

SYSTEM FOR DRILLING A BUILDING SURFACE

TECHNICAL FIELD OF THE INVENTION

The present disclosure relates to a system for drilling on an overhead surface of a building surface. More specifically, to a drilling system for creating an anchor hole at a pre-marked target by drilling on the overhead surface (e.g.,
5 a wall or a ceiling) of the building, thereby allowing an operator to perform automatically or manually the drilling work with ease and safety.

BACKGROUND OF THE INVENTION

During the construction of a building, a framework of the building is first
10 put up, and the walls and ceiling panels are 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 marked, drilled and anchored at the predetermined positions. The marking, drilling or anchoring work, particularly the overhead marking, drilling
15 or anchoring work on the ceilings, is considered as an awkward, monotonous and laborious process, and also requires a substantial amount of time, because marking, drilling or anchoring the overhead surfaces, for example ceiling soffits, needs auxiliary means such as ladders, base frames, stands, scissor platforms and the like and may be adjusted or scaled many times at different
20 positions of the worksite. In addition, there is a falling risk of operators who carry out the drilling work on the auxiliary means at the worksite.

Conventionally, building information modeling (BIM) is a digital representation of physical and functional characteristics of a facility, which is an engineering data model incorporated with information about various aspects
25 and resources of the facility, while 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. In the present disclosure, the RTS is used to pinpoint all anchor positions with a high degree of accuracy on each soffit basing on the BIM.

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.

Deep learning techniques are gaining wide popularity in a variety of application and research areas. Deep learning is one branch of machine learning and includes statistics and predictive modeling, which is a helpful analysis tool to interpret quickly a large amount of data. A deep learning model is trained before it is deployed for its intended application. The deep learning model is trained by feeding it data for which correct answers or responses are known. Typically, the more training data that is used to train the deep learning system, the better the training results.

In a design model using the BIM technology for MEP installations in combination with the RTS and the machine vision technology, the need of doing the marking, drilling, and anchoring operations in tedious, high and harsh ceiling conditions can be eliminated. In constructing the model, attention is paid to clean the crashes amongst the services. A comprehensive hanger system is therefore integrated in the model. Using the RTS, the positions of the hangers are set out on-site for the soffit. With this procedure, the setting out dimensions of the model in a crash-free way can be effectively brought to the site that would

warrant a smooth installation to be carried on-site later.

Nonetheless, needs exist in the construction industry for marking, drilling and anchoring devices to tackle the disadvantage of labor intensity and other drawbacks discussed above. In particular, there is a great need for a drilling device that is effective for creating an anchor hole on a previously marked target made on a building surface so that the anchor hole can subsequently be used to install an anchor therein, and provide a smooth service installation in moving forward.

10 SUMMARY OF THE INVENTION

In order to solve the above-mentioned problems of the conventional technology, an aspect of the present disclosure provides a drilling system for creating an anchor hole at a pre-marked target on a surface of a building that is significantly more effective, economical and convenient. The pre-marked target is initially marked using conventional systems, or using the marking system that is related to the drilling system of the present disclosure. Additionally, after the anchor hole has been created, an anchor can be placed therein using conventional anchoring systems, or using the anchoring system that is related to the drilling system of the present disclosure.

Another aspect of the present disclosure is to provide a drilling system that does not involve complicated hardware installation, thereby allowing the drilling operation to perform safely and with ease.

A further aspect of the present disclosure is to use a crawler scissor lift, which is motorized to support a drill unit from the drilling system, and configured to allow automated or manual movements of drill unit in various directions.

In an exemplary embodiment to achieve the above-mentioned aspects, the

drilling system for creating the anchor hole at pre-marked target on the surface of the building includes a supporting unit movable in three dimensions; and a drilling device removably secured on the supporting unit, wherein the drilling device has a laser position unit to provide a laser light in illuminating a working area containing the pre-marked target, an imaging unit to scan the working area of the surface to capture images of the working area, a processing unit to process the captured images, determine location coordinates of the pre-marked target, and generate drilling data associated with the pre-marked target, a drill unit movable from a first position to a second position, a drilling controller to receive the drilling data and control the drill unit of the drilling device, and a driver unit to drive at least one linear actuator based on the location coordinates, and move the drill unit from the first position to the second position to allow the drill unit in creating the anchor hole on the surface of the pre-marked target based on the drilling data.

More specifically, the drilling device has a laser height detector for detecting a distance between the illuminated working area and the drilling device, and a dust collecting unit mounted adjacent to the drill unit for capturing dust and debris coming from drilling of the surface of the building, and for channeling the dust and debris to a collection bin. The drilling device also has an alarm indicator on the control cabinet for indicating an alarm signal generated by the processing unit, a master emergency switch that would halt the operation of the drilling device when activated, and a ventilator on the control cabinet for allowing air flow to and from the control cabinet. An antenna is provided on the control cabinet of the drilling device, and such is used to enable wireless communication with a remote operation panel.

The drilling device has a built-in load cell which will monitor an upward or advancing force exerted by the drill tool to the surface (e.g., concrete) during

the drilling operation, whereby when the limit is exceeded (mostly when the drill tool hits the rebar), the drilling operation will come to an abrupt halt, rendering the drilling device inoperable, along with the issuance of an alarm. The drilling device also has a removable drill rack capable of being decoupled from the drilling device for safe keeping of the drill tool (e.g., hammer rotary drill) supported by the drill rack.

A master emergency stop is installed in the remote panel, and at an appropriate position in the crawler. Once activated, such will stop the system from operating further. Additionally, a protective cover, which is dustproof, is installed over the drilling device to support and cover the linear actuators.

There are basically three modes of operation for creating anchor hole on the surface of the pre-marked target, and optionally there is further a fourth operation mode. In the first mode of operation, the predetermined marking points on the soffit are designated as the pre-marked target for creating the anchor hole on the surface of the pre-marked target by drilling. In the second mode of operation, the RTS will emit light to the target for drilling on the soffit for drilling, and predrilled pilot holes are designated as the pre-marked target for a subsequent marking by another process. In the third mode of operation, the location tracing of a laser point from a laser emitting device (no necessary from RTS) is used as the pre-marked target for creating the anchor hole on the surface of the pre-marked target for drilling. In the fourth mode of operation, an image of the pre-marked target illuminated by a laser point is captured and displayed on a display device, and the laser point present in the captured image displayed on the display device is used as the pre-marked target for creating the anchor hole based on the drilling data by drilling on the surface of the building. The anchor hole formed by the drilling system is subsequently used to receive an anchor for services installation of the of the mechanical, electrical and

plumbing (MEP) services.

In the drilling system, the supporting unit can be a crawler scissor lift that is fixedly secured thereon by the drilling device, and the imaging unit can have two or more cameras to capture a plurality of images of the working area at different angles. To move the drill unit from the first position to the second position, the location coordinates are used to operate one or more of the x-axis, y-axis and z-axis linear actuators. Also, the processing unit selects a set of the drilling data through a computer input device which is in wired or wireless communication with the processing unit. The drilling data contains at least information on the drill depth and/or algorithm adopted for the application and control of the drill unit to allow a swift and safe operation of the drilling device.

In one preferred embodiment of the invention, the processing unit comprises an image processing module programmed to process the captured images using machine learning to identify an impingement point of the laser light on the working area to generate the drilling data associated with the pre-marked target. The image processing module may be programmed to process the captured images using a deep learning model in which the representations of the impingement point are used to train the model. The deep learning model is advantageously created by:

- a) collecting image data of the captured images of the working area,
- b) generating a classification indicating features of the impingement point of the laser light from the collected image data,
- c) extracting a set of the features based on the image data with the classification to build the deep learning model, and
- d) feeding the deep learning model train data and validation data to perform the classification to train the deep learning model to identify the impingement point in the images in a manner that an acceptable accuracy is

reached for the drill data generation.

In one specific embodiment of the invention, in step b), the working area is divided into a plurality of cells so that features representing the cell in which the impingement point is located is generated from the collected image data; in
5 step c), the deep learning model is built based on the features representing the cell of the impingement point; and in step d), the deep learning model is fed with train data and validation data to perform detection of the cell of the impingement point so as to train the deep learning model to identify the impingement point in the images in a manner that an acceptable accuracy is
10 reached for the drill data generation.

The features of the impingement point of the laser light may be determined according to actual needs and may include but not limited to brightness, size, surface area and the like.

Preferably, the deep learning model is trained to generate the drill data by
15 the general procedures discussed below. Initially two or more sets of arbitrarily assigned weights are used in the forward propagation calculations to give calculated results on the output layer, and the calculated results are then compared with a ground truth value to obtain a deviation (i.e. a total loss value) from the ground truth value by the loss function. The obtained deviation is used
20 to adjust the weights in the backward propagation, and the adjusted weight is used to replace the preceding weight in the forward propagation calculations. Incessant iterations of this adjustment process are made until the loss function reaches a minimum deviation from the ground truth, which is an acceptable accuracy. The model with loss function having the minimum deviation is saved
25 for use as the deep learning model. According to the invention, the deep learning model adopts a SSD network based on the loss function which is composed of a confidence loss function and a position loss function. In other words, the loss

function is defined as follows:

$$L(x, c, l, g) = \frac{1}{N} (L_{conf}(x, c) + \alpha L_{loc}(x, l, g))$$

wherein $L(x, c, l, g)$ is total loss value; $L_{conf}(x, c)$ is confidence loss function;

$L_{loc}(x, l, g)$ is location loss function; N is number of samples; and α is weight;

5 x is feature value; c is confidence; and g is ground true.

BRIEF DESCRIPTION OF DRAWINGS

The advantages of the present disclosure will become more readily apparent to the ordinarily skilled in the art after reviewing the following detailed

10 description and accompanying drawings, in which:

Fig. 1 is a perspective view of a crawler scissor lift;

Fig. 2 is a perspective view of a drilling device for creating an anchor hole at a pre-marked target on a surface of a building according to an exemplary embodiment of the present disclosure;

15 Fig. 3 is a rear view of the drilling device as shown in Fig. 2;

Fig. 4 is an exploded view of the drilling device as shown in Fig. 2;

Fig. 5 is a perspective view of a drill unit in the drilling device as shown in Fig. 2;

Fig. 6 is a side view of the drilling device as shown in Fig. 2; and

20 Fig. 7 is a top view of the drilling device as shown in Fig. 2.

DETAILED DESCRIPTION OF THE INVENTION

An exemplary embodiment of a drilling system for creating an anchor hole at a pre-marked target on an overhead surface (e.g., a wall or a ceiling) of a building will be described in detail below with references to the accompanying drawings. It should be understood that the dimensions of the various portions in the drawings are not depicted to scale and are for illustrative purposes only and

do not represent the true dimensions of the product of the present disclosure. Also, like reference numbers in the various figures of the drawings are used to designate like parts, and that the drilling system of the disclosure may be produced in many different configurations, sizes, forms and materials.

5 As shown in Fig. 1, a movable supporting unit in the form of a crawler scissor lift 10 is provided to allow automated or manual movements in the drilling system, which can be initiated in a motorized or non-motorized manner. The crawler scissor lift 10 is smaller in size and easier to maneuver than a conventional scissor platform, which is a type of mobile carrier that generally
10 facilitates the movement of worksite machines and provides a stable working platform when the worksite machines are elevated to a high level. For instance, the motorized movements of the crawler scissor lift 10 can be initiated by an operator, which can include raising or lowering all units or devices in the drilling system along the z-axis. It is clear that any suitable scissor platform can
15 be substituted for the crawler scissor lift 10 without limitation. In other words, any suitable mobile carrier that can offer the same or similar functions can be used as a substitute.

 The drilling system of the present disclosure requires one or more pre-marked targets already provided on the surface of the building. Such pre-marked
20 target is based on a building model corresponding to a building under construction is created by a building team using the BIM technology. For instance, the BIM-based building model may contain predrilled pilot holes or predetermined marking points for MEP installations. The information on the MEP installations of the building from various members of the building team
25 can also be recorded using the BIM technology. Such information may include, for instance, heating, ventilation and air conditioning information from the mechanical engineering team; lighting, fire protection, and power supply

information from the electrical engineering team; and piping, sewage routes, and drainage information from plumbing team. However, the specific positions for the MEP installations may encounter positional conflicts in that the same physical space is occupied based on the different system designs from the various engineering teams. Efforts (manually) are required to coordinate the services and rearranging such to achieve a crash free model (installation). Subsequently, an integrated hanger system is to be implemented and incorporated into the model. These hangers, after being populated to the model for services either manually or by rule-based software, shall retain the original relative positions of the services, and thus naturally keeping them in a crash free condition. In other words, after the hangers are integrated into the model, they not only provide support for the services, but in this case they also maintain the relative positions of the services intact, thereby making sure that there will be no crashes, as originally envisioned by the BIM through a manual coordination. Using the RTS, the positions of these hangers are further set out on-site on the soffit for service installations with a pinpoint accuracy. With the procedure, the setting out dimensions of the crash-free model can be effectively brought to the site that would later warrant a smooth installation to be carried on-site.

Optionally, the operator can by-pass the integrated hanger system or exclude the implementation of the integrated hanger system in favor of manual operations of the worksite machines, but such would lose the above-stated benefit, which would mean that reworks in part are inevitable. To describe in another way, a smooth on-site installation may not be warranted if the operator does not follow the locations of the hangers to install the services, and much onsite coordination and possibly many reworks may be required as a result.

In one alternative, the pre-marked targets are made on the soffit. In such alternative, the machine vision of the device will identify the center of the mark

for drilling. In another alternative, the location tracing of a laser point from a laser emitting device (no necessary from RTS) is used, which then become the target for drilling.

Once the anchor hole has been drilled into the pre-marked target on the surface of the building drilled, an anchor will be dropped in and installed using the conventional anchoring systems or using the anchoring system that is related to the drilling system of the present disclosure. The related anchoring system, if used, can optionally incorporate the BIM technology in combination with the RTS and the machine vision technology to effectively set out the crash free requirements of the MEP model on site for installation, and eliminate the need of performing anchoring operations in tedious, high and harsh ceiling conditions, in a professional fashion and allow the operator to perform the anchoring work with ease and safety.

As shown in Fig. 2, a drilling device 12 for creating the anchor hole at one of the pre-marked targets on the overhead surface (e.g., a wall or a ceiling) of the building according to a first exemplary embodiment is provided. When the predetermined marking point is used as the pre-marked target for installing an MEP service, a designation for the predetermined marking point is provided regarding which one of the mechanical, electrical and plumbing (MEP) services, which is based on the mark printed on the slab by another device (e.g., the SkyMarker device).

In one alternative, when a pilot hole is used as the pre-marked target for installing the MEP service, a designation or marking for the pilot hole (i.e., adjacent to the pilot hole) is provided regarding which one of the mechanical, electrical and plumbing (MEP) services, which is printed on the slab by another device (e.g., the SkyMarker device). In another alternative, when a laser pointer that manually or mechanically points to a location on the overhead

surface of the building as the pre-marked target for installing the MEP service, the drilling device 12 forms an anchor hole at the pre-marked target as pointed by the laser pointer by drilling on the surface of the building based on the set of drilling data that corresponds to the pre-marked target's type of MEP services.

5 The drilling device 12 allows the operator to perform automatically or manually the marking work with ease and safety. Prior to commence the drilling operations, the drilling device 12 is securely and removably mounted onto the crawler scissor lift 10.

10 With references to Figs. 2 and 3, the drilling device 12 according to the first embodiment includes one or more mounting plates 14 that removably connect the drilling device 12 to the crawler scissor lift 10. A substantial part of the crawler scissor lift 10 is approximately rectangular in shape, and can include any suitable vertical lift configured for a motorized movement for reproducing a force in a reciprocating linear motion. By positioning the crawler scissor lift
15 10 underneath the drilling device 12, the upward and downward movements of the drilling device 12 can be achieved by the physical operation of the crawler scissor lift 10 through the operator. Additionally, the drilling device 12, by operatively coupled or fixedly secured to the crawler scissor lift 10, can move, rotate or change directions.

20 The drilling device 12 is supported by caster wheels 16 mounted on the bottom of a base frame 18 for enabling the movements of the drilling device 12. The caster wheels 16 can be of a rigid or swivel type, and can include a braking or locking feature that prevents the wheels from turning. Specifically, the base frame 18 is guided by at least 4 caster wheels 16 at four corners of the base
25 frame 18. By moving the base frame, the drilling device 12 is easily and conveniently transported onto the lifting unit, and securely mounted thereon by the mounting plate 14.

Positioned on top of the base frame are linear actuators consisting of an x-axis linear actuator 20 with first rail grooves, a pair of y-axis linear actuators 22 each with corresponding second rail grooves, and a z-axis linear actuator 24 with third rail grooves. The pair of y-axis linear actuators 22 is spaced a distance
5 apart by a guard plate 26, and supports the x-axis linear actuator 20 which is operatively mounted thereon. Specifically, the x-axis linear actuator 20 is capable of moving along the second rail grooves of the y-axis linear actuators 22 in the y-axis direction, and the z-axis linear actuator 24 is capable of moving along the first rail grooves of the x-axis linear actuator 20 in the x-axis direction.

10 A protective cover 28 is secured to the z-axis linear actuator 24, which is operatively mounted onto the x-axis linear actuator 20 and capable of moving along the first rail grooves in the x-axis direction. The protective cover 28 provides support to and protects the z-axis linear actuator 24 from damage. Additionally, a drill unit 30 is operatively secured adjacent to the z-axis actuator
15 24. The drill unit 30 is capable of moving along the third rail grooves of the z-axis linear actuator 24 in the z-axis direction.

A dust collecting unit 32, which is secured mounted in the drill unit 30, is further shown in Fig. 3. The dust collecting unit 32 captures dust and debris from drilling the surface of the building, channels the dust and debris to a
20 collection area. Fig. 4 shows a drilling tool rack 34 securely mounted adjacent to the drill unit 30 for supporting and securing one or more drilling tools to be used in drilling the anchor hole into the pre-marked target on the surface of the building. A hammer rotary drill can be used as the drilling tool to form the anchor hole at the surface or soffit. When the drill tool such as the hammer
25 rotary drill is used, it is securely fixed to a rack, and can be removed using minimum effort from its attachment to the z-axis linear actuator 24 of the drilling device by detaching a control wiring, thereby allowing a simple

mechanism for the operator to safely keep custody of the hammer rotary drill on the rack whenever a situational need arises. Additionally, such mechanism enables the rack to host and support the expensive hammer rotary drill that can be removed and taken away with minimum effort during the period when the drilling system is sitting idle on a worksite without any supervision (for instance, during lunch time and/or overnight).

As collectively shown in Figs 2-7, the base frame 18 further supports a laser positioning unit 44, which is placed adjacent to the y-axis linear actuators 22, for illuminating a working area of the surface that contains one or more of the predetermined marking points or pre-marked targets. The base frame 18 further supports a pair of imaging units 46 for scanning the working area to capture one or more images of the working area, and a processing unit 52 to process the captured images. Specifically, each of the imaging units 46 has two or more vision cameras (such as CCD cameras) to register images from the working area. By having more vision cameras, additional images from different angels can be provided to allow a more complete compilation by the processing unit 52. A ventilator 54 is provided on the control cabinet 50 to allow air flowing to or from the space within the control cabinet 50. Specifically, the ventilator 54 is a passive type to induce flow of external air into or out of the control cabinet 50. An alarm indicator 56, which responds to alarm signals from the processing unit 52, is also securely installed on the control cabinet 50. Next to the alarm indicator 56 is an antenna 58, which is further securely installed on the control cabinet 50, for enabling a wireless communication (e.g., WIFI or Bluetooth®).

When the machine vision is used to locate the images captured by the vision camera, the captured image is often susceptible to many minor protrusions on the building surface and generate background spots when these

protrusions are illuminated by reflection light from the background. Such spots may appear as potential targets in the building surface and form false representations of the true target. In order to effectively solve this problem, deep learning algorithm is introduced for use in combination with the machine vision to identify the true representation of the impingement point in the captured images representing location coordinates amongst a pool of potential candidates swiftly and correctly.

In this embodiment, the processing unit 52 comprises an image processing module programmed to process the captured images to identify the true representation of the impingement point to generate the drilling data associated with the pre-marked target using a deep learning model based on Single Shot Detection (SSD) target detection algorithm. The SSD algorithm is a one-stage anchor-based detection algorithm and is known to have the ability of performing accurate position regression and classification output. The SSD algorithm requires short inference time and is easy to deploy, and also can achieve real-time detection speed based on video streams.

Usually, a laser light is emitted, for example by a laser position unit 44 described below, to impinge the predetermined marking point in the working area of the surface. The images of the working area are then captured, for example, by the imaging unit 46. The deep learning model is trained up according to the procedures described herein below. Initially, a plurality of rectangular cells are divided in the working area, and the impingement point is located in one of the cells. A great amount of image data is collected from the captured images of the working area. The image data is processed to generate information regarding their classification and locations indicating the features of the impingement point, including location coordinates, width and length of the cell of the impingement point. Then a set of the features based on the image

data with the designated information on the cell of the impingement point is extracted to build the deep learning model. The images are analyzed for their features based on the use of the detection algorithm. Preferably, MobileNet v2 is employed as the basic model of the SSD network, with the output dimensions of detection heads is defined according to the number of classification of detection target. Advantageously, the detection heads are arranged in feature maps of different sizes, and the number of the detection heads is reduced to three according to a predefined task.

Preferably, the SSD network model defines a loss function below:

$$L(x, c, l, g) = \frac{1}{N} (L_{conf}(x, c) + \alpha L_{loc}(x, l, g))$$

wherein $L(x, c, l, g)$ is total loss value; $L_{conf}(x, c)$ is confidence loss function; $L_{loc}(x, l, g)$ is location loss function; N is number of samples; and α is weight; x is feature value; c is confidence; and g is ground truth.

The model having the loss function based on the smallest deviation is selected and saved as the final modeling weight. In the SSD network, the loss function is formed by taking a sum of classification confidence loss and location regression loss position.

The collected data may be subject to data augmentation through horizontal and vertical rotation, random cropping of the images, and brightness, saturation and chroma enhancement of the images.

After the modeling is established and the loss function is defined, the deep learning model is fed by train data and validation data for detection of the cell of the impingement point to extract the features of the impingement point of the laser light so as to train up the deep learning model with the drill data for drilling operation. During the training process, changes in loss and accuracy in both the train phase and the validation phase are substantially the same to prevent overfitting. The model will be trained for about 50 to 100 epochs until the

modeling accuracy reaches a substantially high and stable value.

This model may be saved in the processing unit 52 and used in combination with the vision cameras to identify the location coordinates of the pre-marked target on the building surface, which coincide with the impingement point, for
5 generation of the drilling data. The drill controller received the generated drilling data to control the drill unit to perform the drilling operation.

The drilling data generated on the basis of the deep learning model can effectively rule out any background spots that might form false target for drilling and allows for identification of the pre-marked target with high
10 accuracy. This deep learning technique is found very useful in the process when the laser light is being used to impinge the drilling location on the building surface, therefore finds a wide application of locating the drill target.

Through the processing unit 52, the operators can choose a set of drilling data that contains at least a corresponding drill depth and one or more drill
15 algorithms used to drill different types of surfaces (e.g., concrete). The drill depth covers the size of the drill (diameter), and drill algorithm covers the way the drilling system is used to form the anchor hole, such as an advancing force and/or speed used in creating the anchor hole.

A laser height detector 60 is further mounted on the control cabinet 50
20 for detecting a distance between the illuminated working area and the drilling device 12 at the first position. The detected distance is processed by the processing unit 52 in assessing the first position. Also, as specifically shown in Fig. 6, a pair of lift brackets 62 is installed on the drilling device 12 to allow lifting of the lift brackets 62 by, e.g., a forklift, side loader, fork truck and etc.

25 In use, the drilling device 12 as collectively shown in Figs. 2-7 is moved along the floor to a desirable location adapted for a drilling operation by an operator using the crawler scissor lift 10. Upon activation by the operator, the

crawler scissor lift 10 on the supporting device ascends to cause the drilling device 12 to rise to the first (standby) position adjacent to the surface of the building to be marked. Deactivation by the user will cause the crawler scissor lift 10 on the support device to descent and thereby lowering the supporting device and drilling device 12 to an OFF position.

At the first position, the laser position unit 44 is activated to emit a laser light that illuminates the working area of the surface. The illuminated area is designated as a working area for the predetermined marking point or pre-marked target. At this point, the working area is illuminated to allow scanning thereof by the imaging unit 46 to capture one or more images of the working area. Alternatively, the working area is illuminated to reveal the pre-marked target without activating the imaging unit 46.

If the imaging unit 46 is activated, the images captured by the imaging unit 46 are provided to the processing unit 52 to gather the captured images. One or more captured images are inspected for visualization features, such as the pre-marked target in the working area, and the inspected features are extracted. After the location coordinates for the pre-marked target are processed and located, the center of the pre-mark target is identified. Specifically, the x-axis and y-axis, of the location coordinates for the pre-marked target are determined by the processing unit 52. Using these coordinates and the input drill depth and algorithms, the processing unit 52 sends signals to the linear actuator drivers 48 for driving one or more of the x-axis, y-axis and z-axis linear actuators 20, 22, and 24 to move the drill unit 30 from the first position to a second (active) position. From the second position, the drilling of the anchor hole into the pre-marked target can be initiated by the drill unit 30.

Alternatively, if the imaging unit 46 is not activated, then the location coordinates for the pre-marked target as illuminated in the working area can be

manually inputted into the processing unit 52 by the operator. Additionally, the operator can manually direct one or more of the x-axis, y-axis and z-axis linear actuators 20, 22 and 24 to move the drill unit 30 from the first position to a second (active) position based on visualizing the pre-marked target as illuminated in the working area.

Having determined the location coordinates, the processing unit 52 sends signals to the linear actuator drivers 48 to drive one or more x-axis, z-axis, and z-axis linear actuators based on the location coordinates in order to move the drill unit 30 from the first (standby) position to the second (active). Specifically, the longitudinal (x-axis), lateral (y-axis) and vertical (z-axis) movements of the drill unit 30 at the first position can be adjusted through first and second grooves, and the vertical movements of the drill unit 30 can be adjusted using the third grooves by taking into account of the distance as measured by the laser height detector. For instance, the drill unit 30 can be pushed upward or downward in the z-axis direction through the third grooves in the z-axis linear actuator 24, moved lengthwise in the y-axis direction through the second grooves in the y-axis linear actuator 22, and moved widthwise in the x-axis direction through the first grooves in the x-axis linear actuator 20.

Generally, the drilling process for making the anchor hole will be commenced by the drilling device 12 whenever the laser point is sensed and process, or whenever a graphic symbol made previously by a marking device or manually is sensed and processed, whereby the laser point or center of the graphic symbol is used to make the anchor hole that is mostly circular in shape. Still, the operator can further make inputs through a computer input device such as a graphics tablet that is in wired or wireless (e.g., WIFI or Bluetooth®) communication with the processing unit 52, and then each of the anchor holes can be drilled by the drilling device 12 based on the various operator inputs.

After each drilling operation, the z-axis linear actuator 24 returns the drill unit 30 into the original position, meaning that the drilling device 12 is returned to the first position. Thereafter, drilling device 12 will be directed to another location to repeat the drilling process.

5 There are three operation modes used by the drilling device 12 for drilling the anchor. In the first mode of operation, the predetermined marking points (as marked by another device) are used as the pre-marked targets to create the anchor hole on the surface of the building based on the drilling data. In the second mode of operation, the laser points emitted by the RTS which contain
10 information of the hanger locations are used as pre-marked targets to create the anchor hole on the surface of the building. In the third mode of operation, the location tracing of any laser point from a laser emitting device is used to indicate the pre-marked targets to create the anchor hole on the surface of the building. The anchor hole is subsequently used to install an anchor corresponding to one
15 of the mechanical, electrical and plumbing (MEP) services.

Optionally, the drilling device 12 may be operated in the fourth operation mode, in which images of the pre-marked targets illuminated by the laser points are captured by the cameras and displayed on a display device. The location of the laser points in the displayed images are then traced and confirmed on the
20 display device, for example by moving a cursor to the locations of the laser points. After the location confirmation, a command may be entered to initiate to move the x-axis linear actuator 20, the y-axis linear actuators 22 and the z-axis linear actuator 24, thereby driving the drilling device 12 to the location coordinates of the pre-marked targets to create the anchor hole on the surface of
25 the building. On completion, the drilling device 12 will return to its standby position using the actuators 20, 22, 24. This fourth operation mode is particularly useful in the case that the first, second and fourth operation modes

do not work properly.

In the above-mentioned drilling system for drilling the pre-marked target on the building surface according to the present disclosure, the crawler scissor lift 10 as shown in Fig. 1 is used to support the drilling device 12. As illustrated in Figs. 2-7, the drilling device 12 is comprised of the mounting plates 14, caster wheels 16, base frame 18, x-axis linear actuator 20, y-axis linear actuators 22, z-axis linear actuator 24, guard plate 26, protective cover 28, drill unit 30, dust collecting unit 32, drilling tool rack 34, laser position unit 44, imaging unit 46, linear actuator drivers 48, control cabinet 50, processing unit 52, ventilator 54, alarm indicator 56, antenna 58, laser height detector 60, and lift brackets 62.

The above foresaid operation units and components are under control of the processing unit 52 located in the control cabinet 50. The processing unit 52 can be of a suitable computer or programmable PLC controller (e.g., Panasonic model no. FPOR-C32T). Additionally, the x-axis linear actuator 20, y-axis linear actuators 22, and z-axis linear actuator 24 are driven by the linear actuator drivers 48, which are located in the control cabinet 38. During operation, the operator can switch the drilling device 12 from an automatic mode to a manual mode to manually control the drilling of the pre-marked target on the building surface.

The above describes the BIM-based drilling device of the present disclosure in detail through the exemplary embodiments for effectively drilling on a surface, e.g., overhead walls and/or ceilings. It should be understood that the scope of the present disclosure is not limited to the above-mentioned embodiments, but is limited by the accompanying claims. Without departing from the object and spirit of the present disclosure, various modifications to the embodiment are possible, but they remain within the scope of the present disclosure.

WHAT IS CLAIMED IS:

1. A drilling system that uses digital information from building information modeling (BIM) for drilling an anchor hole into a pre-marked target
5 on a surface of a building comprising:

a supporting unit movable in at least one of three dimensions; and

a drilling device removably secured to the supporting unit, wherein the drilling device comprises:

10 a laser position unit to provide a laser light in illuminating a working area containing the pre-marked target,

an imaging unit to scan the working area of the surface to capture images of the working area,

15 a processor unit to process the captured images, determine location coordinates of the pre-marked target, and generate drilling data associated with the pre-marked target,

a drill unit movable from a first position to a second position,

a drill controller to receive the drilling data, which contains a drill depth and an algorithm adopted for the application and control of the drill unit,
and

20 a driver unit to drive at least one linear actuator based on the location coordinates, and move the drill unit from the first position to the second position for allowing the drill unit to create the anchor hole on the surface of the pre-marked target based on the drilling data.

25 2. The drilling system of claim 1, further comprising a laser height detector for detecting a distance between the illuminated working area and the drilling device.

3. The drilling system of claim 1, further comprising a dust collector unit securely mounted to the drill unit to capture dust and debris coming from drilling of the surface of the building, and to channel the dust and debris to a collection area.

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4. The drilling system of claim 1, further comprising an alarm indicator securely mounted on the control cabinet for indicating an alarm signal generated by the processing unit.

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5. The drilling system of claim 1, further comprising a ventilator on the control cabinet for allowing air flow to and from the control cabinet.

6. The drilling system of claim 1, further comprising an antenna securely mounted on the control cabinet for enabling a wireless communication.

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7. The drilling system of claim 1, wherein the drill unit further comprises a drilling tool rack for supporting a drilling tool.

8. The drilling system of claim 4, wherein the drill unit and drilling tool rack are protected by a protective cover.

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9. The drilling system of claim 1, wherein the processor unit selects a set of drilling data which contains the drill depth and drilling algorithm to provide a swift and safe operation of the drilling device.

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10. The drilling system of claim 1, further comprising first, second, third and fourth modes of operation for drilling the anchor hole into the pre-

marked target on the surface of the building.

11. The drilling system of claim 10, wherein the first mode of operation uses the predetermined marking points as the pre-marked target for creating the anchor hole based on the drilling data by drilling on the surface of the building.

12. The drilling system of claim 10, wherein the second mode of operation uses the laser point emitted by a RTS locating the position of the hanger that is shown in a crash-free MEP model for creating the anchor hole based on the drilling data by drilling on the surface of the building.

13. The drilling system of claim 10, wherein the third mode of operation uses location tracing of a laser point from a laser emitting device as the pre-marked target for creating the anchor hole based on the drilling data by drilling on the surface of the building.

14. The drilling system of claim 10, wherein the fourth mode of operation uses the laser point present in a captured image of the pre-marked target displayed on a display device as the pre-marked target for creating the anchor hole based on the drilling data by drilling on the surface of the building.

15. The drilling system of claim 1, further comprising:
a removable drill rack capable of being decoupled from the drilling device for safe keeping of a drill tool supported by the drill rack, and
a built-in load cell to monitor an advancing force of the drill tool from exceeding a limit that would render the drilling device inoperable.

16. The drilling system of any of claims 1 to 14, wherein the processing unit determines the location coordinates and the center of the pre-marked target for drilling the anchor hole.

5 17. The drilling system of any of claims 1 to 14, wherein the supporting unit, which is a crawler scissor lift, is fixedly secured by the drilling device.

10 18. The drilling system of any of claims 1 to 14, wherein the imaging unit comprises two or more cameras to capture a plurality of images of the working area at different angles.

15 19. The drilling system of any of claims 1 to 14, wherein the drilling device is moved from the first position to the second position using one or more of the x-axis, y-axis and z-axis linear actuators based on the location coordinates.

20 20. The drilling system of any of claims 1 to 14, wherein the processing unit selects the set of the drilling data that contains the dimensions relating to the depth of the anchor hole and its drilling algorithm through a computer input device which is in wired or wireless communication with the processing unit.

25 21. The drilling system of any of claims 1 to 14, wherein the processing unit comprises an image processing module programmed to process the captured images using machine learning to identify an impingement point of the laser light on the working area to generate the drilling data associated

with the pre-marked target.

22. The drilling system of claim 21, wherein the image processing module is programed to process the captured images using a deep learning model, wherein the deep learning model is created by:

- a) collecting image data of the captured images of the working area,
- b) generating a classification indicating features of the impingement point of the laser light from the collected image data,
- c) extracting a set of the features based on the image data with the classification to build the deep learning model, and
- d) feeding the deep learning model train data and validation data to perform the classification to train the deep learning model to identify the impingement point in the images in a manner that an acceptable accuracy is reached for the drill data generation.

23. The drilling system of claim 22, wherein steps b) to c) comprise:

- b) dividing the working area into a plurality of cells and generating features representing the cell in which the impingement point is located from the collected image data,
- c) building the deep learning model based on the features representing the cell of the impingement point, and
- d) feeding the deep learning model train data and validation data to perform detection of the cell of the impingement point to train the deep learning model to identify the impingement point in the images in a manner that an acceptable accuracy is reached for the drill data generation.

24. The drilling system of claim 22, wherein the deep learning model

is based on a SSD network.

25. The drilling system of claim 24, wherein the SSD network model defines a loss function below:

$$5 \quad L(x, c, l, g) = \frac{1}{N} (L_{conf}(x, c) + \alpha L_{loc}(x, l, g))$$

wherein $L(x, c, l, g)$ is total loss value; $L_{conf}(x, c)$ is confidence loss function; $L_{loc}(x, l, g)$ is location loss function; N is number of samples; and α is weight; x is feature value; c is confidence; and g is ground truth.

10 26. The drilling system of claim 22, wherein the collected data is subject to data augmentation through horizontal and vertical rotation, random cropping of the images, and brightness, saturation and chroma enhancement of the images.