Automatic Relocation of Link Related Data in an Updated Road Map

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Abstract. For a rising number of Intelligent Transportation System (ITS) applications, location information obtained by the processing of sensor data is related to the links of a specific digital road map. Such maps are available from different vendors like Here, TomTom/TeleAtlas and OpenStreetMap (OSM). They are created with different philosophies, resulting in significant differences in the geometry and the topology of the road networks. If a map needs to be updated to a new release, the user faces the problem that a *relocation* of any annotated location data, i.e. a proper mapping of these locations from the old to the new map becomes necessary. For this reason, German Aerospace Center (DLR) developed an accurate, general method for inter map matching and a new software application called "DataRelocator@Map2Map" has been based on it. It enables the automatic relocation of location data between the two maps. Using the new tool, an almost fully automatic relocation is possible and thus the cost of service failures related to the map update can be avoided.

Keywords: Road map update · Link related data
Road network matching · Digital road maps

1 Introduction

A rising number of Intelligent Transportation Systems (ITS) are processing traffic location data, i.e. traffic data including geographical positions are processed in an electronic communications network. Examples include the traffic information of a traffic control centre (about e.g. the location of a traffic jam), traffic telematics applications like e.g. vehicle tracking and navigation via Global Positioning System (GPS), or fleet management, or a whole Advanced Traveller Information Systems (ATIS). Traffic location data are also required in location based services (LBS) displaying e.g. a list of points of interest (POI) on a smart phone. Therefore, the research and development of such ITS applications and telematics solutions requires digital road networks, for example urban or motorway traffic networks are built in a standardized digital form as reference graphs

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(nodes and edges). The digital road map contains the information about the geometry and topology of the road network as well as other information like street names. Today, the three most important manufacturers of digital road maps are: Here [1], TomTom/TeleAtlas [2] and OpenStreetMap OSM [3]. Digital maps from Here and TomTom/TeleAtlas are commercial products while maps from OSM are free. OSM is an open source project with the aim to provide a free world map. All three map manufacturers have different philosophies of data collection and thus there are huge differences concerning the geometry and the topology of the road network between their maps.

At regular intervals of e.g. once per quarter, manufacturers update their maps and publish new releases of their road maps. When comparing two different map releases of one and the same manufacturer, the differences can still be significant (and even more so if the time lag between the releases is large).

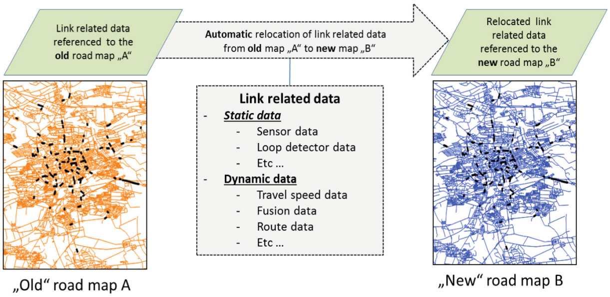

Fig. 1. Automatic relocation of static and dynamic location content from different maps.

For the aforementioned applications, static and dynamic location information as obtained by e.g. the processing of traffic or sensor data is related to the links of a specific digital road map. If an annotated map needs to be updated to a new release, the map user faces the problem that a relocation of the annotated location data from the old to the new map is required. If the amount of location data is huge, manual correction is prohibitive because the effort is too high. Consequently, there is a strong interest in automatic or semi-automatic solutions. Figure 1 illustrates a scenario of the automatic relocation of link related data to an updated map. German Aerospace Center (DLR [4]) designed and implemented a new prototypic software application called DataRelocator@Map2Map that enables the automatic relocation of dynamic and static content (e.g. Bluetooth or induction loop detector location data) between different maps. Using this new tool one saves time and cost and avoids failure, considerably reducing the effort of the relocation process. Two use cases can be derived as follows: (i) simple use case: "old" map and "new" map are from the same road map manufacturer like Here to Here, and (ii) complex use case: "old" map and "new" map are from different map manufacturer like Here to TomTom/TeleAtlas

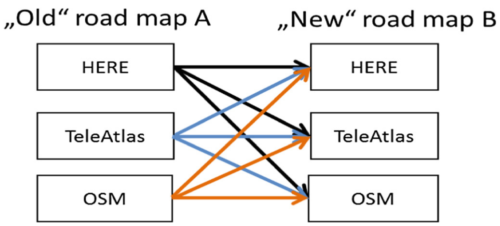

Fig. 2. Possible map combinations for the automatic relocation of link related data between different maps.

(see Fig. 2). The presented relocation approach is already prepared for both cases, because it already comprises data import components for the different vendors of digital road maps (Here, TomTom/TeleAtlas, OSM), and because it uses the method “Geometry Inter Map Matching Extension” (GIMME [5,6]) developed by DLR. In contrast to [8], GIMME is capable of matching different maps from arbitrary vendors. The results are more accurate than for previous approaches, e.g. [7,9]. Nonetheless, the paper focusses on the first use case, and presents the results of first experiments conducted for the use case of relocation of (static) location data after a map update.

2 “DataRelocator@Map2Map” Tool: Technical Realization

The technical realization of the “DataRelocator@Map2Map” application is described in this section.

2.1 Workflow of the Data Processing

Figure 3 depicts an overview about the data processing steps of the new tool for the automatic relocation of link related data from an “old” to a “new” map. The tool consists of two processing submodules: the inter map matching and the data mapping process module. The inter map matching process consists of six processing steps and the data mapper process has two processing steps. They are defined as follows:

Step 1: Load “old” map (A) and “new” map (B) from the database. The “DataRelocator@Map2Map” application has two instances of the so-called “graph loader” module whose role is to load the two input maps (“old” and “new” map) as graph (nodes and edges) from a database into the systems main memory.

Step 2: Map comparison. Identify all identical edges in old map (A) and new map (B) and generate two lists containing the edge ID of all identical edges in the both maps (list A_IDENTICAL) and the second list of edge IDs related to the old map and not identical to the new map (list A_NOT_IDENTICAL). Only the second list of edges of the old map with no identical counterpart in the new map is relevant for inter map matching (see step 3). Regarding the term "identical", the following comparison criteria have been formulated and used:

1. Does the edge ID in the old map also exist in the new map and do both the start- and the end-node ID as well as the respective geo-positions remain the same?
2. Did all other attributes of the edge also remain the same?

For those edges for which the questions of criteria 1 and 2 are answered with "yes", a corresponding ordinal quality attribute is set to "IDENTICAL", corresponding to the highest quality, and they are saved as mapping information between the two maps into the database.

Step 3: Inter-map matching between "old" and "new" map (A, B). The inter map matching (IMM) is applied to each edge contained in the second list (List A_NOT_IDENTICAL) of edge IDs generated in step 2 with the aim to find the homologous edges in the "new" map. For the IMM the geometry inter-map matching extension (GIMME) algorithm has been used. The GIMME algorithm has been described in detail in [5,6]. The final result of the inter map matching process with GIMME contains the mapping information (as assignment of an edge in the old map to its corresponding edge(s) in the new map). The mapping information generated by GIMME contains a matching quality attribute which can take two values: the value "GIMME_POSITIVE" if the map matching with GIMME is successful and the value "GIMME_NEGATIVE" for a failed matching. The mapping information generated by the inter map matching with GIMME is saved into the database.

Step 4: Statistics and shape files generation. The "data relocator" application provides two important functions that can help users with the manual evaluation of the obtained results. The first function deals with the generation of statistics containing the general information about the used maps (e.g. the number of edges or nodes in a map), the result of IMM and of the data mapping processes (see Sect. 3 for more details). The statistics are generated in Hypertext Markup Language (HTML) format and can be visualized using all common existing browsers. The second function concerns the shape file generation for different map scenarios like shapes for old map, new map, for the lists of edges with quality IDENTICAL, with quality GIMME_POSITIVE, or with quality GIMME_NEGATIVE, respectively. The generated shape files can be visualized using common existing shape viewers like e.g. QGIS.

Step 5: Load the data related to the links of the "old" map as input data. The input data like Bluetooth or loop induction location data is assumed to be available in the database and now needs to be loaded into the systems main memory via the SQL interface. After the successful loading process the automatic relocation of these data to the new map can begin.

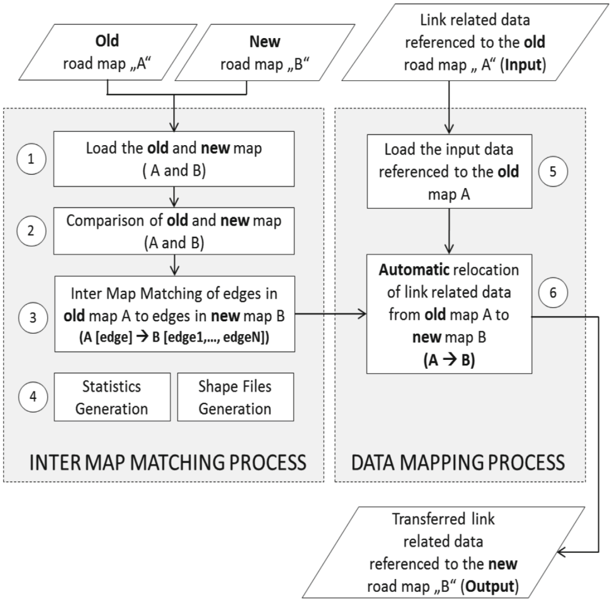

Fig. 3. Data workflow of the "data relocation" application.

Step 6: Automatic relocation of link related data from the "old" map A to the "new" map B. The input data loaded in step 5, and the mapping between old map A and new map B (the result of the IMM in step 3 which has been saved in the database) are used to process and automatically generate the new location data referenced to the new map (B). The resulting data can be saved into the database using the SQL interface.

2.2 System Architecture

Figure 4 shows an overview of the system architecture of the "Data Relocator" tool as designed and implemented by DLR. The "DataRelocator@Map2Map" application consists of the following components:

Data Import Components: The map loader module provides functions to load two digital maps simultaneously (the old and the new map) from different manufacturers (Here, TomTom/TeleAtlas and OSM) as network graph from the database contained in the DLR traffic data platform [10]. Due to space limitation, the process of the net conversion of the original raw digital map as received from the manufacturer into the DLR database net format as used in the traffic data platform cannot be described in this paper. In addition to the map loader module, static and dynamic contents referenced to the old map which need to be relocated in the "new" map can be imported by a data import module integrated into the data mapper module.

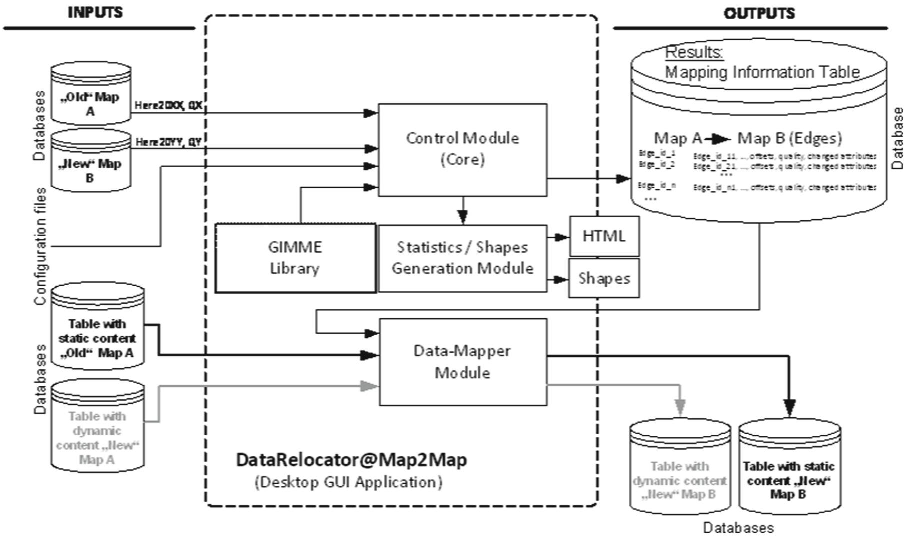

Fig. 4. System architecture of the "DataRelocator@Map2Map" application.

Processing Units: The control module is the core component which implements a series of functions like the IMM between old and new map. The IMM is based on the GIMME algorithm, a detailed description is given in [5,6]. In addition to the IMM function a second major purpose of the module is the computation of the differences between the two maps. The statistics and the shape files for different map scenarios (see Sect. 2.1) are generated by a separate module, the "statistics and shape file generation module". The statistics output generated by this module is in HTML format and can be visualized in all common existing browsers. The shape files generated by this module can be visualized using common existing shape viewers like QGIS. The logic for the automatic relocation of static and dynamic content from the "old" to the "new" map is implemented in the data mapper module.

Data Export Components: The important result of the IMM is the provision of the mapping information between "old" and "new" map with the assignments at the level of the individual edges. A matching result for one source edge is a list of target edges, together with a "positive offset", giving the distance between the start nodes of the source edge and the first target edge, and a "negative offset", giving the distance between the end nodes of the source edge and the last target edge, respectively. The export module provides SQL interfaces for example to save the generated mapping information into the database located in the DLR traffic data platform [10]. Furthermore the mapping data (for static and dynamic content) generated by the data mapper module resulting from the relocation process and related to the "new" map can also be saved into the database customized for this purpose.

The prototype application "DataRelocator@Map2Map" uses a series of configuration files, which contains relevant parameters for example for database settings. It also allows default setting for the selection of the relevant map section configured by parameters defining a respective bounding-box in order to increase the performance of the module by limiting it for example only to the area relevant to the mapping of the location data in question.

3 Experimental Results

In order to demonstrate and to evaluate the newly realized application to automatically relocate the link related data in an updated digital road map, two digital maps from the city of Brunswick, Germany have been chosen. The two maps used for the test case described in this section are from the same manufacturer "Here" but from different release years (more precisely. The version 2015q4 for the "old" map and 2016q4 for the "new" map). A time lag of one year (2015 and 2016) between the two maps has been chosen. The "old" map (source map) is from quarter 4 of 2015 while the "new" map (target map) is from quarter 4 of 2016. Table 1 gives general statistics (e.g. total number of edges and total sum of edge lengths) of both "Here" road maps for the city of Brunswick, Germany used to demonstrate the new tool to automatically relocate the data in an updated map. The numbers in Table 1 shows that more than 7,370 additional edges are added in the new map with a total length difference of about 405 km.

Table 1. General statistics of both "Here" maps for the city of Brunswick, Germany.

Map	Total number of edges	Total sum of edge lengths in [km]
(Old) Brunswick Here2015q4	139,423	18,927.614
(New) Brunswick Here2016q4	146,793	19,333.267

3.1 Results of the Inter Map Matching (IMM)

The results obtained by the inter map matching (IMM, using the Geometry Inter Map Matching Extension (GIMME) algorithm [5,6]) of both "Here" maps for the city of Brunswick, Germany are given in Table 2.

Table 2. Total number and percentages of IMM with GIMME.

Number and percentages of matched edges		
Quality of matching	Relative to the total number of edges in network	Relative to the sum of edge lengths in the network
IDENTICAL	Count: 134,514 (96.48%)	17,878.134 km (94.46%)
GIMME_POSITIVE	Count: 4,656 (3.34%)	1,005.800 km (5.31%)
GIMME_NEGATIVE	Count: 253 (0.18%)	43.679 km (0.23%)

The percentages in the second column of Table 2 refer to the total number of edges in the whole network. In order to prepare the evaluation of the result quality of GIMME, the match rate is still important, the percentage of the matched edges relative to the number of edges that must be matched with GIMME (because the edges have not been marked as IDENTICAL before). The match rate (q_{matched}) determined from the matching results in Table 2 yields a value of 94.85%:

$$q_{\text{matched}} = \frac{4,656}{(4,656 + 253)} \cdot 100\% = 94.85\%. \tag{1}$$

Similarly, the rate of "non-matched" ($q_{\text{non-matched}}$), i.e. the percentage of failed matches is determined as follows:

$$q_{\text{non-matched}} = 100\% - q_{\text{matched}} = 5.15\%. \tag{2}$$

The final quality of results, i.e. the "success rate" and the "error detection rate" could be determined by a costly manual verification whether e.g. a successful match was correct: these rates are defined as

$$q_{\text{success}} = \frac{n_{\text{tp}}}{n_{\text{p}}} \cdot 100\% \qquad q_{\text{error\_detection}} = \frac{n_{\text{tn}}}{n_{\text{n}}} \cdot 100\%. \tag{3}$$

where n_{p} is the number of successful matches ("positives"), n_{n} is the number of non-matches ("negatives"), n_{tp} is the number of "true positives", i.e. the number of correct matches, and n_{tn} is the number of "true negatives", i.e. the number of non-matches where a matching location has in fact no homologous counterpart in the target map. However, good estimators for the aforementioned rates of GIMME are already known from the experiments conducted in [5]: here, a success rate of 99.7% and an error detection rate of 69.0% have been reported. Therefore, the accuracy or "hit rate" can also be estimated without a costly renewed manual counting. The estimated accuracy ("hit rate") of IMM with GIMME is 98.24% and is determined as follows:

$$\begin{aligned} q_{\text{hit}} &= q_{\text{matched}} \cdot q_{\text{success}} + q_{\text{non-matched}} \cdot q_{\text{error\_detection}} \\ &= 94.85\% \cdot 99.7\% + 5.15\% \cdot 69.0\% \\ &= 98.12\%. \end{aligned} \tag{4}$$

Since 96.48% of identical edges of the road network have remained unchanged in the "old" map and the "new" map, i.e. GIMME was not even applied to 96.48% of the edges, the "effective hit rate" is even higher when also including these identical edges:

$$q_{\text{effective\_hit}} = 96.48\% \cdot 100\% + 3.52 \cdot 98.12\% = 99.93\%. \tag{5}$$

In other words, for only 0.07% of the edges a "false-positive" or "false-negative" matching must be expected. In order to obtain an even more differentiated view of the result quality of GIMME, in Table 3 the "match rate" has been differentiated with respect to the "functional road class" (FRC) of an edge.

Table 3. Differentiation of the "match rate" with respect to the functional road class (FRC).

Functional Road Class (FRC)	FRC 0	FRC 1	FRC 2	FRC 3	FRC 4
"Matched rate" [%]	98.68	98.45	98.23	98.63	86.25

According to the result in Table 3, there are significant rates of failed matches for FRC 4 (defined as "These roads" volume and traffic movements are below the level of any functional road class. In addition, walkways and rest area road elements receive functional road class = "4"). Nonetheless, on the main road network, the rates of failed matches are small (<2%).

3.2 Mapping Results of the Location Data to Updated Road Map (Data Mapping)

The tool for the automatic relocation of link related data in an updated map was evaluated with two test data sets. The sets contained location data in form of rows with an edge ID along with an offset from the start node of the edge, given in meters.

- The first data set included the locations of a total of 19 Bluetooth detectors, which are part of RSUs in Brunswick, Germany which are operated by DLR.
- The second set contained the locations of a total of 236 induction loop detectors located in the city of Brunswick, Germany and operated by the German company Bellis GmbH [11].

Table 4 shows the percentages of matching qualities observed after the relocation of the link related data from the old to the new "Here" road network.

Table 4. Result of the relocation of the test data from old to new map.

Number/Percentage of matched location test data		
Quality of matching	Bluetooth detectors	Induction loop detectors
IDENTICAL	Count: 19 (100%)	Count: 171 (72.46%)
GIMME_POSITIVE	Count: 0 (0%)	Count: 64 (27.12%)
GIMME_NEGATIVE	Count: 0 (0%)	Count: 1 (0.42%)

All of the 253 locations of Bluetooth or loop detectors have correctly been mapped into the new map, except for one single detector location. The results are shown in Table 4 and have been confirmed subsequently by a manual inspection. Thus, the objective of realizing a mostly automatic relocation of location data (originally referenced to a network which has now become outdated or "old") to an updated network has clearly been achieved.

4 Conclusion

In this contribution, a prototypic software called "DataRelocator@Map2Map" is presented. This tool is realized with a GUI and enables the automatic relocation of dynamic and static location data in an updated road map. The technical workflow was formulated in six steps including the inter map matching using the geometry inter map matching extension (GIMME) algorithm, data mapping, statistics and shape files generation. In addition, the system and the database architecture as well as the GUI have been described. Digital maps of the manufacturer Here (an "old" map of the release year 2015 in quarter 4 and a "new" map of release year 2016 in quarter 4) together with test data describing the locations of Bluetooth and induction loop detectors in the city of Brunswick, Germany have been chosen to demonstrate and evaluate the new tool. The experiments yielded a hit rate for inter map matching of 98.24%. The effective hit rate was 99.93% because many edges in the "old" and the "new" map were identical. Furthermore by the evaluation with a total of 253 detector locations all except one location have correctly been relocated in the new map.

Thus, the objective of realizing a mostly automatic relocation of location data (originally referenced to a network which has now become outdated or "old") to an updated "new" network has clearly been achieved.

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