

System For Determining And Drilling A Predetermined Drilling Point On Building Surface

Field of the Invention

5 This invention relates generally to a system for drilling
a surface of a building, and more particularly, to a system
for determining and drilling an overhead surface (e.g. a wall
or a ceiling) of the building, which allows an operator to
perform automatically or manually the drilling work with ease
10 and safely.

Background of the Invention

During the construction of a building, a framework of the
building is first put up, and the walls and ceiling panels are
15 next installed. In order to secure mechanical parts and for
service purposes of mechanical, electrical and plumbing (MEP)
services, holes or recesses on the wall surfaces and ceilings
have to be drilled at the predetermined positions. The
drilling work, particularly the overhead drilling work on the
20 ceilings, is considered as an awkward, monotonous and
laborious process, and also requires a substantial amount of
time, because drilling the overhead surfaces, for example
ceiling soffits, needs auxiliary means such as ladders,
platforms, stands and the like and may be adjusted or scaled
25 many times at different positions of the construction site. In
addition, there is a falling risk of operators who carry out
the drilling work on the auxiliary means at the construction
site.

Building information modeling (BIM) is a digital
30 representation of physical and functional characteristics of a
facility, which is an engineering data model incorporated with

information about various aspects and resources of the facility.

Robotic Total Station (RTS) is designed for automatically measuring of slant distances, horizontal and vertical angles and elevations in topographic and geodetic works, tachometric surveys, as well as for solution of application geodetic tasks. The measurement results can be recorded into the internal memory and transferred to a personal computer interface.

Machine vision is a technology used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control and robot guidance in industry. Generally, machine vision includes a combination of hardware and software which, for example, perform objective measurements, such as providing location information to devices in the execution of their functions based on the capture and processing of images.

Using the BIM technology in combination with the RTS and the machine vision technology may effectively eliminate the need of performing the drilling operations in tedious, high and harsh ceiling conditions.

Accordingly, a great need exists in the building and construction industry for a drilling system to tackle the disadvantage of labor intensity and other drawbacks discussed above, and the drilling system is effective for determining and drilling the surfaces at the precise locations.

Summary of the Invention

The present invention has been developed to fulfill the needs noted above and therefore has a principle object of the provision of a drilling system able to determine a predetermined drilling point, which is significantly more

economical and convenient to drill the predetermined drilling point on a building surface, especially on a surface at a big height.

Another object of the invention is to provide a drilling
5 system without complicated hardware installation, which allows to carry out the overhead drilling operation on the ground floor with ease and safely.

A further object of the invention is to provide a drilling system which allows to automatically and/or manually drill a
10 building surface at high accuracy and speed.

The drilling system of the invention may be called an overhead drilling system (ODS).

These and other objects and advantages of the invention are satisfied by providing a system for determining and drilling a
15 predetermined drilling point on a surface in a predefined region of a building, comprising:

a BIM-based building model corresponding to the building, which is created using the building information modeling (BIM), wherein information related to predetermined drilling points
20 of the surface of the building is identified and recorded in the BIM-based building model;

a positioning unit in communication with or loaded with the BIM-based building model, wherein two or more control points are selected in the BIM-based building model, and the
25 positioning unit is configured to identify two or more reference points in the predefined region of the building, the two or more reference points corresponding to the two or more control points in the BIM-based building model,

a drill device movable to the surface of the building to
30 drill the surface at the predetermined drilling point,

a machine vision unit configured to capture and process images of the predefined region to recognize the reference

points, thereby to determine a position of the predetermined drilling point and generate drilling data associated with the predetermined drilling point;

a control device coupled with the machine vision unit to receive the generated drilling data and programmed to control a drill bit of the drill device to coincide with the predetermined drilling point and to actuate the drill device to move towards and drill the building surface at the predetermined drilling point with the drilling data.

In one preferred embodiment of the invention, the system of the invention further comprises a chassis; and an apparatus for moving the drill device and arranged on the chassis. The moving apparatus comprises X axis moving means for moving the drill device in a direction of the X axis, Y axis moving means for moving the drill device in a direction of the Y axis perpendicular to the X axis, and Z axis moving means for moving the drill device in a direction of the Z axis. The X axis and the Y axis define a X-Y plane in parallel to the predefined region of the building surface to be drilled, and the Z axis is perpendicular to the X-Y plane.

Preferably, the X axis moving means comprises two X axis linear actuators positioned at two opposite sides of the chassis to drive linear movement of the drill device in the X axis direction; the Y axis moving means comprises one Y axis linear actuator to drive linear movement of the drill device in the Y axis direction; and the Z axis moving means comprises one Z axis linear actuator to drive linear movement of the drill device in the Z axis direction.

In specific embodiment of the invention, the moving apparatus is operatively coupled with the control device. The control device is configured to control a X axis electric motor mounted on one of the X axis linear actuators for

steering the drill device to move, a Y axis motor mounted on the Y axis linear actuator for steering the drill device to move, and a Z axis motor mounted on the Z axis linear actuator for steering the drill device to move. Preferably, the X axis and Y axis electric motors are selected from servo motors, and the Z axis electric motor is selected from a stepper motor for fine resolution in the micro range and high accuracy operation.

In order to facilitate to recognize and identify the reference points in the predefined region of the building, a marking unit is provided to apply a mark at each of the reference points. Advantageously, the marking unit is operatively coupled with the control device so as to be controlled to move to be coincident with the reference point to be marked and move towards to the surface to apply the mark at the reference point. The marking unit may be arranged on the moving apparatus so that it is movable by the moving apparatus as well. The marking unit according to the invention may be selected from an ink chop or a writing tool.

In some cases, the system of the invention may further comprise a light beam tracker unit for guiding to locate the reference points in the predefined region. The light beam tracker unit may comprise a plurality of crosshair laser pointers, and each of the reference points are assigned two of the crosshair laser pointers defining a reference region in which the reference point is confined.

It is advantageous to employ a robotic total station (RTS) as the positioning unit according to the invention. The RTS is in communication with the BIM-based building model, and the light beam is irradiated by the RTS to impinge onto the reference points in the predefined region.

The machine vision unit of the system according to the invention comprises a light source to illuminate the

predefined region, at least one camera for capturing images of the predefined region, and a processor programmed to extract and verify information of the reference points from the captured images to determine the predetermined drilling point and generate drilling data associated with the predetermined drilling point.

Advantageously, the system according to the invention further comprises a proximity sensor mounted on the drill device to detect a distance between the drill bit and the surface to be drilled, the distance being adapted for the drill device to rise to drill the surface.

A dust collector may be provided in the system of the invention and arranged in such a manner to collect mortar dust generated in the course of drilling the building surface.

To have a better understanding of the invention reference is made to the following detailed description of the invention and embodiments thereof in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a top view of an exemplary system constructed in accordance with an embodiment of the invention.

Figure 2 is a front elevation view of the system shown in Figure 1.

Figure 3 is an exemplary control circuit of a control device of the system according to the invention.

In the various figures of the drawings, like reference numbers are used to designate like parts.

Detailed Description of the Preferred Embodiments

While this invention is illustrated and described in preferred embodiments, the drilling system of the invention

may be produced in many different configurations, sizes, forms and materials.

Referring now to the drawings, Figs. 1 to 3 provide a system 100 for determining and drilling a predetermined drilling point on a surface in a predefined region of a building constructed consistent with a preferred embodiment of the present invention.

A building model corresponding to a building under construction is created using the building information model (BIM). The information about the framework of the building as well as the information about the MEP services of the building, including positions for installations of the MEP services and drilling points in surfaces of the building, is recorded using the BIM information locating pieces. Such drilling points would serve as predetermined drilling points of the surfaces. Other data or information in relation to the building may also be recorded in the BIM model. It would be within the ability of a person skilled in the art to create the building model based on the BIM, which is therefore not elaborated herein. The BIM-based building model is in direct communication with a robotic total station (RTS, not shown). The RTS is also well known in the art and not discussed herein either.

Among the recorded drilling points in the BIM-based building model, a desirable drilling point on a target building surface is identified using a plug-in program, for example Revit software of Autodesk and Trimble Field Point for Revit. The identified drilling point would serve as a predetermined drill point of the surface to be drilled.

For the sake of providing ease of using and implementing the system 100, it would be advantageous to divide the actual building surface of the construction site to be drilled into a plurality of predefined rectangular regions in which the

predetermined drill point of the surface to be drilled is located. One exemplary predefined region may have an area with a length ranging from 1000 cm to 1500 cm and a width ranging from 500 cm to 1000 cm. Such an area enables the drilling operation with ease and more accurately.

Now turning to Figs. 1 and 2, there is illustrated a system 100 for determining and drilling a predetermined drilling point in a predefined region of an overhead building surface, for instance, a ceiling surface, constructed according to one example of the invention. The predefined region corresponds to a drilling region 10 of the floor and is selected to correspond in shape and dimension to the predefined region of the ceiling surface. As illustrated, the system 100 comprises a drill device 20, a travelling chassis 30, and a movement apparatus for moving the drill device 20 and supported on the chassis 30. The drill device 20 may be selected from any drill device known in the art, and in the embodiment, the drill device 20 is DC battery operated drilling machine. The chassis 30 is configured as a travelling frame used to support all the components that make up the movement apparatus which will be discussed herein below.

The movement apparatus comprises X axis moving means for moving the drill device 20 in a direction of the X axis, Y axis moving means for moving the drill device 20 in a direction of the Y axis perpendicular to the X axis, and Z axis moving means for moving the drill device in a direction of the Z axis. As shown in Fig. 1, the X axis and the Y axis define a X-Y plane in parallel to the floor and the predefined region of the ceiling surface to be drilled, and the Z axis is perpendicular to the X-Y plane. In the shown embodiment of the invention, the X axis moving means comprises two X axis linear actuators 42 positioned at two opposite sides of the chassis

30. The two X axis linear actuators 42 are steered by a X axis servo motor 41 which is mounted at one end of one of the two X axis linear actuators, thereby to drive linear movement of the drill device 20 along the X axis linear actuators in the X axis direction. The Y axis moving means comprises one Y axis linear actuator 44 which is arranged on and spans the two X axis linear actuators 42. A Y axis servo motor 43 is mounted at one end of the Y axis linear actuator, thereby to drive linear movement of the drill device 20 along the Y axis linear actuator 44 in the Y axis direction. The Z axis moving means comprises one Z axis linear actuator 46 which is vertically mounted on the Y axis linear actuator 44. A Z axis stepper motor 45 is mounted at one end of the Z axis linear actuator 46, thereby to drive linear movement of the drill device 20 along the Z axis linear actuator 46 in the Z axis direction, namely in the vertical direction with respect to the floor level.

The servo motors 41, 43 and the stepper motor 45 are taken to convert the rotary motion to the linear displacement of the actuators 42, 44 and 46 in their respective directions, accordingly the linear displacement causes the drill device 20 to move in the three different directions so that a drill bit of the drill device 20 coincides with and moves to the predetermined drill point of the surface. In this embodiment, the stepper motor 45 and the servo motors 41, 43 are of the DC type motors which are controllable by their respective motor controllers placed in a control cabinet 50. As a result, the drill device 20 can be moved automatically or by an operator manually in the X, Y and Z axis directions, respectively.

The X axis and Y axis linear actuators 42, 44 are dimensioned to correspond in length to the length and width of the drilling region 10. Therefore, the drill device arranged

on the Y axis linear actuator 46 is movable within the X-Y plane in correspondence with the predefined region and is made to target any point of the ceiling surface to be drilled. The Z axis linear actuator 46 is actuated to cause the drill device 20 to move upward and downward vertically. One or more industrial grade computers (not shown) are placed in the control cabinet 50 to provide the interface so that the operator is able to modify and control the movement of the X, Y and Z axis linear actuators.

As illustrated in Fig. 2, a load pressure sensor 80 is mounted on the Z axis linear actuator 46 to deliver a load signal indicating the drilling depth at the predetermined drilling point. If the drill bit of the drill device 20 travels a length that is more than a maximum threshold which represents a predefined drilling depth, the system 100 would receive an alarm, and the drilling operation stops. Further, an electro-magnetic proximity sensor 90 is mounted on the Z axis linear actuator 46 to detect a distance between the drill bit and the ceiling surface, and this distance is adjustable for better drilling the ceiling surface according to the proximity sensor 90.

One important feature of the system 100 is a machine vision unit to capture and process images of the predefined region. The machine vision unit comprises lighting modules, cameras (such as CCD cameras) having lens and images sensors for capturing images, and a vision processing application to review the images received from the cameras and to extract required information from the images. Specifically, the machine vision unit is configured to capture and process images of two selected reference points in the predefined region, and then manipulate and map a set of target drilling data to the motor controllers of the stepper motor 45 and the

servo motors 41, 43 for moving the drill device 20 to target the predetermined drilling point, which will be described herein below. Various types of machine vision unit are available in the prior art and can be employed in the present invention.

The system 100 further comprises a marking unit for applying a mark at the positions of the two reference points. The marking unit is positioned adjacent to the drill device 20 and comprises an ink chop 60. The marking unit is mounted on the Z axis linear actuator 46 in such a manner that the ink chop 60 is caused to ascend to an active position for applying the mark at the ceiling surface and descend to an idle position where the marking unit does not interfere with the drill device 20 to implement the drilling work.

In order to provide an ease of locating the two reference points in the predefined region, a light beam tracker unit is included in this embodiment of the invention. The light beam tracker unit may comprise a plurality of crosshair laser pointers (not shown). Each of the reference points has two crosshair laser pointers which serve to define a reference region confining the reference point in the reference region. With the aid of the reference region formed by the two crosshair laser pointers, the operator can readily allocate the cameras of the machine vision unit in place, aiming at the reference points in the predefined region to allow capturing of the images of the reference points by the cameras and processing of the images by the machine vision unit.

As mentioned above, two reference points in the predefined region 10 are chosen to control the drilling work in the predefined region of the ceiling surface. In this regard, the RTS is in communication with the BIM-based building model to obtain all the information related to the building and the

predetermined drilling points on the building surfaces for various mechanical, electrical and plumbing (MEP) services. The actual position and dimension data on the building are thus obtained by the RTS using a method known in the art, for example the method discussed in the applicant's pending Hong Kong application no. 18115182.6. The RTS may first select two control points in the BIM-based building model, and the positions of the control points fall within the actual predefined region. After the two control points are determined in the BIM-based building model, the RTS would irradiate light beams to impinge the actual predefined region of the ceiling surface at two reference points in correspondence with the selected two control points in the BIM-based building model. The ink chop 60 of the marking unit may ascend to apply the respective marks at these reference points of the predefined region. The machine vision unit then captures and processes the two marked reference points to recognize and determine their accurate positions. In particular, the position information on the two reference points would be extracted from the captured images of the two reference points and verified by the machine vision unit. With the extracted position information, a set of drilling data on all the predetermined drilling points in the predefined region can be generated. The generated set of drilling data would be transmitted to the computer and the control device, and thus to the motor controllers for the ongoing drilling operation.

Now referring to Fig. 2 again, there is illustrated a dust collector 70 which adjoins the drill device 20 and is mounted in such a manner that the dust collector 70 to collect the hazardous mortar dust generated in the course of drilling the ceiling surface. The dust collector 70 according to this

embodiment of the invention is a DC battery operated vacuum unit.

The above-mentioned operation units and components are under control of a control device (not shown) which may be placed in the control cabinet 50. In the embodiment shown in Figs. 1 to 3, the control device also comprises a DC battery unit inverter system for providing DC power supply to the DC-operated units and components of the system. The control device may be, for example, programmed to implement the system 100 on the basis of a control circuit as shown in Fig. 3 to drill the ceiling surface at the predetermined drilling point. The control circuit illustrates the operational principle on which the operation of the system 100 is based. The computer is connected to the control device through which an interface is available to allow the operator to manipulate the system 100.

As clearly shown in Fig. 3, the control device is operatively coupled with the motor controllers of the X, Y and Z axis linear actuators 42, 44, 46 so that the linear actuators 42, 44, 46 are controlled to move the drill device 20 in three directions shown in Fig. 1. The drill device 20 is first moved in the X-Y plane to a position where it is accurately coincident with the predetermined drilling point on the basis of the drilling data associated with that drilling point. Once the coincidence of the drill bit and the drilling point is determined, the drill device 20 continues to rise to move until the drill bit reaches the drilling point, and then the drill bit is actuated to drill the ceiling surface at the accurate position of the drilling point. As discussed above, the load pressure sensor 80 would monitor the drilling depth of the drill bit so that the drilling depth is not more than the predefined maximum drilling threshold. After the drilling

operation comes to an end, the drill device 20 would lower to its idle position and get ready to drill another point on the same predefined region of the ceiling surface.

In use, the drilling system 100 is moved along the floor by an operator with the aid of the chassis 30 to the drilling region of the floor that is corresponding to a predefined region of the ceiling surface for the drilling operation. At the same time, the RTS in communication with the required BIM-based building model is ready to access and retrieve the information and data on the drilling points designed in the predefined region. Then the load pressure sensor 80 is turned on and the X, Y and Z axis linear actuators 42, 44 and 46 are reset to their zero positions in the X, Y and Z axis directions, respectively.

The zeroing of the linear actuators 42, 44 and 46 is followed by determining the two reference points in the predefined region using the RTS. Then, utilize two crosshair laser pointers to surround each reference point to facilitate the operator to locate the reference point, and allocate the CCD cameras of the machine vision unit in place aiming at the reference points. The CCD cameras start to capture the images of the reference points.

The next step is to calibrate the CCD cameras under the control of the control device. The machine vision unit reviews the captured images of the two reference points and extracts the actual position information about the reference points. The extracted information is used to calibrate each CCD camera. Before the drilling operation is started, it is also necessary to, for example manually carry out calibration of the positional relation between the CCD cameras and the drill device 20 by updating the positional coordinates of the drill device.

After the calibrations are completed, the machine vision unit processes and analyzes the images of the predefined region, so as to extract and verify the information on the predetermined drilling points to generate a set of drilling data including the positions of the drilling points and the drilling depth of drilling holes. On the basis of the generated drilling data, the control device then controls the servo motors 41, 43 which in turn drive linear movement of the X and Y axis linear actuators 42, 44 in the X-Y plane, in such a manner that the drill device 20 is moved to a position where the drill bit of the drill device 20 coincides with the predetermined drilling point of the ceiling surface. Once this coincidence is confirmed, control the stepper motor 45 to drive linear movement of the Z axis linear actuator 46 in the vertical direction and thereby the drill device 20 ascends to the height of the ceiling surface and drills the predetermined drilling point. The drilling process comes to a halt until no signal is received from the load pressure sensor. The drill device 20 then lower to its idle position and is ready for another drilling operation.

The system 100 of the invention also provides a manual mode in which the operator can manually implement the system 100 to drill the building surface.

Thus, the present invention provides a system for effectively and accurately determining and drilling a predetermined drilling point on a surface, e.g. overhead walls and/or ceilings. This system is constructed on the combined use of the BIM technology, the RTS and the machine vision technology, and ensures the operator to carry out the drilling work safely, less labor-intensive, and with ease on the floor level.

While the embodiments described herein are intended as an exemplary marking system, it will be appreciated by those skilled in the art that the present invention is not limited to the embodiments illustrated. Those skilled in the art will
5 envision many other possible variations and modifications by means of the skilled person's common knowledge without departing from the scope of the invention, however, such variations and modifications should fall into the scope of this invention.

What is claimed is:

1. A system for determining and drilling a predetermined drilling point on a surface in a predefined region of a building, comprising:

5 a BIM-based building model corresponding to the building, which is created using the building information modeling (BIM), wherein information related to predetermined drilling points of the surface of the building is identified and recorded in the BIM-based building model;

10 a positioning unit in communication with or loaded with the BIM-based building model, wherein two or more control points are selected in the BIM-based building model, and the positioning unit is configured to identify two or more reference points in the predefined region of the building, the
15 two or more reference points corresponding to the two or more control points in the BIM-based building model,

a drill device movable to the surface of the building to drill the surface at the predetermined drilling point,

a machine vision unit configured to capture and process
20 images of the predefined region to recognize the reference points, thereby to determine a position of the predetermined drilling point and generate drilling data associated with the predetermined drilling point;

a control device coupled with the machine vision unit to
25 receive the generated drilling data and programmed to control a drill bit of the drill device to coincide with the predetermined drilling point and to actuate the drill device to move towards and drill the building surface at the predetermined drilling point with the drilling data.

30 2. The system as claimed in claim 1, further comprising:
a chassis, and

an apparatus for moving the drill device and arranged on the chassis, wherein the moving apparatus comprises X axis moving means for moving the drill device in a direction of the X axis, Y axis moving means for moving the drill device in a direction of the Y axis perpendicular to the X axis, and Z axis moving means for moving the drill device in a direction of the Z axis,

wherein the X axis and the Y axis define a X-Y plane in parallel to the predefined region, and the Z axis is perpendicular to the X-Y plane.

3. The system as claimed in claim 2, wherein the X axis moving means comprises two X axis linear actuators positioned at two opposite sides of the chassis to drive linear movement of the drill device in the X axis direction; the Y axis moving means comprises one Y axis linear actuator to drive linear movement of the drill device in the Y axis direction; and the Z axis moving means comprises one Z axis linear actuator to drive linear movement of the drill device in the Z axis direction.

4. The system as claimed in claim 3, wherein the moving apparatus is operatively coupled with the control device which is configured to control a X axis electric motor mounted on one of the X axis linear actuators for steering the drill device to move, a Y axis motor mounted on the Y axis linear actuator for steering the drill device to move, and a Z axis motor mounted on the Z axis linear actuator for steering the drill device to move.

5. The system as claimed in claim 4, wherein the X axis and Y axis electric motors are selected from servo motors, and the Z axis electric motor is selected from a stepper motor.

6. The system as claimed in any one of claims 2 to 5, further comprising a marking unit for applying a mark at each of the reference points in the predefined region of the building.

7. The system as claimed in claim 6, wherein the marking unit is operatively coupled with the control device so as to be controlled to move to be coincident with the reference point to be marked and move towards to the surface to apply the mark at the reference point.

8. The system as claimed in claim 7, wherein the marking unit is arranged on the moving apparatus so that it is movable by the moving apparatus.

9. The system as claimed in claim 7, wherein the marking unit is selected from an ink chop or a writing tool.

10. The system as claimed in any one of claims 1 to 5, further comprising a light beam tracker unit for guiding to locate the reference points in the predefined region.

11. The system as claimed in claim 10, wherein the light beam tracker unit comprises a plurality of crosshair laser pointers, wherein each of the reference points are assigned two of the crosshair laser pointers defining a reference region in which the reference point is confined.

12. The system as claimed in any one of claims 1 to 5, further comprising a dust collector arranged in such a manner to collect mortar dust generated in the course of drilling the building surface.

13. The system as claimed in any one of claims 1 to 5, wherein the positioning unit is provided as a robotic total station (RTS) in communication with the BIM-based building

model, wherein the RTS irradiates light beams to impinge the reference points in the predefined region.

14. The system as claimed in any one of claims 1 to 5, wherein the machine vision unit comprises a light source to
5 illuminate the predefined region, at least one camera for capturing images of the predefined region, and a processor programmed to extract and verify information of the reference points from the captured images to determine the predetermined drilling point and generate drilling data associated with the
10 predetermined drilling point.

15. The system as claimed in any one of claims 1 to 5, comprising a load pressure sensor to deliver a load signal indicating a maximum threshold of drilling depth at the predetermined drilling point.