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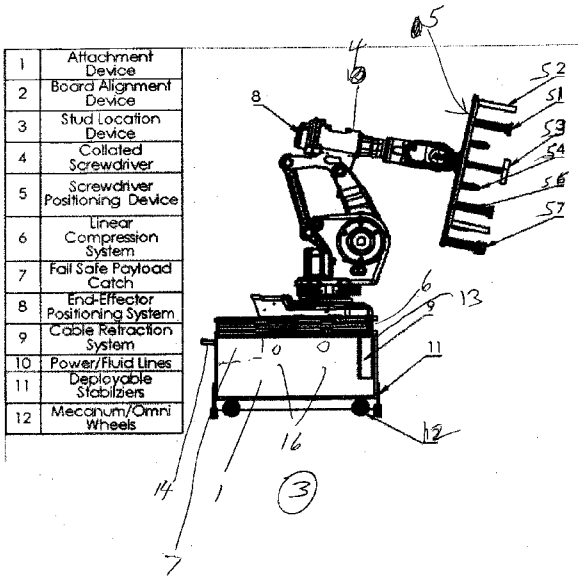
(54) Title: CONSTRUCTION BOARD INSTALLATION ROBOT



(57) Abstract: A construction board installation robot comprises a frame with attached devices to securely hold and subsequently affix to a substructure a construction board, a robotic system consisting multiple joints and links to position the frame, and a cart containing ancillary equipment needed for the completion of the desired task and the ability to move and position the entire assembly under its own power. Positioning is determined dynamically utilizing a series of laser scanners and optical sensors. To assist a laborer with the mounting of boards, the arm and cart are capable of being easily maneuvered either through the use of integrated sensors that direct the actuation of the arm and/or cart wheels as determined by the push or pull of the operator on the device, a method of remote control, and/or independently with control software.

WO 2016/200439 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

— *the filing date of the international application is within two months from the date of expiration of the priority period (Rule 26bis.3)*

CONSTRUCTION BOARD INSTALLATION ROBOT

CROSS-REFERENCES TO RELATED APPLICATIONS.

This application claims the benefit of United States Provisional Application For Patent, Ser. No.: 62/173,348, filed June 9, 2015 and whose contents are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION.

Embodiments of the present invention include construction board installation apparatus, and more specifically, apparatus to automate the installation of construction boards.

BACKGROUND OF THE INVENTION.

Gypsum board or drywall is widely used to create a finish surface for interior walls and ceilings, while sheathing is often used to create a surface for roofing materials. Hanging drywall and installing sheathing during the construction or renovation of buildings is commonplace, arduous, and repetitive.

Current installation practice for drywall is as follows: teams of laborers lift large, heavy sheets of gypsum board and carefully position them against the wall, often at height. A laborer must then affix the board to the structure of the wall. After an appropriate location is determined, usually where a screw will land in a wall stud, the laborer can drive in the screw. Many tens of screws are required to securely mount a board. The entire process is slow and exposes laborers to the possibility of repetitive stress

injury. The process for placement of sheeting is similar and just as arduous and dangerous.

The installation of drywall, sheathing, and other construction boards would both benefit enormously from the use of a device that could, in conjunction with the guidance of a person or independently, place and either fully or partially attach the board to the underlying structure. The device would greatly reduce the strength required to maneuver the large and unwieldy boards and increase worker productivity.

BRIEF SUMMARY OF THE INVENTION.

An object of the present invention is apparatus to assist in the installation of a construction board, such as drywall, sheathing, and plywood.

Another object of the present invention is apparatus to assist in the transport of such construction boards to a chosen installation location.

Yet another object of the present invention is apparatus to assist in the placement of such construction boards at a chosen installation location.

Still another object of the present invention is apparatus to automate the installation of such construction boards.

An embodiment of the present invention comprises a frame with attached devices to securely hold and subsequently affix to a substructure a construction board, a robotic system consisting multiple joints and links to position the frame, and a cart containing ancillary equipment needed for the completion of the desired task and the ability to move and position the entire assembly under its own power. Positioning is determined dynamically utilizing a series of laser scanners and optical sensors. To assist a laborer with the mounting of boards, the arm and cart are capable of being easily maneuvered either through the use of integrated sensors that direct the actuation of the

arm and/or cart wheels as determined by the push or pull of the operator on the device, a method of remote control, and/or independently with control software.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING.

Fig. 1 is a side view of an embodiment of the frame of the invention.

Fig. 2 is a corner view of the embodiment shown in Fig. 1.

Fig. 3 is a side view of an embodiment of the invention.

Fig. 4 is a corner view of the embodiment as shown in Fig. 3, displaced 90 degrees.

Fig. 5 is a corner view of the embodiment as shown in Fig. 4, with vertical extension.

Fig. 6 is a side view of the embodiment as shown in Fig. 3 with construction board attached.

DESCRIPTION OF THE INVENTION.

Various embodiments of the present invention include a frame **5** with attachment devices **12** to securely hold and subsequently affix to a substructure **3** a construction board **2**, a robotic system **4** having multiple joints and links to position the frame **5**, and a cart **1** containing ancillary equipment needed for the completion of the desired task and the ability to move and position the entire assembly under its own power.

Mounted to the end of the robot arm **4** is a device **51** to hold securely construction board **2**, a device **53** to sense the location of studs in the wall **3** or roof **3** when the drywall **2** or sheathing **2** is correctly

positioned, a device **55** to position and a device **54** to drive numerous screws or other fasteners through the material **2** and into the structure **3**.

To assist a laborer with the mounting of boards **2**, the robot arm **4** and cart **1** are capable of being easily maneuvered either through the use of integrated sensors that direct the actuation of the arm **4** and/or cart wheels **12** as determined by the push or pull of the operator on the device, a method of remote control, and/or independently with control software **7**.

Frame

The frame **5** is available in different sizes to fit standard size pieces of drywall, sheathing, and/or other construction board **2**. Mounted to the frame **5** are preferably vacuum suction cups **51** or other well-known devices capable of holding construction boards **2**. The robotic arm **4** attaches to this frame **5**. These holding devices **51** hold the board **2** tightly against the frame **5**. Control signals to activate and maintain the board **2** against the holding devices **51** are initiated and terminated by a command from the human operator or control program. A linear compression system **56** ensures the holding devices **51** are in close contact with the board **2** before they are initiated. To prevent the dangerous possibility of a board **2** falling from a height in the case of power failure, the vacuum system **51** fails "closed" to maintain vacuum and continue to hold the board **2** for as long as possible. Additionally, the control software prevents movement of the robotic arm **4** and frame **5** if it is determined that the level of vacuum present is not great enough to secure the board **2**. Some form of retractable catch mechanism **57** is also present to reduce the likelihood of a board **2** falling from the frame **5**. Some embodiments may also have an auxiliary power supply to maintain functionality until the entire mechanism is in a safe position.

Attached to the frame **5** for the purpose of affixing the construction board **2** to the structure **3** is a mechanism **55** for locating and driving attachment devices, preferably screws or nails. A positioning mechanism **55** positions the powered screwdriver and screw feed **54**, nail driver and nail feed system **54**, or other attachment devices **54**, according to sensor input or a predefined sequence of destinations and, at the request of the

operator or control software **7**, drives a screw or nail through the board **2** and into the structure **2**. Such positioning mechanisms **55** are well known in the relevant art. Further, it is preferred that the frame **5** contain multiple screw/nail-driving mechanisms **54** on the frame **5** to allow for multiple screws/nails to be driven simultaneously.

The frame **5** also possesses sensors or extensions **52** to aid in positioning the frame **5** over a board **2** that is to be placed on a wall **3**. This allows for the board **2** to be consistently positioned on the frame **5**.

Screw/Nail Driving System

As described above, the preferred apparatus of attachment are screws or nails. Screw/nail driving tools and screw/nail loading mechanisms are well known in the relevant art, for example collated screw guns or nail guns. The attachment apparatus **54** is connected to a positioning system **55** that comprises a rail and a system for linear actuation that can be accurately position the driving tool **54** along the length of the rail.

The frame **5** preferably contains multiple rail/driver assemblies **54, 55**; they may be oriented horizontally or vertically.

Once the board **2** is correctly positioned against the wall structure **3** where and to which it is to be attached, a control signal is given by either the operator or a control program **7**. Then, the screw/nail driver **54** traverses the length of the rail and stops to drive a screw/nail either at predetermined intervals or when a sensor **53**, preferably a stud finder, determines that the screw/nail driver is correctly positioned.

Arm

The arm **4** allows for translation and rotation in three dimensions, as appropriate. Additionally, the arm **4** must support the torsional and bending loads associated with the motions necessary for the construction board **2**. One example of a prior art arm system is glass lift mechanisms used by window installers. Other prior art arm systems that may be utilized are

included as part of the Reachmaster Winlet 770, GLG GlasLift 550, or KS Schulten Maschinenbau KS Robot 600. These arms **4** are combined with the frame **5** of the invention to comprise a complete system.

Cart and Platform

The preferred embodiment of the present invention include a combination of a wheeled cart **1** and a raisable platform **6**. The platform **6** is preferably raised with either a scissor type lift or piston mechanism. The lower section comprising of a utility cart **1** to carry controllers **7**, batteries and other support equipment, for the robotic arm **4**, as well to provide storage and support for consumables that the robotic arm **4** uses.

There are preferably various combinations of cart **1** and platform **6** to accommodate both operating weight and reach considerations. The differing combinations ensure that the robotic arm **4** can fully reach the allocated work area within the fully retracted to fully extended platform **6** positions.

In addition, the cart **1** size and height is also coordinated with the need for maintaining a narrow enough width so as to be able to maneuver through doors and be transportable by standard building elevators.

The cart is also equipped with proximity sensors **13** so that operation of the robot **4** is halted if someone or something enters a possible "exclusion zone".

An embodiment of the cart **1** is equipped with electrically powered wheels **12** with an option to be pushed by manual means as well. The wheels **12** have automatic "chucks" that engage each time the unit is under electrical operation and is then stopped to prevent unintended movement of the cart **1** if there is a gradient in the floor on which the cart **1** sits. In manual-push mode, an interlock switch is engaged to allow operation of the wheels **12**. The interlock switch **14** is accessible to the person pushing the unit and failing to push the switch results in the chucks being applied immediately. This configuration of the switch is known as "dead man" switch; it is well known in the relevant art.

Power for the operation of the wheels **12**, controller **7**, and robot **4** is through a combination of a primary utility or generator power through a standard 110/220 V socket and extension cord and a secondary on-board backup battery to provide a minimum safe run time and to power down the system to a safe condition in the event of a primary power loss. The power cord connecting the unit contains an automatic tension/retraction system so that the cord does not pose a tripping hazard to personnel or run afoul of the movement of the wheels. Such configurations are well known in the relevant art.

The cart **1** is preferably under the control of the robotic controller **7** so that the robot **3** and cart **1** act as an integral unit. In other embodiments, the cart **1** is remotely operated using the controller **7** or is able to be manually positioned. In practice, the exact mode is determined by the specific requirements of the application.

The cart **1** is preferably outfitted with motion stabilizers **11** and a system to prevent the wheels **12** from moving during operation. This stability prevents movement of the cart **1** while the robot **4** is working; such movement may negatively affect the accuracy of the work performed by the robot **4**.

The cart wheels **12** are preferably independently controlled and may be omni-wheels or Mecanum wheels to allow for movement in all directions and the ability for the cart **1** to rotate.

Also, the cart controls **7** preferably have laser scanners and vision sensors **16** which allow for the detection of obstacles, people, or any relevant physical object and for any followup actions needed after such detection.

The platform **6** is the attachment point for the robotic arm **4**. In some embodiments, the platform **6** also contains space for any consumables that have to be in proximity with the robotic arm **4** as well as a lifting portion to raise the arm **4**. Power and any other supply lines to the platform are routed through the lifting mechanism. In some embodiments, the platform also

contains a turret to rotate the arm **4**. This turret is powered or manually driven.

In use, the controller **7** locates a construction board **2** in the robot's environment, utilizing the scanners and sensors **16**. The robot arm **4** is maneuvered so that the frame **5** comes into proximity with the board **2**. The board is then held to the frame **5** by the attachment devices **51**.

The controller then determines the target location of the board, utilizing the scanners and sensors **16**. Once location and pose information have been determined, the controller **7** begins the task of the planning the trajectory for the system. Traditional path planning techniques are used to determine an optimal trajectory. The controller **7** then takes the trajectory information and execute the plan to ensure that the system ends up at the appropriate position and pose.

The system is then moved into proximity with the target location. The board **2** is accurately lined up at the target location and then secured there.

This procedure may be repeated as long as desired by the operator.

Although this invention has been described with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of illustration and that numerous changes in the details of construction and arrangement of parts may be resorted to without departing from the spirit and scope of the invention.

CLAIMS.

What is claimed is:

1. A robot for transporting a board from a base position to a target position, the robot comprising:

a cart having moving means to move over a surface;

a platform mounted on the cart;

a robot arm connected to the platform, the arm being movable in three directions;

a frame connected near an end of the arm, the frame comprising:

attachment means to releasably attach the board to the frame; and

alignment means to align the frame with the base position and the target position; and

a controller operationally connected to the cart, the platform, the arm, and the frame.

2. The robot as described in Claim 1, wherein the alignment means comprises laser scanners and/or optical sensors and provides a plurality of observations to the controller.

3. The robot as described in Claim 2, wherein the moving means comprises omni-directional wheels.

4. The robot as described in Claim 2, wherein the frame further comprises installation means to attach the board at the target position.

5. The robot as described in Claim 2, wherein the controller determines a path between the base position and the target position based upon the observations.

6. The robot as described in Claim 5, wherein the cart further comprises avoidance means to detect and treat as an exception an obstacle along the path.

7. The robot as described in Claim 4, wherein the controller determines a path between the base position and the target position based upon the observations.

8. The robot as described in Claim 7, wherein the cart further comprises avoidance means to detect and treat as an exception an obstacle along the path.

9. The robot as described in Claim 7, wherein the board is drywall.

10. The robot as described in Claim 7, wherein the board is sheathing.

11. The robot as described in Claim 7, wherein the board is plywood.

12. A method for transporting a board from a base position to a target position installing the board at the target position, the method comprising the steps of:

(a) obtaining a robot comprising:

a cart having moving means to move over a surface;

a platform mounted on the cart;

a robot arm connected to the platform, the arm being movable in three directions;

a frame connected near an end of the arm, the frame comprising:

attachment means to releasably attach the board to the frame;

alignment means to align the frame with the base position and the target position, the alignment means comprising laser scanners and/or optical sensors and providing a plurality of observations to the controller; and

installation means to attach the board at the target position; and

a controller operationally connected to the cart, the platform, the arm, and the frame;

(b) determining a path between the base position and the target position based upon the observations;

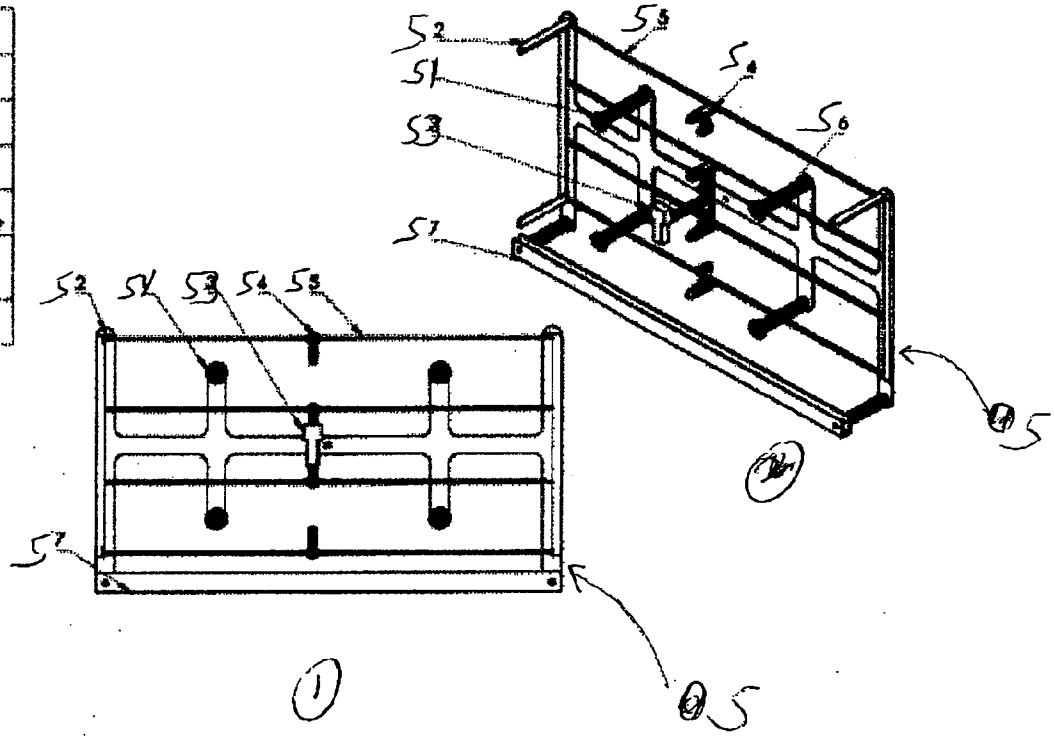
(c) moving the robot proximate to the base position;

(d) attaching the board to the frame via the attachment means;

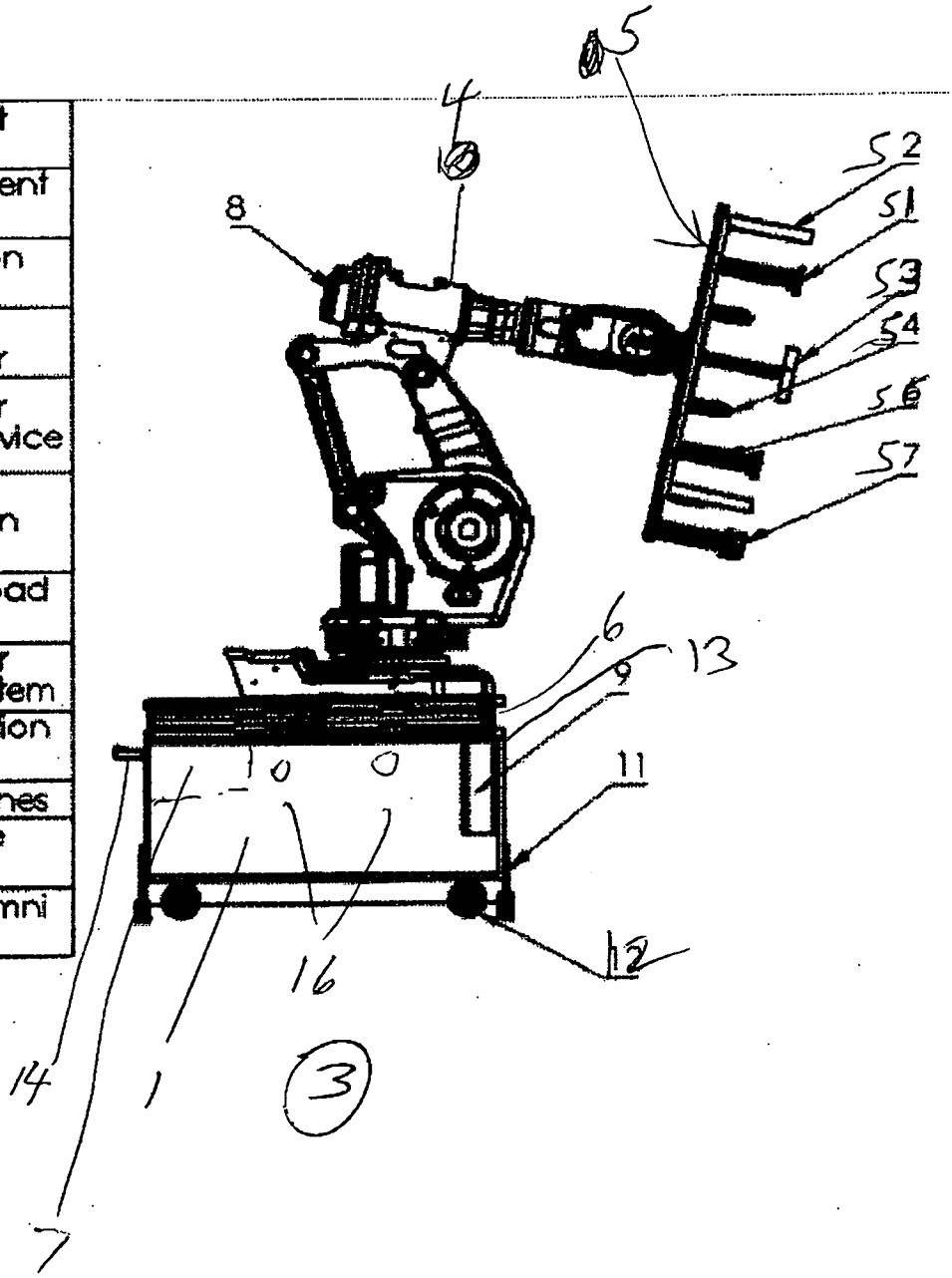
(e) moving the robot proximate to the target position by following the path; and

(g) installing the board at the target position via the installation means.

1	Attachment Device
2	Board Alignment Device
3	Stud location device
4	Collated Screw Driver
5	Screwdriver Positioning Device
6	Linear Compression System
7	Foil Safe Payload Catch



1	Attachment Device
2	Board Alignment Device
3	Stud Location Device
4	Collated Screwdriver
5	Screwdriver Positioning Device
6	Linear Compression System
7	Fall Safe Payload Catch
8	End-Effector Positioning System
9	Cable Retraction System
10	Power/Fluid Lines
11	Deployable Stabilziers
12	Mecanum/Omni Wheels



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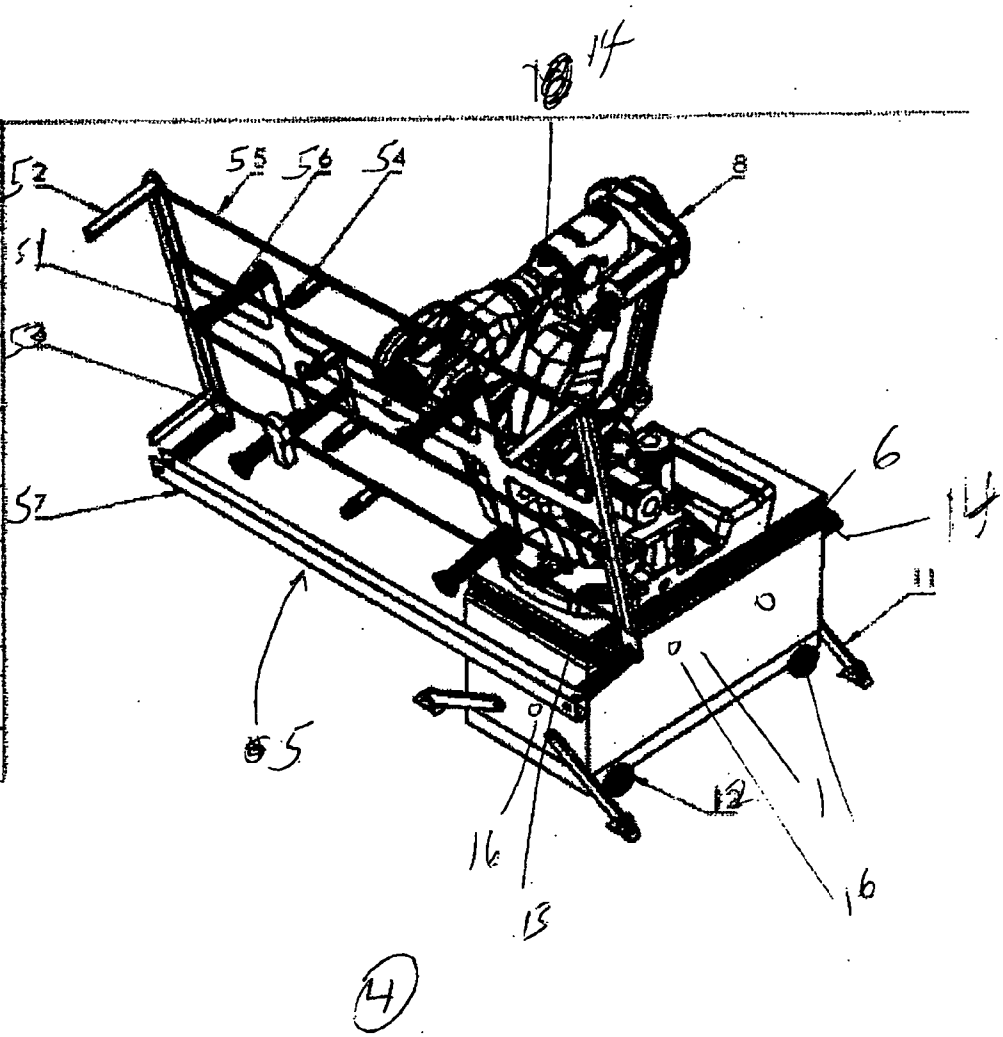
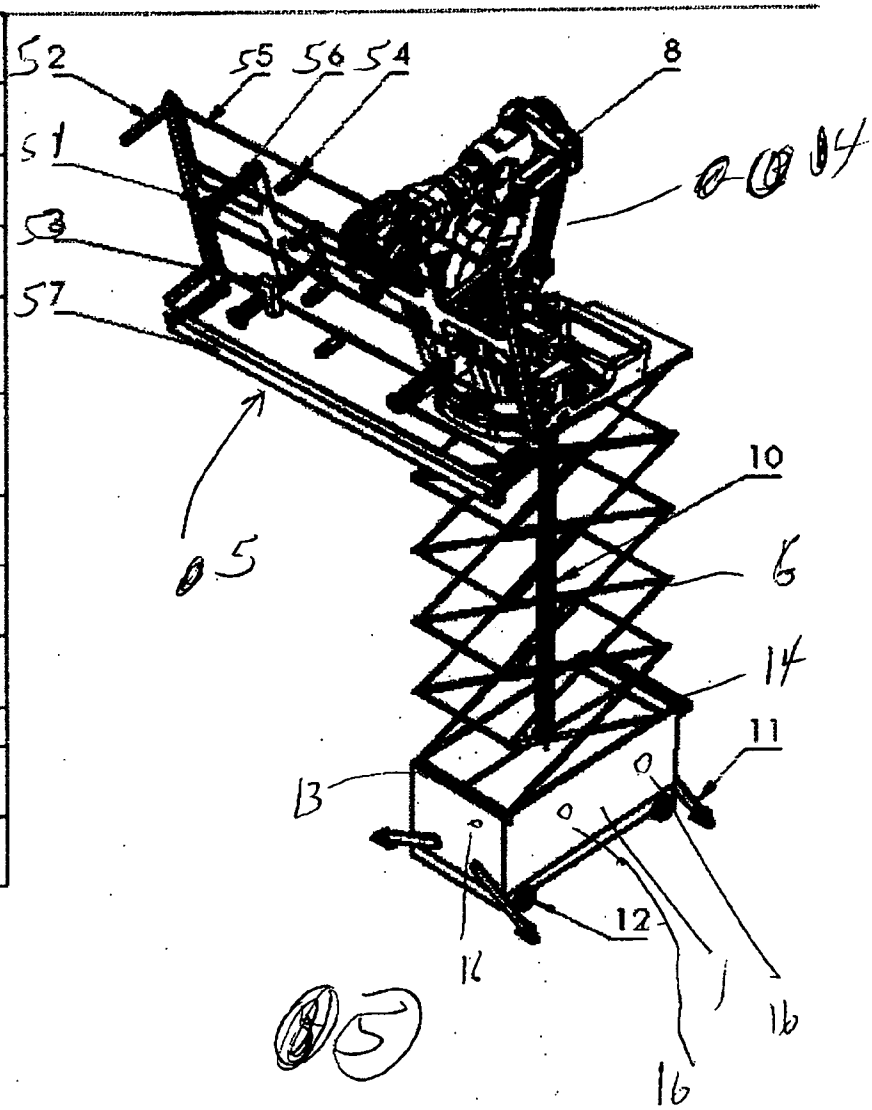
3	Stud Location Device
4	Collated Screwdriver
5	Screwdriver Positioning Device
6	Linear Compression System
7	Fail Safe Payload Catch
8	End-Effector Positioning System
9	Cable Retraction System
10	Power/Fluid Lines
11	Deployable Stabilizers
12	Mecanum/Omni Wheels



(4)

1	Attachment Device
2	Board Alignment Device
3	Stud Location Device
4	Collated Screwdriver
5	Screwdriver Positioning Device
6	Linear Compression System
7	Fall Safe Payload Catch
8	End-Effector Positioning System
9	Cable Retraction System
10	Power/Fluid Lines
11	Deployable Stabilziers
12	Mecanum/Omni Wheels



1	Attachment Device
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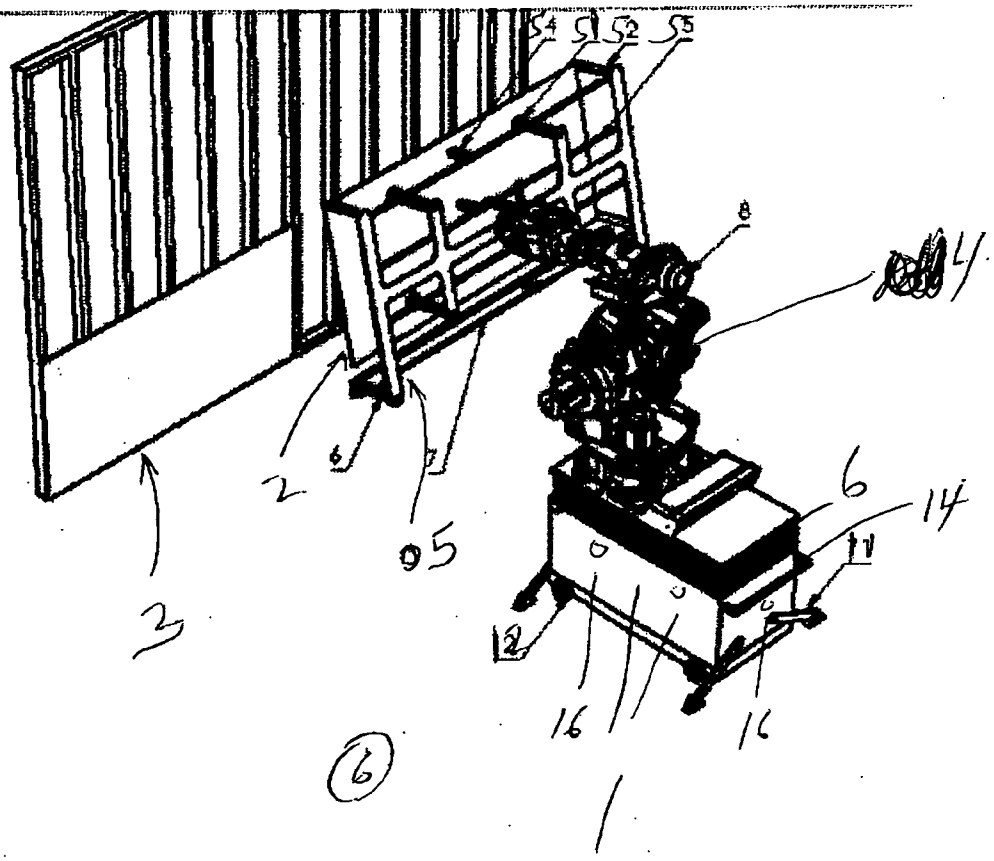
10	Power/Fluid Lines
11	Deployable Stabilziers
12	Mecanum/Omni Wheels



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/00049

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E04F 21/18 (2016.01)
CPC - E04F 21/18
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (8): E04F 21/18 (2016.01)
CPC: E04F 21/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC (8): B25J9/00, E04F21/18, E04F 19/00, E04F 21/00, B25J9/06, B65G61/00, B65G59/00, B25J5/00, B65G59/02, B25J15/00, B62B3/02, B62B3/04, E04G21/16, B66F 19/00, B66F 13/00 (2016.01) --- See Extra Sheet ---

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase; Google Patents; Google Web
Search Terms Used: Drywall, gypsum, board, panel, plywood, sheathing, transport*, install*, hold*, secur*, mov*, robot, automatic, autonomous, machine, omni, arm, manipulator, boom, extend*, three, four, five, six, direction, rotation, freedom --- See Extra Sheet ---

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	JPH 03100265 A2 (TOKYU KENSETSU KK) 25 April 1991 (25.04.1991), entire document, especially fig. 1, 3-5; page 2 of translation, para [2]; page 3 of translation, para [2]; page 4 of translation	1-2, 4-5, 7, 9-12 ---------- 3, 6, 8
Y	US 2015/0003927 A1 (SPISHAK et al.) 01 January 2015 (01.01.2015), entire document, especially fig. 2; para [0027]	3
Y	WO 2013/112907 A1 (ADEPT TECHNOLOGY, INC.) 01 August 2013 (01.08.2013), entire document, especially pg 5, ln 20 - pg 6, ln 31	6, 8
A	CA 2716134 A1 (GESTION BPRR INC.) 30 September 2010 (30.09.2010), entire document	1-12
A	US 2013/0011234 A1 (Pretlove et al.) 10 January 2013 (10.01.2013), entire document	1-12
A	US 2011/0264306 A1 (Bagge) 27 October 2011 (27.10.2011), entire document	1-12
A	US 5,413,454 A (Movsesian) 09 May 1995 (09.05.1995), entire document	1-12
A, P	CN 204920253 U (GUANGXI FENGGE GREEN HOUSE CONSTRUCT TECHNOLOGY CO LTD) 30 December 2015 (30.12.2015), entire document	1-12

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" carlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 July 2016	27 OCT 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/00049

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC: B65G49/067, B65G 49/061, B65G61/00, B65G 59/00, B65G 59/04, E04F21/00, E04F 21/1805, E04F 21/1872, B25J 5/007, B25J 11/0095, B25J 15/06, B25J 17/0283, B25J 18/04, B25J 19/02, B25J9/1602, B25J9/046, G05B 2219/39084, G05B 2219/39118, G05B 2219/39198, G05B 2219/39246, B65H 2555/31, Y10S294/907, B65H 2601/325, B25J15/00, B62B3/02, B62B3/04, B62B 3/108, B62B2203/10
(keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Search Terms Used (conti.): motion, frame, suction, attach*, screw, wheel*, roll*, mobile