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(54) RECOMMENDED SPEED SERVICE

(57) Method for providing recommended speed data to vehicles, wherein a fleet of vehicles (4), adapted to run an algorithm for holistic estimation of a recommended vehicle speed, transmit recommended speed messages (1) to a map service provider (2), said received recommended speed messages (1) are mapped to a corresponding road segment (6) and saved in a database (8), said saved recommended speed data being a basis to compute an aggregated recommended speed information for each corresponding road segment (6), said aggregated recommended speed data being transmitted as aggregated recommended speed message (3) to vehicles subscribed to said map service.

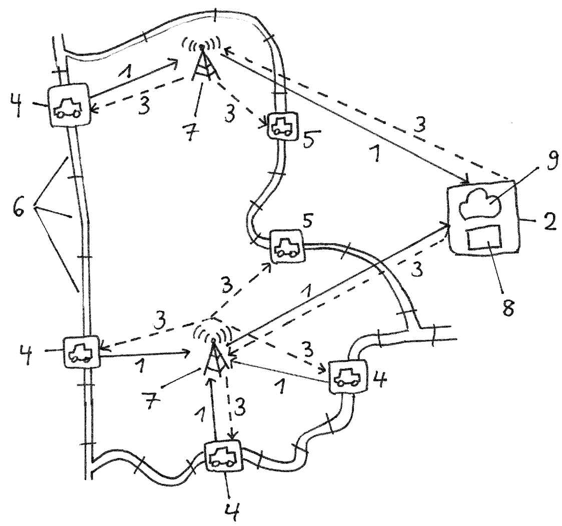

Fig. 1

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Description

[0001] The invention relates to an automatic speed control system for a motor vehicle comprising an ACC function adapted to control the speed of the motor vehicle depending on in-vehicle speed estimation and provided recommended speed information from a map service provider. The invention also relates to a method for such a map service to obtain recommended speed information.

[0002] To safely navigate a motor vehicle in traffic it is paramount to keep a speed appropriate for the current conditions. For most roads there are traffic signs or other regulations specifying the maximum allowed speed. However, a safety concerned human driver will always use his or her common sense to adapt the speed to the surroundings. Examples where the driver decreases the speed include but are not limited to: poor road conditions such as pot holes, gravel, rocks, snow, etc.; bad weather conditions such as heavy rain, snow, fog, etc.; road work areas; areas with occluding objects and/or structures such as other vehicles, hedges, etc.; areas with high risk of children suddenly entering the road, such as residential areas, proximity to schools, etc.; areas with high risk of animal presence; curvy roads.

[0003] An autonomous system that does not have this common sense behavior will either be tuned overly cautiously and drive too slowly, with risk of being turned off, or too aggressively and drive too fast thereby risking accidents. Additionally, a system lacking this functionality is likely to be perceived as unsafe, unnerving and unaware of its surroundings, making the driver likely to turn off the system.

[0004] Current semi-autonomous vehicles typically focus on the existence of other road users and adapting steering and speed to avoid collisions and dangerous situations, and do not change the desired velocity based on the general surroundings. In contrast to the above, some systems use specific scene information such as road wetness to change the desired velocity. This, however, requires specific solutions for each type of scene information, making it difficult to scale to handle a larger number of and more difficult types of scenarios. Finally, these approaches typically rely on manually labeled data or specific reference sensors.

[0005] Somewhat related are End-to-End-Learning systems for autonomous driving that have been suggested in recent years. These systems try to solve the more difficult general sensing and steering problems. However, none of these systems have been demonstrated to work reliably enough to replace more modular and hand-engineered systems. As such they seem unlikely to be employed in a near future.

[0006] Map service providers use a map as a foundation for their services. One way for the service provider to provide the map service is using a cloud, but other possibilities than using a cloud may exist. On top of the map, data is often organized in layers containing different type of information that can be combined in different ways. The road network divided into suitable road segments is a basic such layer. Other layers may contain information about speed limits, traffic signs, landmarks, road condition (smooth, rough, etc.), road cover (wet, snow, ice, etc.) slipperiness, and so on.

[0007] Sending the actual speed of vehicles to the cloud of the map service provider for statistical analysis and provision of the result to the subscribing vehicle fleet has been suggested earlier. But if only few cars have been driven on a road segment, the result can be influenced by how the driver of these vehicles behaves (e.g., if they drive too fast). Typically, this eventually evens out but might require many vehicles to pass the road segment before a statistically "appropriate" speed value can be provided. This might be problematic in dangerous but rather rare situations like driving in fog. In rapidly changing scenarios, a system based on actual speed will either provide an erroneous recommendation or not be able to provide a recommendation at all.

[0008] On the other hand, if the road segment is changed (e.g., during/after road work, other weather conditions), the "appropriate" speed to drive may change suddenly. This can take some time to detect if statistics are based on actual speed from vehicles, especially if the driving pattern varies substantially.

[0009] The problem underlying the present invention is to develop and provide a driver assistance system and service adapted to regulate the vehicle speed to be appropriate for the current driving conditions in an efficient and reliable manner.

[0010] The invention solves this object with the features of the independent claims.

[0011] According to the invention, a map service for providing recommended speed data to vehicles is provided, wherein a fleet of vehicles, adapted to run an algorithm for holistic estimation of an recommended vehicle speed, transmit recommended speed messages to the map service provider. The received recommended speed messages are mapped to a corresponding road segment and saved in a database. For each road segment, the corresponding saved recommended speed data is used as a basis to compute an aggregated recommended speed information. The aggregated recommended speed data is transmitted as an aggregated recommended speed message to vehicles subscribed to the map service. The inventive approach to solve the problem is to use recommended speed data instead of actual speed of the transmitting vehicles.

[0012] The algorithm for holistic estimation of an recommended vehicle speed produces a recommended speed estimation for the ego vehicle. This may be achieved for example by a machine learning model adapted to estimate recommended speed for the ego vehicle by training images recorded by an imaging apparatus of a test vehicle. The algorithm may be capable to sort out a variance of inappropriate speed data caused by unforeseen influences. For example this may include the reduction of speed to exit the road, reducing the speed in order to keep a distance to a preceding vehicle, parking the vehicle, making a u-turn, disregard of speed limits, etc. Therefore, data selection and preparation is already performed by the algorithm of the ego vehicle and culminates in the recommended speed data provided by the algorithm. In order to achieve a higher level of independence from driver-specific influence in the statistics, recommended speed data significantly reduces the number of required vehicles per road segment before a statistically "appropriate" speed value can be provided by the map service. Reliable data can be achieved by using the knowledge of experienced drivers (built into the holistic speed adaption algorithm) already at the first time a road segment is visited. Furthermore, since the holistic speed estimates have a lower variance than actual driver speed, it is thus possible to faster recognize changes of the road segment.

[0013] In other embodiments, a complete traditional Adaptive Cruise Control-system (ACC), potentially based on one or multiple sensors such as camera(s) and/or radar(s), may be run on the entire available dataset. The situations where the ACC system does not perform an explicit action are then used as training data. In other words, a conventional Adaptive Cruise Control system may preferably be run on the training data set, and images are used as training data where the conventional Adaptive Cruise Control system does not perform an explicit action.

[0014] The recommended speed data transmitted may, in its simplest form, provide the recommended speed as is, e.g. a number, possibly an integer, and a position information to combine the speed to a corresponding road segment. Aggregated recommended speed data may be provided by computing the mean recommended speed value from the N last received messages. Map service providers usually have an infrastructure for efficiently passing (either directly or via transponders) messages of this kind to vehicles.

[0015] Preferably, time filtering is applied to a plurality of recommended speed messages to obtain time-filtered aggregated recommended speed data. In the cloud, it is also possible to understand that messages are specific for a certain time period, e.g. to handle rush hours. Therefore, applying time filters allows to build histograms over different time periods, for example each hour and each week day separately, and use that to capture dynamic differences.

[0016] Preferably, the speed estimation algorithm outputs not only a speed but also a confidence measure of the estimate. This confidence measure can then be used by the deployed ACC system when combining it with other speed information. In other words, the speed estimation algorithm preferably outputs a confidence measure of the recommended speed estimate. Sending a confidence level allows the cloud service to weight information sent to it. In its simplest form the confidence level can be binary, e.g. recommended speed is uncertain or certain. By this, the cloud service may choose to ignore messages, e.g. in case the road ahead is unexpectedly blocked for some reason (e.g. due to a queue). Alternatively, the value sent can be a confidence level specifying to what degree the data can be trusted.

[0017] In a preferred embodiment, the recommended speed message contains an estimate of the validity duration of the recommended speed. For example, if the vehicle is blocked by another vehicle, the duration could be in minutes, if there is heavy rain it could be hours, or if a road work area is entered the duration can be several days or even weeks.

[0018] Preferably the recommended speed service contains information from specific scene classifiers computed by vehicles. Any means that provide scene understanding can be used, e.g. vehicles equipped with wetness sensors or equipped with an imaging apparatus. Vehicles with a camera or other imaging sensors typically compute several features. Scene classifiers are used to determine different environmental factors: brightness (e.g. dark,..., light), road surface (e.g. asphalt, concrete, gravel), road cover (e.g. dry, wet, snow, ice), driving condition (raining, snowing, fog, etc.) and so on. Preferably this type of data is included in the transmitted speed messages to the cloud/map service provider. The service can then compute and transmit condition specific aggregated statistics to the vehicles, which allows refined and situation adapted aggregated recommended speed suggestions.

[0019] In a preferred embodiment a recommended speed distribution is used and sent to the service provider instead of a single recommended speed value to capture multiple hypotheses (e.g. grouped into categories such as continue straight on or turn left with different recommended speed values, or directly referring to different road segments of the map). The cloud can build aggregated statistics on this as well and make more advanced aggregated recommended speed suggestions.

[0020] Preferably information from several map layers is used to compute aggregated recommended speed messages. One option to use combined information from several map layers in the cloud is to use slipperiness information if that is available for the road segments. The aggregated recommended speed could then be further reduced if it is determined that slipperiness is not already considered in the recommended speed computation.

[0021] Vehicles equipped with a holistic speed adaption algorithm preferably combine in-vehicle recommended speed data and received aggregated recommended speed data. Vehicles without this algorithm must rely on the aggregated recommended speed value sent to it. If this vehicle can determine brightness, road surface, road cover, and so on, it can use this information to determine a refined condition specific recommended speed value as well. If this is not possible, other sensor information, e.g. ambient temperature can be used to guide in the choice of recommended speed.

[0022] Another preferred embodiment is to provide refined condition specific recommended speed from the ego vehicle to another vehicle via car-to-car communication. In fact, if a vehicle with the ability to compute the driving condition has passed a specific road segment recently, then this can be provided to another vehicle for usage either via transponder or via the cloud, to allow the other vehicle to use a refined condition specific speed recommendation. This option is especially beneficial for providing recommended speed to vehicles lacking the cloud service.

[0023] In a preferred embodiment, the training data is filtered and grouped based on driver characteristics such as cautious, normal, dynamic. Three cases have to be considered. First: In vehicles with a holistic speed recommendation system, this system itself could output speed recommendations corresponding to different driver characteristic modes. These recommendations are transmitted to the service provider, which uses this to generate aggregated recommended speed for the different modes. Second: The service provider generates (in the cloud) the recommendation for the various modes. This could be done through any statistical model or set of rules, e.g., in the simplest case the aggregated recommended speed for the cautious mode could be 0.9 times that of the normal mode. Third: An in-vehicle system modifies the received aggregated recommended speed and modifies it according to any statistical model or set of rules, e.g. in the simplest case the aggregated recommended speed for the cautious mode could again be 0.9 times that of the normal mode.

[0024] A further preferred embodiment of the invention is to transmit both recommended speed and actual speed of a vehicle to the cloud, possibly with information of the kind outlined above (confidence level, scene classification information, etc.) This opens up the possibility to provide aggregated statistics to vehicles by combining these two speed sources. A straight forward approach is just to weight these together, e.g. let the aggregated recommended speed to be transmitted to vehicles for a road segment be formed as

$$X*\text{aggregated recommended speed} + (1-X)*\text{aggregated actual speed}$$

where X is a fixed value between 0 and 1. X can also be adaptively chosen. For example if the variance of the aggregated actual speed is large, then trust the aggregated recommended speed more, i.e. let X be close to 1 in such case.

[0025] To reduce the influence of driver behavior another preferred possibility is to base the weighting on the amount (N1) of data messages available to form the aggregated recommended speed (AggRecSpd) and the amount (N2) of aggregated actual speed (AggActSpd), like

$$W1*N1/(w1*N1+N2)*AggRecSpd + N2/(w1*N1+N2)*AggActSpd,$$

where w1 is a weighting factor (>0; >1 if aggregated recommended speed is weighted higher than aggregated actual speed). If so desired, N1 and N2 can be restricted to some maximum values, and one can choose to only use the most recent messages available in the aggregation computations. Therefore a fast but reliable adaption to changes of a road segments is possible.

[0026] Yet another preferred embodiment is to combine aggregated recommended speed information with road information from the map as such, like sharp left bend, and so on. Fusing map information, aggregated recommended speed and aggregated actual speed is a further preferred possibility.

[0027] The invention also provides for an automatic speed control system for a motor vehicle, comprising an ACC function adapted to control the speed of the motor vehicle and said ACC function is adapted to use in-vehicle speed estimation and received aggregated speed data in said speed control. This part of the invention can be implemented in any commercial motor vehicle. The speed control system outputs a predicted speed to be used as a set speed or desired speed. The predicted speed is fed to an ACC system that determines a suitable action.

[0028] In the following the invention shall be illustrated on the basis of preferred embodiments with reference to the accompanying drawings, wherein:

Fig. 1 shows a schematic view of a map service for recommended speed.

[0029] Figure 1 shows the basic framework of the invention. Recommended Speed Messages 1 are transmitted to the service provider 2 and aggregated recommended speed messages 3 are transmitted to vehicles 4, 5 subscribing to the recommended speed data service. The first class of vehicles 4 run a Holistic Speed Adaption algorithm and provide and receive aggregated recommended speed data 3 from the service provider, whereas the second class of vehicles 5 are other vehicles just subscribing to the aggregated recommended speed data 3. In this arrangement, the aggregated speed data 3 transmitted to the vehicles 4, 5 can contain single road segment 6 data or a set of such data for road segments 6 in a region around each vehicle 4, 5, thus enabling look-ahead based determination of the recommended speed, as well as more efficient route planning. However, any other algorithm providing recommended speed 1 can be used in the suggested framework, since any in-vehicle computed recommended speed 1 has a lower variance and higher situation-adapted accuracy than the pure data of actual driver speed.

[0030] The preferred embodiment is a computational node in a vehicle 4 that runs a Holistic Speed Adaption algorithm and sends recommended speed information to a service provider 2, for example wirelessly via transponders 7 or directly via a communication link. Information is sent on a regular basis, for example every X second or every Y meter driven. In its simplest form the message contains information about the location of the vehicle 4 and the recommended speed computed by the Holistic Speed Adaption algorithm. The recommended speed 1 transmitted can be the recommended speed as a number, possibly an integer, or simply a range information, e.g. "four" representing the recommended speed interval 40-50 km/h.

[0031] Recommended speed messages 1 are received by the service provider 2 from a fleet of vehicles 4 equipped with the Holistic Speed Adaption algorithm. The location of the vehicle encoded in a message is mapped to a road segment 6 by a standard location-to-road-segment mapping algorithm, and the recommended speed information received is saved in a database 8. Hence, for each received and accepted message, a mapping between road segment 6 and recommended speed is saved.

[0032] For each road segment 6, the available recommended speed data are used to compute an aggregated recommended speed, for example, by computing the mean recommended speed value from the N last received messages. In the cloud 9, it is also possible to understand that messages are specific for a certain time period, e.g. to handle rush hours. Therefore, it makes sense to build histograms over different time periods and to use that to capture dynamic differences.

[0033] The invention is applicable to autonomous driving, where the ego vehicle is an autonomous vehicle adapted to drive partly or fully autonomously or automatically, and driving actions of the driver are partially and/or completely replaced or executed by the ego vehicle. Such an automatic speed control system for a motor vehicle or a semi-automatic driver assistance system comprises an Automatic Cruise Control (ACC) function, which is running on an in-vehicle data processing device. This device may process data from several in-vehicle sensors, e.g. imaging sensors, cameras, lidars, etc. The ACC function is adapted to control the speed of the motor vehicle depending on the in-vehicle speed estimation of an appropriate recommended speed and received aggregated recommended speed data, as described in the foregoing.

Claims

1. Method for providing recommended speed data to vehicles via map service, wherein a fleet of vehicles (4), adapted to run an algorithm for holistic estimation of a recommended vehicle speed, transmit recommended speed messages (1) to the map service provider (2), said received recommended speed messages (1) are mapped to a corresponding road segment (6) and saved in a database (8), said saved recommended speed data being a basis to compute an aggregated recommended speed information for each corresponding road segment (6), said aggregated recommended speed data being transmitted as aggregated recommended speed message (3) to vehicles subscribed to said map service.

2. Method according to claim 1, **characterized in that** time filtering is applied to a plurality of recommended speed messages (1) to obtain time-filtered aggregated recommended speed data (3).

3. Method according to claim 1 or 2, **characterized in that** the recommended speed messages (1) contains a confidence level of the recommended speed estimate.

4. Method according to one of the preceding claims, **characterized in that** the recommended speed message (1) contains an estimate of the validity duration of the recommended speed.

5. Method according to one of the preceding claims, **characterized in that** the recommended speed message (1) contains information from specific scene classifiers computed by vehicles equipped with sensor-based scene understanding.

6. Method according to one of the preceding claims, **characterized in that** the aggregated recommended speed messages (3) contains an aggregated recommended speed distribution.

7. Method according to one of the preceding claims, **characterized in that** information from several map layers is used to compute aggregated recommended speed messages (3) .

8. Method according to one of the preceding claims, **characterized in that** vehicles (4) equipped with a holistic speed adaption algorithm combine in-vehicle recommended speed data and received aggregated recommended speed data (3) .

9. Method according to one of the preceding claims, **characterized in that** road condition and/or in-vehicle sensor information is combined with received aggregated speed data (3) to compute a redefined condition specific recommended speed data.

10. Method according to claim 9, **characterized in that** condition specific recommended speed data is transmitted from the computing vehicle via car-to-car communication to another vehicle.

11. Method according to one of the preceding claims, **characterized in that** the recommended speed data is filtered and grouped based on driver characteristics.

12. Method according to claim 11, **characterized in that** driver characteristics are grouped in selectable modes cautious, normal and dynamic.

13. Method according to one of the preceding claims, **characterized in that** transmitted recommended speed messages contain recommended speed data and actual speed data and aggregated recommended speed data (3) is computed by weighting recommended speed data and actual speed data.

14. An automatic speed control system for a motor vehicle comprising an ACC function adapted to control the speed of the motor vehicle depending on in-vehicle speed estimation and received aggregated recommended speed data (3) according to one of the preceding claims.

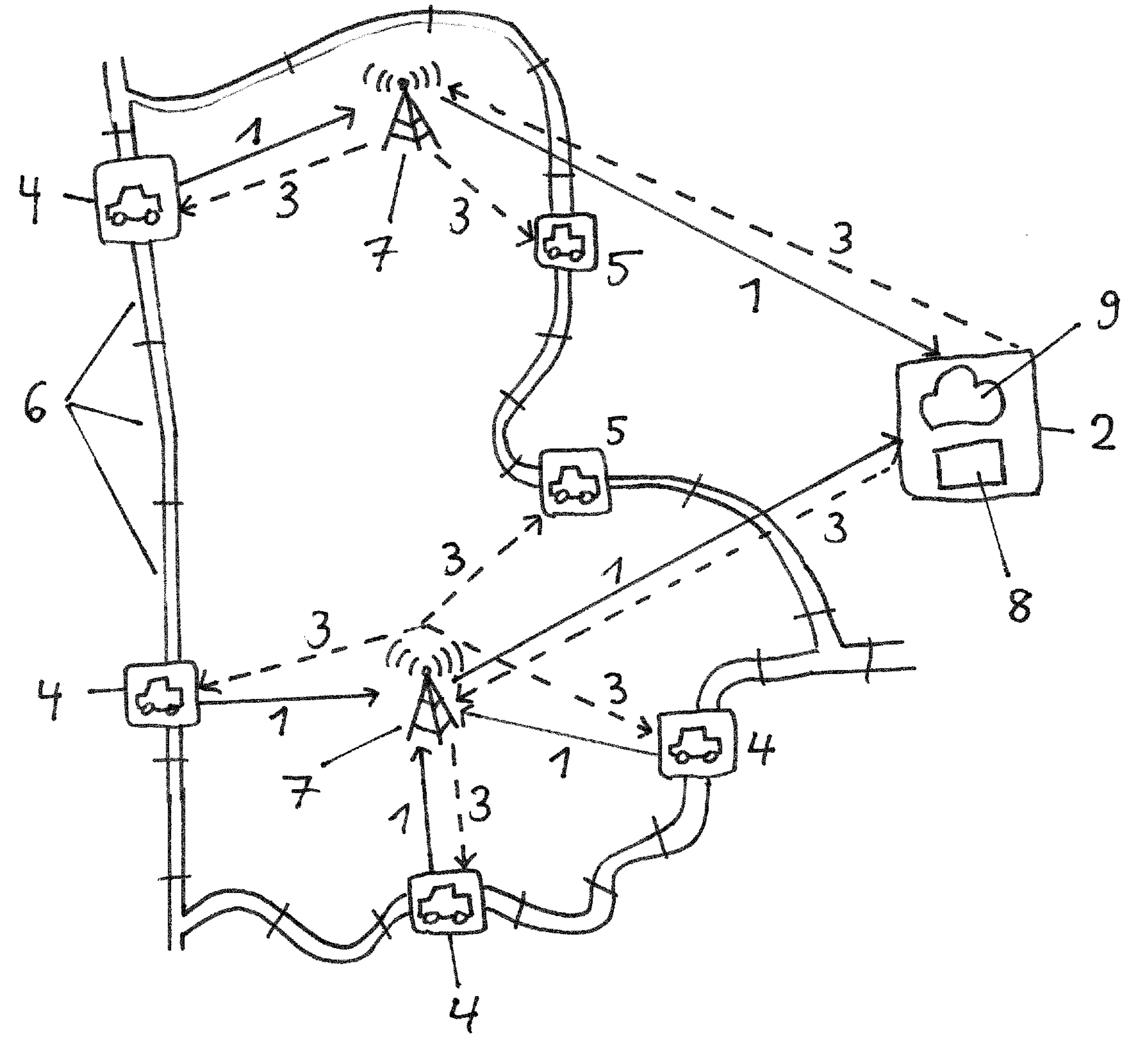

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 3939

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	17 September 2020	Datondji, Sokèmi

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 16 3939

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