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# VANET OBJECT LOCALIZATION SPECIFICS

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Knowing the location of the nodes in a wireless ad-hoc network is highly critical for different network-based applications, in particular in the area of intelligent transportation systems (ITS). Substantial part of ITS applications is based on the concept of Vehicular Ad-Hoc Network (VANET) where moving vehicles are used as nodes in a network to create a mobile network. To have a safe and fast transport system, any vehicle should know its own position as well as absolute or relative positions of neighbouring vehicles.

Although VANET and wireless sensor networks have some characteristics in common, such as the randomness of the availability of a neighbour and the changes in network topology from one time to another, they are different with respect to energy consumption constraints, constantly changing location and a constant demand for information on the current location and specifically for data on the surrounding traffic, routes and much more. The majority of localization methods presuppose that some of network nodes (beacons) know their position, and these nodes act as a source for localization of the rest network nodes. Vehicles, equipped with Global Positioning System (GPS) receivers, mostly are used as beacons. However, not all vehicles have been equipped with GPS. Besides, a GPS-based localization may fail due to occlusions, especially in urban areas. In these situations, the vehicle should use a GPS free method to find its location.

In this article we discuss the range of application requirements, introduce taxonomy of localization mechanisms, and briefly discuss the current state of the art in ranging and positioning technologies best fit for VANETs.

In this article we consider the restrictions and requirements imposed on the localization methods used in various applications running in a real traffic environment and intelligent transportation systems. Also we give an overview of the existing methods of localization and especially their use in VANET networks. Particular attention is being paid to the localization working on the principle of scene analysis as the most, in our view, perspective for the study. In particular, we discuss prospects of the use of methods based on spatial queries to existing GIS platforms.

**Keywords:** intelligent transportation system, wireless sensor network, localization, position estimation

## 1. Introduction

With the rapid evolution of advanced transport systems, the need for accurate and robust vehicle positioning methods increases. A number of localization techniques have been developed to serve a variety of ITS applications [1]. Although these techniques have demonstrated significant performance improvement, there remain situations that give rise to degraded localization accuracy. Due to the characteristics of VANET, the existing relative positioning techniques developed initially for ad-hoc or sensors networks are not directly applicable to vehicular networks [2]. Vehicular Ad-hoc network (VANET) is a special type of short-range wireless communication Mobile Ad Hoc Network (MANET). The distinctive features of both VANET and MANET are movement and self-organization of the nodes. Both VANET and MANET suppose mobility of their nodes. MANET can contain nodes that have un-controlled moving patterns. VANET, in turn, is formed mainly by vehicles whose movement is restricted by such factors as road course, traffic and traffic regulations. Because of these restrictions it is likely that the VANET will be supported by some fixed infrastructure that provide some services and access to stationary networks. MANET and VANET concepts are also different in some other ways. Comparing with the MANETs the characteristics of VANETs can be summarized as:

- dynamic topology: nomadic nodes with very high speed movement cause frequent topology variation;
- mobility models: vehicles move along original trajectories completely different from typical MANET scenarios;
- infinite energy supply: power constraint can be neglected thanks to always recharging batteries;
- localization functionality: vehicle can be equipped with accurate positioning systems (GPS and GALILEO) integrated by electronic maps.

As well as we discuss localization problem, the operating environment of VANET also must be taken into consideration. The VANET can be established in different situations, as City environments, disaster situations, extreme weather conditions, and so on.

Driving means the changing of location, constantly. This means a constant demand for information on the current location and specifically for data on the surrounding traffic, routes and much more. This information can be grouped together in several categories [3].

A very important category is driver assistance and car safety. This includes many different things mostly based on sensor data from other cars. One could think of brake warning sent from preceding car, tailgate and collision warning, information about road condition and maintenance, detailed regional weather forecast, premonition of traffic jams, caution to an accident behind the next bend, detailed information about an accident for the rescue team and many other things. One could also think of local updates of the cars navigation systems or an assistant that helps to follow a friend's car.

Next category is local information as next free parking space (perhaps with a reservation system), detailed information about fuel prices and services offered by the next service station or just tourist information about sights. A possible other category is car maintenance. For example online help from your car mechanic when your car breaks down or just simply service information.

Today internet access became a standard commodity, and many users do not want to do without even in cars. One could think of many useful services, which could be offered, having an internet connection in a vehicle e.g. car maintenance. Wireless LAN is the ideal technology to provide such connections. But if we would use common access points, the building of such an infrastructure would be unaffordable. Due to the short communication ranges, a huge number of access points would be needed to install a seamless wireless network. To allow greater mobility, and to reduce the impact of collisions with multiple users attached to the same access point, multi-hop access mode is being considered. Instead of direct communication with access points, it may be beneficial, extended coverage and bandwidth capacity, to contact access points via other users in multi-hop fashion. Such combined infrastructure and ad hoc networks are so called hybrid networks. The WLAN standard specifies two different operation modes: infrastructure and ad hoc.

The infrastructure mode uses fixed, network access points over which mobile nodes can communicate. These network access points are usually connected to landlines to widen the LAN's capability by bridging wireless nodes to other wired nodes. If service areas of access points overlap, mobile nodes may be handed over between them. This structure is very similar to the present day cellular networks around the world. In an ad hoc network, computers are brought together to form a network "on the fly." There is no fixed structure to the network, there are no fixed points and usually every node is able to communicate with every other node in its communication range.

One could even think of a combination of these two modes to a hybrid network structure. Like this, it would be possible to grant internet access to a large number of mobile nodes over only a few base stations. But there is no standard for such a hybrid mode yet.

The two modes already differ in their design target. On one side, the infrastructure mode is thought for mobile nodes offering access to a wired network (e.g. the Internet). The main component in an infrastructure WLAN is the access point, which manages everything. For communication always a direct link between a node and an access point is required (single hop). On the other hand we have the ad hoc mode, which is thought for infrastructure less networking in a group of mobile nodes, which is by nature multi hop. The ideal thing would be to combine this two operation modes getting a multi hop WLAN, which offers access to a wired network. Since the two modes already differ on the very low MAC layer, there is no way to combine them. But there is still a possibility how to get such a desired WLAN. We could run the WLAN in the ad hoc mode and additionally attach some nodes with a second network card connected to a wired network. These nodes have to act as a gateway between the wireless and wired world.

## 2. Localization Constraints in Real Traffic Environments

This inherent property of (ITS) provides opportunities for developing new applications. In order to define the need for a Spatial-Temporal formulation and to focus on the localization problem, applications have been classified into four families: Safety, Mobility, Efficiency and Telematics [4].

A fundamental function for a driver is to be aware of the relationships between its vehicle (subject vehicle-SV), the other vehicles (principal other vehicles-POV), and other entities within its surrounding environment. Today, this awareness is assisted through the use of a series of onboard perception systems that detect obstacles, track vehicles, assist in the vehicle control process, etc. These are known as driving

assistance systems. These systems are designed to reduce risk during travel by providing means to avoid collisions/crashes. For this purpose, a series of sensors are embarked onto the vehicles to different levels of complexity.

For safety applications, it is necessary to know precisely and on time the location of the SV and its relationships with other road entities within its immediate manoeuvring area. There is little room for uncertainty or malfunctioning of the system. That is no detection/location mistakes are acceptable and such systems have to prove their field reliability. Sample applications include: Navigation and Traffic alerts. Information broadcasts extend the situation awareness horizon of drivers that should allow for vehicle speed optimization, and best trajectory recommendations based on up to date traffic information.

The sharing of information over wide areas allows for the optimization of resources, with the transmission of relevant information on time in a geo-localized manner. This result in an intelligent infrastructure leading to intelligent environments where it will be possible to deploy a collection of vehicles with limited sensing and intelligent capabilities, that is, the efficiency of existing facilities is optimized so that mobility and commerce needs can be met while reducing the needs to construct or expand new facilities.

Telematics applications comprise the conveying essentially vast information over networks where nodes are static and mobile, that is, information is provided via service and content providers. The points of interaction are infrastructure providers and to some extent vehicle manufacturers.

From the applications presented above, it can be observed that it is not sufficient to know the position of the vehicles but expressed relative to the road segment travelled by the vehicles. Current car navigation systems function in that manner that is the absolute position of the vehicle estimated by a combination of data from a GPS receiver, odometer, and a gyroscope is related to the spatial representation of digital roadmaps (nodes and links) via a process known as map-matching. This allows the representation of the location of the vehicle with respect to the context, such as the digital maps. An interpretation of these constraints on the applications is shown on Figure 1.

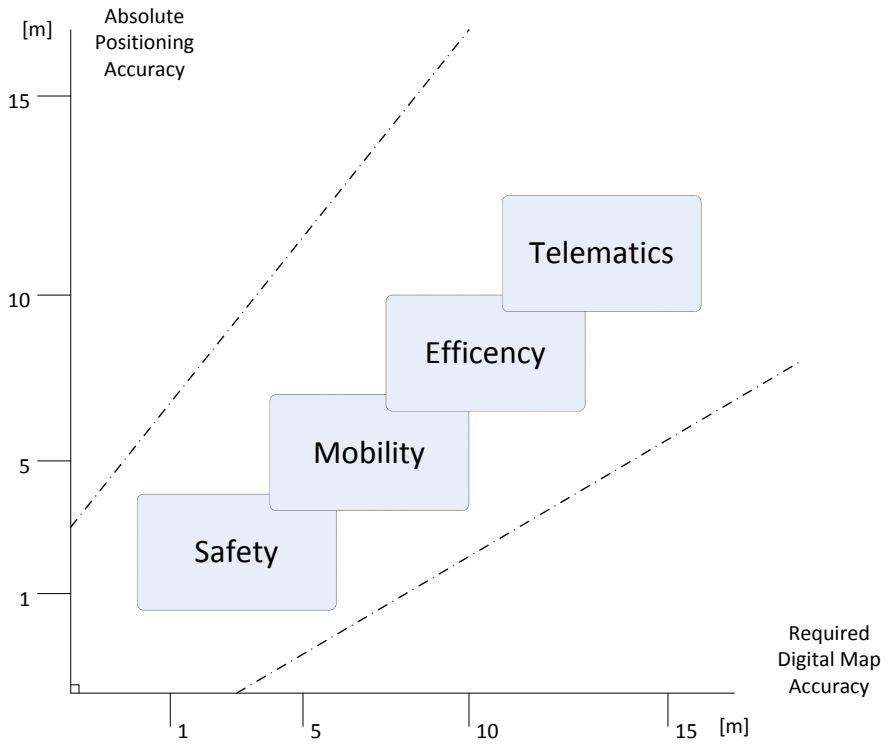


*Figure 1.* Distribution of localization accuracy requirements per application domain

There is interdependency between the requirements in terms of vehicle location estimations and accuracy of the digital maps, that is, both requirements need to be complied with.

Safety: applications dealing with safety depend on the precise localization of the vehicle relative to the digital map. In this case, map-matching errors with longitudinal and lateral positioning errors being

inferior to 5 m are not allowed, particularly in lane level accuracy where sub-meter level accuracy is needed.

Mobility: the requirements are less stringent, and tolerated errors are less than 8 m. The main constraint is to ensure that the correct roads are identified and the corresponding vehicles are associated to them.

Efficiency: accuracy in this case should be around the 10 m mark, and the dynamic sharing of information between vehicles should reduce the need for higher accuracy levels. Contrary to the Safety related applications, Mobility and Efficiency applications are concerned with larger numbers of vehicles distributed over large areas and thus the requirements on knowledge of their presence in these areas should be at times sufficient.

Telematics: the requirements are different. They should operate within a zone basis and also rely very much on the identification of the vehicle within the application zone. The accuracy should be around 15 m. Most applications at the transaction level are mainly large volumes of data.

## 3. Localization Methods

Localization algorithms for wireless sensor networks can be classified according to a number of properties that each algorithm has. These properties often define the overall structure of a localization algorithm, and also impose limitations on it as well [5].

**Anchor-Based versus Anchor-Free**

Many localization methods require beacons or anchor nodes that know their position on some absolute coordinate system with very high or absolute certainty. These methods are called anchor-based methods. In anchor-based methods, the localization problem can be formulated as finding a consistent set of locations of nodes in the network, given the information obtained from anchor-node relations as well as node-node relations. The anchors can be a form of dedicated devices emitting signals periodically, or a different type of sensor nodes that can acquire precise location of themselves from the outside of the network, for example, GPS. Since anchor-based methods require pre-deployed infrastructure, they may be impractical in certain application domains where anchors cannot be placed. On the other hand, anchor-free methods refer to the localization methods that do not require specialized anchor nodes. Since no information from outside of the network is used, an anchor-free method itself does not have a mean to localize the network on the absolute reference frame. Instead, it recovers relative locations of nodes on a relative coordinate system centred on an arbitrary origin. If a sufficient number of anchor positions are given (at least three anchors in two-dimensional space), the output of an anchor-free method can be easily transformed to node locations in an absolute reference frame.

**Centralized versus Distributed**

For centralized algorithms, computation occurs at one specific node or at a computer outside the network, whereas for distributed algorithms, computation load is distributed among nodes in the network. This classification is directly related to how the localization problem is formulated. If a problem is formulated as a global optimization such as convex optimization in [6], the computation must be performed in a centralized way. Because a computing node must have all the necessary information in centralized algorithms, the information required for computation, such as internodes distances, must be relayed to the computing node. Therefore, centralized algorithms may suffer from many collisions and contention during wireless communication around the computing node. This difficulty in communication may prevent the centralized algorithms from being scalable over the size of the network. For this reason, distributed localization algorithms are more popular in wireless sensor networks. In distributed algorithms, each node splits up a computation job in some way; for example, each node is responsible only for finding its own coordinates, or every node computes node locations only in its vicinity and shares its solution with other nodes.

**Proximity, Distance, Angle-of-Arrival**

Localization algorithms use various types of information or measurements to infer locations of nodes in the network. While other types of information can be used (e.g., correlation between sensor data), three major types of measurements will be described here {proximity, distance, and angle-of-arrival}. Proximity is one of the simplest forms of information that a sensor node can obtain about its neighbourhood. While proximity information only provides coarse location estimate, some localization methods can estimate node positions with high granularity using multiple proximity measurements and a priori information about the proximity measurements, such as maximum detection range. Another type of

information used for localization is distance. Distance between sensor nodes is obtained in various forms, such as, received signal strength (RSS), time-of-arrival (ToA), or time-difference-of-arrival (TDoA). Estimating distance from RSS is based on the relation between RSS and distance whose relationship can be modelled as a path-loss equation:

$$P_r = c\frac{P_t}{d^{\alpha}},$$

where $P_r$ – received power, $P_t$ – transmitted power, c – speed of light, d – distance and the path-loss exponent α is typically assumed to lie in the range from 2 to 5 [7]. Distance measurement through ToA uses the relationship between distance and signal propagation time when the signal's propagation speed through the transmission medium is known. If the transmitter and the receiver are synchronized, inter-node distance can be calculated directly from a timestamp included in the ranging packet. TDoA uses two or more different sets of transmission pairs to eliminate the need of time synchronization in ToA. For example, the Cricket location support system [8] uses a combination of RF and ultrasound signal. The last type of measurement is angle-of-arrival (AoA). AoA information can be acquired from directional antennae or an antennae array. Because of the need for multiple antennae, AoA information is less suitable for sensor networks in which the size and complexity of each node is restricted. However, it is possible to estimate sensor locations from only AoA information. The most basic techniques to do it, triangulation, and its extensions, have been studied in the context of wireless sensor network localization.

**Static Network versus Mobile Network**

Most of the existing localization algorithms for sensor networks do not consider node mobility explicitly, assuming that the network is static. While many sensor platforms are not likely to move actively like robots, there are certainly situations that sensors exhibit mobility, thus rendering the network mobile. For example, human-equipped sensors that move passively with people can be such an example. Mobile networks show different characteristics from static networks, such as changing topology, varying connectivity, and latency problem. Therefore, localization algorithms for mobile networks must be designed considering these different (and challenging) characteristics.

## 4. Localization in VANET

Equipping all VANET nodes with specific hardware such as GPS receivers would be one option to gain position information at the nodes. However, since GPS requires line-of-sight between the receiver and the GPS satellites, it may not work well indoors, underground, or in the presence of obstructions such as dense vegetation, buildings, or mountains blocking the direct view to these satellites. Another solution is to provide only a few nodes (so-called anchor or landmark nodes) with GPS and have the rest of the nodes compute their position by using the known coordinates of the anchor nodes [9].

Obviously, in the absence of anchors, nodes are clueless about their real coordinates. The predominant type of approach, involves nodes measuring the distances between nodes themselves and their neighbours, with only some nodes called "beacons" having to be informed of their position through GPS or manual configuration.

While some of such schemes are cleverly engineered, it has remained an open challenge in the field to localize each node precisely. Furthermore, most of the localization schemes determine node positions using optimization techniques and simply assign coordinates to non-localizable nodes corresponding to a local minimum. When there are multiple configurations satisfying a given instance of the localization problem, the returned configuration may not be the one that corresponds to reality. If an erroneous configuration is used by an application, for instance event detection, then incorrect or misleading conclusions may be drawn.

However, by using Scene Analysis to generate location information rather than using the Position Estimates as the actual position, the requirement that the estimates be accurate can be removed. All we now require is that Position Estimates calculated at the same location are similar. Having developed this technique and shown that Position Estimates are indeed repeatable, the next step was to determine how far apart locations need to be for the method to distinguish between them.

Scene Analysis is a pattern recognition method which uses the characteristics of a scene from a particular viewpoint to match patterns. We are interested in static Scene Analysis, in which observed characteristics are compared to pre-stored characteristics for each pattern to determine a match. The advantage of using Scene Analysis is that accurate physical quantities, such as distance, are not required.

However, stored characteristics are needed for each pattern, which could take a long time to collect and require a lot of storage space. Also, changes to the environment may require the characteristics to be re-evaluated.

Scene Analysis has been used in many applications, such as image and speech recognition, as well as location. One of the most well-known indoor location systems, the RADAR system developed by Microsoft [10], uses Scene Analysis to match the signal strengths received from various Wi-Fi Access points to identify location.

## 5. Scene Analysis Methods

Scene analysis involves the monitoring of a wide area around the subject of interest from a specific vantage point. The commonly deployed sensors have broad coverage area and range. Examples include ceiling-mounted video cameras or passive infrared (PIR) sensors.

**Fingerprinting-based localization solutions**

Scenes analysis approaches are composed of two distinctive steps [11]. First, information concerning the environment (fingerprints) is collected. Then, the target's location is estimated by matching online measurements with the appropriate set of fingerprints. Generally, RSS-based fingerprinting is used.

The two main fingerprinting-based techniques are: k-nearest neighbour (kNN) also known as radio map, and probabilistic methods.

The kNN method consists in a first time in measuring RSS at known locations in order to build a database of RSS that is called a radio map. Then, during the online phase, RSS measurements linked to the target are performed to search for the k closest matches in the signal space previously-built. Root mean square errors principle is finally applied on the selected neighbours to find out an estimated location for the target.

Probabilistic Approach - The problem stated in probabilistic approaches is to find the location of a target assuming that there are n possible locations and one observed signal strength vector during the online phase according to posteriori probability and Bayes formula. Thus, the location with the highest probability is chosen. Generally, probabilistic methods involve different stages such as calibration, active learning, error estimation, and tracking with history.

**Non-fingerprinting-based solutions**

RF-based localization can also be achieved without a priori analysis of the radio properties of the environment (i.e., without development of a radio map) [12]. Indoor localization based on triangulation of radio waves is a non-trivial problem because the transmitted signal can suffer obstructions and reflections. As a consequence, Non-Line-of-sight (NLOS) conditions emerge. In the presence of NLOS conditions, the radio signal can travel to the receiver through a non-direct path, giving rise to erroneous distance estimates.

To overcome these problems, the use of UWB radio signals has become the most novel solution in radio frequency-based solutions. The properties of ultra-wide band, short duration pulses mitigate the propagation problems associated with multi-path radio propagation. The most representative example is the system proposed by Venkatesh and Buehrer [13]. They introduced a triangulation localization system based on impulse UWB radio signals, and suggested that the statistical parameters describing the distribution of the received root-mean-square delay spread (RDS) serve as the best discriminate estimator between Line-of-sight (LOS) and NLOS signal propagation. This means that the statistical parameters defining the RDS of the received signal can be compared against a predefined rule set to determine if the signal was received via a direct or indirect path. Subsequently Venkatesh and Buehrer tracked a mobile station though 71 predefined locations within a building, achieving localization accuracies ranging from 1 centimetre to 2 metres. As another example of RF triangulation-based schemes, Krejcar and Cernohorsky [14] presented a localization system that relied on the triangulation of RSS metrics. Room-granularity accuracies were reported but further details of the triangulation or localization schemes were not revealed.

Finally, a system based on a combination of scene analysis and proximity techniques using a Bluetooth ad-hoc network was presented in [15]. Bluetooth inquiry signals were used for localization. In inquiry mode, a Bluetooth device inquires about neighbouring Bluetooth stations. This inquiry process consists of scanning for devices in the vicinity, using a sequence of different power levels. Low power levels will detect devices in close proximity while high power levels will include devices that are located farther away, providing coarse distance estimates in this fashion. This approach requires a fixed or "anchor" node which establishes the position of nearby mobile nodes. Subsequently, the localized nodes can establish the position of other undetected mobiles nodes in their vicinity, creating an ad-hoc localization network. The reported localization error was 1.88 meters.

## 6. Spatial Query over Sensor Networks

One characteristic inherent to scenes analysis approaches approach is that the anchor density and their actual placement determine the solution quality. Obviously, in the absence of anchors, nodes are clueless about their real coordinates. The predominant type of approach, involves nodes, measuring the distances between nodes themselves and their neighbours, with only some nodes called "beacons" having to be informed of their position through GPS or manual configuration [16].

Various new localization and spatial analysis techniques has been introduced by modern geographic information system (GIS) technologies, using digital information, for which various digitized data creation methods are used. For example road map, is a two-dimensional object that contains points, lines, and polygons that can represent cities, roads, and political boundaries such as states or provinces. GIS applications store, retrieve, update, or query some collection of features that have both non-spatial and spatial attributes.

Spatial querying capabilities can be essential for sensor network query systems. For many applications, the ability to query sensor networks in an ad hoc fashion will be a key to their usefulness. Rather than re-engineering the network for every task, as is commonly done now, ad hoc querying allows the same net-work to process any of a broad class of queries, by expressing these queries in some query language. In essence, the network appears to the user as a single distributed agent whose job it is to observe the environment wherein it is embedded, and to interact with the user about its observations.

Geo location information in this case, can be viewed in form a restrictions on the order of the edges around the vertices of graph. While it is a not so trivial task using raster geospatial data, vector type layers can provide valuable information for proper node graph embedding and orientation. For example, shapefile being a popular geospatial vector data format for geographic information systems software describes such geometries as points, polylines, and polygons, and stores non topological geometry and attribute information for the spatial features in a data set.

This data, viewed in road infrastructure context can help to improve localization process, eliminating locations where vehicle, cannot be physically present, and refine location coordinates matching vehicle location with existing roads coordinates. In that sense, roadmap data can be viewed as a graph which embraces node distance sub graph with sub graph vertices placed either on its edges or matching with its vertices.

Location-based spatial queries refer to spatial queries whose answers rely on the location of the inquirer.

Efficient processing of spatial queries is of critical importance with the ever-increasing deployment and use of wireless and mobile technologies. It has certain unique characteristics that traditional query processing and databases does not address.

A common example of spatial data can be seen in a road map. A road map is a two-dimensional object that contains points, lines, and polygons that can represent cities, roads, and political boundaries such as states or provinces. A road map is a visualization of geographic information. The location of cities, roads, and political boundaries that exist on the surface of the Earth are projected onto a two-dimensional display or piece of paper, preserving the relative positions and relative distances of the rendered objects.

The localization problem, when solved in this way, is similar to the graph embedding problem is strongly NP-hard. Algorithm will have in fact to perform exhaustive search in order to eliminate not matching neighbour nodes combinations. Unfortunately, when the size of the instances grows the running time for exhaustive search becomes forbiddingly large, even for instances of small size.

On the other hand, with the increased speed of modern computers, large instances of NP-complete problems can be solved effectively. For example, it is a nowadays routine to solve travelling salesman (TSP) instances with up to 2000 cities [17]. And if the data is structured, then instances with up to 13000 cities can be handled in practice. There is a huge gap between the empirical results from testing implementations and the known theoretical results on exact algorithms.

## 7. Conclusions

Presented review and analysis of the VANET objects localization methods gives a good reason to pay special attention to localization methods based on scene analysis, allowing determining the position of objects that are fundamentally not localizable using other methods. Special attention is given to the scene analysis methods, based on the combination of the distance graphs with a road map. This option allows using standard maps, car navigation systems are usually equipped with, as well as the standard

means of communication, supplemented by distance meter. At the same time the option of implementing the described embodiment, based on the spatial queries has been offered, allowing solving the problem of high computational complexity, typical for scene analysis methods. All this, with the help of the scenes analysis, allows transferring the issue of objects localization from theoretical considerations into practical implementation.

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