Accordingly, improvements to mobile robots are required that help to maximise mobile robot coverage, while minimising the risk of the mobile robot experiencing hazards as it navigates an environment.

In one aspect, the present disclosure refers to a method of controlling a mobile robot capable of carrying out an operation within an environment, the method comprising: storing an environment map in a memory, the environment map including data to enable the robot to navigate the environment; further storing in the memory data corresponding to one or more hazard areas encountered by the mobile robot during previous operations, the hazard areas corresponding to areas within the environment map; identifying a position of the robot within the environment map; and reducing a tilt threshold of the robot when the mobile robot is navigating within an area of the environment that corresponds to a previously encountered hazard area.

As a result, the mobile robot will be controlled in a way such that it continues to push its manoeuvring capabilities and therefore the coverage of the mobile robot will be maximised. However in areas where the mobile robot has experienced hazards previously, the mobile robot will behave more cautiously by reducing the tilt-threshold, and will reduce the likelihood that it experiences the hazard again. Crucially, the reduced tilt threshold will only be applied in areas of the environment map where the mobile robot determines it could be at risk, and therefore coverage can be maximised whilst also reducing the risk of the mobile robot experiencing hazards.

The data corresponding to one or more hazard areas may be location data. The data corresponding to one or more hazard areas may be stored as a layer on top of the environment map. As a result, the location of hazard areas can be more easily mapped within the environment map, and without requiring a second full map for hazard areas. This may reduce the amount of data needed to be stored, and may also reduce the amount of processing required from the control system on the mobile robot.

A hazard area may be an area in which the mobile robot has experienced a hazard event. A hazard event may comprise the mobile robot becoming stuck, or a hazard event may comprise the mobile robot experiencing an over-tilt threshold event. As a result, the mobile robot will reduce the tilt-threshold in areas where it has become stuck or over-tilted previously, and will navigate these areas more cautiously when navigating these areas in operations.

where the hazard has been removed. This in turn can help to improve coverage of the mobile robot.

The tilt threshold of the robot may only be reduced when the mobile robot is navigating within an area of the environment that corresponds to a previously encountered hazard area having a probability factor above a predetermined threshold. As a result, if a hazard is removed, then it can effectively be removed from the data corresponding to one or more hazard areas over time and the mobile robot can ignore any old hazard areas which no longer contain a hazard.

The method may comprise measuring the tilt of the mobile robot while it carries out an operation in an environment using one or more of the list comprising a gryo, an IMU and an accelerometer. As a result, the on board components are able to instantly provide an accurate tilt measurement to the control system of the mobile robot, and this can help the mobile robot quickly identify when it may have encountered a hazard to allow it the best opportunity to resolve the problem itself without requiring intervention from a human.

This disclosure further provides a mobile robot capable of carrying out an operation within an environment, the mobile robot comprising: storage in memory for storing an environment map; storage in memory for storing data corresponding to one or more hazard areas encountered by the mobile robot during previous operations; a control system for controlling the mobile robot while carrying out an operation within the environment, wherein the control system is configured to use a first tilt threshold in controlling the mobile robot in a normal operation mode, and is configured to use a second tilt threshold in controlling the mobile robot in a cautious operation mode when the mobile robot is navigating within a hazard area.

In another aspect, the present disclosure refers to a mobile robot capable of carrying out an operation within an environment, the mobile robot comprising:

storage in memory for storing an environment map;

storage in memory for storing data corresponding to one or more hazard areas encountered by the mobile robot during previous operations, the hazard areas corresponding to areas within the environment map; and

a control system for controlling the mobile robot while carrying out an operation within the environment, the control system comprising a navigation unit for identifying a position of the robot within the environment map,

wherein the control system is configured to use a first tilt threshold when controlling the mobile robot in a normal operation mode, and is configured to use a second tilt threshold when controlling the mobile robot in a cautious operation mode when the mobile robot is navigating within a hazard area.

As a result, the manoeuvring capabilities of the mobile robot can be pushed where possible, and the coverage of the mobile robot will be maximised. However in areas where the mobile robot has experienced hazards previously, the mobile robot will behave more cautiously by reducing the tilt-threshold, and will reduce the likelihood that it experiences the hazard again. Crucially, the reduced tilt threshold will only be applied in areas of the environment map where the mobile robot determines it could be

CLAIMS

1. A method of controlling a mobile robot capable of carrying out an operation within an environment, the method comprising:

storing an environment map in a memory, the environment map including data to enable the robot to navigate the environment;

further storing in the memory data corresponding to one or more hazard areas encountered by the mobile robot during previous operations, the hazard areas corresponding to areas within the environment map;

identifying a position of the robot within the environment map; and

reducing a tilt threshold of the robot when the mobile robot is navigating within an area of the environment that corresponds to a previously encountered hazard area.

2. A method of controlling a mobile robot as claimed in claim 1, wherein the data corresponding to one or more hazard areas is location data.

3. A method of controlling a mobile robot as claimed in claim 1 or claim 2, wherein the data corresponding to one or more hazard areas is stored as a layer on top of the environment map.

4. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein a hazard area is an area in which the mobile robot has experienced a hazard event.

5. A method of controlling a mobile robot as claimed in claim 4, wherein ~~a~~ the hazard event comprises the mobile robot becoming stuck.

6. A method of controlling a mobile robot as claimed in claim 4, wherein ~~a~~ the hazard event comprises the mobile robot experiencing an over-tilt threshold event.

7. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein the memory is on-board memory on the robot.

8. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein a hazard area is an area of predetermined size the centre of which is a location where a hazard was encountered.

9. A method of controlling a mobile robot as claimed in claim 8, wherein the area of predetermined size is a circle with a radius of between 0.1m and 0.5m.

10. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein the method further comprises updating the data corresponding to one or more hazard areas when a new hazard is encountered by the mobile robot during an operation.

11. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein the data corresponding to one or more hazard areas comprises a probability factor associated with each hazard area, and the method comprises reducing the probability factor for a particular hazard area when the mobile robot navigates through the particular hazard area without encountering a further hazard.

12. A method of controlling a mobile robot as claimed in claim 11, wherein the tilt threshold of the robot is only reduced when the mobile robot is navigating within an area of the environment that corresponds to a previously encountered hazard area having a probability factor above a predetermined threshold.

13. A method of controlling a mobile robot as claimed in any one of the preceding claims, wherein the method comprises measuring the tilt of the mobile robot while it carries out an operation in an environment using one or more of the list comprising a gryo, an IMU and an accelerometer.

14. A mobile robot capable of carrying out an operation within an environment, the mobile robot comprising:

storage in memory for storing an environment map;

storage in memory for storing data corresponding to one or more hazard areas encountered by the mobile robot during previous operations, the hazard areas corresponding to areas within the environment map; and

a control system for controlling the mobile robot while carrying out an operation within the environment, the control system comprising a navigation unit for identifying a position of the robot within the environment map,

wherein the control system is configured to use a first tilt threshold when controlling the mobile robot in a normal operation mode, and is configured to use a second tilt threshold when controlling the mobile robot in a cautious operation mode when the mobile robot is navigating within a hazard area.

15. A mobile robot as claimed in claim 14, wherein the second tilt threshold is less than the first tilt threshold.

16. A mobile robot as claimed in claim 14 or claim 15, wherein the data corresponding to hazard areas is stored as a layer on top of the environment map.

17. A mobile robot as claimed in any one of claims 14 to 16, wherein the control system is configured to update the data corresponding to hazard areas when a new hazard is encountered by the mobile robot as it carries out an operation in the environment.

18. A mobile robot as claimed in any one of claims 14 to 17, wherein the data corresponding to hazard areas comprises a probability factor associated with each hazard area, and the control system is configured to reduce the probability factor for a particular hazard area when the mobile robot navigates through the particular hazard area without encountering a further hazard.

19. A mobile robot as claimed in claim 18, wherein the control system is configured to only use the second tilt threshold when the mobile robot is navigating within an area of the environment that corresponds to a previously encountered hazard area having a probability factor above a predetermined threshold.

20. A mobile robot as claimed in any one of claims 14 to 19, wherein the mobile robot comprises one or more of a gryo, an IMU and an accelerometer to provide a tilt measurement corresponding to the current tilt of the robot to the control system.