

GROUT JOINT CLEARING ROBOT

Technical Field

The present disclosure relates to the field of clearing of grout joints between tiles. In particular, the present disclosure relates to a robot for clearing of grout joints between tiles and more particularly, to grout removal from grout joints between tiles and other grout sealed surfaces.

Background

After application of tiles and tile setting is concluded, tile grouting is required to be performed. Tile grouting involves adding grout in the joints between the tiles. However, before tile grouting, the grout joints would have to be cleared of debris to ensure that only tile grout is present in the grout joints. The clearing of the grout joint involves the removal of tile spacers, hardened tile adhesive, or any other foreign objects present in the grout joints after tile setting. Currently, a human is required to use a tool with his/her hands to scrape out debris from the grout joint.

In some cases, tiles are intended to be retained but the existing grout become old or dirty. In these cases, the existing grout is removed and replaced to refurbish the flooring. The available devices include static and electrically powered hand-held devices that are meant to take over the above grout removal process which can be very labour intensive.

Static hand-held grout removal devices have a blade that is guided by a user through a grout joint to manually cut or grind the grout away. Generally, the devices have an elongated handle which extends towards a blade retainer, wherein blades are fixedly or removably received. These static devices are inexpensive, however, they require a greater expenditure of time and energy. Nevertheless, one advantage of manual grout removal is that it is generally less forceful and more easily controlled which may be useful to avoid tile damage and to preserve the tiles for reuse.

Electrically powered devices have either a rotary motion or a reciprocating motion that is imparted to the blade. Rotary motion type grout removal devices generally involve a rotating abrasive disc that fits into the grout joint and is spun against the grout. The housing for the disc may include rollers or similar guiding apparatus that aids in the guidance of the

blade along a joint and/or to adjust the depth of cut. The rotary type devices also have the disadvantage of being more difficult to control and for causing greater damage to edges of the tiles.

Reciprocating or vibrating type power grout removal devices generally involve a planar chisel or blade which fits into joint, and which may be vibrated at high frequency and low amplitude along an axis parallel to or perpendicular to the blade's edge. The blade fits within the grout joint and rapidly grinds through the grout with low damage to the surrounding tiles. Straight chisel-like blades, circular disc blades, and sickle-type blades may be interchangeably accommodated within the device. Reciprocating or vibrating type devices may cause less damage to the tiles and may have low clean-up burden. However, these devices may be costly and are not as fast as rotary removal devices.

For competitive reasons, powered grout removal is preferred as manual grout removal is too slow (and thus too expensive) for the consumer.

Another aspect, in grout removal, is that dust and residue are generated during grout removal process which may be higher with rotary type grout removal devices. Hence, dustless grout removal, or grout removal with minimal dust, has become increasingly important for contractors owing to the wasted time and diminished efficiency resulting from dust clean-up. Therefore, devices that allow for rapid grout removal and which have minimal dust generation and dispersion may be preferred.

In view of the foregoing problems, it is desired for a grout removal device that provides a high degree of control, that is cost effective and allows for a cleaner operation. The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of the prior art system.

Brief Summary of the Invention

The present disclosure describes a grout joint clearing robot defined in appended claim 1. The grout joint clearing robot is capable of clearing a grout joint and/or removing grout from a grout line that corresponds to a grout joint or a gap between tiles. The grout joint clearing robot is capable of carrying out operations for a plurality of grout lines. The grout joint clearing robot is also capable of performing general grout joint clearing operations along

the grout lines. The grout joint clearing robot has an end effector that is configured for the removal of grout and other debris from the grout lines. The joint clearing robot is configured to remove tile adhesive, tile spacers, grout, cement, concrete and other debris from a grout joint.

5 The grout joint clearing robot is configured to perform the required clearing operations in an operational zone that comprises the grout lines. The required clearing operations is performed through a series of automated movements. The grout joint clearing robot has a grout clearing tool that is moved through a series of positions for the required clearing operations. The grout clearing tool may be subject to vibrations to increase the
10 effectiveness of the required clearing operations.

 The grout joint clearing robot is configured to perform the grout joint clearing operations in accordance with pre-set instructions. The grout joint clearing robot may be configured to obtain information from the operational zone and to autonomously perform the grout joint clearing operations.

15 The grout joint clearing robot is configured to performing cleaning of debris that resulted from the grout clearing operations. The debris are suctioned from the surface immediately following the grout clearing operations and are stored in a container in the grout joint clearing robot.

Brief Description of the Drawings

20 The foregoing and other features and advantages of the present disclosure will be more fully understood from the following description of various embodiments, when read together with the accompanying drawings, in which:

 Fig. 1 is a front isometric view of the grout joint clearing robot according to the present disclosure;

25 Fig. 2 is a rear isometric view of the grout joint clearing robot according to the present disclosure;

 Fig. 3 is a side view of a part of the grout joint clearing robot with a grout clearing tool in the stored position according to the present disclosure;

 Fig. 4 is a front isometric view of a part of the grout joint clearing robot with grout
30 clearing tool in the stored position according to the present disclosure;

Fig. 5 is a side view of a part of the grout joint clearing robot with the grout clearing tool in the deployed position according to the present disclosure;

Fig. 6 is a front view of a part of the grout joint clearing robot with grout clearing tool in the deployed position according to the present disclosure;

5 Fig. 7 is a front isometric view of a part of the grout joint clearing robot with grout clearing tool being angularly displaced from the deployed position according to the present disclosure; and

Fig. 8 illustrates an embodiment of the grout clearing tool.

Detailed Description

10 This disclosure generally relates to a semi-autonomous or autonomous robot for the clearing of grout joints that are located between tiles in a zone that is designated for grout joint clearing operations in relation to tile replacement or grout replacement. The robot is capable of removing of grout from the grout joints. A grout joint clearing operation involves a tool entering the grout joint for removal of debris from the grout joint.

15 With reference to Figs. 1 and 2, the grout joint clearing robot **10** comprises a frame **12**, a drive system **14**, a power system **16**, a grout joint clearing system **18**, a sensing system **26** and a control system **28**. The grout joint clearing system **18** comprises a clearing tool **24** that is configured for grout joint clearing and grout removal.

20 The frame **12** is configured to support the aforementioned systems of the grout joint clearing robot **10** including the drive system **14**, the power system **16**, the grout joint clearing system **18**, the sensing system **26** and the control system **28**. Frame **12** may be configured to provide attachment and containment structures for coupling or accommodating the aforementioned systems. The aforementioned systems are coupled or accommodated on the frame **12** through the attachment and containment structures.

25 The frame **12**, from a top view, may be round, square or rectangle in shape, or a combination thereof. For example, the front of the robot may be squared off, while the rear of the robot is rounded. The frame **12**, from a side or front view, is substantially planar and has an upper surface on the topside and a lower surface on the underside. The aforementioned systems may be coupled or accommodated on the topside or the underside of the frame **12**.

30 In an embodiment, the frame **12** may be configured as a chassis.

The grout joint clearing robot **10** may have a longitudinal axis extending along a forward and rear direction and a transverse axis oriented perpendicular to the longitudinal axis. In an embodiment, frame **12** has a longitudinal axis that corresponds to the longitudinal axis of the grout joint clearing robot **10**. The forward and rear directions correspond to the forward and rear orientations of the grout joint clearing robot **10**. The forward and rear orientations of the grout joint clearing robot **10** are in turn determined by the placement of the various systems. In an embodiment, frame **12** has a forward region **12a** and a rear region **12b** and the forward and rear orientations of the grout joint clearing robot **10** correspond to the forward and rear regions **12a**, **12b** of the grout joint clearing robot **10**.

The frame **12** comprises a pair of rails **13** positioned on opposite sides thereof. The pair of rails **13** are positioned on the topside of the frame **12**. Pair of rails **13** may be removably engaged to the upper surface of the frame **12**. The pair of rails **13** are spaced apart so as to form a pair of borders on the sides of the central part of the frame **12** that is available for support of the various systems, as required. The pair of rails **13** are mutually parallel. In an embodiment, the pair of rails **13** are parallel with the longitudinal axis of the frame **12**. At the front of the frame **12**, the forward ends of the pair of rails **13** extend beyond the edge of forward region **12a**. The forward ends of the pair of rails **13** are forward of the edge of forward region **12a**. At the rear of the frame **12**, the opposite rear ends of the pair of rails **13** extend beyond the edge of rear region **12b**. The opposite rear ends of the pair of rails **13** are posterior to the edge of rear region **12b**. In an embodiment, at the rear of the frame **12**, the opposite rear ends of the pair of rails **13** are aligned with the edge of rear region **12b**.

With reference to Figs. 1 and 2, the drive system **14** is configured for generally moving the grout joint clearing robot **10** along a surface that is intended for the conduct of grout clearing operations. The drive system **14** is mounted to the frame **12**. The drive system **14** is configured to drive the grout joint clearing robot **10**. The drive system **14** may comprise a plurality of drive and driven wheels. The frame **12** is supported above a surface by the drive and driven wheels. A motive force is applied to the drive wheels to move the grout joint clearing robot **10** by a drive motor. The driven wheels are not subject to a motive force. In an embodiment, the drive wheels may be provided with a steering force to change the direction of the grout joint clearing robot **10**. The driven wheels and the drive wheels may be

positioned on the frame **12** as required. The driven wheels are spaced away from the drive wheels.

In embodiment, the drive system **14** comprises a pair drive wheels **52** and a driven wheel **54**. In an alternative embodiment, drive system **14** comprises a plurality of drive wheels **52** and a plurality of driven wheels **54**.

With reference to Fig. 1, the drive system **14** comprises one or more drive motors (not shown) contained within a compartment **56**. The compartment **56** is positioned on the underside of the frame **12**. Compartment **56** may be removably coupled to the lower surface of the frame **12**. The pair of drive wheels **52** are driven by the drive motor(s) through a drive shaft (not shown) located in the compartment **56**. The drive shaft may be transversely orientated to the longitudinal axis of the frame **12**. The pair of drive wheels **52** are positioned on opposite sides of the grout joint clearing robot **10**. The pair of drive wheels **52** are connected to the drive shaft from opposite sides of the compartment **56**. The pair of drive wheels **52** may be positioned substantially in the middle of the frame **12**, relative to the longitudinal axis thereof. The drive wheels **52** may be substantially equidistant from the forward and rear regions **12a**, **12b** of the frame **12**. In an alternative embodiment, the drive wheels **52** may be positioned at either the forward region **12a** or the rear regions **12b**.

With reference to Fig. 2, the driven wheel **54** may be a free spinning wheel. The driven wheel **54** may be a swivel castor wheel. The frame **12** has a mounting tab **58** extending therefrom. The driven wheel **54** is rotatably coupled to the mounting tab **58**. Mounting tab **58** is mounted to the frame **12** and extends along a direction that is substantially perpendicular to the longitudinal axis of the frame **12**. Driven wheel **54** is rotatably supported on the mounting tab **58**. Driven wheel **54** is rotatable relative to the mounting tab **58** and the frame **12**. The driven wheel **54** is mounted to the rear region **12b**. The driven wheel **54** is coupled to the mounting tab **58** positioned at the rear region **12b**.

With reference to Fig. 2, the power system **16** is mounted to the frame **12**. The power system **16** is positioned on the underside of the frame **12**. Power system **16** may be removably coupled to the lower surface of the frame **12**. Power system **16** may be positioned adjacent to the compartment **56**. Power system **16** may be positioned at the rear region **12b** of the frame **12**.

The power system **16** is configured to provide power to the grout joint clearing robot **10**. The power system **16** provides power for the operation of the drive system **14**, the grout joint clearing system **18**, the sensing system **26** and the control system **28**. In an embodiment, the power system **16** regulates the amount of power supplied to the drive system **14**, the grout joint clearing system **18**, the sensing system **26** and the control system **28**. In an embodiment, the power system **16** may be a battery. The power system **16** may be contained in a compartment or dry box to protect the power system **16** from dirt and water. The power system **16** is configured to supply and regulate power to the various components, in the grout joint clearing robot **10**, including motors, imaging sensors (including cameras), LIDAR, sensors and processors, and includes components such as batteries, voltage converters, regulators.

With reference to Fig. 2, the grout joint clearing robot **10** further comprises an electrical box **60**. The electrical box **60** may be positioned on the topside of the frame **12** and along a side thereof. The electrical box **60** may be removably coupled to upper surface of the frame **12**. The electrical box **60** comprises the electrical signal connections and electrical power connections that are required for the operation of the grout joint clearing robot **10**. The electrical signal connections and electrical power connections mutually connect, as required, the aforementioned systems.

With reference to Figs. 1 and 2, the grout joint clearing system **18** is configured to remove tile adhesive, tile spacers, grout, cement, concrete and other debris in the grout joints. The grout joint may be cleared by the grout joint clearing system **18**, prior to a grouting operation. The grout joint clearing system **18** comprises a mounting assembly **20**, a clearing device **22** and a clearing tool **24**.

The mounting assembly **20** is mounted to the frame **12**. The mounting assembly **20** is positioned on the topside of the frame **12**. The mounting assembly **20** may be removably coupled to the upper surface of the frame **12**. In an embodiment, the mounting assembly **20** is engaged to at least one of the rails **13**. The mounting assembly **20** may be removably engaged to at least one of the rails **13**. The mounting assembly **20** is provided adjacent to the forward region **12a** of the frame **12**.

In an embodiment, the mounting assembly **20** comprises at least one stanchion **62** that

extends vertically from the frame **12**. The stanchion **62** is free standing on the topside of the frame **12**. The stanchion **62** is mounted on one of the rails **13**.

Stanchion **62** may have a lower solid plank portion **64**. The plank portion **64** has a rectangular cross-section. The length of the plank portion **64** is vertically orientated relative to the frame **12**. The sides **64a** of the plank portion **64** may be parallel to the longitudinal axis of the frame. An outer side **64a** of the plank portion **64** may be parallel to the side of the frame **12**. A forward edge **64b** of the plank portion **64** is positioned forward of the edge of the forward region **12a**. The opposite rear edge **64b** of the plank portion **64** may be positioned in line with the edge of the forward region **12a**. In an alternate embodiment, the opposite rear edge **64b** of the plank portion **64** may be also positioned forward of the edge of the forward region **12a**. The end **64c** is positioned opposite the end coupled to the frame **12**.

The stanchion **62** may have an upper portion **66** having sides **66a**, edges **66b** and an end portion **66c**. A through hole **66d** extends between the opposite sides **66a**. The upper portion **66** is positioned on the end **64c** of the plank portion **64**. The upper portion **66** is narrower than the plank portion **64** when viewed from the front of the frame **12**. A side **66a** of the upper portion **66** is aligned with the side **64a** of the plank portion **64**. These sides **66a** and **64a** are internal relative to the frame **12**. The outer sides **66a** and **64a** are not aligned. The outer side **66a** is spaced from the outer side **64a**. The upper portion **66** has slanted edges **66b** that extend from the edges **64b** of the plank portion **64** and that end at the end portion **66c**. The end portion **66c** may have a u-shaped profile

Preferably, a pair of stanchions **62** are provided. The pair of stanchions **62** are mounted on the pair of rails **13**. The pair of stanchions **62** are mutually spaced apart. The respective sides **64a** are mutually facing and are mutually parallel. The respective forward edges **64b** of the pair of stanchions **62** are positioned forward of the edge of the forward region **12a** of the frame **12**. The respective through holes **66d** are vertically aligned. The respective through holes **66d** are transversely aligned relative to the longitudinal axis of the frame **12**. The planes of the respective openings of the through holes **66d** are all mutually parallel. The respective through holes **66d** are positioned forward of the edge of the forward region **12a**.

With reference to Figs. 1 and 2, the clearing device **22** is supported on the mounting

assembly **20**. The clearing device **22** has pegs **68** extending from opposite sides. The pegs **68** are rigidly engaged to the clearing device **22**. Pegs **68** may be removable from the clearing device **22**. In an embodiment, the clearing device **22** has a housing **70** and the pegs **68** extend from the housing **70**. The pegs **68** may be positioned equidistant from the sides of the housing **70**.

In an embodiment, the clearing device **22** is supported on a stanchion **62**. Preferably, the clearing device **22** is supported on the pair of stanchions **62**. The clearing device **22** is positioned between the pair of stanchions **62**.

The pegs **68** are configured to engage into the through holes **66d** of the upper portion **66** of each stanchion **62**. With the pegs **68** positioned in the respective through holes **66d**, the clearing device **22** is vertically orientated relative to the frame **12**. The longitudinal axis of the clearing device **22**, in the vertical orientation, may be perpendicular to the longitudinal axis of the frame **12**. The longitudinal axis of the clearing device **22**, in the vertical orientation, may be parallel to the longitudinal axis of the at least one stanchion **62**. The clearing device **22** is spaced from the edge of the forward region **12a** of the frame **12**. The clearing device **22** is forward of the edge of the forward region.

With reference to Fig. 1, the clearing device **22** has a tool mount **22a** for a tool that performs the grout joint clearing operations. The tool mount **22a** is configured to receive a tool. In an embodiment, a tool is fixed to the tool mount **22a**. The tool mount **22a** is forward of the edge of the forward region **12a** of the frame **12**. In an embodiment, the tool mount **22a** is engaged to the housing **70**. In alternative embodiment, the tool mount **22a** is configured to be movable relative to the housing **70**. The tool mount **22a** may extend transversely relative to the longitudinal axis of the clearing device **22** and may have an engagement end that engages the clearing tool **24**.

The clearing tool **24** is mounted to an end of the clearing device **22**. In the vertical orientation of the clearing device **22**, the clearing tool **24** is spaced from the forward region **12a** of the frame **12**. The clearing tool **24** is positioned forward of the forward region **12a** of the frame **12**. The clearing tool **24** is positioned below the frame **12**.

In an embodiment, a coupling portion **24a** of the clearing tool **24** may be aligned with the edge of the forward region **12a** and the clearing tool **24** extends downwards to an

operational portion **24b**. The coupling portion **24a** is configured for engagement to the clearing device **22**. The coupling portion **24a** is configured for engagement to the tool mount **22a** of the clearing device **22**. The operational portion **24b** is configured for entering a grout joint and to clear the grout joint. The operational portion **24b** is configured for the removal of grout.

In an embodiment, the clearing tool **24** is fixed relative to the clearing device **22**. The clearing tool **24** is held in a fixed position by the clearing device **22** at the tool mount **22a**. The clearing tool **24** may be mounted in a manner that does not permit any movement relative to the clearing device **22**. In an alternative embodiment, the clearing tool **24** is rotatable relative to the clearing device **22**. The clearing tool **24** is movably held by the clearing device **22** at the tool mount **22a**. The clearing tool **24** may be mounted in a manner that allows a rotating movement relative to the clearing device **22**.

The clearing tool **24** is a blade selected from the group comprising a straight blade, chisel-like blade, a circular disc blade and a sickle-type blade. The figures show the clearing tool **24** formed as a sickle-type blade which is the preferred embodiment. The sickle-type blade is formed from spring steel and heat treated for additional hardness. The sickle-type blade has curved shape operation portion **24b**. This operation portion **24b** allows for pushing out grout, cement, concrete and other debris from a grout joint.

In an embodiment, Fig. 8 shows a chisel-like blade. The operation portion **24b** is formed at the free end opposite the coupling portion **24a**. The operation portion **24b** has a straight with teeth **24c** and having an extended tip **24d**.

The clearing tool **24** is movable relative to the frame **12**. The grout joint clearing robot **10** is configured for the movement of the clearing tool **24**. Clearing tool **24** may be movable relative to the housing **70** and/ or the frame **12**. The clearing tool **24** is movable between a first position and a second position. In the first position the clearing tool **24** is stored. The clearing tool **24** is stored to allow for free movement of the grout joint clearing robot **10**. In the first position the clearing tool **24** is positioned away from the surface that is designated for grout joint clearing operations. The clearing tool **24** may be positioned closer to the housing **70** and/ or the frame **12**. In the second position the clearing tool **24** is deployed for the required grout joint clearing operations. In the second position the clearing tool **24** is

positioned into a grout joint in the surface that is designated for grout joint clearing operations. The clearing tool **24** may be positioned away from the housing **70** and/ or the frame **12**.

With respect to Figs. 1 and 2, the sensing system **26** is mounted to the frame **12**. The sensing system **26** is configured to detect a plurality of grout lines where each grout line corresponds to a grout joint between tiles. The grout joint clearing robot **10** may be fitted with a series of sensors of various types, as described herein, for performing localization, object detection, mapping, etc. In an embodiment, the sensing system **26** comprises at least one LIDAR **46** and at least one imaging sensor **48** to observe a composite field of view in front of the grout joint clearing robot **10**.

The LIDAR **46** may be positioned above the frame **12** by a support **72**. Support **72** comprises a pair of vertical posts **72a** positioned on opposite rails **13**. The posts **72a** extend vertically from the respective rails **13**. The pair of posts **72a** are mutually spaced apart. The pair of posts **72a** are mutually facing. A horizontal post **72b** is positioned at the respective free ends of the vertical posts **72a**. The post **72b** extends horizontally between the pair of posts **72a**. The support **72** comprises a platform **72c** on which the LIDAR **46** is mounted. The LIDAR **46** may be removably mounted to the platform **72c**.

The imaging sensor **48** is coupled to the mounting assembly **20**. The imaging sensor **48** is coupled to a forward edge **64b** of a stanchion **62**. The imaging sensor **48** is mounted to a mounting **74** fixed to the forward edge **64b** of the stanchion **62**. The imaging sensor **48** may be removably mounted to the mounting **74**. The imaging sensor **48** may be positioned over the clearing tool **24**. The imaging sensor **48** may be positioned over the tool mount **22a** of the clearing device **22**.

In the context of this specification, a composite field of view refers to a field of view that includes a downward viewing portion as well as a forward viewing portion. The downward viewing portion captures to a region directly in front of the grout joint clearing robot **10** to view the grout line to be cleared, and clearing device **22** and/or the clearing tool **24** during grout clearing and/ or grout removal operations. The forward viewing portion captures the grout line as it extends forward of the grout joint clearing robot **10** towards the edge of the tiles and adjacent surroundings which may include adjacent and intersecting grout

lines, as well as walls and edge of the tiles.

In some embodiments the imaging sensor **48** may be a camera comprising an optical sensor and associated optical assemblies including one or more lenses to project or direct light onto the optical sensor. In some embodiments a camera may include multiple optical sensors each with an optical assembly such that each optical sensor has a different field of view and/or different magnification. In some embodiments multiple optical assemblies may be used to project or direct light onto a single optical sensor such that it has a composite field of view such that different regions of the imaging sensor capturing different views.

The sensing system **26** is further configured to detect the position and movement of the drive system **14** and the grout joint clearing system **18**. The sensing system **26** is configured to receive feedback regarding the position and movement of the drive system **14** and the grout joint clearing system **18**. The sensing system **26** may comprise one or more sensors to detect the position and movement of the drive system **14** and the grout joint clearing system **18**. In an embodiment, the sensing system **26** may further comprise a robot motion sensor **50** that is configured to detect motion of the grout joint clearing robot **10**. The robot motion sensor **50** may be positioned in the compartment **56**. The robot motion sensor **50** may be an encoder connected to the drive system **14**.

The control system **28** is mounted to the frame **12**. In an embodiment, the control system **28** may be accommodated in the electrical box **60**. The control system **28** comprises at least one processor and at least one memory. The control system **28** is configured to receive input from the sensing system **26** and to control the drive system **14**, power system **16** and the grout joint clearing system **18** to perform grout clearing operations and/ or remove grout in the grout joints. Mapping data may be provided to the control system **28**. The at least one processor may control the robot in accordance with instructions implemented in the software, including, for example, controlling the drive system **14**, determining routes, reading and processing data from the sensing system **26**, etc.

The grout joint clearing robot **10** may be provided with an algorithm to autonomously recognise grout lines. The grout lines may be recognized with sub millimetre precision. The LIDAR **46** may enable the grout joint clearing robot **10** to map the room autonomically. This allows for a user to place the grout joint clearing robot **10** anywhere in the room, give it a

start command, and the grout joint clearing robot **10** is able to begin the mapping without any further or prior user inputs (such as inputting the floor plan). After the mapping is done, the grout joint clearing robot **10** will align itself to a grout line and start the grout joint clearing process.

5 In an embodiment, the control system **28** is configured to process at least a plurality of images and a plurality of LIDAR scans to map a zone that is designated grout clearing operations and in particular to map a zone designated for grout removal. The control system **28** is to control the drive system **14** and the grout joint clearing system **18** to perform grout clearing operations and/ or to remove grout in the grout lines in that grout removal zone. The
10 control system **28** is configured to process at least a plurality of images and a plurality of LIDAR scans to map a zone and to mark locations of the tiles and the grout joints.

In an embodiment, the control system **28** is configured to generate a grout joint clearing plan and/ or a grout removal plan after generating a map of the zone in accordance with predetermined criteria. In an embodiment, the control system **28** is configured to receive
15 input from the imaging sensor **48** and the robot motion sensor **50** to control the movement of the frame **12** through the drive system **14**.

In an embodiment, the clearing device **22** is a linear actuator **22**. In the first position of the clearing tool **24**, the linear actuator **22** is retracted and in the second position of the clearing tool **24**, the linear actuator **22** is extended. In the first position of the clearing tool **24**,
20 the tool mount **22a** is positioned closer to the housing **70** and/ or the frame **12** and in the second position of the clearing tool **24**, the tool mount **22a** is positioned further from the housing **70** and/ or the frame **12**.

Figs. 3 and 4 illustrate the grout joint clearing robot **10** with the clearing tool **24** in the first position. The clearing tool **24** is in the stored position which is raised from the surface and moved closer to the housing **70** and/ or the frame **12**. Figs. 5 and 6 illustrate the grout
25 joint clearing robot **10** with the clearing tool **24** in the second position. The clearing tool **24** is in the deployed position which is lowered into the grout joint in the surface and moved away from the housing **70** and/ or the frame **12**.

In a further embodiment, the linear actuator **22** is provided in the housing **70** and has a
30 rod **22b**. In the first position of the clearing tool **24**, the rod **22b** is retracted into the body **70**.

In the second position of the clearing tool **24**, the rod **22b** is extended from the body **70**. The linear actuator **22** is configured to control extension and retraction of the rod **22b** to control the position of the clearing tool **24** with respect to the housing **70** and/ or the forward region **12a** of the frame **12**. In an embodiment, the linear actuator **22** is configured to regulate the speed and the distance of the extension and retraction of the rod **22b**. Hence, the velocity of the linear movement of the clearing tool **24** may be regulated accordingly. In addition, the distance of the clearing tool **24** from the housing **70** and/ or the frame **12** can be regulated as required. The clearing tool **24** may be positioned between the first and second positions.

The linear actuator **22** is a type selected from a group comprising electro-mechanical type, a hydraulic type, a pneumatic type or a piezoelectric type. Preferably, the linear actuator **22** is an electro-mechanical type. A motor (not shown) is connected to the liner actuator **22** for effecting the extraction and retraction of the rod **22b**. The motor may be connected to and control by the control system **28**. In an embodiment, the linear actuator **22** has an inbuilt potentiometer that can be read to determine its relative distance from points with known resistance. The potentiometer may be connected to the sensing system **26**.

In a further embodiment, the sensing system **26** comprises an actuator motion sensor **30** configured to detect the retraction and extension of the linear actuator **22**. The control system **28** is configured to receive input from the actuator motion sensor **30** to control the retraction and extension of the linear actuator **22**. The positional feedback from the actuator motion sensor **30** enables the grout joint clearing robot **10** to be autonomous in positioning its clearing tool **24** to perform grout clearing operations.

With respect to Fig. 1, in an embodiment, grout joint clearing robot **10** comprises an oscillation motor **32**. The oscillation motor **32** is provided in the clearing device **22**. The oscillation motor **32** that imparts a high frequency oscillation motion to the clearing tool **24**. The oscillation motor **32** is controlled by the control system **28**. The oscillation motor **32** is connected to the control system **28** for powering on and off. The oscillation motor **32** is configured to derive power from the power system **16**. In an embodiment, the control system **28** is configured to receive input from the oscillation motor **32** through the sensing system **26**.

The oscillation motor **32** provides a high frequency oscillating motion to the clearing tool **24** which allows it to break grout, cement or concrete stuck in the grout joint between

tiles. The clearing tool **24** may be provided with jagged teeth **24c** on the convex side of the blade which augments the ability to remove debris stuck in the grout joints. The oscillation motor **32** may be enclosed in a housing **32a**.

In an embodiment, the clearing tool **24** is coupled to the clearing device **22** through the oscillation motor **32**. In a preferred embodiment, the oscillation motor **32** is provided on the linear actuator **22**. The oscillation motor **32** is interposed between the rod **22b** and the tool mount **22a**. The high frequency oscillation motion imparted from the oscillation motor **32** is transmitted to the clearing tool **24** through the tool mount **22a**.

In a further embodiment, oscillation motor **32** may be a brushless motor. The oscillation motor **32** may be further modified for controlling heat generated during grout clearing operations. This includes reducing the vibrating power of the oscillation motor **32** and, installing heat sinks and fans on the oscillation motor **32**.

With reference to Fig. 7, in an embodiment, the clearing device **22** is rotatably mounted to the mounting assembly **20**. The clearing device **22** is rotatable relative to the frame **12** and the mounting assembly **20**. The clearing device **22** is rotatable from the vertically orientated position wherein the clearing tool **24** is adjacent to the frame **12** to an inclined position wherein the clearing tool **24** is angularly displaced from the frame **12** and back to the vertically centred position. As the clearing device **22** pivots from the vertically centred position to the inclined position, the distance between the clearing tool **24** and the forward region **12a** of the frame **12** increases as the tilt angle changes from 0 degrees to 45 degrees, or more. The pivoting movement of clearing device **22** from the vertically centred position to the inclined position enables the grout joint clearing robot **10** to clear out debris from the grout joint. In particular, the pivoting movement allows the grout joint clearing robot **10** to hook onto tile spacers and remove them from between tiles.

The clearing device **22** is pivotable relative to the frame **12** to effect the movement of the clearing tool **24** from the second position to a third position. At the third position the clearing tool **24** is angularly spaced away from the frame **12**.

The clearing device **22**, particularly in the form of the linear actuator **22**, is rotatably mounted to the mounting assembly **20**. The oscillation motor **32**, the rod **22b** and the tool mount **22a** are movable along with the clearing tool **24**.

A pivot arrangement is provided in the mounting assembly **20** to allow for the clearing device **22** to pivot between the vertically centred position and the inclined position. The peg **68** of the clearing device **22** is rotatably supported in the stanchion **62**. In an embodiment, the pegs **68** of the clearing device **22** are rotatably supported in the pair of stanchions **62**. In an embodiment, bearing assemblies are provided between the stanchions **62** and the respective pegs **68**. The pegs **68** are engaged in the through holes **66d** with the bearing assemblies.

A rotatory motor **34** is provided to effect the rotational motion of the clearing device **22**. The rotatory motor **34** is coupled to the mounting assembly **20** through a support **76**. The support **76** is mounted to an outer side **64a** of a plank portion **64** of a stanchion **62**. The support **76** is positioned so as to allow the rotatory motor **34** to be aligned to a hole **66d**. The rotatory motor **34** is coupled to a peg **68** through the hole **66d**. Rotatory motor **34** is able to effect the rotational motion of the clearing device **22** through the peg **68**. The rotatory motor **34** is configured to control a pivot angle of the clearing device **22**. In an embodiment, the support **76** is provided on the same stanchion **62** as the mounting **74** for the imaging sensor **48**.

The rotatory motor **34** may be connected to and controlled by the control system **28**. In an embodiment, the rotatory motor **34** has an encoder **35** that provides positional feedback. The encoder **35** may be connected to the sensing system **26**.

In a further embodiment, the sensing system **26** comprises a device motion sensor **36** configured to detect the pivot angle of the clearing device **22**. The control system **28** is configured to receive input from the device motion sensor **36** to control the rotational movement of the clearing device **22** through the rotatory motor **34**. The positional feedback from the device motion sensor **36** enables the grout joint clearing robot **10** to be autonomous in positioning its clearing tool **24** to perform removal of the tile spacers. In an embodiment, the device motion sensor **36** may be positioned with the rotatory motor **34**.

With reference to Figs. 1 and 2, the grout joint clearing robot **10** further comprising a cleaning system **38** for cleaning debris in the grout joints and debris on the surface that is undergoing grout clearing operations. The cleaning system **38** is mounted to the frame **12**. In an embodiment, the cleaning system **38** comprises a vacuum device **40** having an air intake

port **42** to suction debris and a receptacle **44** for deposit of the suctioned debris. Debris may include grout, cement, concrete, tile spacers and other types of matter removed from the grout lines.

The vacuum motor **45** and the receptacle **44** are positioned on the topside of the frame **12**. In an embodiment, the receptacle **44** is positioned on the upper surface of the frame **12** between the pair of rails **13**. The receptacle **44** may be positioned towards the rear region **12b**. The motor **45** may be positioned above the upper surface of the frame **12** through a supporting connection with the receptacle **44**.

The motor of the vacuum device **40** is controlled by the control system **28**. This motor is connected to the control system **28** for powering on and off. This motor is configured to derive power from the power system **16**. In an embodiment, the control system **28** is configured to receive input from this motor **32** through the sensing system **26**.

The air intake port **42** is axially aligned to the clearing tool **24** in the second position. The air intake port **42** is substantially in line with the clearing tool **24** in the second position. The air intake port **42** is positioned below the frame **12** and posterior to the clearing tool **24**. The clearing tool **24** is ahead of the air intake port **42** relative to the forward orientation and the travel direction of the grout joint clearing robot **10**. The alignment allows for the air intake port **42** to pass over the grout line that is underdoing grout cleaning operations. In an embodiment, air intake port **42** has a width that transversely spans over the grout line.

With reference to Fig. 3, the air intake port **42** is connected to the receptacle **44** through the vacuum motor **45**. A tube **47** leads from the air intake port **42** to the vacuum motor **45**. In an embodiment, the air intake port **42** is maintained in position by the tube **47**. Tube **47** is positioned rear to the clearing device **22**. In an embodiment, the tube **47** is positioned between the clearing device **22** and the forward region **12a** of the frame **12**.

The skilled person would appreciate that foregoing embodiments may be modified or combined to obtain the grout joint clearing robot **10** of the present disclosure.

Industrial Applicability

This disclosure describes a grout joint clearing robot **10** that is capable of removing grout and other debris from grout joints. The grout joint clearing robot **10** is capable of

effectively removing concrete and cement from the grout joints. The grout removal joint clearing **10** is capable of removing grout and other debris from grout joints that are as thin as 1mm in width.

5 The robot may be modified to serve similar functions, such as but not limited to, a grout joint clearing robot **10**. The clearing tool **24** can be replaced and/ or added with a rotary brush to clean the grout joints with the addition of detergent if required. The robot may be further modified to add a steamer that is followed by the cleaning system **38**. This will allow for autonomous deep cleaning of the grout joints with the same control logic and sensors.

10 Further end effectors can be added, for example, if the tiles have chamfers and thus regular cleaning of the chamfered edges. In such cases, a rotary abrasive brush may be needed. The same operation applies if grout in the grout joint is required to be removed and replaced, or merely just cleaned. For grout cleaning a rotary non-abrasive brush may be used.

15 Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein.

20 Where technical features mentioned in any claim are followed by reference signs, the reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, neither the reference signs nor their absence have any limiting effect on the technical features as described above or on the scope of any claim elements.

25 One skilled in the art will realise the disclosure may be embodied in other specific forms without departing from the disclosure or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the disclosure described herein. Scope of the invention is thus indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

Claims

1. A grout joint clearing robot (10) comprising:

a frame (12);

a drive system (14) mounted to the frame (12), the drive system (14) being configured to drive the grout joint clearing robot (10);

a power system (16) mounted to the frame (12), the power system (16) configured to provide power for the operation of the grout joint clearing robot (10);

a grout joint clearing system (18) comprising:

a mounting assembly (20) mounted to the frame (12);

a clearing device (22) supported on the mounting assembly (20);

a clearing tool (24) mounted to an end of the clearing device (22), the clearing tool (24) being movable relative to the frame (12) between a first and a second position wherein in the first position the clearing tool (24) is stored and in the second position the clearing tool (24) is deployed for grout joint clearing;

a sensing system (26) mounted to the frame (12), the sensing system (26) being configured to detect the position and movement of the drive system (14) and the grout joint clearing system (18) and being configured to detect a plurality of grout lines where each grout line corresponds to a grout joint between tiles; and

a control system (28) mounted to the frame (12), the control system (28) comprising at least one processor and at least one memory, and being configured to receive input from the sensing system (26) and to control the drive system (14), power system (16) and the grout joint clearing system (18) for clearing the grout lines prior to a grouting operation.

2. The grout joint clearing robot (10) of claim 1 wherein the clearing device (22) is a linear actuator (22) and wherein in the first position the linear actuator (22) is retracted and in the second position the linear actuator (22) is extended.

3. The grout joint clearing robot (10) of claim 2 wherein the sensing system (26) comprises an actuator motion sensor (30) configured to detect the retraction and extension of the

linear actuator (22) and wherein the control system (28) is configured to receive input from the actuator motion sensor (30) to control the retraction and extension of the linear actuator (22).

- 5 4. The grout joint clearing robot (10) of claim 2 or 3 wherein the liner actuator (22) is a type selected from a group comprising an electro-mechanical, a hydraulic, a pneumatic or a piezoelectric types.
- 10 5. The grout joint clearing robot (10) of claim 1, 2, 3 or 4 wherein the clearing device (22) comprises an oscillation motor (32) that imparts a high frequency oscillation motion to the clearing tool (24) wherein the oscillation motor (32) is controlled by the control system (28).
- 15 6. The grout joint clearing robot (10) of claim 5 wherein the clearing tool (24) is coupled to the clearing device (22) through the oscillation motor (32).
- 20 7. The grout joint clearing robot (10) of any one of preceding claims wherein the clearing device (22) is rotatably mounted to the mounting assembly (20), the clearing device (22) being pivotable relative to the frame (12), the clearing tool (24) being movable from the second position to a third position wherein the clearing tool (24) is angularly spaced away from the frame (12).
- 25 8. The grout joint clearing robot (10) of claim 7 wherein a rotatory motor (34) is coupled to the mounting assembly (20) to effect the rotational motion of the clearing device (22), wherein the rotatory motor (34) is configured to control a pivot angle of the clearing device (22) and wherein the rotatory motor (34) is controlled by the control system (28).
- 30 9. The grout joint clearing robot (10) of claim 8 wherein the sensing system (26) comprises a device motion sensor (36) configured to detect the tilt angle of the clearing device (22) and wherein the control system (28) is configured to receive input from the device motion

sensor (36) to control the rotational movement of the clearing device (22) through the rotary motor (34).

10. The grout joint clearing robot (10) of any one of the preceding claims wherein the clearing tool (24) is fixed relative to the clearing device (22).

11. The grout joint clearing robot (10) of any one of the preceding claims 1 to 9 wherein the clearing tool (24) is rotatable relative to the clearing device (22).

12. The grout joint clearing robot (10) of any one of the preceding claims wherein the clearing tool (24) is a blade selected from the group comprising a straight blade, chisel-like blade, a circular disc blade and a sickle-type blade.

13. The grout joint clearing robot (10) of any one of the preceding claims further comprising a cleaning system (38) mounted to the frame (12), the cleaning system (38) comprising a vacuum device (40) having an air intake port (42) to suction debris and a receptacle (44) for deposit of the suctioned debris.

14. The grout joint clearing robot (10) of claim 13 wherein the air intake port (42) is axially aligned to the clearing tool (24) in the second position and wherein the air intake port (42) is positioned below the frame (12), and posterior to the clearing tool (24).

15. The grout joint clearing robot (10) of any one of the preceding claims wherein the sensing system (26) comprises at least one LIDAR (46) and at least one imaging sensor (48) to observe a composite field of view in front of the grout joint clearing robot (10) and wherein the control system (28) is configured to process at least a plurality of images and a plurality of LIDAR scans to map a grout removal zone and to control the drive system (14) and the grout joint clearing system (18) to clear the grout lines in the grout removal zone.

16. The grout joint clearing robot (10) of any one of the preceding claims wherein the sensing system (26) comprises a robot motion sensor (50) configured to detect motion of the grout joint clearing robot (10) and wherein the control system (28) is configured to receive input from the robot motion sensor (50) to control the movement of the frame (12) through the drive system (14).