked of.

5.2 Editing Mode and Record of Quality Description

The editing functionality of the GUI allows the operator to correct or complete the results of the automatic procedure. All ATKIS objects for which any incorrectness has been detected are copied to a special file where all errors are recorded. From a list of items the operator can select the type of the detected error, e.g. wrong attribute road width, geometric deviation exceeds tolerance. Missing objects and copies of objects with large geometry deviations can be edited in this record file. There is no functionality to assign topological relations with other ATKIS objects or to build up a complete topology. This it not necessary since the results are reported to the responsible authority. For this purpose it is sufficient to provide the information needed to locate and identify the errors.

6. CONCLUSIONS

We presented the concept of quality management of the Authoritative Topographic-Cartographic Information System ATKIS® in Germany as it is proposed at the BKG. Within the production flow the vector data actually are automatically checked for conformity with the underlying ATKIS data model in an operational way. Checking the consistency of the data with reality is much more time consuming. To solve this task in an economical way we presented a prototype of a knowledge-based photogrammetric cartographic system, which we developed to speed up the whole production workflow in quality control. This system is designed to increase the efficiency of the updating process by combining automatic procedures with user interaction in a GIS environment. First results show the range of the concept. However the system has to be tested on a large amount of data sets to rate its performance. The quality check on completeness in the sense of commission has to be refined to increase the reliability of the automatically derived result.

References

AdV, 2000, *Progress Report 2000*. http://www.adv-online.de/english/index.htm#top, http://www.adv-online.de/intern/g_stelle/dokument/adv2000_e.zip

Baltsavias, E, Grün, A., van Gool, L., 2001, *Automatic Extraction of Man-Made Objects from Aerial and Space Images(III),* A.A. Balkema Publishers, Lisse / Abingdon / Exton(PA) / Tokio.

Baumgartner A., Eckstein W., Meyer, H. Heipke C., Ebner H., 1997: *Context-supported road extraction*. In Grün, A., Baltsavias, E.P., Henricsson, O., (eds), Automatic Extraction of Man-Made Objects from Aerial and Space Images (II), Birkhäuser Verlag Basel, pp. 299-308.

Endrullis, M., 2000, *Bundesweite Geodatenbereitstellung durch das Bundesamt für Kartographie und Geodäsie (BKG),* In R. Bill and F. Schmidt, eds., ATKIS - Stand und Fortführung, Beiträge zum 51. DVW-Seminar am 25. und 26. September 2000 an der Universität Rostock, Schriftenreihe des DVW, Band 39, Verlag Konard Wittwer, Stuttgart pp. 39-52.

Förstner, W., Liedtke, C.-E. and Bückner, J. eds., 1999, *Semantic Modeling for the Acquisition of Topographic Images and Maps / SMATI 99,* http://www.ipb.uni-bonn.de/SM/smati99.html.

Gülch, E., 2000: *Digital Systems for automatd cartographic feature extraction,* In. International Archives of Photogrammetry and Remote Sensing, Vol. XXXIII, B2, pp. 241-256.

Joos, G., 2000, Zur Qualität von objektstrukturierten Geodaten. In Schriftenreihe des Studienganges Geodäsie und Geoinformation der Universität der Bundeswehr München, Nr. 66.

Lang, F., Förstner, W. 1996: *3D-city modelling with a one-eye stereo system,* In. International Archives of Photogrammetry and Remote Sensing, Vol. XXXI, B4, pp. 261-266.

Liedtke C.-E., Bückner J., Pahl M., Stahlhut O., 2001: *Knowledge based system for the interpretation of complex scenes,* In E. Baltsavias, A. Gruen, L.,van Gool (eds.), Automatic Extraction of Man-Made Objects from Aerial and Space Images (III), A.A.Balkema Publishers, Lisse / Abingdon / Exton(PA) / Tokio, pp. 3-12.

Quint, F., Sties, M., 1995: *Map-based semantic modeling for the extraction of objects from aerial images,* In: Grün, A., Kübler, O., Agouris, P. (eds.), Automatic Extraction of Man-Made Objects from Aerial and Space Images, Birkhäuser Verlag, Basel, pp. 307-316.

Straub, B.-M., Wiedemann, C., 2000: *Towards the update of geodata by automatic object extraction*, In Serpico S.B. (ed.), SPIE Vol. 4170, Image and Signal Processing for Remote Sensing VI. 304-315.

Vosselman, G., 1996: Uncertainty in GIS supported road extraction, In. International Archives of Photogrammetry and Remote Sensing, Vol. XXXI, B3, pp. 909-917.

Walter, V., 1999, "Automated GIS data collection and update". In D. Fritsch and R.H. Spiller, eds., *Photogrammetric Week `99,* Wichmann, Heidelberg, pp. 267-280.

Wallace, S.J., Hatcher, M.J., Priestnall, G., Morton, R.D., 2001: *Research into a framework for automatic linear feature identification and extraction*, In E. Baltsavias, A. Gruen, L. van Gool (eds.), Automatic Extraction of Man-Made Objects from Aerial and Space Images (III), A.A.Balkema Publishers, Lisse/Abingdon/Exton(PA)/Tokio, pp. 381-390.

Wiedemann, C., 2001: *Extraktion von Straßennetzen aus optischen Satellitenbildern,* Dissertation Lehrstuhl für Photogrammetrie und Fernerkundung, TU München.

Wiedemann, C., Heipke, C., Mayer, H., Hinz, S., 1998a: *Automatic Extraction and Evaluation of Road Networks from MOMS-2P Imagery,* In. International Archives of Photogrammetry and Remote Sensing, Vol. XXXII, Part 3/1, pp. 285-291.

Wiedemann, C., Heipke, C., Mayer, H., Jamet, O., 1998b: *Empirical evaluation of automatically extracted road axes*, In: Empirical Evaluation Methods in Computer Vision, Ed. Bowyer, K.J., Phillips, P.J. IEEE Computer Society Press, pp. 172-187.