CLAIMS

1. An autonomous grouting robotic apparatus comprising:

a frame;

a grout cleaning arrangement comprising:

a sponge belt forming a loop;

a tank;

a sponge belt cleaning and tensioning assembly comprising a plurality of rollers;

a front sponge guide assembly configured to guide the sponge belt over a forward tip; and

a front support assembly mounted to the frame and which is configured to support the front sponge guide assembly and to control a height of the front sponge guide assembly and a tilt angle of the front sponge guide assembly with respect to a vertical axis of the autonomous grouting robotic apparatus;

a grout extruder comprising a grout extruder mounting assembly which either supports a grout storage container or is configured to receive and support a removable grout storage container, and a motorised plunger, wherein the grout storage container or the removable grout storage container ends in a nozzle with a slot and is configured to receive the motorised plunger, and the grout extruder mounting assembly is configured to control a location and a height of the nozzle and to control a tilt angle of the nozzle with respect to the vertical axis of the autonomous grouting robotic apparatus;

a power system configured to provide power to the autonomous grouting robotic apparatus;

a drive system configured to drive the autonomous grouting robotic apparatus;

a control system comprising at least one processor, at least one memory, at least one LIDAR, at least one imaging sensor, and at least one motion sensor, wherein the at least one imaging sensor is mounted to the frame to observe a composite field of view in front of the autonomous grouting robotic apparatus, and the at least one motion sensor is configured to detect motion of the autonomous grouting robotic apparatus, and the control system is configured to process at least a plurality of images and a plurality of LIDAR scans to map a room and identify a plurality of grouting line where each grouting line corresponds to a gap between tiles, and to control the drive system, the grout extruder and the grout cleaning arrangement to control extrusion of grout from the nozzle and to clean excess grout off tiles, such that when extruding grout, the slot is aligned along the grouting line.

2. The autonomous grouting robotic apparatus as claimed in claim 1 wherein the slot of the nozzle ends in a nozzle tip, and when viewed from the side, a front face of the nozzle is inclined rearward with respect to the nozzle tip and the vertical axis such that an angle from the grouting line to the front face is greater than 90 degrees, and when viewed from the front the nozzle has a symmetrical chamfered profile such that a left side and a right side each define an opening angle with the vertical axis of less than 45 degrees.

3. The autonomous grouting robotic apparatus as claimed in claim 2 wherein the slot comprises a plurality of gaps each separated by projection separator that protrudes out of the slot to compress grout into the tile gap.

4. The autonomous grouting robotic apparatus as claimed in claim 1, 2 or 3 wherein the grout extruder mounting assembly is mounted on the front sponge guide assembly such that tilting the front sponge guide assembly also tilts the grout extruder mounting assembly.

5. The autonomous grouting robotic apparatus as claimed in claim 4 wherein the grout storage container is a grout cartridge and the grout extruder mounting assembly comprises a lower mount and an upper mount, wherein the lower mount has an inverted U shaped profile such that when mounted to the front sponge guide assembly the arms of the U define a gap through which the belt passes, and the upper mount is configured to support the grout cartridge and comprises a pair of guide rails which extend rearward of the upper mount and are connected to an end cap which supports the motorised plunger arrangement, and a linear actuator arrangement is configured to control extension and retraction of the grout cartridge along the guide rails to control a location of the nozzle tip with respect to a front face of the upper mount, and wherein the upper mount is configured to be driven away from the lower mount so as to control an orientation of the nozzle tip as the front sponge guide assembly is tilted.

6. The autonomous grouting robotic apparatus as claimed in claim 5 wherein the front sponge guide assembly comprises a main support structure on which the grout extruder mounting assembly is mounted, and a plurality of rollers that defines a forward belt path around the main support structure comprising a first front powered roller to receive and drive the belt, a tip roller located distal of the front powered roller with a smaller diameter than the front powered roller to define the forward tip and guide the belt over and then under the front powered roller and towards a rear guide roller for guiding the belt back towards the sponge belt cleaning and tensioning assembly.

7. The autonomous grouting robotic apparatus as claimed in claim 6 wherein the frame comprises a body frame and a front frame extending forward of the body frame, and the front support assembly comprises a first support structure mounted to the front frame which supports a pivot arrangement and a second support structure which supports the front sponge guide assembly, wherein a height of the second support structure is adjustable with respect to the first support structure, and the pivot arrangement comprises a front pivoting mount that supports a front pivoting roller and a rear roller wherein the front pivoting roller guides the sponge belt coming from the sponge belt cleaning and tensioning assembly towards the front powered roller and the rear roller receives the sponge belt from the rear guide roller and direct the belt to the sponge belt cleaning and tensioning assembly, and the front sponge guide assembly is connected to the front pivoting mount, and tilting of the front sponge guide assembly is driven by the second support structure which causes pivoting of the front pivoting mount and front pivoting roller.

8. The autonomous grouting robotic apparatus as claimed in claim 7 wherein the rear roller is a pivoting roller which is independently pivotable with respect to the front pivoting roller such that a pivot angle of the rear roller may be different to a pivot angle of the front pivoting roller.

9. The autonomous grouting robotic apparatus as claimed in claim 7 further comprising a set of cascading pivoting rollers, wherein each roller in the set of cascading pivoting rollers is pivotable such that a total pivot angle or a pivoting range of the cascading pivoting rollers is larger than a pivot angle or a pivoting range of each individual pivoting roller, and either the set of pivoting rollers comprises the front pivoting roller and one or more additional pivoting rollers, or the set of pivoting rollers comprises the rear roller and one or more additional pivoting rollers and the rear roller is also a pivoting roller that is independently pivotable with respect to the front pivoting roller such that a pivot angle of the rear roller may be different to a pivot angle of the front pivoting roller, or the set of pivoting rollers comprises two sets of pivoting rollers, the first set comprising the front pivoting roller and one or more additional pivoting rollers and the second set of pivoting rollers comprises the rear roller and one or more additional pivoting rollers and the rear roller is also a pivoting roller that is independently pivotable with respect to the front pivoting roller such that a pivot angle of the rear roller may be different to a pivot angle of the front pivoting roller.

10. The autonomous grouting robotic apparatus as claimed in claim 7, 8 or 9 wherein the second support structure comprises a left frame and a right frame, and one or more guide rails that extend between the left and right frames and pass through apertures in the main support structure of the front sponge guide assembly and a threaded rod extends between the left and right frames and passes through a threaded nut in a horizontal slide arrangement in the main support structure of the front sponge guide assembly and one or both of the left and right frames comprises a motor arrangement to drive rotation of the threaded rod which drives the threaded nut along the threaded rod such that the horizontal slide arrangement translates horizontal movement into a rotation and tilting of the front sponge guide assembly, and a plurality of guide rods and one or more threaded rods connect the first support structure to the second support structure and one or more motors drive rotation of the threaded rods to adjust the height of the first support structure with respect to the second support structure.

11. The autonomous grouting robotic apparatus as claimed in any preceding claim wherein the frame comprises a body frame and a front frame extending forward of the body frame and the at least one imaging sensor comprises at least two imaging sensors which observe a composite field of view wherein at least one sensor is mounted to a distal end of the front frame in a forward direction and at least one imaging sensor is mounted to the distal end of the front frame in a downward direction.

12. The autonomous grouting robotic apparatus as claimed in any preceding claim wherein the plurality of rollers direct the sponge belt through a serpentine path within the cleaning and tensioning

assembly and the plurality of rollers comprises a plurality of squeezing rollers, a plurality of rinsing rollers, a plurality of powered drive rollers and a plurality of tensioning rollers, wherein at least two of the plurality of squeezing rollers are located in the tank and receive the sponge belt from the front support assembly and are configured to squeeze grout out of the sponge belt and direct the sponge belt towards the plurality of rinsing rollers which are located in the tank, and at least one of the tensioning rollers directs the sponge belt out from the sponge belt cleaning and tensioning assembly towards the front pivoting roller and each of the tensioning rollers are mounted to a motor configured to adjust a position of the tensioning roller to control a tension in the sponge belt.

13. The autonomous grouting robotic apparatus as claimed in any preceding claim wherein the control system is configured to:

map a room and identify the plurality of grout lines within the room by driving the autonomous grouting robotic apparatus around the room and collecting the plurality of images, the plurality of LIDAR scans, and motion data from the at least one motion sensor, and using a simultaneous localization and mapping (SLAM) algorithm to process the plurality of LIDAR scans and motion data to generate a map of the room, and processing the plurality of images to identify the plurality of grouting lines corresponding to gaps between tiles in the room;

grouting a room by progressively selecting each grouting line in the map until all grouting lines are selected and grouted and for each selected grouting line:

driving the autonomous grouting robotic apparatus to a starting location;

dispensing grout into the grouting line from the grout extruder mounted on the autonomous grouting robotic apparatus by controlling the location of the nozzle of the grout extruder and driving the autonomous grouting robotic apparatus to follow the grouting line wherein a precise location and a rotation angle are continuously updated using motion data from the at least one motion sensors and a plurality of images from the at least one image sensors captured as the autonomous grouting robotic apparatus moves;

retracing the grouting line and cleaning excess grout from the grouting line using the sponge belt guided by the front sponge guide assembly mounted on the autonomous grouting robotic apparatus,

wherein if the grout line is an edge grout line, the grout extruder and the front sponge guide assembly are tilted by a tilt angle to direct the nozzle and belt over the edge grout line.

14. The autonomous grouting robotic apparatus as claimed in claim 13 wherein the motion sensors comprises one or more odometry sensors configured to monitor rotation of one or more wheels of the autonomous grouting robotic apparatus.

15. The autonomous grouting robotic apparatus as claimed in claim 13 or 14 wherein identification of grout lines is performed after mapping the room using the SLAM algorithm.

16. The autonomous grouting robotic apparatus as claimed in claim 13, 14 or 15 wherein when identifying the plurality of grouting lines and when updating the precise location and the rotation angle, the plurality of images are processed by a computer vision method to identify a plurality of lines, and the plurality of lines are then split by angle into a plurality of buckets where each bucket is of a pre-determined angular range and for each bucket, an average direction of the lines in the bucket is determined, and the middle of each line is projected on a norm of an average direction of the bucket to obtain a projected point, and the lines are clustered by the projected points where each cluster corresponds to a single real grouting line whose direction and center is set to the median direction and center of the lines in the cluster.

17. The autonomous grouting robotic apparatus as claimed in claim 16 wherein the pre-determined angular range bucket is 15 degrees.

18. The autonomous grouting robotic apparatus as claimed in any preceding claim further comprising a marker, wherein the marker is adapted to be mounted to the nozzle, the grout storage container or the removable grout storage container, or the grout extruder is configured to receive a removable marker cartridge comprising a marker, and the control system is further configured to mark out a tiling map using the marker based on a tiling plan stored by the at least one memory.

19. The autonomous grouting robotic apparatus as claimed in claim 18 wherein the control system is configured to generate the tiling plan after generating a map of the room according to one or more design criteria.

20. A method of controlling an autonomous grouting robotic apparatus comprising:

mapping a room and identifying a plurality of grout lines within the room by driving an autonomous grouting robotic apparatus around the room and collecting a plurality of images from at least one imaging sensor mounted on the autonomous grouting robotic apparatus, a plurality of LIDAR scans from at least one LIDAR mounted on the autonomous grouting robotic apparatus, and motion data from at least one motion sensor configured to detect motion of the autonomous grouting robotic apparatus, and using a simultaneous localization and mapping (SLAM) algorithm to process the plurality of images, plurality of LIDAR scans and motion data to generate a map of the room, and processing the plurality of images to identify a plurality of grouting lines corresponding to gaps between tiles in the room;

grouting a room by progressively selecting each grouting line in the map until all grouting lines are selected and grouted and for each selected grouting line:

driving the autonomous grouting robotic apparatus to a starting location;

dispensing grout into the grouting line from a grout extruder mounted on the autonomous grouting robotic apparatus by controlling a location of a nozzle of the grout extruder and driving the autonomous grouting robotic apparatus to follow the grouting line wherein a precise location

and rotation angle are continuously updated using motion data from the at least one motion sensors and a plurality of images from the at least one imaging sensors captured as the autonomous grouting robotic apparatus moves;

retracing the grouting line and cleaning excess grout from the grouting line using a sponge belt guided by a front sponge guide assembly mounted on the autonomous grouting robotic apparatus,

wherein if a grout line is an edge grout line, the grout extruder and the front sponge guide assembly are tilted by a tilt angle to direct the nozzle and belt over the edge grout line.

21. The method as claimed in claim 20 wherein the motion sensors comprises one or more odometry sensors configured to monitor rotation of one or more wheels of the autonomous grouting robotic apparatus.

22. The method as claimed in claim 20 or 21 wherein identification of grout lines is performed after mapping the room using the SLAM algorithm.

23. The method as claimed in claim 20, 21 or 22 wherein when identifying the plurality of grouting lines and when updating the precise location and the rotation angle, the plurality of images are processed by a computer vision method to identify a plurality of lines, and the plurality of lines are then split by angle into a plurality of buckets where each bucket is of a pre-determined angular range and for each bucket, an average direction of the lines in the bucket is determined, and the middle of each line is projected on a norm of an average direction of the bucket to obtain a projected point, and the lines are clustered by the projected points where each cluster corresponds to a single real grouting line whose direction and center is set to the median direction and center of the lines in the cluster.

24. The method as claimed in claim 23 wherein the pre-determined angular range bucket is 15 degrees.

25. The method as claimed in any one of claims 20 to 24 further comprising generating a tiling plan after generating a map of the room according to one or more design criteria.

26. An autonomous tile marking robotic apparatus comprising:

a frame;

a marker support assembly which supports a marker having a marker tip, and the marker support assembly is configured to control a location and a height of the marker tip and to control a tilt angle of the marker tip with respect to a vertical axis of the autonomous tile marking robotic apparatus;

a power system configured to provide power to the autonomous tile marking robotic apparatus;

a drive system configured to drive the autonomous tile marking robotic apparatus;

a control system comprising at least one processor, at least one memory, at least one LIDAR, at least one imaging sensor, and at least one motion sensor, wherein the at least one imaging sensor is mounted to the frame to observe a composite field of view in front of the autonomous tile marking robotic apparatus, and the at least one motion sensor is configured to detect motion of the autonomous tile marking robotic apparatus, and the control system is configured to process at least a plurality of images and a plurality of LIDAR scans to map a room and to mark locations of tiles according to a tile plan, and to control the drive system and the marker support assembly to control marking.

27. The autonomous tile marking robotic apparatus as claimed in claim 26 wherein the control system is configured to generate the tiling plan after generating a map of the room according to one or more design criteria.

28. A method of controlling an autonomous tile marking robotic apparatus comprising:

mapping a room by driving an autonomous tile marking robotic apparatus around the room and collecting a plurality of LIDAR scans from at least one LIDAR mounted on the autonomous tile marking robotic apparatus, and motion data from at least one motion sensor configured to detect motion of the autonomous tile marking robotic apparatus, and using a simultaneous localization and mapping (SLAM) algorithm to process the plurality of LIDAR scans and motion data to generate a map of the room;

marking a plurality of marking locations for laying tiles according to a tiling plan by marker mounted on a marker support assembly mounted on the autonomous tile marking robotic apparatus by controlling a location of a marker tip of a marker support assembly and driving the autonomous tile marking robotic apparatus to follow a marking path wherein a precise location and rotation angle is continuously updated using motion data from the at least one motion sensor and a plurality of images captured from at least one imaging sensor mounted on the autonomous tile marking robotic apparatus as the autonomous tile marking robotic apparatus moves, wherein if a marker location is an edge marker location the marker support assembly is tilted by a tilt angle to direct a tip of the marker over the edge marker location.

29. The method as claimed in claim 28 further comprising generating the tiling plan after generating a map of the room according to one or more design criteria, the tiling plan comprising a plurality of marking locations.

30. A computer readable medium comprising instructions for causing a processor to implement the method of any one of claims 20 to 25 or 28 to 29.