DEVICE AND METHOD FOR USE IN CLEANING A FACADE

RELATED APPLICATION/S

This application claims the benefit of priority of U.S. Provisional Patent Application No. 62/627,785 filed on 8 February 2018, the contents of which are incorporated herein by reference in their entirety.

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to a method, device, system and/or non-transient memory for use in controlling cleaning a building facade.

Robots may be used to clean facades of buildings. Such systems may be mounted to an elevator frame that is supported by a crane. In some cleaning system, a robotic machine is operated by a person manually. In other systems a specific robot is designed for a specific building, at a cost of in the millions of dollars and is not readily adaptable for use with other buildings.

In some systems a robot executes a cleaning routine and the crane changes the elevation of the frame so the robot can execute the cleaning routine at other elevations. The robot's routine is pre-programmed to be customized to the design of the building that it is intended to clean. Likewise the crane is configured to operate to a pre-programmed routine that is customized to the building, e.g. based on known window sizes and spacings. Thus the robot, as configured for the building, cannot be applied to differently designed building. Further any dynamic changes in the configuration of the building facade, e.g. an opening of a window, cannot be accounted for by the crane or robot.

Thus there exists a need for a new way to clean a building facade.

SUMMARY OF THE INVENTION

A first aspect of the present invention provides a computer implemented method for controlling a cleaning process of one or more building facades from a building maintenance elevator of a building. The method comprises receiving a multi-dimensional map of at least a portion of at least one facade of the building; and determining, according to the multi-dimensional map, an ordered sequence of instructions. The ordered sequence of instructions comprises robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on a basket of an elevator platform of the building, and elevator platform instructions for controlling a position of the basket. The robotic arm instructions and the elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one façade along a plurality of different floors. The method further comprises forwarding

the robotic arm instructions to the robotic system for controlling the at least one robotic arm of the robotic system via at least one first interface; and forwarding the elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface. The second interface is different from the at least one first interface. The first and second interfaces are different communication interfaces. The multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.

In some embodiments, according to the cleaning pattern, a cleaning tool at a distal end of each of the at least one robotic arms follows a vector that traces the cleaning pattern. In some embodiments, determining the ordered sequence of instructions comprises calculating the robotic arm instructions based on the multi-dimensional map, a determined current position of the cleaning tool, and a determined elevation of the elevator platform.

Additionally or alternatively, in some embodiments, the method comprises determining a path planned for the elevator platform based on a selection of surfaces to be cleaned; and determining the elevator platform instructions based on said path. The path includes at least one of: (a) one or more movements in elevation; and (b) one or more horizontal movements. The second interface is a communication interface to a control system that is integral to a crane. The control system determines the position of the elevator platform based on said elevator platform instructions.

Additionally or alternatively, in some embodiments, the at least one first interface is a communication interface to a control system that is integral to the robotic system.

Additionally or alternatively, in some embodiments, the method comprises updating at least part of the multi-dimensional map during a time period in which the ordered sequence of instructions is determined.

Additionally or alternatively, in some embodiments, the method comprises updating the multi-dimensional map from correlated sensor data from a plurality of multi-dimensional measurements recorded from different perspectives.

Additionally or alternatively, in some embodiments, different parts of the robotic arm instructions control different robotic arms.

Additionally or alternatively, in some embodiments, the robotic arm instructions configure the different robotic arms for operate simultaneously for a least part of a robotic arm instruction execution period.

Additionally or alternatively, in some embodiments, the method comprises determining a position of the robotic arm and updating the multi-dimensional map, using simultaneous localization and mapping. In some embodiments, the method comprises determining the robotic arm instructions based, in part on said determined position of the robotic arm.

Additionally or alternatively, in some embodiments, the method comprises receiving a plurality of selections of respective portions of an image that corresponds to the at least facade, and determining the ordered sequence of instructions based on said selections.

Additionally or alternatively, in some embodiments, the robotic arm instructions configure each of the at least one robotic arms to move with at least six degrees of freedom.

Additionally or alternatively, in some embodiments, the elevator platform instructions configure the elevator platform to move with at least three degrees of freedom.

Additionally or alternatively, in some embodiments, the method further comprises generating instructions for operating a reverse osmosis cleaning system configured for cleaning the at least one facade at a distal end of the at least one robotic arm.

Additionally or alternatively, in some embodiments, the multi-dimensional map is a three dimensional map.

Additionally or alternatively, in some embodiments, the method comprises measuring a contact force between the at least one robotic arm and the at least part of the at least one facade during execution of the cleaning pattern, wherein the robotic arm instructions are adapted for closed loop control of the contact force.

In some embodiments, the method more specifically comprises:

generating instructions for operating a reverse osmosis cleaning system configured for cleaning the at least one facade at a distal end of the at least one robotic arm; and

measuring a contact force between the at least one robotic and the at least part of the at least one facade during execution of the cleaning pattern, wherein the robotic arm instructions are adapted for closed loop control of the contact force.

In a second aspect of the present invention there is provided a device for controlling cleaning of a building facade from a basket of an elevator platform of building. The device comprises at least one processor. The at least one processor is configured to receive a multi-dimensional map of at least a portion of at least one facade of the building; and determine, according to the multi-dimensional map, an ordered sequence of instructions. The ordered sequence of

instructions comprise: robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on the basket of the elevator platform, and elevator platform instructions for controlling a position of the basket. The robotic arm instructions and the elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one façade along a plurality of different floors. The at least one processor is further configured to forward the robotic arm instructions to the robotic system for controlling the at least one robotic arm of the robotic system via a first interface and to forward the elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface. The second interface is different from the first interface. The first and second interfaces are different communication interfaces. The multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.

Each of the embodiments of the first aspect of the present invention may also apply to the second aspect of the present invention.

In a third aspect of the present invention there is provided a system/apparatus for cleaning a building facade. The system has the device of the second aspect of the present invention, and the at least one robotic arm. The system may include an interface for communicating between the at least one robotic arm and the device. In some embodiments the interface is a wireless interface.

In some embodiments, the at least one robotic arm is a robotic arm manipulator of a reverse osmosis cleaning system having a cleaning tool at a distal end of each of the at least robotic arms. In some embodiments, the cleaning tool is a brush.

In some embodiments, the at least one robotic arm comprises at least one force sensor configured for measuring a contact force between the at least one robotic arm and the at least part of the at least one facade during execution of the cleaning pattern. The robotic arm instructions are adapted for closed loop control of the contact force. In some embodiments, the at least one force sensor comprises a force sensor that measures force based on a displacement a cleaning tool with respect to a component on a distal end of a robotic arm of said at least one robotic arm. The at least one force sensor may additionally or alternatively comprise at least one torque sensor in a respective joint of a robotic arm of said at least one robotic arm.

The use of the reverse osmosis cleaning system may exist in some embodiments without the at least one force sensor, and the use of the at least one force sensor may exist in some embodiments without the use of the reverse osmosis cleaning system. However, in some embodiments of the

invention, the system includes both the reverse osmosis cleaning system and the at least one force sensor.

Additionally or alternatively, in some embodiments, the system includes a mounting structure has a mounting frame. Each of the at least one robotic arm is mounted on the mounting frame and the mounting structure further having a clamping assembly that extends, in an adjustable configuration, from mounting frame to adjusts a position of the mounting frame on the elevator

platform to fix the mounting frame within the elevator platform. In some embodiments, the clamping assembly has an adjustable length.

Additionally or alternatively, the clamping assembly may mount to an adjustable position on a rail of the mounting frame. The rail may include a plurality of mounting features at different lengths along the rail to provide said adjustable position.

In some embodiments, the apparatus includes at least four of said clamping assemblies.

Optionally, the system is comprised of at least two assemblies that are physically separated from each other, wherein the device is in one of the assemblies and the at least one robotic arm is in another one of the assemblies. In some embodiments, whether physically separated or not, the assembly that includes the device is retrofitted to operate with the assembly that includes the at least one robotic arm. In other words the device may be configured to operate with a robotic arm that is already in operation.

In a fourth aspect of the present invention there is provided a non-transient computer readable medium instructions for execution of a program for controlling cleaning of a building facade from an elevator platform of an elevator system. Execution of the instructions by at least one processor configures the processor to receive a multi-dimensional map of at least a portion of at least one facade of the building; and determine, according to the multi-dimensional map, an ordered sequence of instructions. The ordered sequence of instructions comprises robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on a basket of the elevator platform of the building, and elevator platform instructions for controlling a position of the basket. The robotic arm instructions and the elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one facade along a plurality of different floors. Execution of the instructions by at least one processor further configures the processor to forward the robotic arm instructions to the robotic system for controlling the robotic arm of the robotic system via a first interface; and to forward the elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface. The second interface is different from the first interface. The first and second interfaces are different communication interfaces. The multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.

Each of the embodiments of the first aspect of the present invention may also apply to the fourth aspect of the present invention.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In

WHAT IS CLAIMED IS:

1. A computer implemented method for controlling a cleaning process of one or more building facades from a building maintenance elevator of a building, comprising:

receiving a multi-dimensional map of at least a portion of at least one facade of the building;

determining, according to the multi-dimensional map, an ordered sequence of instructions, comprising:

robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on a basket of an elevator platform of the building, and

elevator platform instructions for controlling a position of the basket;

wherein said robotic arm instructions and said elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one facade along a plurality of different floors;

forwarding said robotic arm instructions to the robotic system for controlling the at least one robotic arm of the robotic system via at least one first interface; and

forwarding said elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface which is different from the at least one first interface;

wherein the first and second interfaces are different communication interfaces; and,

wherein the multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.

2. The computer implemented method according to claim 1, wherein according to the cleaning pattern, a cleaning tool at a distal end of each of the at least one robotic arms follows a vector that traces the cleaning pattern.

3. The computer implemented method according to claim 2, wherein determining the ordered sequence of instructions comprises calculating the robotic arm instructions based on the multi-dimensional map, a determined current position of the cleaning tool, and a determined elevation of the elevator platform.

4. The computer implemented method according to claim 1 wherein the method comprises:

determining a path planned for the elevator platform based on a selection of surfaces to be cleaned, the path including at least one of: (a) one or more movements in elevation; and (b) one or more horizontal movements; and

determining the elevator platform instructions based on said path,

wherein the second interface is a communication interface to a control system that is integral to a crane, the control system determining the position of the elevator platform based on said elevator platform instructions.

5. The computer implemented method according to claim 1 wherein the method comprises updating the multi-dimensional map from correlated sensor data from a plurality of multi-dimensional measurements recorded from different perspectives.

6. The computer implemented method according to claim 1, wherein the method comprises using simultaneous localization and mapping to a) determine a position of the robotic arm and b) update the multi-dimensional map.

7. The computer implemented method according to claim 1, wherein the method comprises receiving a plurality of selections of respective portions of an image that corresponds to the at least facade, and determining the ordered sequence of instructions based on said selections.

8. The computer implemented method according to claim 1, wherein the method further comprises generating instructions for operating a reverse osmosis cleaning system configured for cleaning the at least one facade at a distal end of the at least one robotic arm.

9. The computer implemented method according claim 1 wherein the multi-dimensional map is a three dimensional map.

10. The computer implemented method according to claim 1 wherein the method comprises measuring a contact force between the at least one robotic arm and the at least part of the at least one facade during execution of the cleaning pattern, wherein the robotic arm instructions are adapted for closed loop control of the contact force.

11. A device for controlling cleaning of a building facade from a basket of an elevator platform of a building, comprising:

at least one processor configured to:

receive a multi-dimensional map of at least a portion of at least one facade of the building;

determine, according to the multi-dimensional map, an ordered sequence of instructions, comprising:

robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on the basket of the elevator platform, and

elevator platform instructions for controlling a position of the basket;

wherein said robotic arm instructions and said elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one facade along a plurality of different floors;

forward said robotic arm instructions to the robotic system for controlling the at least one robotic arm of the robotic system via a first interface; and

forward said elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface which is different from the first interface;

wherein the first and second interfaces are different communication interfaces; and,

wherein the multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.

12. A system for cleaning a building facade, the system having the device of claim 11 and the at least one robotic arm.

13. A system according to claim 12, wherein the at least one robotic arm is a robotic arm manipulator of reverse osmosis cleaning system having a cleaning tool at a distal end of each of the at least robotic arms.

14. The system according to claim 12, wherein the at least one robotic arm comprises at least one force sensor configured for measuring a contact force between the at least one robotic arm and the at least part of the at least one facade during execution of the cleaning pattern, wherein the robotic arm instructions are adapted for closed loop control of the contact force.

15. The system according to claim 14, wherein the at least one force sensor comprises at least one of:

a force sensor that measures force based on a displacement a cleaning tool with respect to a component on a distal end of a robotic arm of said at least one robotic arm; and

at least one torque sensor in a respective joint of a robotic arm of said at least one robotic arm.

16. The system according to claim 12, wherein the system includes a mounting structure having a mounting frame, wherein each of the at least one robotic arm is mounted on the mounting frame and the mounting structure further having a clamping assembly that extends, in an adjustable configuration, from mounting frame to adjusts a position of the mounting frame on the elevator platform to fix the mounting frame within the elevator platform.

17. The system according to claim 16, wherein the clamping assembly has an adjustable length, wherein the clamping assembly mounts to an adjustable position on a rail of the mounting frame, and wherein the rail includes a plurality of mounting features at different lengths along the rail to provide said adjustable position.

18. A non-transient computer readable medium instructions for execution of a program for controlling cleaning of a building facade from an elevator platform of an elevator system, wherein execution of the instructions by at least one processor configures the processor to:

receive a multi-dimensional map of at least a portion of at least one facade of the building;

determine, according to the multi-dimensional map, an ordered sequence of instructions, comprising:

robotic arm instructions for controlling at least one robotic arm of a robotic system mounted on a basket of the elevator platform of the building, and

elevator platform instructions for controlling a position of the basket;

wherein said robotic arm instructions and said elevator platform instructions are temporally intertwined to execute a cleaning pattern covering at least part of the at least one facade along a plurality of different floors;

forward said robotic arm instructions to the robotic system for controlling the at least one robotic arm of the robotic system via at least one first interface; and

forward said elevator platform instructions to a building maintenance elevator component for controlling the elevation of the basket via a second interface which is different from the at least one first interface;

wherein the first and second interfaces are different communication interfaces; and,

wherein the multi-dimensional map being dynamically updated to represent a current configuration of the facade using sensor data derived from at least one sensor supported on the elevator platform, wherein the at least one sensor comprises at least one camera and mono simultaneous localization and mapping (mono-SLAM) being performed for each of the at least one sensor.