Automatic Generation of Wayfinding Maps

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Abstract

The paper presents the work in progress to use the digital data of the Authoritative Topographic Cartographic Information System (ATKIS), the geobase information system of the German national mapping agencies, to automatically deduce location maps. It is possible to render directions in different ways. First of all there is to distinguish between a textual and a graphic kind of route description. The paper focuses on different graphic representations. One possible graphic illustration of the route description can be designed as a hierarchy of map clippings in different levels of details ranging from small to large scale. As another possibility the wayfinding instructions can be visualized as a route map from start- to endpoint, where the relevant streets as well as the important landmarks along the streets are presented.

1 Introduction

ATKIS (Authoritative Topographic Cartographic Information System) is the digital topographic base data of the German national mapping agencies designed at three different scales. The so-called base model has an associated scale of approximately 1:25.000. Besides deducing printed topographic maps from these data sets, they have a great potential for a wide range of applications. The national mapping agencies try to develop more useful applications to benefit from this digital database in order to make it more profitable.

One possible application is the generation of individual wayfinding maps. Different possibilities to create such a kind of map exist. A first schedule line is to distinguish between a textual and a graphic portrayal. This paper focuses on two different graphic representations. The graphic illustration of the route description can be portrayed as a hierarchy of map clippings in diverse levels of details, for example two different scales: a coarse level of detail to show an overview of the urban area and a fine scale map to portray the road network (similar to a city map) including the destination. Depending on the situation an extension with a third level of scale is required and displays a very detailed clipping to outline the immediate neighbourhood. The coarsest level should only include the main traffic axes of a city, this requires that the road classification has to be part of the ATKIS database. In this paper the important structures of urban road networks are identified based on a geometric-topologic analysis. The content of the ATKIS data concept is investigated regarding these structures. Also methods for the automatic deduction of these relevant streets are studied.

As a second possibility the driving instruction can be interpreted as a route map from start- to endpoint, where the relevant streets as well as the important landmarks along the streets are presented. The automatic generation of such a presentation requires first of all the navigational information, then it is necessary to identify the important landmarks along the route, especially in the vicinity of turning points or junctions. Such points of reorientation are bridges, rails, prominent buildings or vegetation like a big tree or a park. The paper describes the kinds of landmarks, which can be extracted from the ATKIS database. Furthermore the integration of landmarks from another digital database will also be investigated.

2 Related Work

2.1 Road network generalization

The issue to identify the important structures of urban road networks leads back to the generalization task. In this domain, especially for road networks, a few number of research efforts

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have been undertaken. On the one hand there are approaches dealing with graph theory to determine and quantify the functional importance of road segments (e.g. Richardson 1996). The main principles are the segmentation of the road network in single graphs, assigning each segment an arc cost (e.g. travel time or distance), and the calculation of the minimum cost spanning tree for the network. The results are calculated arc weights giving a partial ordering of the arcs which can be used as a basis for the attenuation of the network in generalization (Thomson 1995). Because of using the minimum weight spanning tree, (that means a connected graph links all nodes by using the least number of edges with the most important weight), the connectivity of the network is provided (Mackaness 1993).

A second kind of approach for network generalization is done by (Kreveld 1998). In this work the graph theory approach is criticised since the geometric aspects of coalescence and imperceptibility of the portrayed elements as well as the semantic aspects such as avoiding large detours are not taken into account explicitly. The outlined ideas are implemented in parts and a test data set can be run via the World Wide Web (Peschier 1997).

A further procedure is based on the theory of perceptual organization, particularly on one of the gestalt laws: the 'good continuation' grouping principle (Thomson 1999). For that purpose, the so-called 'strokes' are built from the arc segments of the network presenting contiguous linear elements perceived from human cognition. It is asserted that an general correspondence exists between the perceptual salience of strokes and their functional importance in the network. A stroke ranking basing on the length information leads to an order of importance. The longer the stroke, the more important the road segment is. If only a selection of the important strokes is taken, this leads to an attenuated network.

The connection between a percental network attenuation and the required map scale is given through the principles of selection theory (Töpfer 1966).

2.2 Route map

The problem to give someone route instructions for getting from an start point to an destination point can be solved by conveying the navigational information by route directions. These guiding information can be given as a description (textual statement) or a depiction (as a kind of graphic represented routing graph), both seem adequate to convey sufficient information for arriving at a destination (Tversky 1998).

It is stated by Tversky (1999) that the structure of route descriptions and of route depictions are identical. Moreover, even the semantic content is similar. The components of both are landmarks, orientations and actions.

Agrawala (2000) remarks that the World Wide Web online mapping services typically provide directions as a set of maps complemented with text descriptions. But these portrays do not represent a plain route instruction, because they ignore important design goals for effective route maps: readability, clarity, completeness and convenience. The authors have designed and implemented some kind of computer-generated maps that mimic the style of hand-drawn route maps in order to achieve an effective compromise of the required design goals (see Agrawala 2001).

The implementation lacks the use of landmarks in the route maps, for example in long-distance directions even the geographic names of the cities are missing. Experiments have shown that people react to the absence of landmarks. The reason is that landmarks are essentially used as sub-goals along the route: people progress along a route by orientating themselves towards a landmark (Michon 2001).

In a further experiment (Lovelace 1999) landmarks were classified in four different types: landmarks at a choice point, potential (but not used) landmarks at choice points, on route (along the path) landmarks and off-route landmarks (not neighboured to the followed path, but with some orientation value). The research indicates that the appearance of landmarks correlates significantly with quality of route directions. Especially for unfamiliar route directions landmarks at turning points and just on-route points are quite frequently used.

The use of landmarks is so important because they serve multiple purposes in wayfinding: they help to organize space because they are reference points in the environment and they support the navigation by identifying choice points, where a navigational decision has to be made (Golledge 1999). Landmarks are characterized by particular visual characteristics, a unique purpose or meaning or they may be in a central or prominent location that makes them effective as a landmark (Sorrows 1999).

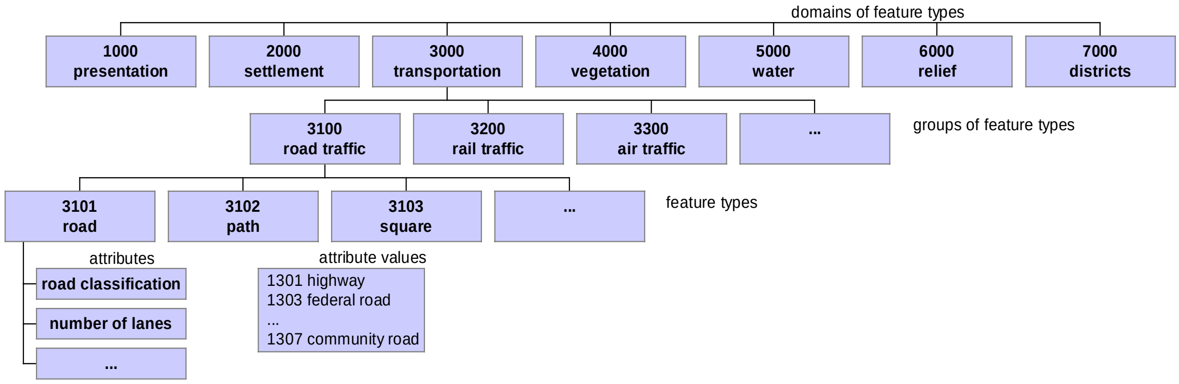

Figure 1: The ATKIS concept

3 Introduction of the ATKIS – Concept

The Authoritative Topographic Cartographic Information System (ATKIS) is a joint project of all German national mapping agencies and can be described as a geobase information system. Within the framework of ATKIS several different data types exist: the digital topographic maps, digital terrain models, digital orthophotos and the digital landscape model, which is used here (ATKIS, 2002).

The model illustrated in Figure 1 is structured according to objects. It distinguishes between seven 'domains of feature types': presentation objects, settlement, transportation, vegetation, water, relief and districts. Each class is subdivided in 'groups of feature types' and further in 'feature types', marked by a number code. At the level of 'feature types' special thematic attributes are attached to the objects. For example, for roads exist among other things the attribute 'road classification' with the possible attribute values: highway, federal road, state road, district road and community road.

The data are stored in vector data structure in the national grid reference system and have an accuracy of 3 metres for the important feature types (for example roads). The feature types and attributes in the feature catalogue will be filled in continuously each (periodic) maintenance of the data. A complete description of the concept is given in the object catalogue (ATKIS-OK 2001).

4 Map Hierarchy

The generation of wayfinding maps in form of a map hierarchy involves deriving different levels of detail from one single database. This study focuses on the representation of the road network, because it is the most important part of the database to convey the navigational information needed in a location map. The used ATKIS database contains the complete existing road network and bases on the scale 1:25.000. Therefore the fine scale of the location map hierarchy is a representation of the ATKIS data content. An extension in a larger scale representation (e.g. 1:10.000) for more clarity and readability is possible.

To provide a coarser scale the importance of the roads has to be modelled in the ATKIS concept in order to automatically select these elements, which are necessary to be portrayed according to their outstanding functional meaning. Inspecting the ATKIS catalogue reveals different possibilities to assign importance to a road: There is an attribute called ‘function of traffic’, with the distinctions ‘long-distance traffic’ or ‘transit traffic’ for example, but it is not included yet, because it is to expensive to capture the information.

On the other hand, for the feature type ‘roads’ there is the attribute ‘road classification’ (see Figure 1) and, in fact, the attribute values are attached to each road segment. A visualization of all roads classified higher than a ‘community road’ and in addition all road segments with more than one lane for each driving direction shows an extremely reduced but in fact characteristic representation of the road network.

As an example the combination with a layer presenting the urban area of the small town Aurich produces a visualization of a coarser scale for the location map. This example is shown in Figure 2. The automatic labeling with the classification names of the roads is possible. In general, in an overview map of a location map all important means of travel have to be regarded, that means arriving by car, by train or even by aeroplane have to be taken into account. In this example the town is too small for a train station or airport and so the road network is the most important navigational information for the map.

For comparison a topographic map of this area is given in Figure 3, in which the important transit roads are emphasized with cartographic methods.

If it is required to generate overview maps with a more detailed network, the task reduces to the generalization problem. The creation of an coarser scale from the ATKIS data leads to the idea to attenuate the network relying on geometric-topologic properties in order to extract the functional important roads only.

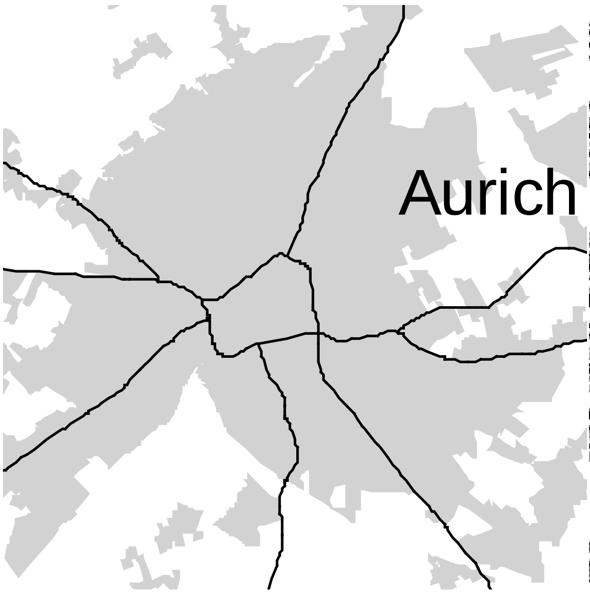

Figure 2: ATKIS data, higher classified roads only and urban area layer (in grey)

Figure 3: Small town Aurich, topographic map, scale 1:100,000

The approach tested here is the ‘good continuation’ grouping principle. The implementation from the work by Sester (2000) is used to calculate the data. As described above in this approach an importance ranking of strokes is established and used to select the required segments by cutting off a percental part. Figure 4 shows the complete ATKIS data network for Aurich. In Figure 5–7 the results of several attenuated versions, that are calculated each with a different percent of data, are given. They show the continuous reduction of the network in 10%-steps. A good characteristic of the approach is the elimination of short road segments to simplify the whole network. Though not specially weighted in the calculation the higher classified roads remain in the attenuated networks as the underlying principle prioritizes long and straight lines. Besides clearly visible structures like round shapes (see the arrows in Figure 7, for example the semi arc in the down right quarter and the elliptical curve left from the transit road directing north) are retained.

Disadvantages of the approach (and implementation) are that some small irregular structures are formed, for example in the top right quarter a small angled shape is visualized (Figure 7, the arrow directing left). As a general deficiency of the approach, long roads that are very close to each other are retained and form unintentional parallel structures. Furthermore disconnections within the reduced network are possible. Therefore a completely automatic generalization with the aim of a high quality cartographic result is not achievable.

Figure 4: Complete ATKIS road network

Figure 5: Road network, 10% reduced

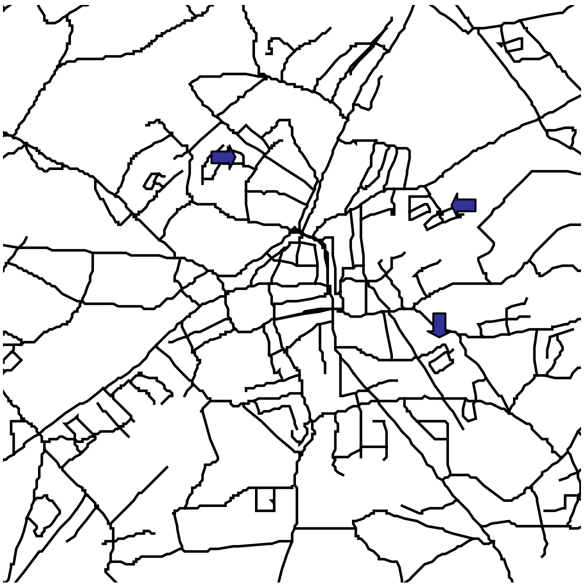

Figure 6: Road network, 20% reduced

Figure 7: Road network, 30% reduced

But a comparison of Figure 7 with the topographic map with scale 1:100,000 (see Figure 2) shows on the one hand that a 30% percent attenuation of the network corresponds with the content of a map scaled in 1:100,000 and on the other hand that the approach works at least satisfying: nearly the same selection of streets is visualized in both maps. So it is to state that the approach of the ‘good continuation’ principle leads to an acceptable result to create different level of details for wayfinding maps.

5 Route Maps

The second way to give route directions is to generate route maps. In these versions only the desired navigational information including additional landmarks are given. Again the used data are ATKIS data.

5.1 The approach for generating route maps

For automatic derivation of a route map from the ATKIS database the data structure must be suited for routing tasks. First of all, a road line network dataset is required. Then special traffic information like one-way streets or allowed driving directions on intersections has to be given. Unfortunately ATKIS data do not meet these criteria. For example the structure of roads is not closed. In general the roads are stored as linear features, but it can occur that squares are defined as polygons and thus the topology of the network may be destroyed. Furthermore actual traffic sign information is not taken into account. So the investigation has to start with a routing graph, which is chosen by hand.

The next step is to identify the potential landmarks and to extract them from the data. Before this, the ATKIS concept is examined with respect to the object classes and their attributes to identify all information that can be used as landmarks. Further data sources are investigated concerning their applicability for the extraction of landmarks.

Finally the data are imported in a professional GIS-Software to test merging and clipping of the calculated route with the thematic attributes of the data to designate appropriate landmarks, that aid the wayfinding task.

5.2 Examination of the databases for potential landmarks

Investigation of ATKIS data: The content of the ATKIS feature catalogue is examined for all objects and attributes enhancing the route description.

The objects directly connected with the given route are the first group to recover, that means feature types crossing the roads of the route. Analysing the data reveals some typical classes of objects, which often intersect with roads and paths (see Table 1).

Table 1: Route crossing objects

Domains of feature types	Groups of feature types	Feature types
3000 transportation	3100 road traffic	3101 roads 3104 roads (complex)
	3200 rail traffic	3201 tram rails 3205 railroad network
	3500 traffic buildings	3513 tunnel 3514 bridge, over-/underpass
5000 water	5100 water area	5101 stream, river, creek 5102 canal

The next group of potential landmarks comprises all objects, in ATKIS mostly area features, lying directly next to the route. After a first investigation of the feature catalogue the listed feature types in Table 2 were chosen to be potential candidates for landmarks.

In ATKIS the features are assigned to different feature types by using a four digit number code, (see Tables 1 and 2). The substitution of the feature number code with the text notation is possible. For each feature type an attribute ‘geographic name’ and where appropriate ‘shortcut name’ is provided. (Whether the attribute value is set or not depends on the acquisition date of the data set.) But for every record with a geographic name (and/or shortcut name) an automatic labelling is possible.

A striking characteristic of the ATKIS data is the lack of the representation of single buildings. Although a feature type ‘buildings’ is planned, until now this information is not yet included. To overcome this difficulty and to extract buildings for supplying landmarks a second authoritative data source is used: the cadastral map.

Table 2: Selection of landmarks besides the route

Domains of feature types	Groups of feature types	Feature types
2000 settlement	2100 built-up area	2122 landfill 2126 powerhouse 2127 transformer station 2133 heat plant
	2200 clearway	2201 sports facilities 2213 cemetery 2221 stadium 2224 swimming pool 2225 zoo 2226 public park
	2300 buildings and further facilities	2316 tower 2317 chimney 2327 pin wheel 2332 monument 2351 wall
5000 water	5100 water area	5111 sea 5112 lake, pond

Investigation of cadastral data: The digital cadastral map (in Germany called ALK) gives evidence about all parcels of land, the proof of ownership and administrative units.

Furthermore the illustrative part of the real estate cadastre serves the purposes of all kind of planning, so it is constituted by such a law that the buildings are part of it. The digital version of the cadastral map (in former times on paper) is under construction, but in most parts of Germany the map with scale 1:1000 is already completed. Similar to the ATKIS concept the content of the cadastral map is based on a feature catalogue in which the represented objects and their signatures are defined.

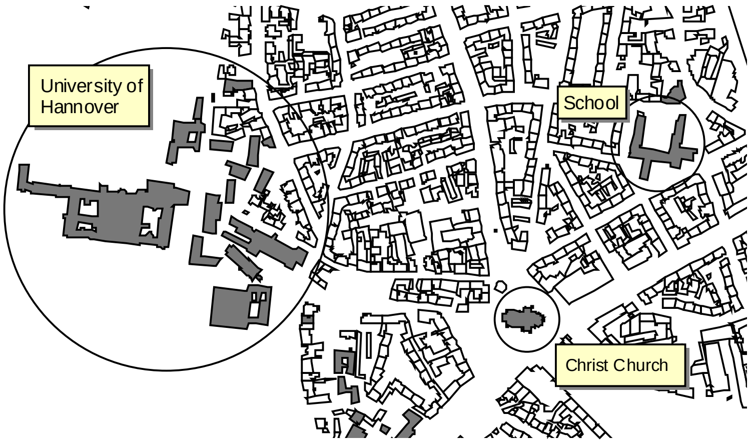

Figure 10: Public buildings (in grey) in cadastral map

Due to the object oriented representation an extraction of individual buildings is practicable and can be combined with the ATKIS data.

There are four different types of buildings in the cadastral map: residential buildings, outbuildings (including industrial buildings), underground buildings (e.g. subway stations) and public buildings. This classification of buildings alone will not generate useful landmarks. Additionally the building objects have the attribute ‘name’ standing for the proper name of residential buildings, in case they have a prominent meaning (occurs not often), or the function and the proper name of public buildings (e.g. Kindergarten, city hall, theatre, church).

Figure 10 visualizes a clipping from the cadastral map to give an impression of the frequency of public buildings. For some instances the name is added to point out what kind of buildings and names can be extracted. The examples given here are appropriate as landmarks: they are outstanding in their surroundings because of their size and architecture. Possibly, they also appear on traffic signs or decal information because of their functional meaning, so they can be easily identified on the route.

5.3 Exemplary presentation

To gain insight of such a routing graph enriched with landmarks all data sets are imported into a commercial GIS-Software (here: ArcView 3.2 from ESRI).

In the first step the routing graph is generated together with the street names and distances between the turning points. The start- and endpoint are marked with labels and the route is depicted as a simple linear feature. To get an impression of the route see the overlay between the routing graph and the topographic map of the same area in Figure 11, top left.

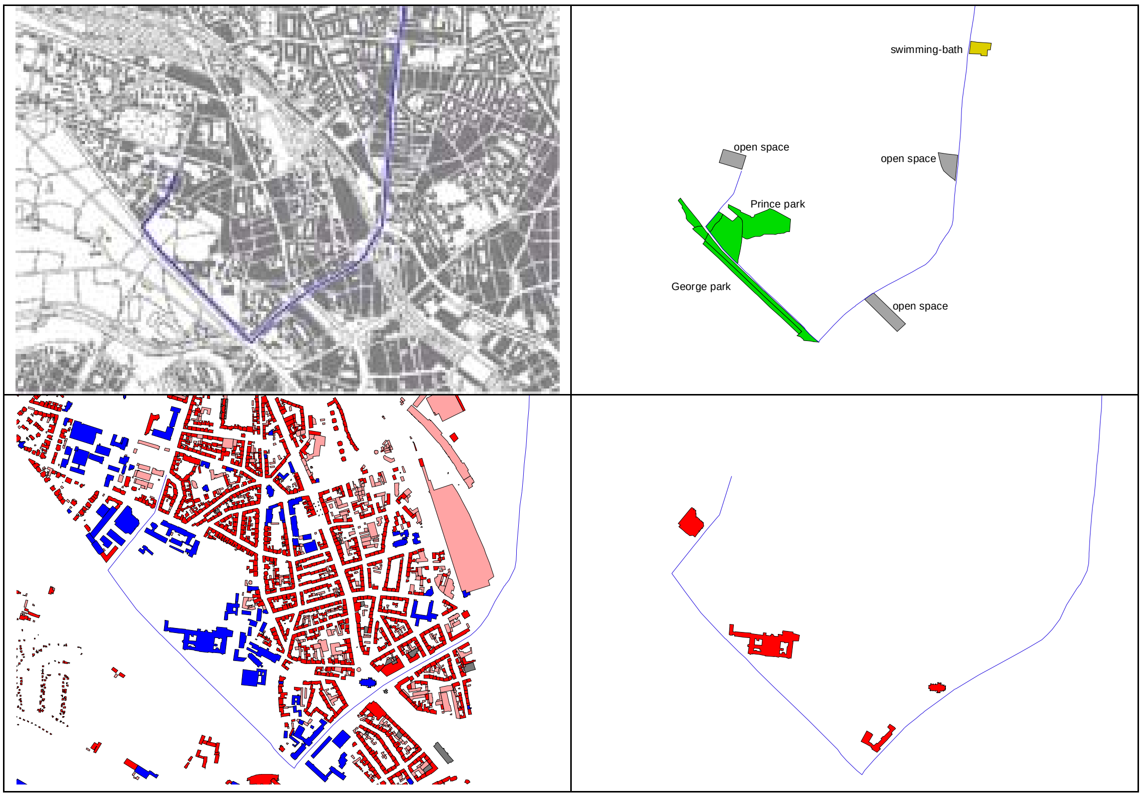

Figure 11: Landmarks on maps. Top left: topographic map with chosen route; Top right: extracted landmarks from ATKIS database; Low left: all buildings in cadastral map; Low right: extracted buildings

Then the route is buffered with a empiric tested distance buffer of 20 metres to select the route-neighboured features. For this first study this simple solution is used, of course, for correct selected objects directly neighboured to and viewable from the route other algorithms have to be chosen (e.g. Delaunay triangulation).

The route buffer is intersected with all pre-selected features (see Tables 1 and 2) from the ATKIS database. The output can be automatically labelled with the names or functions of the objects (Figure 11, top right). The same procedure is done for the digital cadastral database: the interesting features are pre-selected, that means all buildings with a special name attribute are chosen, and then intersected with the buffered routing graph. In Figure 11, down right there are the results from the extraction process.

In the end all landmarks are combined in one representation. The portrayal of the chosen route is given in Figure 12. The route starts (at the arrow) in the north of Hannover and leads to our institute (ikg – Institute for Cartography and Geoinformatics, see the icon). In the route map several important landmarks are given to simplify the wayfinding task for the user. The presentation here is a first study only showing the extracted geometries. Until now no considerations about a cartographic portrayal are done.

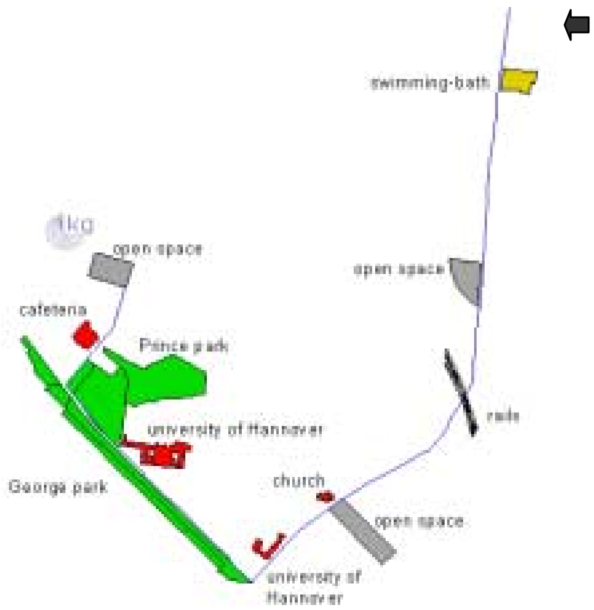

Figure 12: Combination of all extracted landmarks with their labels

6 Conclusions

This article demonstrates two different possibilities to generate wayfinding maps using the ATKIS database. The first way generates a hierarchy of maps consisting of two or more levels of detail and scale. The finer scale including the location and its surrounding streets is a representation of the ATKIS content. The coarser scale for the overview map has to be an extract from the ATKIS data. Therefore an attenuation of the road network is needed and leads back to the general problem of network generalization. In a first test the 'good continuation' grouping principle is used and the results show that it works satisfying. The automated generation of a coarser scale consisting of the important streets and most of the characteristic structures of the network is practicable. As a second way to generate a wayfinding map the creation of a route map in combination with landmarks as a guiding assistance is introduced. Therefore the extraction of landmarks from the ATKIS database is tested and evaluated to be effective. It is shown that the numerous feature types and attributes pertaining to the data are adequate for producing landmarks. Data integration of additional data sets (here the cadastral map) is a promising chance to successfully enrich route maps with adequate landmarks. An automatic production is technical practicable and part of future work.

Next steps are the detailed investigation of the feature catalogue to define a ranking of importance of potential landmarks. To control the quantity of landmarks the idea of buffering first the area around the turning points of the routes and then if still necessary the straight elements between them will be investigated in detail. Furthermore a strategy based on information theory will be developed, which supports the selection of the important landmarks to prevent an oversupply of information. A cartographic representation (for example for a application on a PDA) will be created.

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