

Description

Method for preventing a collision between an autonomous vehicle and a user in a movement range of the autonomous vehicle and system

The present invention relates to a method for preventing a collision between an autonomous vehicle and a user in a movement range of the autonomous vehicle. Furthermore, the present invention relates to a system for preventing a collision between an autonomous vehicle and a user in a movement range of the autonomous vehicle.

Autonomous vehicles are increasingly becoming a reality. The manufacturers are attempting to increase the autonomy of motor vehicles and trucks in road traffic. Autonomous vehicles, such as for example unmanned forklift trucks, are in productive use in warehouses and at production sites in order to optimize the logistics chain. Both in road traffic and in industry the avoidance of collisions between these autonomous vehicles and users or people is of the highest priority. This is a decisive technical challenge which has to be met.

US 2015/228 195 A1 and US 2017/345 292 A1 have as their content, for example, an improved way of taking into account pedestrians who are crossing a road. US 2015/228 195 A1 discloses, for example, the displaying of a pedestrian crossing on the road.

US 9 884 585 B1 has as its content the comparison of the respective path of a vehicle and of a pedestrian and a provision of a display for the pedestrian.

In the field of road traffic, the technological solutions for this challenge are concentrated nowadays on the optimization of

the use of onboard sensors. For example, vehicles are known which have radar sensors for sensing the surroundings. Both in road traffic and in industry it is known that free passage or a safe zone is indicated to a user, for example, by the autonomous vehicle stopping in front of the user. However, this is a rather implicit indication. In industry it is additionally known to use onboard signals of the autonomous vehicles to indicate a risk. For example, corresponding flashing lights on the autonomous vehicles are used. However, this is only a preventative step.

The object of the present invention is to disclose a solution as to how a collision can be reliably prevented between an autonomous vehicle and a user in a movement range of the autonomous vehicle.

This object is achieved according to the invention by means of a method and by means of a system having the features according to the independent claims. Advantageous developments of the present invention are specified in the dependent claims.

A method according to the invention serves to prevent a collision between an autonomous vehicle and a user in a movement range of the autonomous vehicle. The method comprises receiving a time-dependent, planned path of the autonomous vehicle and a time-dependent, planned path of the user. Furthermore, the method comprises determining a time-dependent path network by means of a path network unit, wherein the time-dependent path network describes the planned paths. In addition, the method comprises determining collision information which describes an overlap of the planned paths in the time-dependent path network, and determining a safe zone for the user on the basis of the collision information, wherein the safe zone describes an area in the movement range which is safe for the user with respect to a collision with the

autonomous vehicle. Finally, the method comprising providing a display for the user by means of a display device, wherein the display describes the safe zone.

The method is intended to be used to prevent a collision between the autonomous vehicle and the user. The user can be, in particular, a person who is located in the movement range of the autonomous vehicle. This movement range describes the area in which the autonomous vehicle is maneuvered autonomously. At least the path network unit is used to carry out the method. A time-dependent path network is determined by means of this path network unit. This time-dependent path network describes at least the planned paths of the autonomous vehicle and of the user. The planned paths of the autonomous vehicle and of the user therefore describe how the autonomous vehicle and the user will move in future. The respective planned paths can describe, for example, corresponding reference points along the path and associated times. On the basis of the planned paths it is therefore possible to determine the time at which the user and the autonomous vehicle will be located at which position.

Moreover, the collision information is determined by means of the path network unit. This collision information describes whether there are overlaps between the planned paths in the time-dependent path network or not. A safe zone or a free passage can then be determined in accordance with this collision information by means of the path network unit. This safe zone describes an area in the movement range of the autonomous vehicle which is safe for the user with respect to a collision with the autonomous vehicle. In other words, no overlap therefore occurs between the planned paths in this safe zone. In this safe zone there is therefore no risk of a collision between the autonomous vehicle and the user. On the basis of this safe zone, the user is provided with a display

which describes the safe zone. In other words, the safe zone or the free zone is therefore displayed to the user.

In comparison with known methods for preventing a collision between an autonomous vehicle and a user, the method according to the invention has the advantage that the collision is prevented in a centralized fashion, and the safe zone or free passages are signaled explicitly to the user. This central collision prevention is carried out by means of the mechanism for managing the time-dependent path network by means of the path network unit. The explicit signaling is carried out by means of the display device whose display is determined on the basis of the evaluation of the time-dependent path network. Overall, a collision between an autonomous vehicle and a user can therefore be prevented more reliably.

According to the invention, in addition an unsafe zone, in which there is a risk of a collision between the autonomous vehicle and the user, and a zone of increased attention between the safe zone and the unsafe zone are determined on the basis of the collision information. The unsafe zone and the zone of increased attention are also displayed to the user. In this case, the safe zone can be displayed to the user, for example, in green. Furthermore, the unsafe zone can be displayed in red. The zone of increased attention, which describes a transition area between the safe zone and the unsafe zone, can be displayed, for example, in orange. Therefore, the user can easily perceive which route he has to take and whether he is still in the safe zone.

The planned paths are preferably received by a communication unit and are transmitted to the path network unit. Alternatively or additionally, the collision information is transmitted from the path network unit to the communication unit. The communication unit serves, on the one hand, to

communicate with the autonomous vehicle and the user or a terminal of the user. This means that the communication unit can receive information or signals from the autonomous vehicle and/or the user and can transmit them thereto. For example, the communication unit can receive information or data relating to the planned paths from the autonomous vehicle and the user. On the other hand, the communication unit serves to communicate with the path network unit. The planned paths or corresponding data which describe the planned paths can be transmitted to the path network unit by the communication unit. The communication unit can also receive the collision information from the path network unit. In addition, the communication unit can be designed to actuate the display device to present the display. This can ensure overall that reliable communication is carried out.

In one embodiment, in addition to the planned path of the user a reservation for the planned path is received, and this reservation is confirmed in accordance with the collision information. The user can at least indirectly transmit the reservation, together with the planned path, to the communication unit, and these data can then be transmitted to the path network unit. In this context, the reservation can relate to the entire planned path of the user. It is also possible to provide that the reservation relates to an overlap of the planned paths of the autonomous vehicle and of the user. If it is detected by means of the path network unit on the basis of the collision information that there is no risk of a collision for the reserved area of the path, this reservation can be correspondingly confirmed. For this purpose, a corresponding signal can be transmitted to the user or to a terminal of the user. The reservation confirmation can also be provided directly by displaying the safe zone.

In a further embodiment, blocking information is transmitted to the autonomous vehicle if the collision information describes an overlap of the planned paths, wherein the blocking information describes that the path which is planned by the autonomous vehicle is blocked. In order to protect the user against a collision with the autonomous vehicle, a relatively high priority can be assigned to said vehicle. If it is detected on the basis of the collision information that an overlap of the planned paths is present, a block can be issued for the travel of the autonomous vehicle along the planned path. In this way, a collision between the autonomous vehicle and the user can be reliably prevented.

The planned path of the autonomous vehicle is preferably changed in accordance with the blocking information, and the changed path is transmitted to the path network unit. If the autonomous vehicle receives the blocking information, a first variant consists in the fact that the autonomous vehicle changes the planned path. In this case, a changed path which deviates from the original planned path is therefore determined. A further variant consists in the fact that after the reception of the blocking information the autonomous vehicle carries out the travel on the planned path but adapts the travel correspondingly. For this purpose, for example the speed of the autonomous vehicle can be adapted, or the autonomous vehicle can be correspondingly stopped during the travel along the planned path. The changed, time-dependent path can be transmitted to the path network unit mediated by the communication unit. In this way, the path network unit can update the time-dependent path network on the basis of the changed path.

Furthermore it is advantageous if a position of the autonomous vehicle and/or a position of the user are/is determined continuously, and the planned paths are updated continuously.

For this purpose, for example corresponding sensors can be used by means of which the autonomous vehicle and/or the user can be continuously sensed. On the basis of the sensed positions it is then possible to update the planned path of the autonomous vehicle and/or the planned path of the user continuously and make them/it available to the path network unit. In this way, the path network unit can update the time-dependent path network continuously. It is also preferably provided that the communication unit is determined continuously by means of the path network unit. In this way, a collision between the autonomous vehicle and the user can be prevented with a high level of certainty.

In a further embodiment, the user is informed about a possible collision with the autonomous vehicle if it is detected on the basis of the collision information that the planned paths overlap. There can be provision that the autonomous vehicle which is moving is assigned a higher priority than the user or the person since the autonomous vehicle cannot be easily brought to a standstill. If the possible collision or the overlap of the planned paths is detected when there is such a prioritization of the autonomous vehicle, corresponding information can be transmitted to the user. The user can therefore be informed that he will collide with the autonomous vehicle. Basically, the priorities can be distributed as desired.

According to a further refinement, changes to the planned paths are determined by means of the path network unit, and the changes are transmitted to the autonomous vehicle and/or the user. For example, the current positions and destinations of the autonomous vehicle and/or of the user can be monitored continuously by means of the path network unit. The path network unit can determine optimum paths for the autonomous vehicle and/or the user on the basis of the current positions

and/or the destinations. These paths can then be transmitted, for example, as a suggestion to the user and preferably to the autonomous vehicle and/or the user. There is preferably provision that the suggestion for an optimized path is transmitted to the autonomous vehicle, and the display, which describes the safe zone and which is presented to the user, is correspondingly adapted. This permits reliable prevention of a collision between the autonomous vehicle and the user. In addition, the paths of the participants can be optimized. For example, by means of the path network unit it is possible to determine whether the autonomous vehicle arrives at a destination more quickly if it changes its path or if it moves along the planned path and in the process interrupts the travel.

A virtual crosswalk is preferably displayed as the display to the user. Such a virtual crosswalk or an image of a crosswalk can be displayed to the user in the free zone. In particular, such a crosswalk is displayed in the area in which the planned paths of the user and of the autonomous vehicle overlap. If the autonomous vehicle is moved, for example, in a corridor or on a route, the virtual crosswalk or the image of the crosswalk can be displayed on this route. Therefore it is intuitively communicated to the user that he can enter or can cross through the area in which the crosswalk is displayed.

In a further embodiment, the display device is part of a terminal which can be carried by the user. The portable terminal can be, for example, a smartphone, a tablet or the like. A corresponding application can be made to run on this terminal in order to provide the display. An image of the movement range of the autonomous vehicle can be presented on this display device, which is formed, for example, by a screen of the terminal. In addition, the display can be presented. The portable terminal can be VR glasses, data glasses or the like.

The terminal can be a visual output device which is worn on the user's head.

In an alternative embodiment, the display is projected onto a floor, and/or the display is displayed on the floor by means of the display device. The display can be projected, for example, onto the floor. For this purpose, corresponding projection devices can be used which are mounted, for example, on a ceiling of an industrial building. In addition, the projection devices can be attached to the autonomous vehicle. According to a further embodiment, a floor on which corresponding display elements are present which together form the display device can be provided, in particular, in an industrial building, a warehouse or a factory. These display elements can be, for example, corresponding OLED displays or LED strips.

The method according to the invention is preferably carried out in a factory and/or in a warehouse. The method can be used, for example, in a factory or production building in which the autonomous vehicle serves to support the fabrication. The user can be a pedestrian or worker who is also moving in this factory or in this warehouse building. In particular, the method is therefore suitable for industry. There may also be provision that the method is used in road traffic.

The method has been described for an autonomous vehicle and a user. The method can also be expanded to a plurality of autonomous vehicles and/or a plurality of users.

A system according to the invention serves to prevent a collision between an autonomous vehicle and a user in a movement range of the autonomous vehicle. The system comprises a path network unit for receiving a time-dependent, planned path of the autonomous vehicle and a time-dependent, planned

path of the user. In addition, the path network unit serves to determine a time-dependent path network, wherein the time-dependent path network describes the planned paths. Moreover, the path network unit serves to determine collision information which describes an overlap of the planned paths in the time-dependent path network. The path network unit also serves to determine a safe zone for the user on the basis of the collision information, wherein the safe zone describes an area in the movement range which is safe for the user with respect to a collision with the autonomous vehicle. Furthermore, the system comprises a display device for providing a display for the user, wherein the display describes the safe zone. Furthermore, the system can comprise a communication unit which serves to communicate or transmit data between the autonomous vehicle, the user or a terminal of the user and the path network unit.

The preferred embodiments which are presented with respect to the method according to the invention and the advantages thereof apply correspondingly to the system according to the invention.

Further features of the invention emerge from the claims, the figures and the description of the figures. The features and feature combinations specified in the description above and the features and feature combinations specified in the description of the figures below and/or shown in the figures alone can be used not only in the respectively specified combination but also in other combinations without departing from the scope of the invention.

The invention will now be explained in more detail on the basis of preferred exemplary embodiments and with reference to the appended drawings, in which:

FIG 1 shows a schematic illustration of a warehouse building in which an autonomous vehicle and a user are located;

FIG 2 shows a schematic illustration of a system for avoiding a collision between the autonomous vehicle and the user;

FIG 3 shows a schematic illustration of the time-dependent, planned paths of the autonomous vehicle and of the user;

FIG 4 shows an exemplary illustration of a display on the factory floor; and

FIG 5 shows a display on the floor according to a further embodiment.

Identical or functionally identical elements are provided with the same reference symbols in the figures.

FIG 1 shows a schematic illustration of a factory 1 in which an autonomous vehicle A and a user B are located. The autonomous vehicle A can be, for example, an autonomous forklift truck. The user B is a human or a pedestrian. The autonomous vehicle A is located on the route to a destination 2. The autonomous vehicle A is located here in a first corridor 3 and is planning the route to the destination 2 via a second corridor 4, wherein it plans to turn off to the left from the first corridor 3 into the second corridor 4. The user B would like to cross this second corridor 4. The view of the autonomous vehicle A to the user B is obstructed by a wall 5 here. As a result there is an increased risk of a collision taking place between the autonomous vehicle A and the user B.

In order to avoid the collision between the autonomous vehicle A and the user B, a system 6 is used. Such a system 6 is illustrated schematically in FIG 2. This system 6 comprises a communication unit 7 which receives a time-dependent, planned path P1 from the autonomous vehicle A. This is indicated here by the arrow 9. Moreover, the communication unit 7 can receive a time-dependent, planned path P2 from the user B. This is indicated by the arrow 10. The user B can transfer a reservation for his planned path P2 together with the planned path P2.

Moreover, the system 6 comprises a path network unit 8 which is connected to the communication unit 7 for transmitting data. The planned paths P1, P2 are transmitted from the communication unit 7 to the path network unit 8 (arrow 11). A time-dependent path network, which describes the planned paths P1, P2, is determined by means of the path network unit 8. This is indicated by the arrow 12. A collision signal, which describes whether an overlap occurs between the planned paths P1, P2, is determined by means of the path network unit 8.

In this respect, FIG 3 shows an example which shows a schematic view of the planned path P1 of the autonomous vehicle A and of the planned path P2 of the user B. The respective planned paths P1, P2 show the respective reference points which are reached at the times t1 to t10. In this context it is to be detected that there is an overlap of the paths P1 and P2 between the times t9 and t10. The path network unit 8 transmits the collision signal or the information that there is an overlap of the paths P1, P2 to the communication unit 7 (arrow 13). Since the human user B has priority over the autonomous vehicle A, the communication unit 7 transmits a blocking signal to the autonomous vehicle A and the time of the possible collision in the path network (arrow 14).

According to a first variant, the autonomous vehicle A can change the planned path P1 or calculate a planned path. According to the example in FIG 1, this can be achieved in that the autonomous vehicle A does not turn off to the left from the first corridor 3 into the second corridor 4 but rather turns off to the right into the second corridor 4. In this case, a changed path is calculated for the autonomous vehicle A (arrow 15) and is transmitted to the communication unit 7 and from there to the path network unit 8. The time-dependent path network can then be updated by means of the path network unit 8 (arrow 16). In this context it is detected that there is no overlap between the paths P1 and P2. In this case, a display device 19, which is assigned to the user B, can be correspondingly actuated (arrow 17). In addition, the reservation of the user B can be confirmed to the user. For example, the display device 19 can be assigned to a terminal 18 of the user B. The terminal 18 may be a smartphone, VR glasses, data glasses or the like. A display 20, which displays a safe zone 23 to the user B, can be provided by means of the display device 19. In this safe zone 23 there is no risk of a collision between the autonomous vehicle A and the user B. A virtual crosswalk 21 is displayed on the floor 22 or in the second corridor 4 here as the display 20.

According to a further variant, the autonomous vehicle A can remain on the planned path P1 and calculate its own trajectory again. For example, the speed by means of which the autonomous vehicle A is moved along the planned path P1 can be adapted. This changed, planned path can then be transmitted correspondingly to the communication unit 7 and from there to the path network unit 8. If the autonomous vehicle A reduces its speed or stops, for example, during the travel along the planned path P1, there is no risk of a collision with the user B. This can be detected during the checking of the time-

dependent path network by means of the path network unit 8. In this case, the display 20 is provided to the user B.

The respective paths P1, P2 can be specified by the autonomous vehicle A and the user B. There can also be provision that the respective positions of the autonomous vehicle A and of the user B are sensed continuously with corresponding sensors, for example radar sensors or infrared sensors. In addition, movements of the autonomous vehicle A and of the user B can be transmitted continuously to the path network unit 7. Deviations from the planned paths P1, P2 can then be detected and communicated to the autonomous vehicle A and to the user B. There may also be provision that priorities relating to a right of way are specified in a flexible way. For example, the autonomous vehicle A can be assigned a higher priority than the human user B, since the autonomous vehicle A cannot simply brake. In this case, the user B can be informed that a collision can take place with the autonomous vehicle A.

Modern factories will have floor plans in which floor-based vehicles, robots and even production units are moved in a mobile and autonomous fashion. In a further embodiment, the safe zone 23 can be displayed on the floor 22. Moreover, unsafe zones 24 can be displayed on the floor 22. For example, the safe zones 23 can be displayed as a green line, and the unsafe zones 24 as a red line. Such a display 20 could be implemented, for example, by a corresponding projection with projection elements. For example, corresponding lasers could be arranged on the ceiling of the factory 1. Alternatively, illuminated floor tiles 26, which are provided, for example, by means of OLED matrices or LED strips, could be used. FIG 4 shows in this respect an example in which the floor 22 of the factory 1 is covered with illuminated floor tiles 26. In this context, the safe zone 23 and the unsafe zone 24 are displayed for the planned paths P1, P2. In addition, a zone 25 of increased

attention is displayed. This zone of increased attention 25 can be displayed, for example, in orange. By means of these displays, the user can be intuitively informed where he can safely move and at which locations there may be the risk of a collision with an autonomous vehicle A.

There can also be provision that the positions and destinations of the autonomous vehicle and of the user are recorded continuously. The optimum routes can then be calculated by means of the path network unit 8 and transmitted, for example, to the non-human participants. The floor tiles 26 can herein be illuminated for the human participants.

FIG 5 shows a further example in which safe zones 23 and unsafe zones 24 as well as zones of increased attention 25 are displayed dynamically. This can also be done independently of the planned paths P1, P2. In this context, the zones of increased attention 25 are displayed as transition areas between the safe zones 23 and the unsafe zones 24. In combination with working areas for humans and working areas for machines the path network unit can determine the areas which are safe for human users B.

By using the system 6 and, in particular, the path network unit 8 a central control unit is provided which monitors the planned paths P1, P2 and which can block paths and can display virtual crosswalks 21 to the user B. This display 20 or the virtual crosswalk 21 can be displayed to the user B on his smartphone or a VR device. A display of the infrastructure may also be used. This provides the advantage that, in order to avoid a collision between the autonomous vehicle A and the user B, not only exclusively onboard sensors are used but also the centralized unit in the form of the path network unit 7. By means of the display of the virtual crosswalk 21, it can be explicitly displayed to the user B that it is possible to

safely cross the corridor 4 or a road. In this way, the user can be given a feeling of safety in comparison with implied signals, for example warning lights on autonomous forklift trucks. The checking of the paths P1, P2 and the prediction of the paths P1, P2 by the path network unit 8 permit optimum adaptation of the routes in order to avoid delays. For example, an autonomous vehicle A can reach the destination 2 more quickly if it selects a different route and avoids a delay owing to a stop.

Patent Claims

1. A method for preventing a collision between an autonomous vehicle (A) and a user (B) in a movement range of the autonomous vehicle, comprising the steps:

- receiving a time-dependent, planned path (P1) of the autonomous vehicle (A) and a time-dependent, planned path (P2) of the user (B),
- determining a time-dependent path network by means of a path network unit (8), wherein the time-dependent path network describes the planned paths (P1, P2),
- determining collision information which describes an overlap of the planned paths (P1, P2) in the time-dependent path network,
- determining a safe zone (23) for the user on the basis of the collision information, wherein the safe zone (23) describes an area in the movement range which is safe for the user (B) with respect to a collision with the autonomous vehicle (A), and
- providing a display (20) for the user (B) by means of a display device (19), wherein the display (20) describes the safe zone (23), wherein
- in addition an unsafe zone (24), in which there is a risk of a collision between the autonomous vehicle (A) and the user (B), and a zone of increased attention (25) between the safe zone (23) and the unsafe zone (24) are determined on the basis of the collision information, and the unsafe zone (24) and the zone of increased attention (25) are displayed to the user (B).

2. The method as claimed in claim 1, characterized in that the planned paths (P1, P2) are received by a communication unit (7) and are transmitted to the path network unit (8), and/or in that the collision information is transmitted from the path network unit (8) to the communication unit (7).

3. The method as claimed in claim 1 or 2, characterized in that in addition to the planned path (P2) of the user (B) a reservation for the planned path (P2) is received, and this reservation is confirmed in accordance with the collision information.

4. The method as claimed in one of the preceding claims, characterized in that blocking information is transmitted to the autonomous vehicle (A) if the collision information describes an overlap of the planned paths (P1, P2), wherein the blocking information describes that the path (P1) which is planned by the autonomous vehicle (A) is blocked.

5. The method as claimed in claim 4, characterized in that the planned path (P1) of the autonomous vehicle (A) is changed in accordance with the blocking information, and the changed path is transmitted to the path network unit (8).

6. The method as claimed in one of the preceding claims, characterized in that a position of the autonomous vehicle (A) and/or a position of the user (B) are/is determined continuously, and the planned paths (P1, P2) are updated continuously.

7. The method as claimed in one of the preceding claims, characterized in that the user (B) is informed about a possible collision with the autonomous vehicle (A) if it is detected on the basis of the collision information that the planned paths (P1, P2) overlap.

8. The method as claimed in one of the preceding claims, characterized in that changes to the planned paths (P1, P2) are determined by means of the path network unit (8), and the

changes are transmitted to the autonomous vehicle (A) and/or the user (B).

9. The method as claimed in one of the preceding claims, characterized in that a virtual crosswalk (21) is displayed as the display to the user.

10. The method as claimed in one of the preceding claims, characterized in that the display device (19) is part of a terminal (18) which can be carried by the user.

11. The method as claimed in one of the preceding claims, characterized in that the display (20) is projected onto a floor (22), and/or the display (20) is displayed on the floor (22) by means of the display device.

12. The method as claimed in one of the preceding claims, characterized in that the method is carried out in a factory (1) and/or in a warehouse.

13. A system (6) for preventing a collision between an autonomous vehicle (A) and a user (B) in a movement range of the autonomous vehicle (A), comprising:

- a path network unit (8) for receiving a time-dependent, planned path (P1) of the autonomous vehicle (A) and a time-dependent, planned path (P2) of the user (B), in order to determine a time-dependent path network, wherein the time-dependent path network describes the planned paths (P1, P2), in order to determine collision information which describes an overlap of the planned paths (P1, P2) in the time-dependent path network, and in order to determine a safe zone (23) for the user on the basis of the collision information, wherein the safe zone (23) describes an area in the movement range which is safe

- for the user (B) with respect to a collision with the autonomous vehicle (A), and
- a display device (19) for providing a display (20) for the user, wherein the display (20) describes the safe zone (23), wherein
 - the system (6) is designed in addition to determine an unsafe zone (24), in which there is a risk of a collision between the autonomous vehicle (A) and the user (B), and a zone of increased attention (25) between the safe zone (23) and the unsafe zone (24) on the basis of the collision information, and to display the unsafe zone (24) and the zone of increased attention (25) to the user (B).