IMAGE-BASED DRIVER'S GUIDANCE SYSTEM

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ABSTRACT:

The paper presents a low-cost navigation system, which is based on digital terrestrial images. The database of the test area is filled by digital images about road junctions, crossings, and other „irregularities” taken with a high-resolution commercial camera. The developed guidance system solves the usual problem within urban circumstances (one or two way streets etc.), which is followed by a systematic image query along the found optimal path. The queried images of the database are extended by simple navigational instructions (arrows) to give visual information for the driver. The obtained image-based itinerary contains more information than the widely used navigation systems, and allows better navigation performance in unknown situations. The paper gives an overview about the planning of the field works, the execution of data acquisition by GPS and photography, as well as the database built-up and how the whole data set is structured and stored. It is followed by the presentation of the implemented algorithms. The use of the developed system is shown on an example executed in Budapest, Hungary.

1. INTRODUCTION

Due to the low-cost vehicle navigation systems, more than 5 million navigation systems are expected to be sold in the European Union by 2005. These low-cost systems either integrate GPS receivers or are based on PDAs.
The interfaces of this system – also called HMI (Human-Machine Interface) – have three main components:

- Display interface
- Voice interface
- Control interface

The usability of the vehicle navigation system depends on the practicability of those components. For the users the usability is defined as a function as (Burnett 2000):

- Effectiveness: achievement of user's goals, such as reaching a destination with no wrong turnings.
- Efficiency: resources required by users to achieve those goals.
- Satisfaction: effect on users' opinions

The visualization possibility of these traditional systems are divided into three main groups (Lovas 1999): in the first case a small display shows basic navigation instructions, for example the direction of the next turning, only as simple arrows, and short text messages on a small and usually monochrome LCD display. The VDO Dayton 4150 system uses this solution as shown in Figure 1a. The advantages of these systems are their low price, and simplicity. The next solution provides more navigation instructions for the drivers on a larger display, usually on a color LCD or DVD display. These systems present the current position of the vehicle on a navigation map, and some additional information (Figure 1b). An interesting, new developing way is the three dimensional representation of the surrounding environment from bird's eye view. This so-called BIRDVIEW system shows the current route emphasizing typical orienteering buildings (e.g. churches, bridges, towers etc.) (Figure 1c).

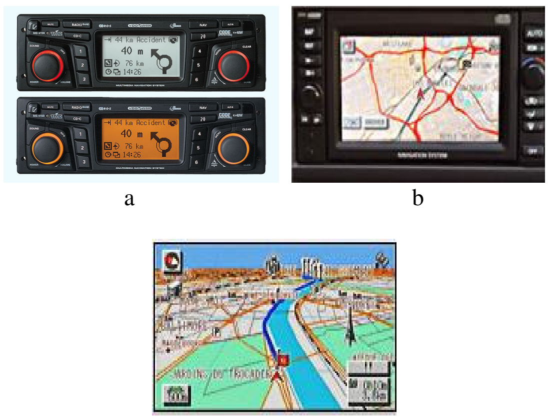

Figure 1. The visualization solutions of the traditional navigation systems.

In our solution the navigation instructions are completed with digital terrestrial images which were taken about the junctions in urban areas. The traditional navigation instructions (arrows, text messages etc.) extended by the terrestrial images on the display provide much better instruction for the drivers. In this paper we present the development of the mentioned system. The investigation consists of three main parts:

- Building a test path in a CAD/GIS environment, which supports basic GIS functions (for example solving the shortest path problem in urban areas) and has an application programming interface (API).
- The field work (taking photos about road junctions with a high resolution commercial camera, and positioning by GPS)
- Application development for continuously presenting the images as navigation instructions along the calculated path.

2. DATABASE CREATION

2.1 Topology building

At first we got the digital large-scale topographic map. It shows the neighborhood of the Budapest University of Technology and Economics. We inserted the raster image into the model space of the Hungarian reference system (called EOV). We used a second-order polynomial transformation to eliminate the distortion of the digital image, which caused by the scale difference.
The next step was the digitizing of the road network in order to build the digital representation of the network. We used directed graphs to describe the test network. Every lane is represented as a weighted edge of the graph. More complex problem is the modeling of the junctions (Jiang 2002). Originally the developers tried to solve the turning problems in junctions by expanding the network describing all turning directions with edges (Kirby 1969). In this solution the junctions are represented as sub-networks consist of more edges and nodes as shown in Figure 2. The disadvantages of this solution are the increased computational time and computer memory need. Others solved the turning direction problem without changing the topology of the network. For example Ziliaskopoulus and Mahmassani suggest an Extended Forward Star Structure (EFSS) to model the junctions. We used the first solution because of its simplicity. Figure 3 shows the test network in AutoCAD Map.

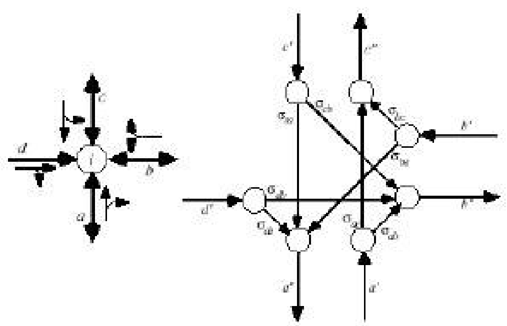

Figure 2. Junction modeling by expanding the network (Kirby 1969)

After we had edited the network in the CAD environment, we had to build the network topology. Three different types of topology are known in AutoCAD Map software: the node, the network, and the polygon topology. These topologies are built up by three different geometrical primitives: nodes, edges, and polygons. In our research we have applied the network topology. It is based on the node-edge relations. In this particular case the digitized lanes are the edges, and the nodes establish the connections between the edges.

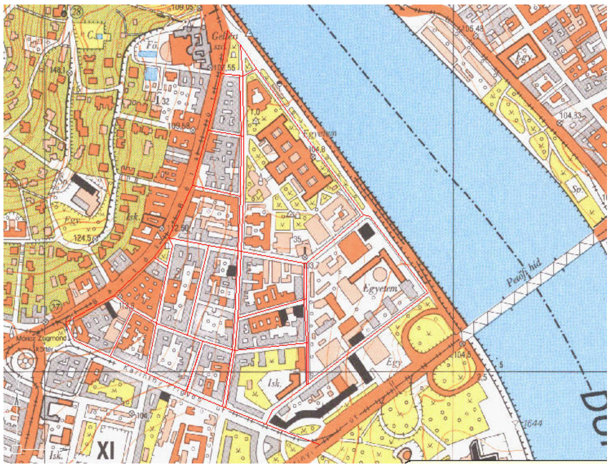

Figure 3. The test path in Budapest

The information of the network topology are stored in a relational database, which is linked to the certain geometrical primitives. The structure of the relational database of edges is shown in Table 1.

ID	Start node	End node	Direction	Direct resistance	Inverse resistance

Meanings of the fields are the following:

- ID: unambiguous identifier
- Start/End node: pointer of the start/end node of the edge
- Direction: direction of the current edge. If the direction of the edge and lane is the same, then the value is 1, otherwise it is –1. If the direction does not depend on the editing, then the value is 0. The initial value is 0.
- Direct and inverse resistance: the „cost” of the edge.

The shortest path algorithms use this resistance to weight the edges. The initial value of the weights is the length of the edges.

2.2 Field work

The next step was taking photographs about the junctions from the driver’s viewpoint. The images were taken at a resolution of 2048*1536. The location of the exposure was measured by a single geodetic GPS receiver (Leica SR530). Thereafter we inserted automatically the photos in the model space as blocks by their coordinates. The filename and the path of the files are stored as the attribute of the blocks.

3. DEVELOPMENT PHASE

AutoCAD Map provides a number of GIS functions for example, route finding. Our goal was to find and link the pictures of the junctions along the current path, therefore some software developments were required. AutoCAD provides the well-known ActiveX mechanism to manipulate entities from other applications. Figure 4 shows the available programming environment:

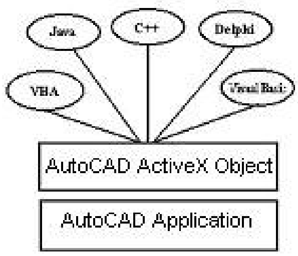

Figure 4. Programming environments

Although AutoCAD has an own Basic programming environment (Visual Basic for Application), we have developed an executable application in MS Visual Basic. The software finds the entities (blocks) representing the insertion points of the pictures in a predefined buffer region along the optimal path. Then the program reads the attribute of the blocks as a file path, and shows the current image. The queried images of the database are extended by simple navigational instructions (arrows) to give additional information for the driver. From the orientation angles of the edges the application calculates and shows the direction of the next turning. In addition the program displays the neighbouring part of the current junction on topographic map.

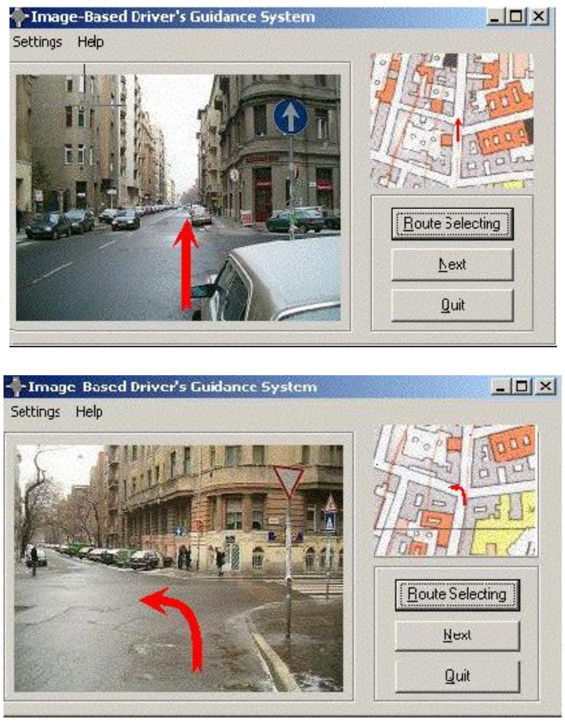

Figure 5. The graphical user interface of the application

4. CONCLUSION

In this paper we presented an AutoCAD Map based GIS software using network topology. We believe that this development provides more information, and gives easy-to-understand navigation instructions for the drivers. In the future we plan to automate the data collection by digital video camera and implement this method in a platform independent system, which enables the use on PDAs.

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