Flow Lanes and Map Features for Vehicle Navigation Mapping

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FLOW LANES AND MAP FEATURES FOR VEHICLE NAVIGATION MAPPING

Introduction

A geographic information system (GIS) is a system for archiving, retrieving, and manipulating data that has been stored and indexed according to the geographic coordinates of its elements. The system generally can utilize a variety of data types, such as imagery, maps, and tables. GIS technology can be integrated into Internet-based mapping applications such as software applications that display interactive digital maps and utilize digital maps for operations such as vehicle navigation and/or control.

Increasingly, local data such as sensor data collected by a vehicle as it travels through a geographic area is being used with map data. In such instances, a vehicle may utilize sensor data to localize itself within an environment. For example, a vehicle may utilize GPS data from a GPS sensor to determine a general location of a vehicle relative to a map, and imagery from a camera sensor to determine a more precisely localized position of the vehicle. The set of physical features that a vehicle may use to localize itself in a geographic area may vary from location to location. Such variances in localization processes due to local conditions make it difficult to provide a common way of describing how a vehicle should move as part of following a navigation plan.

Summary

The present disclosure is directed to systems and methods for providing geographic information including data indicative of a flow lane that a vehicle can follow to facilitate improved vehicle navigation and/or control. A flow lane can provide an indication of a path of travel for a vehicle relative to a map or other source of geographic information, as well as a reference for localizing a vehicle’s location relative to the flow lane. In some examples, a flow
lane can represent an ideal path of travel for a vehicle or other moveable object. Additionally, a flow lane can indicate a safely drivable region in which a vehicle may travel relative to the ideal path of travel. For instance, data indicative of a flow lane may include data indicative of a flow line representing a path that a vehicle can follow, and one or more distance(s) to the left and to the right of the flow line that define a drivable region relative to the flow line.

**Detailed Description**

A vehicle map service is provided that includes a flow lane that can indicate a path a vehicle can follow in association with a route or geographic area. More particularly, a flow lane can facilitate improved vehicle navigation and control by providing an indication of a path of travel for a vehicle relative to a map or other source of geographic information. Moreover, a vehicle can be localized in a geographic area relative to the flow lane. The vehicle can be localized using a set of physical features in an environment that is potentially different from a set of physical features used to define the flow lane.

According to an aspect of the present disclosure, a flow lane may be defined as one or more particular positions relative to the earth or planet. For example, a flow lane may be defined using latitude and longitude coordinates (e.g., WGS84) or another coordinate system to define positions relative to the earth. Additionally, and/or alternatively, a flow lane may define a relationship of the flow lane to physical features in an environment (e.g., lane lines, signs, geographic attributes, etc.). A flow lane may further be defined as a shape, such as by using a polyline or distance relative to a flow line to define a shape indicating a drivable area in the environment.

A flow lane may be defined as one or more positions in an environment and/or as a relationship to physical features in the environment. A vehicle may localize or otherwise
determine its position in the environment relative to a flow lane. In such a case, the vehicle may use the flow lanes alone to perform motion planning to drive the vehicle towards its destination.

According to an aspect of the present disclosure, information relating to how a vehicle should move relative to a map can be specified independently of which physical features in an environment are used to determine the vehicle’s location with respect to the map. For instance, a flow lane may be defined relative to a first set of physical features in an environment. A vehicle may use a second set of physical features, which may or may not include one or more of the physical features of the first set, to localize itself with respect to a map, and more particularly, with respect to a flow lane of a map. Such a formulation allows the information about how a vehicle should move relative to a map to be specified independently of which physical features are used to determine the vehicle’s location with respect to the map. Moreover, the information can be specified independently while also allowing the vehicle to use any and/or all of the physical features to localize itself with respect to a flow lane of a map.

As a specific example, the vehicle may use sensor data (e.g., to identify a location and/or physical features in an environment). The sensor data may be used to determine the vehicle’s location with respect to physical features whose position is known relative to the flow lane (e.g., using sensor data to identify a direct position or relationship to physical features), and thereby to the vehicle’s location with respect to the flow lane itself. Additionally, or alternatively, the sensor data may be used to determine the flow lane’s location with respect to the map.

In some examples, flow lanes may be used as part of localization that moves from a physical level to a lane level, and from the lane level to a segment level. The segment level references a traditional navigation map, such as may include a road network described by roads and intersections, where the roads may contain lanes that are available on the lane level referenced by their containing segments. The lane level can reference a local flow lane map.
which describes the path of travel the vehicle is on, how the vehicle can safely move and make progress within that path of travel, and how the vehicle can switch between paths of travel safely. The flow lane can also have a physical form on the physical level, but cannot be observed directly by the vehicle in example embodiments. The physical level references a map of features the vehicle can observe, such as signs, curbs, lines, etc., as well as the physical form of flow lanes. The physical level does not directly describe where the vehicle can and should go in example embodiments. The vehicle can determine its position relative to physical features using sensor data, translate its physical position to the lane level as a lane position, and then translate its lane position to the segment level as a segment position. At the physical level, the vehicle observes physical features. Because the vehicle location relative to some physical features is known, the vehicle location relative to the flow lane and thus the desired path of travel is also known. At the segment level, the flow lanes are related to the high-level road graph on which a driver can plot a course from source to destination.

Similarly, in some examples, flow lanes may be used as part of localization that moves from the segment level to the lane level, and from the lane level to the physical level. The vehicle can determine its location relative to a map, translate its location to a lane level position, then identify a set of physical features that should be visible based on the corresponding flow lane data.

FIG. 1 depicts a block diagram of an example computing environment 100 in which embodiments of the present disclosure may be practiced. Environment 100 includes one or more vehicle computing devices(s) 102, one or more server computing system(s) 132, and one or more server computing system(s) 156. The environment 100 can be implemented using other suitable architectures, such as a single computing device or additional computing devices.
Vehicle computing device(s) 102, server computing system(s) 132, and server computing system(s) 156 can be implemented using any suitable computing device(s). Each system can include one or more processors (e.g., 104, 134, and 158) and one or more memory devices (e.g., 106, 136, and 160). The processors can include any suitable processing device, such as a microprocessor, microcontroller, integrated circuit, logic device, or other suitable processing device. The memory devices can include one or more computer-readable media, including, but not limited to, non-transitory computer-readable media, RAM, ROM, hard drives, flash drives, or other memory devices. The one or more memory devices can store information accessible by the one or more processors, including computer-readable instructions (e.g., 110, 140, and 164) that can be executed by the processors. Instructions 110 can be executed by processor(s) 104 to implement vehicle map service system (VMSS) 112, instructions 140 can be executed by processor(s) 134 to implement remote map service system (RMSS) 142, and instructions 164 can be executed by processor(s) 158 to implement remote vehicle service system (RVSS) 166.

VMSS 112 can store and/or perform operations on vehicle map service data 120 which can include map data 122, sensor data 124, flow lane data 126, and/or machine-learned model data 128. VMSS 112 can communicate (e.g., send or receive one or more signals or data) with one or more client systems including: the one or more vehicle systems 130 (e.g., a navigation system that can receive vehicle map service data and output a local map via graphical user interface displayed on a display device); and/or vehicle map service clients 116 which can subscribe to and/or publish vehicle map service data. Further, VMSS 112 can include a vehicle map service data service 114 that can be configured to manage and provide information associated with the vehicle computing device 102 to clients and/or other subscribing entities. VMSS 112 can also manage, send, and/or receive information associated with the one or more basemap service systems 118 which can include one or more computing devices and/or software...
applications that can perform one or more actions and/or operations associated with providing a basemap.

RMSS 142 can include a map information service 144 configured to compute map data and other data determined according to example aspects of the present disclosure and provide such data to vehicle computing device(s) 102 and/or server computing system(s) 156. RMSS 142 can implement a mapping application, a virtual globe application, or any other suitable RMSS. RMSS 142 can provide for the archiving, retrieving, and manipulation of geospatial data that has been indexed and stored according to geographic coordinates, such as latitude, longitude, and altitude coordinates, associated with the geospatial data. RMSS 142 can combine satellite imagery, photographs, maps, models, and other geographic data, and Internet search capability so as to enable a user to view imagery of the planet and related geographic information. RMSS 142 can store and/or perform operations on vehicle map service data 146 which can include map data 148, sensor data 150, flow lane data 152, and/or machine-learned model data 154. The map data 148 associated with RMSS 142 can further include route data, geographic imagery, and/or data associated with various waypoints. RMSS 142 may provide flow-lane data to vehicle computing devices 102 in some examples.

RVSS 166 can provide map data and other data determined according to example aspects of the present disclosure. RVSS 166 can store and/or perform operations on vehicle map service data 170 which, similar to the vehicle map service data 120, can include map data 172, sensor data 174, flow lane data 176, and/or machine-learned model data 178. RVSS 166 may include a vehicle information service 168 configured to manage and provide vehicle information to clients or other subscribing entities. RVSS 166 may provide flow-lane data to vehicle computing devices 102 in some examples.
As shown in FIG. 1, the memory devices can also store data (e.g., 108, 138, and 162) that can be retrieved, manipulated, created, or stored by the processors. The data can include, for instance, map data (e.g., 122, 148, and 172), sensor data (e.g., 124 150, and 174), flow lane data (e.g., 126, 152, and 176), machine-learned model data (e.g., 128, 154, and 178), and other data. The data can be stored in one or more databases. The one or more databases can be connected to the computing devices by a high bandwidth LAN or WAN, or can also be connected to the computing devices through network 180. The one or more databases can be split up so that they are located in multiple locales.

The map data (e.g., 122, 148, 172), can be associated with and/or include geographic data including one or more maps that are indexed according to geographic coordinates (e.g. latitude, longitude, and/or altitude) of its constituent elements. The sensor data (e.g., 124, 150, 174) can include data associated with one or more sensor outputs of the vehicle computing device(s) 102, server computing system(s) 132, and server computing system(s) 156. For example, the sensor data can include one or more outputs from one or more LIDAR devices, one or more cameras, one or more microphones, one or more sonar devices, and/or one or more radar devices.

The flow lane data (e.g., 126, 152, 176), can include data associated with one or more flow lanes. Flow lanes may be defined using latitude and longitude coordinates in one example. For instance, a flow line may be defined as a sequence of latitude/longitude coordinates. Additionally, a flow lane may be defined using a distance to the left and right of the flow line to define a safe drivable area. A vehicle may determine its position relative to a flow lane using map data (e.g., 122, 148, 172), sensor data (e.g., 124, 150, 174), and/or machine-learned model data (e.g., 128, 154, 178). For instance, a vehicle may determine its position relative to physical features in an environment and then localize itself relative to the flow lane. In some examples, a flow lane can be determined based on historical data, such as observational data associated with
vehicles. For instance, a path may be identified based on observing where vehicles move through an area. The flow lane can then be defined using latitude and longitude coordinates so that it can be universally utilized. Additionally, a flow lane may be defined relative to physical features in an environment. In some examples, VMSS 112 may utilize the flow lane to assist and/or guide a vehicle along a path. In particular, the flow lane data may be used to navigate and/or control motion of the vehicle.

The machine-learned model data (e.g., 128, 154, 178), can include one or more machine-learned models or training data associated with one or more machine-learned models that can be used by the vehicle computing device(s) 102, server computing system(s) 132, and server computing system(s) 156 to detect and/or recognize the state of the environment external to the vehicle computing device(s) 102, server computing system(s) 132, and server computing system(s) 156. For example, the machine-learned model data (e.g., 128, 154, 178), can include a plurality of machine-learned models that can be used by the vehicle map service system 112, remote map service system 142, and/or remote vehicle service system 166 to detect and/or recognize one or more objects, scenes, and/or events. Furthermore, the machine-learned model data (e.g., 128, 154, 178), can include field collected data that is associated with sensor observations (e.g., image data, radar data, sonar data, LIDAR point cloud data, and/or audio data) from one or more sensors (e.g., one or more cameras, one or more radar devices, one or more sonar devices, one or more microphones, and/or one or more LIDAR devices).

The vehicle computing device(s) 102, the vehicle map service system 112, the RMSS 142, and/or the RVSS 166 can communicate (e.g., send and/or receive one or more signals or data including the vehicle map service data) via a network 180. The network 180 can include any type of communication network, including a local area network, wide area network, a cellular network, or some combination thereof. The network 180 can also include one or more
direct connections that can be used for direct communication between the vehicle computing
device(s) 102, the vehicle map service system 112, the RMSS 142, and/or the RVSS 166.
Communication can be carried via network 180 using any type of wired and/or wireless
connection, using a variety of communication protocols (e.g. TCP/IP, HTTP, SMTP, and/or
FTP), encodings or formats (e.g. HTML or XML), and/or protection schemes (e.g. VPN, secure
HTTP, or SSL).

Figure 2 depicts a flowchart illustrating an example process 200 for providing flow lane
data in response to client computing device request(s) in accordance with aspects of the present
disclosure. Those of ordinary skill in the art, using the disclosures provided herein, will
understand that various steps of any of the processes disclosed herein can be adapted, modified,
rearranged, omitted, and/or expanded without deviating from the scope of the present disclosure.
One or more portions of the processes described herein can be implemented by one or more
computing devices. One or more portions of the processes described herein can be implemented
as an algorithm on the hardware components of the devices described herein (e.g., as in FIG. 1)
to, for example, generate map data including flow lane data associated with one or more
geographic information for a geographic area.

At 202, a flow lane is determined for a path of travel in a geographic area. In some
examples, a flow lane may be determined based on historical map service data. A flow lane may
be determined from an analysis of historical sensor data and/or map data associated with vehicles
traveling a path. In other examples, satellite imagery and other data depicting vehicle travel
and/or travel ways may be used. One or more machine-learned models may be trained to detect
a flow lane based on the path of travel of vehicles.

At 204, a flow line is defined for the flow lane. The flow line may be defined as a
sequence of latitude and longitude coordinates. Additionally, and/or alternatively, a flow line
may be defined as a relationship of the flow line location to physical features in a geographic area. In some examples, the flow line can be defined relative to map data. At 206, a travel area is defined for the flow lane relative to the flow line. In some examples, the travel area can be defined by distance relative to a flow line. In some examples, the travel area may be defined relative to physical features.

At 208, one or more request(s) are received in association with geographic information for the geographic area. In some examples, the request(s) can be received from a vehicle computing system associated with a vehicle. At 210, map data is provided in response to client computing device request(s). For example, the vehicle map service system 112 can transmit map data associated with a current geographic location to a client system including a basemap system. At 212, flow lane data is provided in response to client computing device request(s). For example, the vehicle map service system 112 can transmit flow lane data defining a flow line and drivable area relative to the flow line. Additionally, and/or alternatively, the flow lane data may define a relationship of the flow lane to physical features visible in the world such as lane stripes or signs.

Figure 3 depicts a flowchart illustrating an example process 300 for initiating one or more control actions based on a location of the vehicle relative to a flow lane in accordance with aspects of the present disclosure. FIG. 3 depicts an example of performing localization from the physical level to the lane level, and from the lane level to the segment level.

At 302, map data and flow lane data associated with a geographic area can be obtained. In some examples, the map and flow lane data can be obtained from a remote map service system. At 304, sensor data associated with a geographic area can be obtained from one or more sensors. At 306, physical features in the environment can be identified based at least in part on sensor data, map data, and/or flow lane data. In some examples the physical features may be
identified and classified. For instance, a physical feature may be classified as a stop sign, speed limit sign, building, lane stripe, etc.

At 308, the location of a vehicle relative to physical features identified from the sensor data can be determined. For instance, the location of a vehicle relative to a lane line or street sign may be determined. At 310, the vehicle can be localized relative to the flow lane based on flow lane data. At 312, one or more control actions can be initiated based on a location of the vehicle relative to the flow lane. In some examples, a control action may be implemented to position the vehicle relative to the flow lane. For instance, a control action may include controlling the vehicle to follow the flow lane. Specifically, a control action may include avoiding potential obstacles while remaining within the drivable area defined by the flow lane and making forward progress along the flow lane.

Figure 4 depicts a flowchart illustrating example operations 400 for localizing the vehicle relative to the one or more physical features identified from flow lane data in accordance with aspects of the present disclosure. FIG. 4 depicts an example of performing localization from the segment level to the physical level.

At 402, map data and flow lane data associated with a geographic area can be obtained. At 404, sensor data associated with a geographic area is obtained. At 406, a location of a vehicle relative to a map is determined based at least in part on map data and/or sensor data. At 408, one or more flow lanes can be identified based on the location of the vehicle. In some examples, a flow lane may be identified based on a most effective route. For instance, the flow lane may be identified to be the most effective route to get to a destination indicated by the user from the current location of the vehicle. At 410, one or more physical features in an environment external to the vehicle are identified based on the flow lane data. At 412, the vehicle can be localized relative to the one or more physical features identified in the flow lane data.
Figures

FIG. 1
FIG. 2
FIG. 3
FIG. 4
Abstract

The present disclosure provides systems and methods for providing geographic information including data indicative of a flow lane that a vehicle can follow to facilitate improved vehicle navigation and/or control. A flow lane can provide an indication of a path of travel for a vehicle relative to a map or other source of geographic information, as well as a reference for localizing a vehicle’s location relative to the flow lane. In some examples, a flow lane can represent an ideal path of travel for a vehicle or other moveable object. Additionally, a flow lane can indicate a region in which a vehicle may travel relative to the ideal path of travel.