User Centric Mapping for Car Navigation Systems

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Abstract

The use of multiple representations of the same data is a common requirement for several purposes of the implemented geographical information system studies. However these representations should be produced by considering the requirements of the system user. In practice, car navigation process also requires multiple representations as user interfaces of different phases of the navigation process. For such use, the user basically requires interact with well designed maps, which represent the real world as accurately as possible, for succeeding the navigation task comfortably and also easily in an unfamiliar environment. Covering this requirement is merely possible when generalizing the road data by considering the possible manoeuvres that the user will do while navigating. This study proposes an approach, which aims to increase the accuracy of the navigation maps by designing them depending on the navigation route calculated in navigation process, to succeed in this task.

Key Words: Car navigation, map design, generalization, multiple representations, automation.

1. Introduction

Cartography is the science, art, and technology of making, using, and studying maps. Continued technological developments have affected cartography as with the other disciplines. In particular, developments in computer technologies and the use of geographical information systems (GIS) have led to significant changes in map production and generalization processes. Successful automation of these processes has become a major goal of cartographers and related researchers (Mackaness, 2007). Additionally, since micro computer technology has led to reduce the dimensions of the display media, small display presentation of the world reality became a research base for cartography (Sarjakoski and Sarjakoski, 2005).

As a primitive result of these current standing studies, usability of the digital maps for navigation purposes increased and navigation systems have recently become an integral part of everyday life. Currently, navigation systems, which can be considered as advanced tools that integrate positioning, communication, digital mapping, computer, and small display hardware technologies in a single system, are used for several purposes as aircraft, marine, nautical, pedestrian, and car navigation. Maps are used as a communication tool in navigation systems for sharing the results of the processing system with the user. Therefore, a significant attention should be paid while designing navigation maps. In this context, presentation of the redundant data in limited dimensions, which is considered as small display cartography, is still a complicated problem (Timpf et al., 1992; Sarjakoski and Sarjakoski, 2005; Dogru and Ulugtekin, 2006). Multiple Representation Database (MRDB) approach, which can be used to store the same real world phenomena at different levels of accuracy and resolution, can be considered as a solution to overcome this problem together with the other studies on small display cartography (Dogru, 2004; Dogru and Ulugtekin, 2006).

In this study, car navigation map design is selected as an application base since current car navigation systems still have visualisation problems for displaying redundant map content in practice. Car navigation maps should be considered in two different dimensions: the first one is the base data which involves the road network data on which network algorithms, such as finding shortest optimal path, are executed. The second one is the data derived from the base data and used as user interface in navigation process (Dogru, 2004; Liu et al 2005; Dogru and Ulugtekin, 2006). In this model base data should be considered as the digital landscape model and user interfaces should be considered as the digital cartographic model (Weibel and Dutton, 1999). Although user interfaces may be designed as maps with generalized road networks, base network data should never be generalized in order to obtain the accurate results of network analysis executed to determine navigation route. Today, predefined selection and classification strategies are implemented on road network and areal data respectively for deriving generalized user interfaces of navigation process in commercial systems. This study proposes a new approach to produce car navigation maps by applying an application dependent and user centric generalization process at the existing data. In this context, the second part of the paper presents the need for using multiple representations of world reality in car navigation process and how this requirement is covered by current navigation systems. Third part presents the proposed approach and then the following part explains the details of implementation together with the results of the study. Finally, the paper is concluded with the upcoming future works of the study.

2. Requirement for the Use of Multiple Representations at Car Navigation Process

Although there is only one world reality, its representation in a database may vary according to aim, content or display scale of the application. The use of different representations derived from a single database is especially increased by the development of GIS applications, since different GIS applications require different representations. The need to obtain these representations of the reality enforced the researchers to develop the idea of Multiple Representation Databases for deriving and using multiple representations efficiently (Kilpelainen, 1997; Ruas, 2002; Dunkars, 2004; Sarjakoski, 2007).

Car navigation process can basically be considered as an application that requires different levels of representations varying from detailed ones at large scales to general overviews of the data at smaller scales (Ulugtekin and Dogru, 2005). Dogru and Ulugtekin (2006) defined these representation levels in four categories in addition to base (first) level, from which higher representation levels are derived, as district, county, city and national levels (from second level to the fifth respectively) according to their uses at different phases of the navigation process. Since each representation level displays areas in different dimensions, they have differences in reference scale and level of detail. For example, city and national levels are used for obtaining general overviews of the determined navigation route, while district and quarter levels are used to assist the driver, navigating in a city, with its detailed road network representations. Besides, base level is considered as the most detailed data from which the other representation levels are derived. Thus, display of the base level without generalization is not possible for navigation purposes since its' complex content will decrease the visual perception of the driver.

Current car navigation systems also use a method based on multiple representations. In this method, implemented systems include a zoom level and selection strategy to generalize the map content for different phases of navigation process. In this context, predefined zoom levels and contents (displayed roads, areas or point of interests (POIs)) of them are determined by defining the data that will be selected to be displayed at each level. The use of these zoom levels is organized according to the speed or the position of the car: when the speed reduces or when the car navigates in an urban area, detailed representations at large scales are used, otherwise less detailed maps are used to communicate the navigation information to the driver. In most commercial systems user can also define the zoom level of the displayed map manually. Since the zoom levels and their contents are determined independently from navigation route that is calculated by using network analysis, predefined strategies result in standard maps with same content in each navigation process. Hence the system does not either optimize the density of the displayed data or increase the accuracy of the presented information (as land use information of surrounding areas) of a route based on different route selections. As a result of this deficiency, optimization of the displayed data via generalization is still a challenging problem in current systems since navigation maps should display accurately the world reality in particular road network. As it is clearly seen in the displayed screenshots of a commercial navigation system (Figure 1), this deficiency can reduce the visual perception of the driver via displaying complicated data, as junctions, in detail.

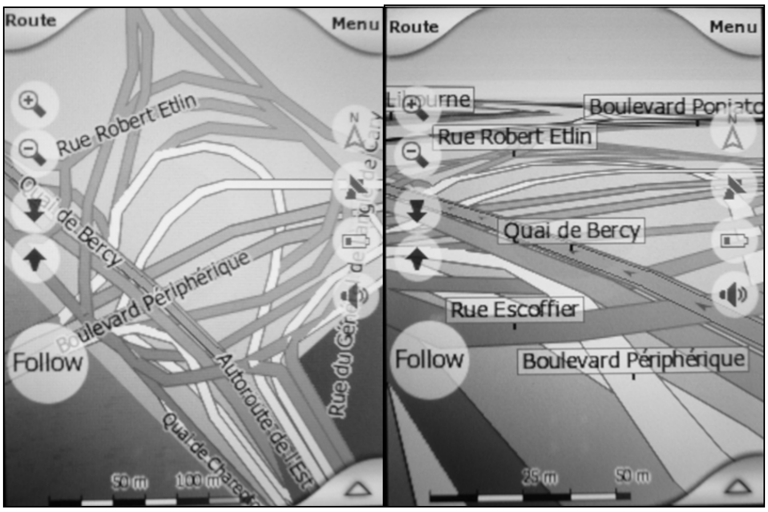


Figure 1. 2D and perspective junction representations used in a current navigation system

As the technology develops it should be possible to improve current systems by considering user requirements. Studies for developing 3 dimensional (3D) navigation systems have already started (Li, and Ting, 2000; Nurminen, 2006; Coors and Zipf, 2007; Strassenburg and Kleciak, 2007; Zhu and Li, 2008). Real time navigation, which enables the system to update navigation data in real-time or to produce on the fly maps based on calculated route, will be the next step of this improvement. The executed study presented in this aims to cover above stated deficiencies by proposing a new user centric map design approach to improve currents systems in particular by means of perspective representations of navigation maps.

3. Proposed Approach

In this study, a user centred approach for navigation oriented generalization is proposed to add value of current navigation systems in use. The basic aim of this approach is to derive car navigation maps from the base data, which includes road network and building data with their required attributes, not only automatically, but also user centrically. This task will be succeeded by:

- enabling the user to produce on the fly maps by using generalization methods executed based on calculated route, and
- increasing the accuracy of the displayed data surrounding the calculated route by defining new areal units based on route.

The use of the outputs of this study will in particularly overcome the optimization and accuracy problems of data that will be displayed at perspective representations of the navigation process.

Perspective representations are generally used for increasing the visual perception of the driver by displaying the detailed maps in a similar way to 3D displays. Since perspective view of a reality is obtained without using data of third dimension, height, it does not represent the world reality as well as 3D representations. However perspective representations are still widely used at navigation systems, especially for detailed representations named as district and county levels by Dogru and Ulugtekin (2006), because they don't need as much processing time and power as 3D display methods required.

Commercial navigation systems generally use maps with a content of land use, POI and road network information as the user interface (in practice). Stated land use data is obtained by symbolizing the areal data based on predefined land use attributes. Additionally, predefined selection and zoom level strategy is also used for deriving the data of the user interfaces.

This study aims to derive navigation maps automatically, in particularly, when predefined land use information is not available for use. In this context, building data and its attributes, which includes the intended use of them, are used to determine the land use characteristics of a specific region. In general, this land use determination process is executed by applying a comparative determination method, which uses calculated area information of buildings, depending on land use characteristics. For this purpose, buildings in a block are classified according to their intended uses (industrial, settlement and etc.) then the total areas of the buildings are determined depending on the use classes. Finally these calculated values are compared with the area of the block and then the land use characteristic of the block is determined by using threshold values. When this commonly used method is used, base map (1^{st} representation level) displayed in Figure 2a is classified as presented in Figure 2b. Factories in upper right part and buildings in lower left part of the data do not affect land use classification process, because their areas are not sufficient to be considered when compared with the total area of related block. Additionally, road network segments will not be generalized since they have similar types (see Figure 2b) or they will be generalized according to selection strategy that uses the type of the roads for decision making.

Since the fundamental aim of the proposed approach is to generalize base navigation data by considering the user requirements, it defines additional constraints to generalization process based on the calculated route. Selecting the objects (both linear and areal objects) that can be visible for the driver during navigation and visualizing them as precisely as possible are the basic ideas of this approach.

Proposed approach is applied to increase the accuracy of land use for areal objects neighbouring to the calculated route. This task is achieved by dividing the surrounding areas of the calculated route into basic units that will be reconsidered for land use determination process. Buffer zone method, which is also used by Elias (2002) for automatic location map derivation process, is applied for basic unit determination process. Differently from Elias' approach, buffer zone is defined along the route to separate the surrounding areas of the route in to at least two parts as intersecting and surrounding areas. The width of the buffer zone is defined by empiric tests as a distance that covers the objects that can be slightly recognized by the driver. In this context, at least the first row of objects next to the most segments of the route is included by the buffer zone. Basic units created as a result of the determination process are reclassified by using comparative determination method as stated above. Since the total area of each areal object decreases, the accuracy of the land use determination process increases. As it is seen in Figure 2e, when this approach is applied on the calculated route it is possible to visualize the land use characteristics of industrial (dark grey area) and settlement areas (light grey area displayed at lower left part of the figure). Perspective views of the classification results also presented in

Figure 2c and 2f for standard determination and proposed approach respectively.

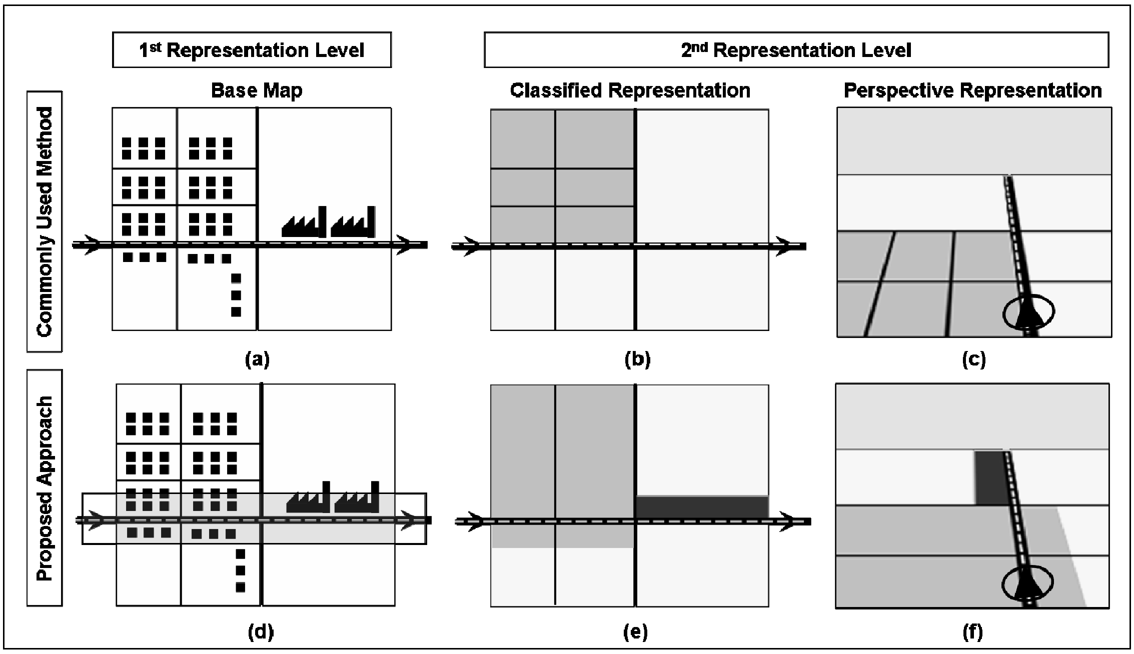


Figure 2. Derivation of 2nd representation level by using different approaches

This approach processes on the linear objects by adding a road segment selection strategy. This strategy considers the relations of the road segments with the calculated route and uses visibility criteria for selecting neighbouring road segments. In this context, firstly adjacent segments of the route is determined and secondly an algorithm, which selects the road segments related to the adjacent segments, is iterated to determine the road segments that will be displayed. This algorithm is developed by using the stroke approach of Thomson and Richardson (1999). For the use of this study, limits on acceptable angles of deflection are modified (Thomson, 2006). In the proposed approach, limits for the angle deflection value are determined based on the principle of the visibility of the road segments intersecting to the navigation route at an intersection in urban area. According to this idea, arcs which have approximately 90° angle deflection are not selected for display. Differently from predefined selection strategies, this method is based on the geometric relations of the road segments instead of using attributes. Therefore, it is possible to unselect some of the road segments in a road class while selecting the others in the same class as it is displayed in Figure 2e.

The methods presented in this paper require navigable road network data and building geometries with their attributes as the input data. The aim of the implemented prototype is to derive navigation maps from this data. Similar works have already been executed by Elias (2002) for deriving location maps from ATKIS data and Agrawala (2002) for visualizing route maps. They also examined selected routes for deriving simplified route maps. However, navigation map design in a user centric way has different requirements from these studies. First of all differently from route map and location map design, the aim of the navigation map design is to visualize the world reality, in particular road network, as accurately as possible, because exact position of the driver calculated by using a positioning method is visualized at the navigation system. Therefore level of the generalization applied on the data should be optimized for user centric navigation mapping. Additionally, this study does not only considers the calculated route for display it with its related data as previous studies but it also aims to represent whole map data related to route by optimizing it various generalization methods.

4. Implementation

The aim of the implementation is to show the usability of proposed approaches. For this purpose, derivation of the district level (second level) from the base data (first level presentation) was considered the main task of this implementation. Dogru and Ulugtekin (2006) defined district level as the second level of a multiple representation database created for navigation applications. This level is derived from the data of the base level that includes 1:5000 scaled base maps of the area. The aim of this derivation process is to optimize the base data for district level representations. As a result of optimization process, district level includes:

- land use data as settlement, industrial, bare or green area,
- boundaries of areal units,
- point of interests (POIs),
- all roads and related text.

Proposed approach of this study enables the user to generalize the road network while deriving above defined contents (land use classes and POIs) differently from previous works.

In this study, a database including the areal geometric data of a district at Istanbul and the road network of the related area was used as base level. Only data including buildings with their attributes, which indicate their intended uses, is used from the 1 : 5 000 scaled base data, which was obtained from The Besiktas Municipality. Linear data of the road network and its navigation data were obtained from Basar Computer Systems. In this data, highways and higher order roads are presented as lines for each direction while streets and urban roads are represented as single line. In addition to road classes, traffic direction of each road segment and required navigation data are also defined in attribute table.

Implementation is being realized in the COGIT Laboratory of IGN France, the French National Mapping Agency. GeOxygene, which is an open source and a modular software platform dedicated to geographical information research applications implemented in the same laboratory, is used for implementation of the approach (Badard and Braun, 2004).

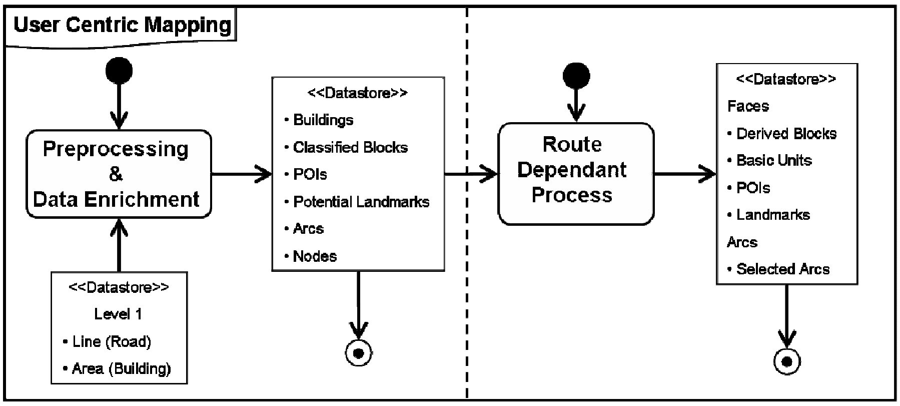


Figure 3. Activity diagram of user centric mapping process

As the first step of the study, existing data was imported in to the GeOxygene platform. By the way it is defined in a database supported by the platform that is PostGIS. Additionally, relations of the data were also defined in the system. As it is seen in Figure 3, user centric mapping process basically includes two sub processes that are called as pre-processing and route dependent process. Pre-processing processes are executed just one time to enrich the existing data to prepare it for the following process, whereas route dependant process repeats for each route selection, for producing user centred navigation maps. The route dependant process uses

the pre-processed data obtained as a result of enrichment processes.
Pre-processing and data enrichment studies starts with the creation of a topological network (see Figure 4). Road network data is used in this context. During this process firstly, a topological road network is created. New faces surrounded by road segments (arcs) are secondly determined and their relations with buildings were also provided. After providing relations, faces are stored as blocks, and then they are classified according to their land use characteristics in the following stages (land use detection and classification) of the process. Geometric and attribute data of buildings are used to determine main land use classes as settlement, industrial and bare or green areas. Additionally, buildings that are considered as POIs (as restaurant, pharmacy, school, and etc.), are selected and saved as an object class according to their usage characteristics. Finally, potential landmarks, which are prominent, identifying features in the environment of the way finding human that enable him to locate himself in his surrounding, are also selected based on the visibility criteria (Hampe and Elias, 2004). Total number of the stages of the buildings was used for achieving this task. As a result of pre-processing works, input data is enriched as classified blocks, buildings, POIs, potential landmarks, arcs and nodes.

As it is clearly understood from Figure 5, the route dependent process starts with the route selection and ends when the data of second representation level is derived by integrating the results of the parallel processes. The route is selected by computing the shortest path between a defined origin and a destination node based on Dijkstra (1959) algorithm. This determined shortest path is modelled as a group in the database, because it is the collection of arcs and nodes. Route dependent process includes two parallel processes (areal: upper part and linear: lower part processes) that should be implemented separately. Created arcs and determined faces (blocks) of the pre-processing works are used as the input data of the areal and the linear processes respectively. Selected route is considered as the main data of both processes as an input.

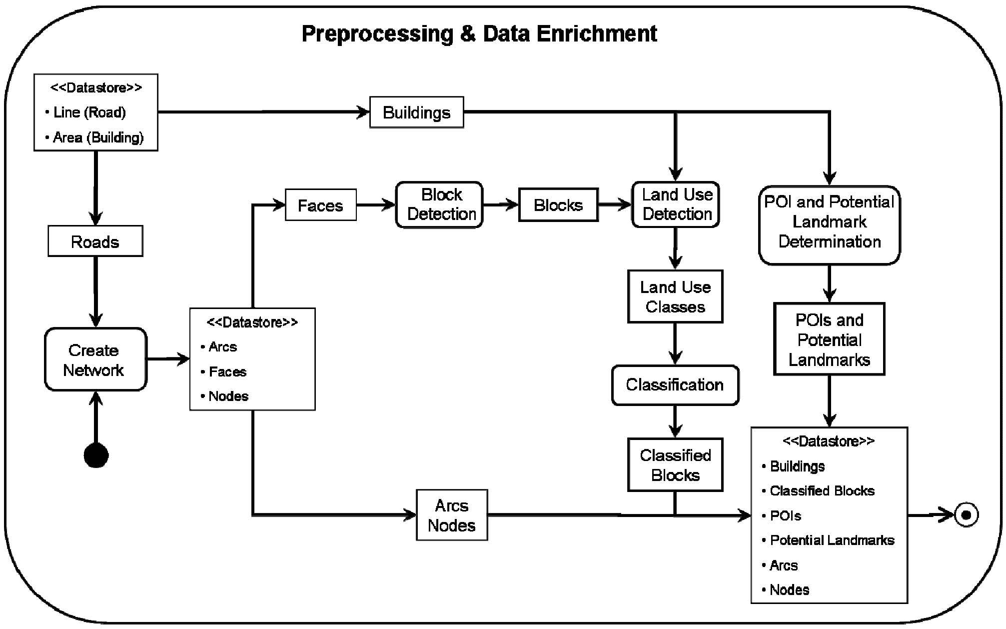


Figure 4. Activity diagram of the preliminary process

4.1. Areal Process

This process aims to determine automatically the areal representations of the surrounding faces of the selected route, which will be used at the district level of the navigation process proposed by Dogru and Ulugtekin (2006). Proposed method based on basic unit determination and reclassification of these units is applied to increase the accuracy of the determined land use classes of neighbouring areas along the calculated route. Thus, it will be possible to increase the visual perception of the driver and to let him form a more accurate mental map by overlapping the presented map and the reality that is first recognized while driving. The whole process is implemented in four main stages that are determination of basic units, determination of land use characteristics, classification and symbolization.

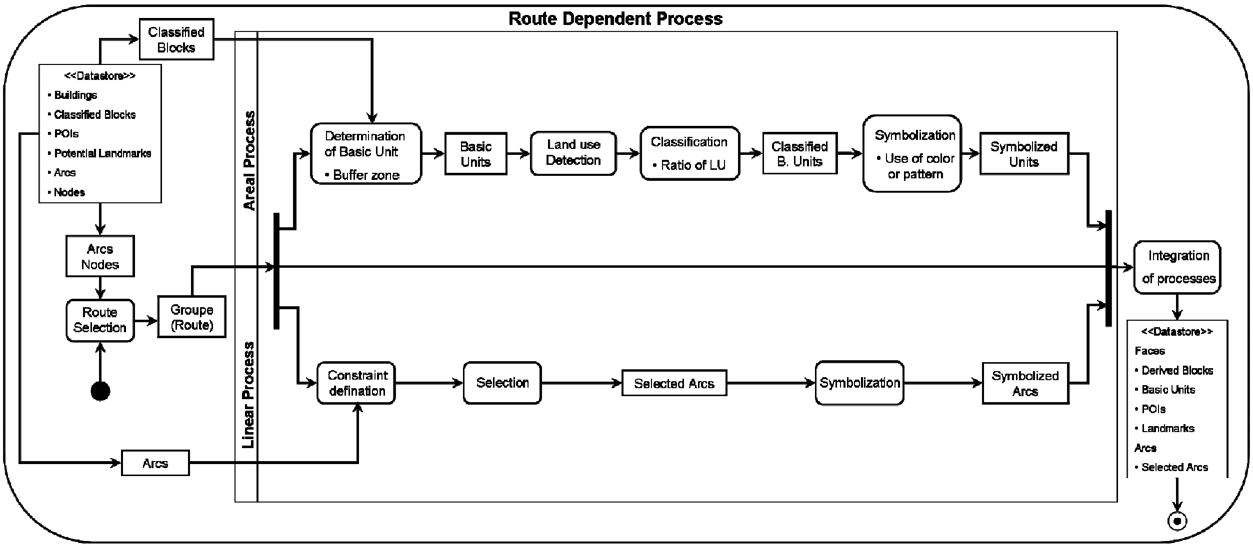


Figure 5. Activity diagram of route dependent process

As it is explained in detail in the third section, a buffer zone with a width of 50 meters was defined along the calculated route and surrounding faces of the route were divided into separate parts as intersecting and surrounding areas that are basic units, of the buffer zone. Then they were classified as in the following stage as settlement, industrial, and green or bare land, after their land use characteristics were determined by using land use detection process that is explained in section three. Predetermined thresholds were used for determining the land use classes in this stage. Threshold values were determined by empiric tests. In the final stage areal data are symbolized by using different colours or patterns based on its land use class. Within the context of symbolization buildings that are considered as POIs and Landmarks, which are determined from the potential landmarks intersecting the basic units, were also visualized in the final output.

4.2. Linear Process

As the first step of the linear process the relations between arcs and selected route were defined. In this context; fist degree relation describes the relation between the route and its' adjacent arcs. It means that the adjacent arcs of the route are considered as the first degree related arcs of the network. Arcs which have an acceptable angle of deflection from the first degree related arcs are considered as the second degree related arcs. All arcs of the network are classified by using this method and the arcs that will be displayed in the map in the second stage of the linear process are selected according to their relations. Finally, selected arcs were symbolized according to their road types. Differently from the current methods, which select road segments according to their type, this approach enables the system to keep all road segments related with navigation route and omit the others although they are in the same road class with the selected ones. This means that the applied selection process of this approach is based on the selected route instead of predefined road classes. In addition to optimizing the data displayed at the user interface, the authors propose that this method will also overcome the visualization problems of the interchanges as illustrated in Figure 1.

4.3. Results and Discussion

When the results are evaluated, it is clear that the linear and the areal selection and visualisation strategy implemented in this study will add value of current systems. Results of the implementation related with areal objects are displayed in Figures 6, 7 and 8. As it is presented in Figure 6, use of the basic unit determination and reclassification approach for areal objects increases the precision of land use. Figure 6b and 6c represent the maps derived from the data presented in Figure 6a by using current classification strategy and proposed approach respectively. As it is displayed in the figures, although the areas along the calculated route are classified as settlement area and visualized with grey colour by using current approaches, some parts of the same areas (areas of basic unit intersecting buffer zone) are represented with white to indicate that they are bare or green areas by using proposed approach. In both maps, buildings are generalized and only the buildings which are considered as POI or landmark are represented. Results of the use of proposed approach are also presented in Figure 7 as perspective views of the Figure 6a and 6c.

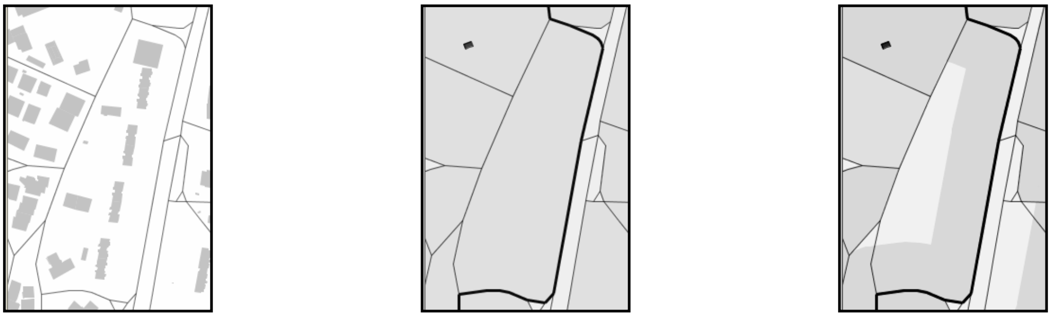
(a) (b) (c)

Figure 6. a) Original data **b)** Classification result with current approach **c)** Classification result with proposed approach

(a) (b)

Figure 7. a) Perspective representation of b **b)** Perspective representation of c

In some cases, the use of basic units does not only affect the land use classification of intersecting basic units as displayed in Figure 6 but also causes changes in classification of the basic unit which surrounds buffer zone as presented in Figure 8. Since most of the building areas of the area presented in Figure 8a are included by the determined buffer zone, they are considered as a part of the basic unit intersecting the buffer zone during land use reclassification process. Therefore, a change occurs on the land use classification of surrounding basic unit (the part that is further from the route than the neighbouring basic unit) and it is represented in different colour that is white as bare or green area in Figure 8c. However neighbouring basic unit of the route is still represented as settlement area with grey colour. As represented in Figure 9, a system using predefined and pre-classified data displays the same block represented in Figure 8 as a one block differently from proposed approach. This means, proposed method will also serve as a tool although a system uses pre-defined datasets by enabling to display more precise land use information.



(a) **(b)** **(c)**

Figure 8. Effect of the separation on surrounding basic unit **a)** Original data **b)** Classification result with current approach **c)** Classification result with proposed approach

Optimization of the displayed road network by considering the calculated navigation route will also improve the perception of the driver by only displaying the roads that he/she can see during navigation process.

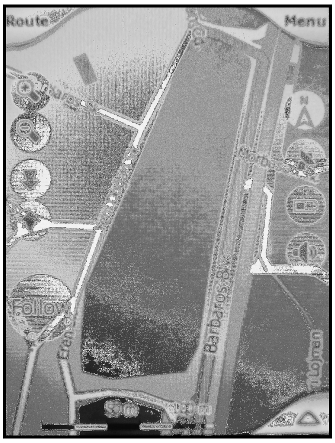
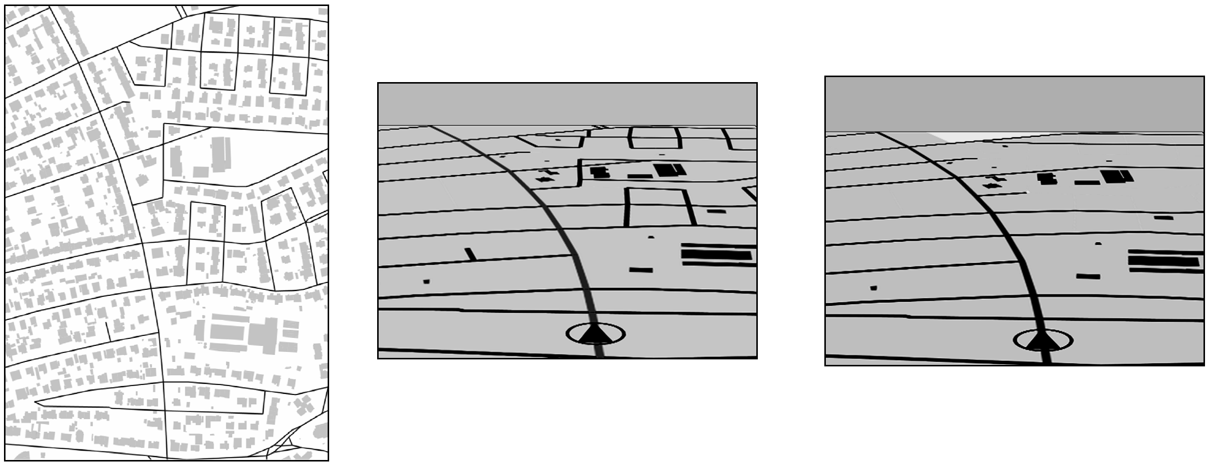


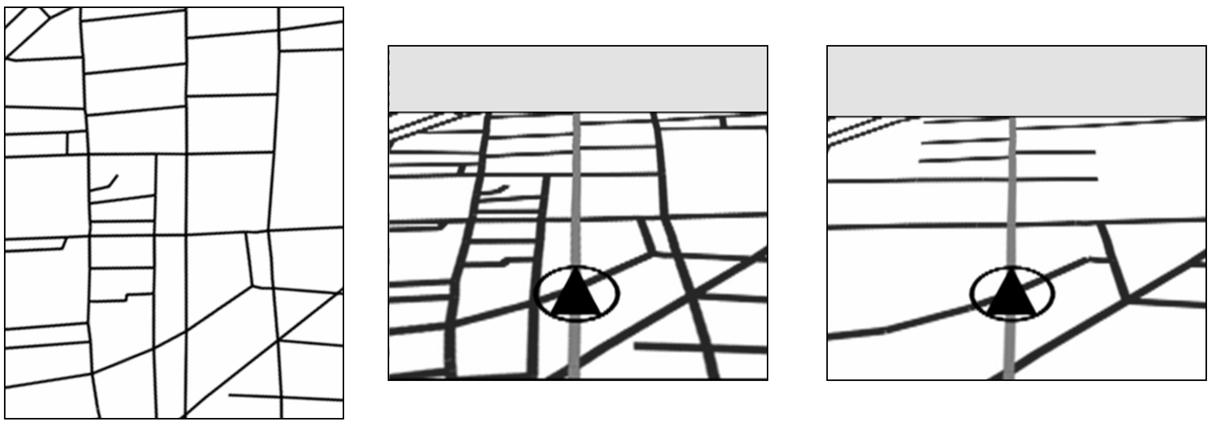
Figure 9. Visualisation of the same area of Figure 8 in a system that is currently in use

As it is stated in previous sections, use of the proposed line selection process instead of predefined selection strategies especially aims to optimize the contents of the perspective representations. Differently from the current approaches, this approach enables the user to generalize the road network independently from attributes of the roads as road type, speed limit, and etc. This selection process basically depends on the determination of the road segments related with calculated navigation route. As presented in Figure 10b and 10c, which are the maps derived from the base data presented in Figure 10a, when proposed approach is used; only related road segments of road network are presented instead of whole road network. As a result, content of the map decreases in terms of linear data and it reduces the complexity of presented data. Another part of the network is also presented in Figure 11 as more zoomed in presentations. The result of the proposed approach in terms of generalization of the road network is clearly displayed in this Figure.



(a) **(b)** **(c)**

Figure 10. a) Original data **b)** Visualization of roads with current approach **c)** Visualization of roads with proposed approach



(a) **(b)** **(c)**

Figure 11. a) Original data **b)** Visualization of roads with current approach **c)** Visualization of roads with proposed approach

5. Conclusion and Future Works

As a conclusion, this paper presents a new approach for producing navigation maps that will be used as the user interface for most detailed representation level of car navigation process. The use of this approach will enable the user to produce user centric navigation maps depending on the calculated shortest path. Since the content of the derived maps will change for each route selection, this approach can also be considered to be used as a part of real time and 3D navigation studies.

Studies still continue for implementing and improving proposed approaches. New methods will be proposed and implemented for generalization of the complex junctions. Achieving his task is considered as the primary future work of this study. Results of the study will also be evaluated by means of the usability of these maps in practice. In this context questionnaires will be applied to determine the usability of derived maps for navigation system users. Additionally, because the hardware used in car navigation systems has still some limitations in terms of memory and processing capacities, efficiency of the system will be evaluated by means of processing time. Deriving higher representation levels automatically will be another future work of this study as well as developing new approaches for generalizing complex road network structures.

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