

Description

Operating method for a loading system and automation system for controlling a loading system

The invention relates to an operating method for a loading system designed to load or move a load along a route, with which in order to avoid a collision between the load and objects in the environment, during the loading process an environment image file is recorded cyclically by means of an imaging sensor system.

The invention also relates to an automation system designed to control a loading system for loading or moving a load along a route, comprising an imaging sensor system arranged to scan an environment, a sensor data computing unit designed to cyclically capture sensor data of the sensor system and to create an environment image file and a control unit configured for fault safety designed to control the loading system.

In the context of the invention, functional safety is understood to mean the concepts and specifications described in ISO standard 13849-1. The standard DIN EN ISO 13849-1 "Sicherheit von Maschinen - Sicherheitsbezogene Teile von Steuerungen" [Safety of machinery - safety-related parts of control systems], sets specifications for the design of safety-related parts of controllers.

Collisions of a load of a crane, wherein in particular ISO containers are considered to be a load, with the environment or surroundings, wherein in this regard in particular stacks of ISO containers are assumed, or other obstacles, pose a problem with manually controlled cranes and also with

automatically controlled cranes. Collisions may result in damage to the crane itself, to the load or to objects in the environment or the crane surroundings, but also in injury or death of persons. Crane operators therefore require equipment for avoiding and preventing collisions.

WO 2020/221490 A1 already discloses a method for collision-free movement of a load with a crane.

The link

<https://new.siemens.com/global/en/markets/cranes/harbor-cranes/load-collision-prevention-system.html> also discloses a solution for controlling loading systems. Here a sensor node captures the crane environment with the aid of sensors (Radar, LIDAR, ultrasound etc.). A control node is responsible for the actual motion control of the crane. The sensor node creates two or three-dimensional maps of the crane environment from the sensor data. The sensor node determines the position of the load either by its own measurement with the aid of its sensors or it is communicated to it in another way. For collision detection, the sensor node continuously calculates whether objects in the crane environment violate a protected area around the load. Once the protected area is violated, the sensor node sends a stop signal to the control node. The control node has the control of the movement of the crane and in the event of an imminent collision, can now stop the crane as a function of the stop signal.

The control node is typically embodied as a PLC (programmable logic controller). On account of the high demands on storage and computing power for the processing of the sensor data and storage of the map, the sensor node is generally an industry PC with corresponding high-performance software. The hardware

currently used with the industry PC is not certified according to the valid safety criteria and the TÜV would not permit such a system as a safety controller. The high demands on storage and computing power are due to the high-frequency and sometimes three-dimensional capture of the environment.

The object of the present invention is to provide an operating method for a loading system, in which it is possible, despite the increased occurrence of data, to implement the collision avoidance on a specially certified controller designed for functional fault safety.

The object is achieved for an operating method for a loading system in that a digital load image file describing a spatial overall extent of the load is provided, an environment image file is cyclically recorded by means of an imaging sensor system, a protective distance is added to the data of the load image file and a collision model image file is therefore provided and a cutout file is provided as a virtually recorded image file with a viewing angle from a position of the load as a function of the route, wherein the cutout file is obtained as a reduced representation from the environment image file, a differential image file is provided from the collision model image file and the cutout file by means of differentiation, an evaluation step is carried out, wherein the differential image file is examined for a possible collision.

In the context of the invention, the following is understood from the term "from a position". The position could be a source or zero point in the load or any selected point in or on the load. This position need not necessarily lie in the center point, but it must be ensured that all components or

computing methods involved have the same understanding of this position or the reference point.

The method of the invention presented avoids the problem of the sensor node requiring a lot of information from the control node and possibly even having to be adjusted in a project-specific manner. As a solution it is proposed to move the collision calculation to the control node, the sensor node therefore transmits its view of the crane environment cyclically to the control node. From this reduced representation of the environment information, the control node is able to carry out a collision calculation. The calculations required for this could therefore also be carried out on a safety controller, in particular an automation controller designed for functional fault safety, and would therefore be certifiable by a TÜV or other institutions.

A continuation of the method makes provision with the imaging sensor system to record a point cloud as an environment image file and from the point cloud to convert the cutout file as a data-reduced first depth image from the perspective of a virtual camera from a position of the load as a function of the route, wherein the collision model image file is present as a second depth image or is converted herein.

Accordingly, a reduced depth image of the crane environment is obtained from an environment image file, which requires a very high quantity of data, with the aid of a "virtual camera" (cutout algorithm). Furthermore, a depth image of the load including a safety region of the load is now present. The present depth images can be subtracted from one another without an increased computing outlay. In a thus produced differential image, it is possible to identify whether a

safety area or protected area is violated. With the depth images, each point describes a distance value. In the simplest case, this distance value is the distance between an object surface and the sensor. The first depth image shows the crane environment as a distance from a position of the load or a load recording means and is updated dynamically. The second depth image can represent the surface of the protected area, for instance, and therefore forms the protected area around the load from the same position. It is possible to dynamically adjust the protected area on the basis of a driven speed.

To this end, an enveloping surface in the second depth image is adjusted dynamically about the protective distance.

In respect of an improved reaction time, the method provides that the differentiation for the provisioning of the differential image file from the collision model image file and the cutout file is not completed or the subtraction of the depth images starts in a focus area, since as soon as a first negative result exists, a collision statement can be made.

In order to achieve the best possible reaction time in the prediction of a possible collision, a differentiation can also begin in a focus area.

With a negative result, the protected area is violated and the crane reduces its speed or stops. With respect to the reaction time, a reaction to the collision avoidance can be initiated with the first negative result. In respect of a safety certification according to SIL or PL level, the collision detection is very well suited according to this method. Since this involves a simple arithmetic computing operation, namely subtraction, which can safely and quickly be made available as

a certified function in a safety controller designed for functional safety.

In respect of the nodes cited in the introduction, such as the sensor node and the control node, the method is advantageously executed on a sensor data computing unit and a control unit. The load image file is provided during a commissioning of the loading system, the sensor data, which is determined by means of the imaging sensor system, is captured cyclically on a sensor data computing unit and stored as the environment image file. The cutout file is calculated as a reduced representation of the environment image file on the sensor data computing unit or on a further computing unit, the conversion of the cutout file into the first depth image is carried out on the sensor data computing unit or on the further computing unit and the differentiation from the collision model image file and the cutout file is executed on a control unit designed for fault safety.

It is considered to be advantageous here for the collision calculation to be shifted onto the control node or onto the control unit. A collision calculation on the basis of two-dimensional depth images can now be carried out on the control node without effort.

In the context of the invention, there are two widespread forms of representation for a result of the stereoscopy or the recording of the image files. On the one hand, the point clouds and on the other hand depth images. A depth image is essentially the representation of a depth in a two-dimensional image by means of color coding. Here a grayscale representation is in most cases selected, but an encoding similar to a thermal image camera is also used now and again.

The depth images preferably have Cartesian coordinates which are scanned equidistantly. As a result of a known proximity in depth images, many evaluations can be carried out more easily and 2D processing operations applied.

A container crane or a container bridge is advantageously used as a loading system and a container or a container including a load receiving means is used as a load.

For the automation system cited in the introduction, the object is achieved in that a digital load image file describing a spatial overall extent of the load is present in the control unit designed for fault safety, the control unit designed for fault safety has a collision algorithm, which is designed to add a protective distance to the data of the load image file in order thus to provide a collision model image file, the sensor data computing unit has a projection means, which is designed to provide a cutout file as a virtually recorded image file with a viewing angle from one position of the load as a function of the route, wherein the projection means is designed to obtain the cutout file as a reduced representation from the environment image file, the collision algorithm is further designed to create a differential image file from the collision model image file and the cutout file by differentiation and an evaluation means is present, which is designed to examine the differential image file for a possible collision.

In order to minimize the computing outlay on a control unit designed for fault safety, the imaging sensor system and the sensor data unit is designed to record a point cloud as an environment image file and furthermore the projection means is

designed to convert the cutout file, from the point cloud, as a data-reduced first depth image from the perspective of a virtual camera from a position of the load as a function of the route, wherein the collision model image file exists as a second depth image in the control unit designed for fault safety.

Furthermore, the control unit designed for fault safety has an adjustment means, which is designed to dynamically adjust an enveloping surface area generated in the second depth image by the protective distance. A continuous adjustment of the safety regions during operation of a loading system is often required, since the design of the attachments may vary from system to system, and it is thus possible to react quickly to a system newly put into operation. The dynamic adjustment of the protected area is also dependent on the speed with which the load is currently moved, therefore e.g. with a high speed, the protected area can be selected to be large and with a lower speed the protected area can be selected to be smaller, but external disturbances, e.g. a known uncertainty or a noise of the sensor can be taken into account.

In respect of a rapid reaction time, the collision algorithm has a focusing means, which is designed to begin the subtractions of the depth images in a focus area, in order to obtain the best possible reaction time with respect to the collision.

A differentiation for the provisioning of the differential image file from the collision model image file and the cutout file may not necessarily be completed. Since, if the subtraction of the depth images starts in a particularly

relevant focus area, a stop signal can be output as soon as the differentiation supplies a negative result.

The drawing shows an exemplary embodiment of the invention, in which

FIG 1 shows a block diagram representation of an automation system,

FIG 2 shows a side view of a loading system (crane),

FIG 3 shows a simplified representation of the environment with container stacks and simplified depth images from the bird's eye view,

FIG 4 shows a side view of the crane with a load and a protected area and

FIG 5 shows the same side view of the crane with a load and a protected area, which is violated.

According to FIG 1, an automation system 100 is designed to control a loading system for loading or moving a load L along a route x. The automation system 100 is essentially divided into a sensor data computing unit 12 and a control unit 14, wherein the control unit 14 is a certified programmable logic controller designed for functional safety. According to the prior art, the problem was that extensive quantities of data of projection images could only be evaluated on a high-performance industry PC. The invention now advantageously proposes that only one cutout file is provided as a reduced representation from an environment image file UBD for a

possible collision calculation on the control unit 14 of the control unit.

A point cloud 20 made from sensor data 11 is obtained from the real world U by means of an imaging sensor system C, for instance LIDAR. This sensor data 11 is cyclically stored in a memory 15 of the sensor data computing unit 12 as the point cloud 20. The environment image file UBD is produced therefrom.

The control unit 14 designed for fault safety, in particular for functional fault safety, is basically designed to completely control the loading system. In accordance with the invention, a collision calculation is now also carried out on the control unit 14 by means of a collision algorithm 30. The collision algorithm 30 implemented on the control unit 14 is designed to add a protective distance SA to the data of the load image file LBD and thus to provide a collision model image file KMD. For different systems, the control unit 14 can also have further collision model image files KMD2. The collision algorithm 30 is further designed to create a differential image file DBD from the collision model image file KMD and the cutout file VAD from the sensor data computing unit 12. The differential image file DBD obtained by the differentiation is examined for a possible collision of the load L with the environment U by means of an evaluation means 32.

The imaging sensor system 10 and the sensor data computing unit 12 are designed here to record the point cloud 20 as an environment image file UBD and further the projection means 31 is designed, from the point cloud 20, to convert the cutout file VAD as a data-reduced first depth image 22 from the

perspective of a virtual camera 24 (see FIG 2) as a function of the route x . The collision model image file KMD is present in the control unit 14 designed for fault safety as a second depth image 23.

The conversion of the sensor data 11 or the recorded point cloud 20 into a depth image 22 need not necessarily take place in the sensor data computing unit 12, but can also take place in a further outsourced computing unit 13.

The control unit 14 designed for fault safety further has an adjustment means 33, which is designed to dynamically adjust an enveloping surface 26 generated in the second depth image 23 by the protective distance SA (see FIG 2).

The control unit 14 designed for fault safety also has a focusing means 34, which is embedded in the collision algorithm 30 for instance and is designed to begin the subtraction of the first depth image 22 and the second depth image 23 in a focus area 28 in order to obtain the best possible reaction time with respect to the collision or a statement relating to a future collision. Since as soon as a negative result exists in the subtraction, this is a sign that the protected area SA is or will be violated and the control unit 14 can emit a speed reduction or a stop signal.

FIG 2 shows a container crane CC with a container C as a load L, wherein the container C is held by a load receiving means LM. The container crane CC can move a load L or the container C at a height h along a route x . The imaging sensor system 10 is installed on the container crane CC and on the load receiving means LM and provides for a receiving of the environment U by means of the environment image file UBD. The

sensor data 11, which the imaging sensor system 10 supplies, is forwarded to the sensor data computing unit 12. In accordance with the invention, in the sensor data computing unit 12 only a reduced image of the environment is now forwarded to the control unit 14 for a collision calculation. As a virtual camera 24, which forms a view from the origin of the container C, is used, only that section along the route via which the container C is also located is required from the environment image file UBD.

To this end, FIG 3 shows the explanation using simplified depth images from a bird's eye view of the environment. In the upper half of FIG 3, a first container stack 41, a second container stack 42 and a third container stack 43 are shown by way of example. In the lower half of FIG 3, the simplified depth images are shown as a collision image KB, an environment image UB, a cutout image AB and a differential image DB. The representation in the drawing is significantly simplified. In practice, spherical depth images are presumably used.

In a top view onto the container stack 41,42,43, the environment image UB represents this as black or gray surfaces. The collision image KB was generated from the collision model image file KMB as a second depth image 23. A generated enveloping surface 26 was added to the second depth image 23 by the protective distance SA. This enveloping surface 26 shows the protected area which is not permitted to be violated. The differential image DB specifies a negative result with the subtraction of the cutout image AB from the environment image UB and the collision image KB, so that the control unit 14 can evaluate that a collision is preferred and accordingly can reduce the speed or even send a stop signal.

If it is considered that in particular the edge regions of the container stack 41,42,43 may be hazardous for a collision, a focus area 28 in which the subtraction is firstly begun could lie in an edge region of the container stack 41,42,43.

FIG 4 shows by way of example the container crane CC, how it wants to position the container C with its load receiving means LM between the second container stack 42 and the third container stack 43. Since with the differentiation in the collision algorithm 30 using the evaluation of the data images it is calculated that the enveloping surface 26 is not touched, the container C can be positioned between the second container stack 42 and the third container stack 43 until the end.

By contrast, FIG 5 shows a positioning of the container C between the second container stack 42 and the third container stack 43, wherein the container C is aligned too far from the third container stack 43 and when the container C is moved further with the loading system, it would be indicated according to the collision algorithm 30 that the enveloping surface 26 is violated and the control unit 14 would thereupon emit a stop signal.

Claims

1. An operating method for a loading system designed to load or move a load (L) along a route (x), with which during the loading process for avoiding a collision between the load (L) and objects in the environment (U)
 - a digital load image file (LBD) describing a spatial overall extent of the load (L) is provided,
 - an environment image file (UBD) is recorded cyclically by means of an imaging sensor system (10),
 - a protective distance (SA) is added to the data of the load image file (LBD) and a collision model image file (KMB) is thus provided and
 - a cutout file (VAD) is provided as a virtually recorded image file with a viewing angle from one position of the load (L) as a function of the route (x), wherein the cutout file (VAD) is obtained as a reduced representation from the environment image file (UBD),
 - a differential image file (DBD) is provided from the collision model image file (KMD) and the cutout file (VAD) by means of differentiation,
 - an evaluation step is carried out, wherein the differential image file (DBD) is examined for a possible collision.
2. The operating method as claimed in claim 1, wherein with the imaging sensor system (10) a point cloud (20) is recorded as an environment image file (UBD) and from the point cloud (20) the cutout file (VAD) is converted as a data-reduced first depth image (22) from the perspective of a virtual camera (24) from a position of the load (L) as a function of the route (x), wherein the collision model image file (KMD) is present as a second depth image (24) or is converted herein.

3. The operating method as claimed in claim 2, wherein an enveloping surface (26) generated in the second depth image (23) by means of the protective distance (SA) can be adjusted dynamically.

4. The operating method as claimed in one of claims 1 to 3, wherein the differentiation for the provisioning of the differential image file (DBD) from the collision model image file (KMD) and the cutout file (VAD) is not completed or the subtraction of the depth images (22,24) is started in a focus area (28), since as soon as a first negative result exists, a collision statement can be made.

5. The operating method as claimed in one of claims 2 to 4, wherein

- the load image file (LBD) is provided during commissioning of the loading system,
- sensor data (11), which is determined by means of the imaging sensor system (10), is captured cyclically on a sensor data computing unit (12) and stored as the environmental image file (UBD),
- the cutout file (VAD) is calculated as a reduced representation of the environment image file (UBD) on the sensor data computing unit (12) or on a further computing unit (13),
- the conversion of the cutout file (VAD) into the first depth image (22) is carried out on the sensor data computing unit (12) or on a further computing unit (13),
- the differentiation from the collision model image file (KMD) and the cutout file (VAD) is carried out on a control unit (14) designed for fault safety.

6. The operating method as claimed in one of claims 1 to 5, wherein

a container crane (CC) or a container bridge is used as a loading system and a container (C) or a container (L) including a load receiving means (LM) is used as a load (L).

7. An automation system (100) designed to control a loading system for loading or moving a load (L) along a route (x) comprising

- an imaging sensor system (10) arranged to scan an environment,
- a sensor data computing unit (12) designed to cyclically capture sensor data (11) of the sensor system (10) and to create an environment image file (UBD),
- a control unit (14) configured for fault safety and designed to control the loading system,

characterized in that

- a digital load image file (LBD) describing a spatial overall extent of the load (L) is available in the control unit (14) designed for fault safety,
- the control unit (14) designed for faulty safety has a collision algorithm (30), which is designed to add a protective distance (SA) to the data of the load image file (LBD) and thus to provide a collision model image file (KMD),
- the sensor data computing unit (12) has a projection means (31), which is designed to provide a cutout file (BAD) as a virtually recorded image file with a viewing angle from one position of the load (L) as a function of the route (x), wherein the projection means (31) is designed to obtain the cutout file (VAD) as a reduced representation from the environment image file (UBD),

- the collision algorithm (30) is further designed to create a differential image file (DBD) from the collision model image file (KMD) and the cutout file (VAD) by means of differentiation and an evaluation means (32) is available, which is designed to examine the differential image file (DBD) for a possible collision.

8. The automation system (100) as claimed in claim 7, wherein the imaging sensor system (10) and the sensor data computing unit (12) are designed to record a point cloud (20) as an environment image file (UBD), furthermore the projection means (31) is designed, from the point cloud (20), to convert the cutout file (VAD) as a data-reduced first depth image (22) from the perspective of a virtual camera (24) from a position of the load (L) as a function of the route (x), wherein the collision model image file (KMD) exists in the control unit (14) designed for fault safety as a second depth image (24).

9. The automation system (100) as claimed in claim 8, wherein the control unit (14) designed for fault safety has an adjustment means (33), which is designed to dynamically adjust an enveloping surface (26) generated by the protective distance (SA) in the second depth image (23).

10. The automation system (100) as claimed in one of claims 7 or 9, wherein the collision algorithm (30) has a focusing means (34), which is designed to begin the subtraction of the depth images (22,23) in a focus area in order to obtain a best possible reaction time with respect to the collision.