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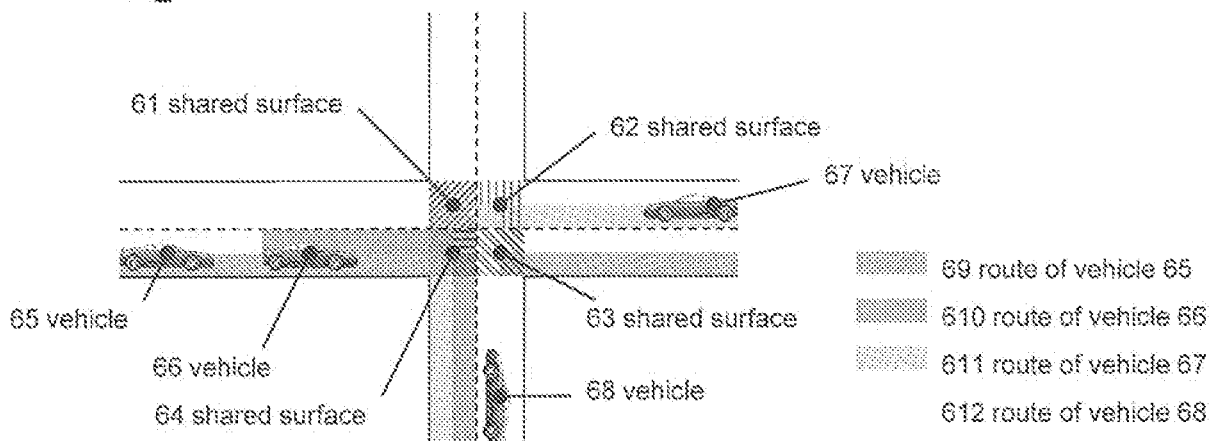
Method and a device for scheduling vehicles at intersections

- (57)

The invention relates to a method and a device for scheduling dual-mode vehicles at intersections, i.e., vehicles being configured to be steered in manual mode by a driver and in automatic mode by an auto-pilot. In order to provide a more efficient and safer scheduling method, it is proposed that the method comprises the steps of requesting vehicle travel data of vehicles within a predetermined distance from an intersection; in response thereto, receiving the requested vehicle travel

data from intersection-crossing vehicles, determining shared surfaces of the intersection for each intersection-crossing vehicle based on the received vehicle travel data, determining a schedule for the intersection-crossing vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each intersection-crossing vehicle; and steering the intersection-crossing vehicles in automatic mode across the intersection based on the determined schedule.

Fig. 6



Description

[0001] The invention relates to a method and a device for scheduling vehicles at intersections.

[0002] Road intersections are dangerous places due to the crossing of driving lanes of vehicles coming from and going to different directions. Nowadays, such conflicts of driving lanes are generally solved by traffic lights, which often follow a stringent sequence, which may also be modified based on traffic measurements of road side sensors.

[0003] A scheduling method for vehicles at intersections based on traffic lights is known from US 6985090 which describes a traffic light cycle optimization method for controlling a system of multiple traffic signals in order to optimize traffic light cycles at single and/or neighboring intersections. Another method is known from US 5083125 which describes a traffic pre-emption method and system, which proposes a traffic light-managed intersection in normal operation, with the ability of pre-emption by e.g. emergency vehicles.

[0004] Other known traffic control or collision avoidance systems that are not based on optimizing the use of traffic lights are usually not applicable to road intersections. For example, US 5278554 proposes to control city traffic with reduced stopping by means of a road traffic control system with alternating non-stop traffic flow which allows and prioritizes non-stop traffic flow for main streets over traffic flow in secondary streets. US 6275773 describes a GPS-based collision avoidance method and system comprising an automatic mode that overrides vehicle control in case of emergency. This system is also not related to intersections in particular and operates only in case of emergencies.

[0005] However, scheduling vehicles at intersections based on active (e.g. traffic lights) or passive (e.g., panels, stop signs,) road-side signs most often leads to polluting, energy-inefficient, expensive and time-consuming stop-and-go phenomena. Furthermore, a drivers lack of attention may still lead to collisions at intersections, whether or not road-side signs are installed.

[0006] Therefore, it is an object of the invention to provide a safer and more efficient method and device for scheduling vehicles at intersections without the need for active or passive road-side traffic signs at the intersection.

[0007] This object is achieved by the subject-matter according to the independent claims 1 and 9, respectively. The dependent claims refer to preferred embodiments of the invention.

[0008] According to an aspect of the invention, a method and a device for scheduling vehicles at intersections is proposed. The vehicles may in particular be dual-mode vehicles, i.e., vehicles being configured to be steered in manual mode by a driver and in automatic mode by an auto-pilot. The use of the term vehicle therefore implies a Dual Mode Vehicle (DMV) in the context of this invention.

[0009] The method may comprise the step of requesting vehicle travel data of vehicles within a pre-determined distance from an intersection. In response to this request, the method may comprise the step of receiving the requested vehicle travel data from intersection-crossing vehicles. In the context of this invention, an intersection-crossing vehicle is a vehicle within a pre-determined distance of the intersection that is approaching the intersection to traverse the intersection.

[0010] It is further proposed that the method may include the step of determining shared surfaces of the intersection for each intersection-crossing vehicle based on the received vehicle travel data. In the context of this invention, a shared surface is a partial surface area of the intersection that is defined from the intersection of driving lanes at the intersection. In other words, surface areas of the intersection where any two intersection crossing vehicles that are entering the intersection from different directions could possibly collide by following their driving lanes are the shared surfaces of the intersection. It may also be possible to define the surface area using the driving paths of the intersection-crossing vehicles instead of the road lanes.

[0011] The method may further include the step of determining a schedule for the intersection-crossing vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each intersection-crossing vehicle. The determined schedule preferably determines a time interval for every shared surface of every intersection-crossing vehicle, within which the intersection-crossing vehicle is scheduled to traverse this shared surface, and wherein the time intervals of different intersection crossing vehicles for the same shared surfaces do not overlap. In other words, the time intervals for a dedicated shared surface are mutually disjoint so that no two vehicles are on the same shared surface within the same time period when crossing the intersection.

[0012] The method may further include the step of steering the intersection-crossing vehicles in automatic mode across the intersection based on the determined schedule. The invention may assume that all vehicles are equipped with an apparatus configured according to the above-described method. This also implies that all vehicles are Dual Mode Vehicles (DMV) that can be operated in two modes: a manual mode for manual steering by the driver and an automatic mode for automatic steering by an auto-pilot at dedicated road intersections. At such intersections, DMV may communicate with each other to determine a schedule to rule the access of surfaces shared between all incoming and outgoing lanes in order to avoid collisions.

[0013] The scheduling method thus adapts in real time to the current traffic situation and schedules traffic across the intersection without the need for passive or active road-side signs. As a consequence, the method according to the invention reduces polluting, energy inefficient and time-consuming stop-and-go phenomena at the intersection. Additionally, driving safety is increased.

[0014] According to another aspect of the invention, the method may further comprise the step of determining a velocity-time distribution for the intersection-crossing vehicles for arriving at the determined shared surfaces of the intersection-crossing vehicles at a time or time interval according to the determined schedule. In other words, based on the overall schedule for arriving at the shared surface, a speed profile for every vehicle that is crossing the intersection is calculated wherein the speed profile ensures that the vehicle arrives at each of his determined shared surface at a time as determined by the overall schedule.

[0015] In order to minimize the time for steering all the vehicles safely across the intersection, the determined schedule may minimize a travel time for crossing the road intersection, wherein the travel time is a maximum time of one of the intersection-crossing vehicles for traversing the intersection or a sum of travel times for all intersection-crossing vehicles.

[0016] It is further proposed that the method may comprise the step of transmitting the determined schedule to the intersection-crossing vehicles so that the intersection-crossing vehicles can determine their own speed profile to reach their set of shared surfaces based on the received schedule. This may be beneficial due to the fact that the overall flexibility and adaptability of the scheduling method is increased as every vehicle can self-optimize independently its speed profile towards the intersection as long as it is consistent with the overall schedule. For example, based on the overall schedule, the vehicle can determine its most fuel-efficient speed profile based on the vehicle-specific engine characteristic, or in case a vehicle has to deviate unexpectedly from its speed profile in order to brake for crossing pedestrians, the vehicle can re-calculate a new speed profile to match the overall schedule without giving notice to the other vehicles.

[0017] In order to reduce the transmitted data, it is further proposed that only a vehicle-specific schedule may be transmitted to each intersection-crossing vehicle. According to another aspect of the invention, the received vehicle travel data from each intersection area vehicle may comprise at least the current vehicle position, current vehicle velocity and the targeted intersection exit of said vehicle.

[0018] According to another aspect of the invention, the steps of requesting vehicle travel data, receiving the requested vehicle travel data, determining shared surfaces of the intersection, and determining a schedule for crossing the intersection may be carried out by the intersection-crossing vehicle that is the last vehicle to arrive at the intersection, i.e., the latest vehicle whose distance from the intersection fell below the pre-determined value. In other words, the last vehicle to enter an intersection zone triggers the calculation or the re-calculation of the schedule for traversing the intersection. This ensures a clear allocation of roles within the group of intersection-crossing vehicles, since, every time a new vehicle enters

the intersection area, an update of the schedule is necessary. The schedule may also be calculated by stationary unit located at the intersection.

[0019] According to another aspect of the invention, a device for scheduling vehicles at intersections may comprise a sender for requesting vehicle travel data from vehicles within a pre-determined distance from an intersection and a receiver for receiving the requested vehicle travel data from intersection-crossing vehicles. The device may further include means for determining shared surfaces of the intersection for each intersection-crossing vehicle based on the received vehicle travel data. The device may further include a scheduling unit for determining a schedule for the intersection-crossing vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each intersection-crossing vehicle.

[0020] According to another aspect of the invention, the device may comprise an auto-pilot unit for steering the intersection-crossing vehicles in automatic mode across the intersection based on the determined schedule. In this context, an auto-pilot unit automatically steers the vehicle according to a calculated speed profile and driving route while maintaining a minimum speed-dependent distance from other vehicles. By way of example, such an auto-pilot unit could be based on one of the already available electronic driving aids with autopilot mode.

[0021] According to another aspect of the invention, the sender may be further configured to transmit the determined schedule to all intersection-crossing vehicles and to receive said determined schedule.

[0022] Preferably, the sender may be configured to send a request for vehicle travel data after the vehicle is within a pre-determined distance from an intersection for the first time. According to another aspect of the invention, the device may further comprise sensor means for detecting a vehicle velocity, orientation and position. By way of example, the sensor means may include a GPS sensor, a vehicle speed sensor, a sensor measuring the vehicle orientation or a sensor measuring the distance from other vehicles.

[0023] Preferably, the device may further include a navigation unit. Preferably, the navigation unit may be further configured to calculate a driving route and a velocity-time distribution for the intersection-crossing vehicles for arriving at the determined shared surfaces as determined by the schedule for crossing the intersection.

[0024] According to another aspect of the invention, the device may switch to automatic mode to steer the intersection crossing vehicle across the intersection based on the calculated driving route and velocity-time distribution of the navigation unit.

[0025] The invention is explained below in an exemplary manner with reference to the accompanying drawings, wherein

Fig. 1 illustrates the shared surface of an intersection

- composed by two one-way, one-lane roads;
- Fig. 2 illustrates the shared surfaces of an intersection composed of two two-way roads, each being comprised of two lanes;
- Fig. 3 illustrates an example where a new vehicle enters the intersection area and determines the schedule for crossing the intersection according to an embodiment of the invention;
- Fig. 4 shows a flow diagram of steps involved in the method for scheduling vehicles at intersections according to an embodiment of the invention;
- Fig. 5 illustrates the application of the invention for an intersection with de-ported shared surfaces;
- Fig. 6 illustrates the scheduling of four vehicles at an intersection according to an embodiment of the invention;
- Fig. 7 illustrates a block diagram of a device for scheduling vehicles at intersection according to another embodiment of the invention.

[0026] The invention aims at allowing road-side passive (panels, stop signs,) or active (traffic lights) signs to be removed. As an alternative to such traffic signs, the method or device according to the invention proposes to temporarily assume vehicle control by means of an automatic control mode that switches from manual steering by a driver to automatic steering by an auto-pilot to steer the vehicle and to control the vehicle velocity at well identified, dedicated intersections.

[0027] Figs. 1 and 2 illustrate the shared surfaces of an intersection composed by two one-way, one-lane roads and of an intersection composed of two two-way roads, each being comprised of two lanes. Such dedicated road intersections can be composed of any simple or complex road intersection with at least two roads. Figs. 1 and 2 illustrate an example where the roads are composed by one or several lanes on which vehicles evolve in line but it is obvious that the invention is not restricted thereto.

[0028] The crossing or common surface the lanes 12 in Fig. 1 have in common is named a shared surface 11. Thus, Fig. 1 shows one of the simplest types of an intersection consisting of two or more lanes (not shown) sharing one surface, on which only one vehicle can travel at a time. This quantum situation can be duplicated and combined together as many times as necessary to form any more complicated type of road intersection. A more complex example is illustrated in Figure 2.

[0029] Fig. 2 illustrates the shared surfaces of an intersection composed of two two-way roads, each being comprised of two lanes. In a road intersection of higher complexity, there can be several different shared surfac-

es; in particular, in case of two-way roads or when turn left is allowed, a surface common with several roads 22 is cut into several shared surfaces 21, each identified by its unique set of composing lanes. For example, the intersection in Fig. 2 is composed of 4 lanes: 22a, 22b, 22c and 22d and 4 shared surfaces 21ac, 21bc, 21bd, 22ad resulting from the intersection of two of the four lanes. The lanes 22a and 22b as well as the lanes 22c and 22d do not intersect and therefore do not form a shared surface.

[0030] In the context of the invention, any (simple or complex) combination of driving paths and shared surfaces, of which the access and crossing is to be regulated according to the method and device of the invention and of which geographic proximity allow them to be considered as one single entity, is defined as an intersection to which the invention can be applied.

[0031] Fig. 3 illustrates an example where a new vehicle enters the intersection area and determines the schedule for crossing the intersection according to an embodiment of the invention.

[0032] Embedded and/or road side sensors detect the vehicle position, speed and direction; the destination in the range of the intersection, i.e. which exit of the intersection the vehicle will take, is either given by the driver of the vehicle or by a navigation device. In manual mode, the driver has full control of the vehicle. In step S31, the vehicle Althen enters the range of a road intersection, i.e., the distance of the vehicle Alfrom the intersection is smaller than a pre-determined value. In step S32, the invention apparatus identifies other vehicles travelling in this intersection area, as well as their position, speed and destination (in the range of the intersection). Then, in step S33, vehicle □All determines a schedule for all vehicles that have to cross the intersection (including itself) such that there is no collision and that travel times are minimized (by minimizing either maximum travel time or sum of travel times) towards a pre-determined maximum speed. After the intersection schedule has been determined and broadcasted by vehicle All, all vehicles compute in step S34 their optimal speed profile to cross their shared surfaces on a scheduled time and the invention apparatus of every vehicle overrides steering and speed control by switching to the auto-pilot to drive the vehicle with computed parameters until the vehicle has crossed the dedicated intersection.

[0033] In case a vehicle must stop for any reason and thus cannot reach a shared surface on the scheduled time, then the schedule must be computed again for all vehicles. Then new schedule is computed by the vehicle that has arrived as the last vehicle at the intersection, i.e., the vehicle whose distance from the intersection is the last to fall below the pre-determined value. It is also possible to discard stopped vehicles, such as parked vehicles, as long as they do not block traffic.

[0034] The intersection must be dedicated to properly equipped Dual Mode Vehicles (DMV) only, and the invention method assumes there is no non-equipped ve-

hicle or any other obstacle on roads of dedicated intersection. The invention might be first applied in usage scenarios where this condition can be met more easily, e.g. in city states such as Singapore or restricted traffic areas, such as airports, where many different commercial vehicles are in use that could all be equipped with a device according to the invention.

[0035] The intersection itself could be equipped with additional safety measures. For instance, magnetic sensors can detect arrival of new vehicles, a road-side beacon can probe for the presence of the invention apparatus in each newly arriving vehicle and eventually all DMV can automatically be stopped in case of an emergency; vehicles may also be enhanced with collision avoidance features.

[0036] In order to operate, the invention therefore requires that all vehicles that are crossing the intersection to be equipped with a device according to the invention, as well as sensors to detect precisely position, speed and orientation of the vehicle. Possible sensors include, but are not limited to, Global Positioning System, accelerometer, gyroscope, radar, sonar, laser, sensors used together with road-side magnetic or optical marks, or any combination of those. Vehicles must also be equipped with one or several communication means which allow them to receive and transmit information from/to each other, and eventually with road-side beacons if a local map is not stored on the embedded device.

[0037] Fig. 4 shows a flow diagram of steps involved in the method for scheduling vehicles at intersections according to an embodiment of the invention. Outside of an intersection area, the invention apparatus is in standby mode until the vehicle comes in range of an intersection in step S1. In order to operate, the scheduling algorithm needs the earliest dates at which each vehicle can reach the shared surfaces of an intersection. These dates are computed based on distance from the vehicles current position and the shared surfaces and based on a maximum legal speed along the way to the shared surfaces. For instance, the maximum speed could be computed in-real time based on the current legal speed limit, or also taking into account current vehicle performances, road shape, or weather conditions. Hence, the position, speed profile and preferably the orientation of each vehicle must be known. In addition, the scheduling algorithm requires the minimum time during which the shared surface may be occupied by each vehicle. It is strongly related to the origin of vehicle, which can be deduced from current position, and the destination, i.e., from which side of shared surface the vehicle intends to leave the intersection. Distances and shared surface dimensions can be obtained by several means, e.g., from map data stored on board or from a local roadside beam that transmits such data to approaching vehicles. All this information is requested in step S2 before an intersection-crossing vehicle enters the dedicated road of an intersection. In step S3, the vehicle that requested the data from other intersection-crossing vehicles, receives the requested data.

[0038] In step S4, the vehicle checks whether all the requested data has been received. In case not all the requested data is received on time, then in step S5, it is checked whether the vehicle is about to enter a dedicated road of the intersection. If the vehicle is not entering a dedicated road of the intersection, then the vehicle is trying to receive further information data from other vehicles in step S3. If, however, the vehicle is about to enter a dedicated road of the intersection, then the vehicle must stop as illustrated by step S6 for safety reasons by means of an auto-pilot that takes over control of the vehicle. Other vehicles will continue using the last received schedule until a new one can be computed and sent.

[0039] Once all data is received in step S4, the next step S7 consists of determining the order at which vehicles will travel across the shared surfaces of the intersection, i.e., the schedule, comprising the dates at which each vehicle must reach each shared surfaces on its route and for how much time these shared surfaces are allocated to a vehicle, is computed. Only one vehicle is allowed to use each shared surface at a time for obvious safety reasons, but the possibility that several shared surfaces are allocated to the same vehicle has to be taken into account. For example, this is the case, if a vehicle, such as a bus or a truck, is longer than the width of a single shared surface. All shared surfaces and vehicles must be scheduled together at the same time because they are interdependent. Each vehicle might travel different shared surfaces in a different sequence and within different possible time windows, which may interfere on other vehicle or shared surface schedules.

[0040] Various traffic modeling and scheduling methods exist to determine the above-mentioned intersection schedule for all shared surfaces for a limited number of intersection-crossing vehicles under the condition that the time intervals for a shared surface are mutually disjoint so that no two vehicles are on the same shared surface within the same time period when crossing the intersection.

[0041] For example, due to the complexity of the scheduling problem, instead of an optimal analytical solution, it is preferable to determine a sub-optimal schedule by using optimization techniques such as dynamic programming, resource allocation algorithms or heuristics, or combinations thereof. In other words, instead of an optimal analytical solution in terms of the minimized travel, a "slightly" sub-optimal numerical solution is calculated while satisfying the constraint of a collision-free crossing of the intersection.

[0042] Another preferable approach is to determine the optimal solutions for each shared surface, and to combine them afterwards to determine the overall schedule. For modeling purposes, another preferred option is to develop a Petri Net model of the general scheduling problem and to design a respective controller in the form of another Petri Net.

[0043] Furthermore, it is beneficial to set up dioid equations describing the scenarios allowed by each shared

surface, which eases the computation of the schedule using an algorithm derived from either dynamic programming or resource allocation algorithms or more didbid-specific controllers based on, for instance, residuation theory.

[0044] After the schedule for crossing the intersection has been computed, it is broadcasted in step S8 to all other vehicles. In order to increase efficiency and to reduce communication overhead, each vehicle may receive only its own time table.

[0045] Then, in step S9, the invention apparatus computes a self optimal speed profile from the current position to the exit of the intersection, in order to traverse the shared surfaces exactly during the time intervals as determined by the schedule. It is important not to be late or in advance at the shared surfaces, as they are allocated based on the determined schedule to each vehicle for a sharp and specific time window. For this reason, the speed profile is determined by the invention apparatus and the vehicle steering and velocity are automatically controlled by it all along the way in step S10 by switching to the auto-pilot mode.

[0046] As illustrated in step S11, as long as a vehicle has not yet crossed an intersection, it is configured to listen and to receive requests for vehicle travel data from other vehicles, for instance from a newcomer vehicle that enters the intersection area before it has reached the exit of the intersection. If a vehicle receives a request for vehicle travel data in step S11, the vehicle sends in step S12 a response thereto comprising all requested information to the newcomer vehicle, so that the newcomer vehicle is capable of computing and broadcasting an updated schedule (step S13).

In step S12, it is also possible for emergency vehicles to require high priority in schedule by sending a respective pre-defined identification code along with other information.

[0047] In case a new schedule is received in step S13, the vehicle specific speed profile may be adjusted again in step S9 to comply with new schedule.

[0048] Once a vehicle has quit the intersection (step S14), it will not answer broadcasted requests for information anymore. Moreover, vehicle may switch back to manual mode in step S15. In step S16, the vehicle initiates the switching back to manual mode so that the human driver can take over control of the vehicle. Before vehicle control is completely given back to the human driver in step S16, it may be safer to ensure that the driver is ready to take over again the control of vehicle.

[0049] Fig.5 illustrates the application of the invention for an intersection with departed shared surfaces. Turning can dramatically decrease the efficiency of traffic flows as the vehicles must slow down in curves. In particular, turning left can lead to a significant speed decrease and to long shared surface occupancy duration. A road and traffic flow structure as shown in Fig. 5, although not mandatory, would best take advantage of the scheduling method of the invention. Based on the road

structure of Fig. 5, the shared surfaces 52 and 53 are deported from the original intersection area 51 by means of slip-roads 53. Thus, it is advised to adapt road structures to translate turning at an intersection 51 into deported shared surfaces 52 usage scheduling, by means of slip-roads 53, where possible. Many motorway interchanges are already built with similar designs worldwide.

[0050] Fig. 6 illustrates the scheduling of four vehicles at an intersection according to an embodiment of the invention. Vehicle 66 arrives first at 000 to turn right at the intersection, i.e., when vehicle 66 enters the intersection area, no other intersection-crossing vehicle is currently within the intersection area. Since there is no other vehicle within the intersection area, vehicle 66 computes speed profile and switches to autopilot.

[0051] Meanwhile, vehicle 67 arrives at 002 to turn left at the intersection. After having detected the presence of vehicle 66, vehicle 67 requests vehicle travel data information from vehicle 66 and, after having received said vehicle travel data from vehicle 66, vehicle 67 computes the schedule for the shared surface 64 as this is the only common shared surface of routes 69 and 611. The computed schedule allocates shared surface 64 to vehicle 66 within the time interval from 006 to 007 and to vehicle 67 from 007 to 009.

[0052] Durations of time intervals allocated to the shared surfaces are related to distance required to drive on a shared surface as well as the speed profile. Vehicle 66 may be required to slow down to match its schedule, i.e. not to arrive too early at the shared surface 64.

[0053] Vehicle 68 arrives at 004 to drive straightforward through the intersection. The arrival of vehicle 68 triggers a similar re-calculation of the schedule as described for the vehicle 67. Vehicle 65 arrives at 005 also with a driving path that will lead vehicle 65 straightforward through the intersection. Vehicle 65 travels across the shared surfaces 64 and 63, thus every vehicle and shared surface is directly or indirectly concerned. In such a case, all vehicles and shared surfaces must be rescheduled, as there are a lot of strong interactions between them due to competitive, overlapping driving plans. For instance, vehicle 67 might need shared surface 64 for a long period of time, as it needs to slow down dramatically in order to operate a left turn. This might be directly penalizing vehicles 65, but also indirectly vehicle 68. Indeed, if vehicle 65 must slow down because of vehicle 67 using shared surface 64, then it may use shared surface 63 for a longer period of time. Hence, although vehicle 68 will not drive through shared surface 64, schedules of these two items are strongly related.

[0054] Fig. 7 illustrates a block diagram of a device 70 for scheduling vehicles at intersections according to another embodiment of the invention. The device 70 comprises a sender 71 for requesting vehicle travel data from vehicles within a pre-determined distance from an intersection. The sender 71 is further configured to transmit the determined schedule to all intersection-crossing vehicles and to receive said determined schedule in case

the schedule is determined by another vehicle. After the vehicle is entering an intersection area, i.e., the vehicle is within a pre-determined distance from the next intersection for the first time, the sender 71 is configured to send a request for vehicle travel data to other vehicles within the intersection area.

[0055] The device further includes a receiver 72 for receiving the requested vehicle travel data from intersection-crossing vehicles. The device 70 further comprises means 74 for determining shared surfaces of the intersection for each vehicle based on the received vehicle travel data and a scheduling unit 75 for determining a schedule for the vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each vehicle. Furthermore, the device 70 includes an auto-pilot unit 77 for steering the vehicles in automatic mode across the intersection based on the determined schedule. The device 70 further includes sensor means 78 for detecting a vehicle orientation 78a, velocity 78b and position 78c. The device also comprises or is connected to a navigation unit 76 wherein the navigation unit 76 calculates a driving route and a velocity-time distribution for the vehicles for arriving at the determined shared surfaces as determined by the schedule for crossing the intersection. The auto-pilot unit 77 switches to automatic mode to steer the vehicle across the intersection based on the calculated driving route and velocity-time distribution of the navigation unit 76.

[0056] Features, components and specific details of the structures of the above described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are readily apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination, for the sake of conciseness of the present description.

Claims

1. A method for scheduling vehicles at intersections, the vehicles being configured to be steered in manual mode by a driver and in automatic mode by an auto-pilot, the method comprising the steps of :
 - requesting vehicle travel data of vehicles within a pre-determined distance from an intersection;
 - in response thereto, receiving the requested vehicle travel data from intersection-crossing vehicles, wherein an intersection-crossing vehicle is a vehicle within the pre-determined distance of the intersection that is approaching the intersection to traverse the intersection;
 - determining shared surfaces of the intersection for each intersection-crossing vehicle based on the received vehicle travel data, wherein a shared surface is a partial surface area of the

intersection that is defined from the intersection of intersection-crossing vehicles driving paths at the intersection; and wherein the shared surfaces of an intersection-crossing vehicle are the shared surfaces of the intersection that are crossed by the intersection-crossing vehicle;

- determining a schedule for the intersection-crossing vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each intersection-crossing vehicle;
- steering the intersection-crossing vehicles in automatic mode across the intersection based on the determined schedule.

2. The method according to claim 1, wherein the determined schedule determines a time interval for every shared surface of every intersection-crossing vehicle, within which the intersection-crossing vehicle is scheduled to traverse said shared surface, wherein the time intervals of different intersection crossing vehicles for the same shared surfaces are mutually disjoint.
3. The method according to at least one of the claims 1 or 2, further comprising the step of determining a velocity-time distribution for the intersection-crossing vehicles for arriving at the determined shared surfaces at a time according to the determined schedule.
4. The method according to at least one of the preceding claims, wherein the determined schedule minimizes a travel time for crossing the intersection, wherein the travel time is a maximum time of one of the intersection-crossing vehicles for traversing the intersection or a sum of travel times for all intersection-crossing vehicles.
5. The method according to at least one of the preceding claims, further comprising the step of transmitting a vehicle-specific schedule to the intersection-crossing vehicles.
6. The method according to at least one of the preceding claims, wherein the received vehicle travel data from each intersection area vehicle comprises at least the current vehicle position, current vehicle velocity and the targeted intersection exit of said vehicle.
7. The method according to at least one of the claims 3 to 6, wherein at the step of determining the velocity-time distribution, each intersection area vehicle calculates its own velocity-time distribution based on the determined schedule.
8. The method according to at least one of the preced-

ing claims, wherein the steps of requesting vehicle travel data, receiving the requested vehicle travel data, determining shared surfaces of the intersection, and determining a schedule for crossing the intersection is carried out by the latest intersection-crossing vehicle whose distance from the intersection fell below the pre-determined value.

9. A device (70) for scheduling vehicles at intersections, the vehicles being configured to be steered in manual mode by a driver or in automatic mode by an auto-pilot, the device comprising :

- a sender (71) for requesting vehicle travel data from vehicles within a pre-determined distance from an intersection;
- a receiver (72) for receiving the requested vehicle travel data from intersection-crossing vehicles, wherein an intersection-crossing vehicle is a vehicle within the pre-determined distance of the intersection that is approaching the intersection to traverse the intersection;
- means (74) for determining shared surfaces of the intersection for each intersection-crossing vehicle based on the received vehicle travel data, wherein a shared surface is a partial surface area of the intersection that is defined from the intersection of intersection-crossing vehicles driving paths at the intersection, and wherein the shared surfaces of an intersection-crossing vehicle are the shared surfaces of the intersection that are crossed by the intersection-crossing vehicle;
- a scheduling unit (75) for determining a schedule for the intersection-crossing vehicles for a collision-free crossing of the intersection based on the determined set of shared surfaces for each intersection-crossing vehicle;
- an auto-pilot unit (77) for steering the intersection-crossing vehicles in automatic mode across the intersection based on the determined schedule.

10. The device according to claim 9, wherein the sender (71) is further configured

- to transmit the determined schedule to all intersection-crossing vehicles and
- to receive said determined schedule.

11. The device according to claim 10, wherein the sender (71) is further configured to send a request for vehicle travel data after the vehicle is within a pre-determined distance from an intersection for the first time,

12. The device according to claim 10 or 11, wherein the device (70) further comprises sensor means (78) for

detecting a vehicle velocity, orientation and position.

13. The device according to one of the preceding claims 10 - 12, wherein the device further comprises a navigation unit (76).

14. The device according to claim 13, wherein the navigation unit (76) is further configured to calculate a driving route and a velocity-time distribution for the intersection-crossing vehicles for arriving at the determined shared surfaces as determined by the schedule for crossing the intersection.

15. The device according to claim 14, wherein the auto-pilot unit (77) switches to automatic mode to steer the intersection crossing vehicle across the intersection based on the calculated driving route and velocity-time distribution of the navigation unit (76).

Fig. 1

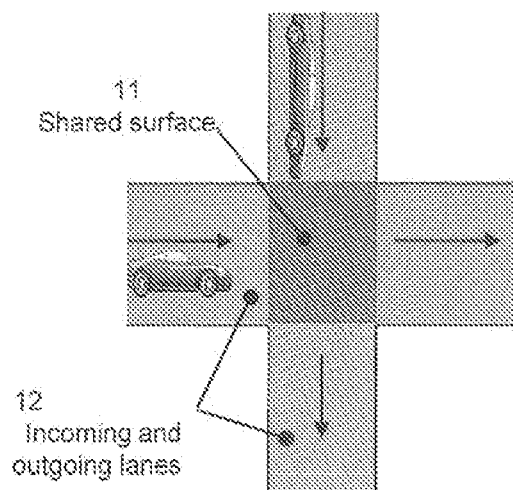


Fig. 2

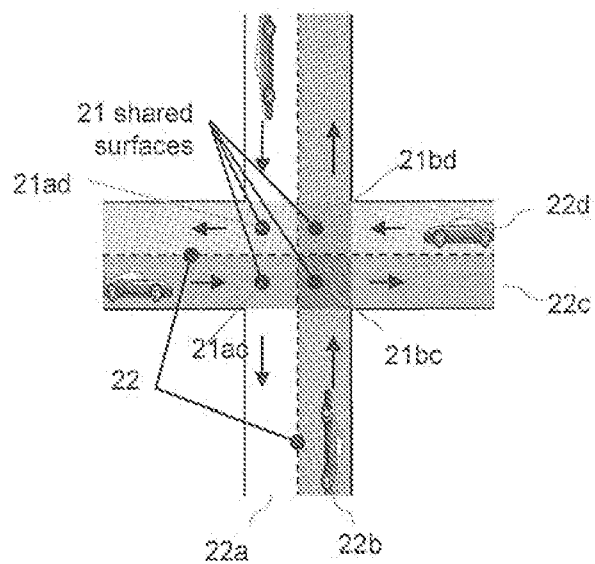


Fig. 3

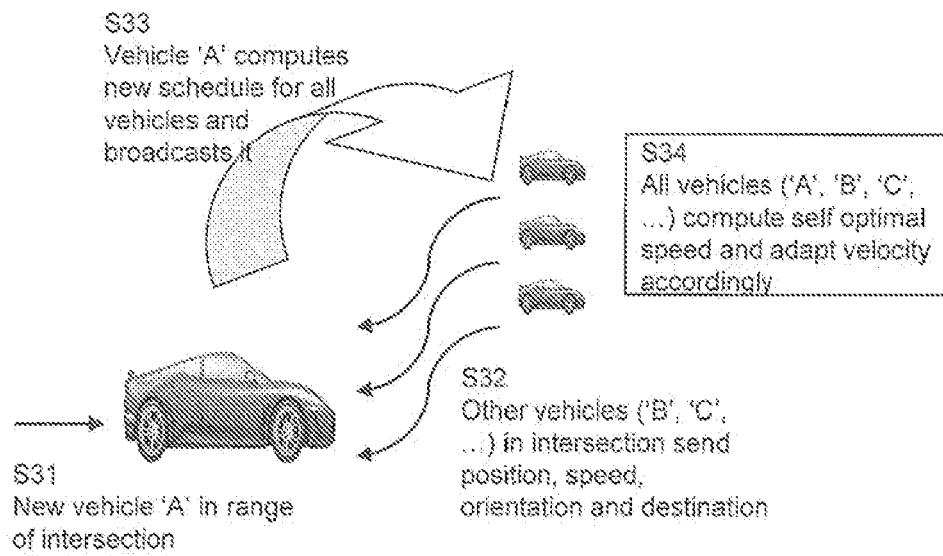


Fig. 4

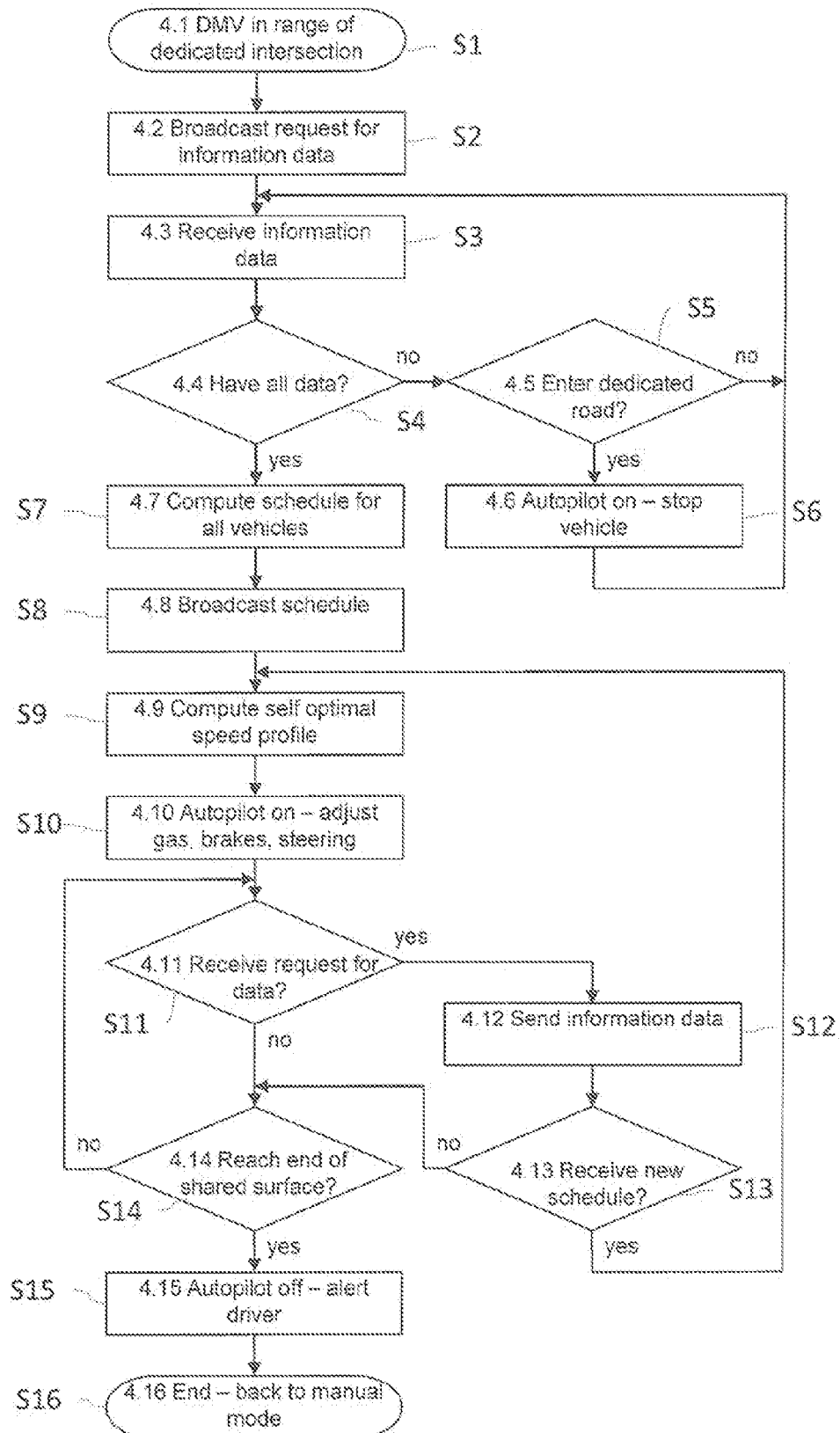


Fig. 5

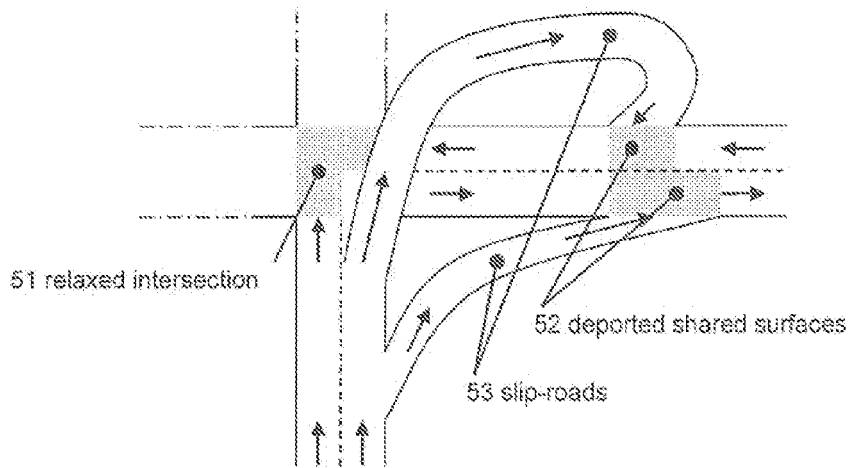


Fig. 6

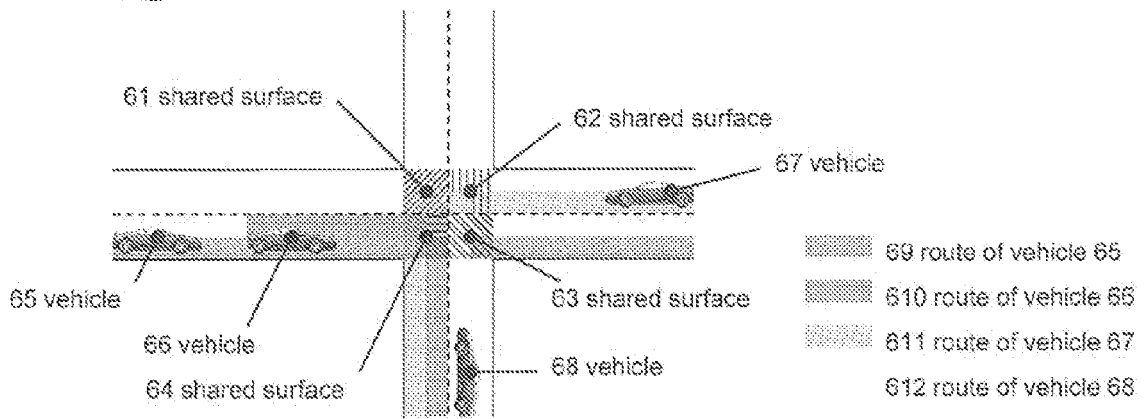
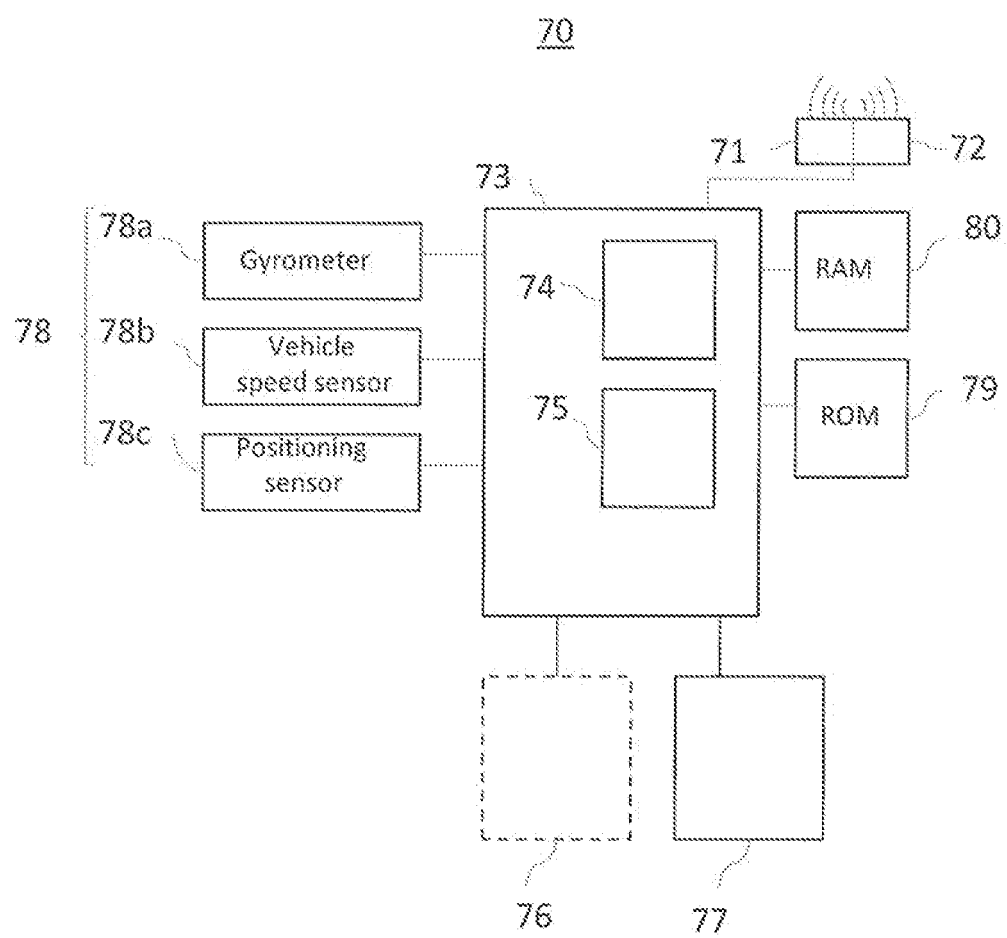


Fig. 7





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Application Number
EP 09 16 6513

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Place of search The Hague		Date of completion of the search 3 March 2010	Examiner Nanos, Alexander
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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