



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
10.08.2011 Bulletin 2011/32

(51) Int Cl.:
B66C 1/02 (2006.01) **B65G 47/00 (2006.01)**
B65G 61/00 (2006.01)

(21) Application number: **11000780.4**

(22) Date of filing: **01.02.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(72) Inventors:
• **Zupancic, Danijel**
1295 Ivancna Gorica (SI)
• **Santavec, Miha**
1370 Logatec (SI)

(30) Priority: **01.02.2010 SI 201000033**

(74) Representative: **Marn, Jure**
Ljubljanska ulica 9
2000 Maribor (SI)

(71) Applicant: **Trimo d.d.**
8210 Trebnje (SI)

(54) **Method and apparatus for assembling building shell elements**

(57) Automated assembly of building shell (comprised of facades, roofs, dividing walls and ceilings) in connection with building from phase of design to phase of erection, comprising all phases of optimized assembly of building shell. In particular, the assembly of sandwich panels onto metal sub-frame, said sub-frame being carrying member of roofs and facades is disclosed. This system can be used in way of analogy for assembly of glass facades and other elements of building shell where

the basic element is finished enough to have it directly mounted or attached or otherwise incorporated into building shell.

An automated assembly, positioning elements of a building shell in correct sequence onto a correct position into the building shell is disclosed. A method for automated assembly using a robot working in the outside environment without direct involvement of assembly workforce is further disclosed. This method provides for tracking ability and is essentially automated.

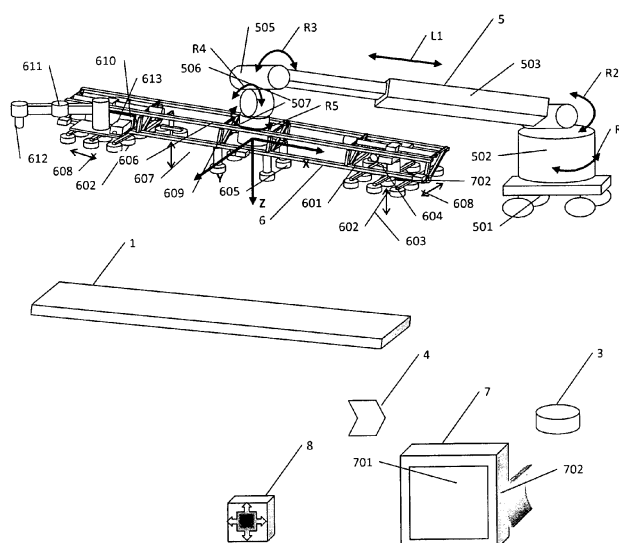


Fig. 3

Description

Field of invention

[0001] Civil engineering, assembly, sandwich panels.

Technical problem

[0002] Technical problem is optimization of assembling of building shell elements. The designers of the building shell design the shell having in mind requirements of the customer and technical norms and standards. In that they are usually not concerned with sequence of manufacturing of particular elements of the shell or actual assembly on the building itself. The manufacturers of shell elements take project as a whole and adapt manufacturing of said elements to criteria of simplest manufacturing, simplest packaging or simplest and most effective transport (provided this part of the process is in their domain). It is quite customary that assembly is provided by someone else other than manufacturer of shell elements. If the assembly provided is also customer most of the times order comprises sequence of delivery, and seldom exact sequence of building elements in such a way that no unnecessary manipulation is undertaken on the building site. The assembly team therefore faces challenge of obtaining elements of the shell on the building site which need to be laid out, if necessary turned around and each element using manpower of assembly worker prepared to be lifted on position for part of the shell provided in order. This may result in inconsistency regarding documentation, manufacturing batch, wrong element marking, similar marking of positions of similar dimensions (but manufactured from different batches of material), switch due to human factor and also incorrect manufacturing of sub-frame. There can be many other sources of inconsistency, however these are frequent enough and result in increase of cost for assembly teams who are already exposed to hardship in working outside. In addition assembly teams are exposed to work in elevated conditions which is connected to additional risks both for their safety and others connected in same processes.

State of the Art

[0003] Logistics of shell elements or panels is based on markings of particular packets in which panels of same lengths or lengths which are shorter from bottom up in each packet (for those shells showing shorter panels). On the site of the assembly the packets containing panels are positioned around buildings, on the floor. The packaging is removed, and then the assembly team using technical accessories (mechanical, vacuum grippers etc.) panels from packets are prepared to be lifted onto required height. Before that 2 workers of the assembly team provide for basic operations such as: removal of protective foil, correct turning, positioning of grip, posi-

tioning of elements of temporary attachments, providing for cut-outs etc.

[0004] Then the panel is lifted on required height by means of crane operated by the third member of assembly team. The fourth and the fifth members of the team who are elevated to desired height by means of lifting cage (at higher elevations they are in cage of suspended scaffold) manipulate the panel onto position on the shell and attach it using electrical or battery operated hand tools. In case of longer (heavier) panels these operations are even more difficult and therefore the assembly team can have up to 10 member all of which are exposed to hard work conditions, outside environment and elevations. Use of lift, lifting cages, suspended scaffolds etc. is more and more used and is now normal practice in all developed countries of the world, however several operations during assembly of building shell elements is still connected to work of assembly workers whose work result in quality and tracking ability of anticipated sequence.

Description of new invention

[0005] Method and apparatus for assembling building shell elements solve above referenced technical problem by showing automated assembly of building shell elements, apparatus for robotic assembly and method for robotic assembly of building shell elements with its use on assembly position.

[0006] This invention belongs to technical solutions in civil engineering for automated assembly of building shell (comprised of facades, roofs, dividing walls and ceilings) in connection with building from phase of design to phase of erection onto the position of building shell and is comprised of all phases of optimized assembly of building shell. In particular this invention belongs class of assembly of sandwich panels onto metal sub-frame, said sub-frame being carrying member of roofs and facades, however in general this system can be used in way of analogy for assembly of glass facades and other elements of building shell where the basic element is finished enough to have it directly mounted or attached or otherwise incorporated into building shell.

[0007] The subject of this invention is method comprised of all phases of project from writing the project documentation, work preparation, manufacturing of elements, packaging, transport of elements onto the building site and assembly onto pre-determined position of building shell. The method is integrated process with virtual construction and de-construction logic and physical preparation for real automated assembly into correct position of building shell. The subject of this invention is therefore method supported by specially developed programming tools. In addition the subject of this invention is technology (equipment) of automated assembly performing steps of said method and positioning elements of building shell in correct sequence onto correct position into building shell. The subject of this invention is also method for automated assembly using robot working in outside en-

vironment and performing steps of said method in order to position and assembly of building shell element without direct involvement of assembly workforce. The method provides for tracking ability and essentially automated. The invention therefore solves both problem of workforce not presented in elevations as well as follows logic of correct sequence on parts of building shell which is particularly important with specific building shells with various elements of building shell (e.g. 3D shells).

[0008] The subject of this invention is method based on assumption that each element of building shell - panel 1 is different. Therefore, from design to final positioning this element should be marked so in addition of its unique identification (ID) it shows also position - location. ID 101 provides for geometry, properties, attachment to sub-frame, batches (colors) of materials, technology parameters, sequence and time of manufacturing etc. At the end of manufacturing the ID is determined and for each particular element of building shell all properties can be stored for automated assembly and tracking can be enabled. Parallel to this process preliminary decision (later identification) regarding the location - IL 102 of this element of building shell is decided according to herein described method during phase of project documentation, and is followed during all phases of the process until final assembly of element onto predetermined position in the building shell is achieved.

[0009] The method follows virtual model of construction and de-construction in all phases of assembly. During manufacturing and stacking into packets the model assumes the principle as the panels are physically removed from the building and stacked in reversed sequential order into smaller for logistics and assembly suitable packets - packets 2. In such fashion transported packets on the building site allow for automated assembly and finishing of building shell without workforce on elevations.

[0010] Below the particulars of this invention are shown with aid of figures whereas the figures show integral part of this application and show:

Figure 1 shows schematics of identifications and connections ID and IL throughout the process and according to model for element of building shell with the following:

ID(1) - first part of identification (during preparation of project documentation)

ID(2) - additional data for identification (during technology preparation)

ID(3) - additional data for identification (during manufacturing and packaging)

ID - unique identification of element of building shell

ILv - identification of location on virtual building shell (in 3D project, virtual presentation of building shell or similar)

ILvp - identification of location on building shell taking into account virtual de-construction into

packets (technological way of method of manufacturing and packaging)

ILp - identification of virtual location of the element in already finished packets and having regard for principle of de-construction (reverse order of assembly) — ID also receives data on location

ILpf - identification of virtual location of element and virtual need of packet for correct sequence of assembly in particular phase of assembly - sequence of loading related to requests from the building site

ILk - identification of location from project and physical location of panel in packets

It should be stressed that numbers in figure 1 are NOT connected to figures 2 and 3 and are only used to show examples of how the packets are numbered in exemplary packet.

Figure 2 shows packet and method of stacking and identification of panels in packet.

Figure 3 shows technology of automated assembly of building shell elements.

[0011] The subject of invention is in particular design of virtual building with virtual building shell. The designer makes project of virtual shell using 3D model. During design of virtual shell particular elements of the shell are identified with element identification (ID 101) and location identification (IL 102). Then the designer de-constructs the building shell in such a manner that from virtual shell the elements are virtually removed and stacked in (assigned to) particular packets (shown by P and number of packet, figure 1), in the same order as removed. The information of particular packets is transmitted to the manufacturer of the elements actually manufacturing the panels and forming the packets, and further transports said packets to the building site. There, the system comprised of at least two robots (micromanipulator 5 and micromanipulator 6) is used to have said elements actually assembled into building shell.

[0012] The subject of the invention is also method for automated assembly of the panels using robots and new technology (equipment) for assembly of building shell elements on the building itself. Below this part of invention is described (fig. 2, fig. 3).

[0013] Panels 1 in packets 2 are therefore described virtually and actually using appropriate ID 101 markings and within that marking also IL 102. This marking can be in different forms such as bar code, chip or other form of marking. Said marking is positioned in appropriate position so it can be read and does not disturb the final look of the building after the building is finished.

[0014] In the embodiment the packets 1 are transported to the building site 2 in form of the packets in which the panels are stacked in the order they are to be assembled.

bled, i.e. in sequence 1 to x where x is the last in the order. The first the panel with marking IDx is accessible, said panel carrying information on IL1. The marking IDx states (for this particular first panel) that panel was manufactured as ID1, and carries marking IL1 as it is first to be assembled. After all the panels from the first packet are mounted, packet No. 2 is to be mounted where panel ID x+y is on the top with marking ILx+1.

[0015] The apparatus (hereinafter referred also to as "equipment") for automated assembly is equipped with suitable computer controlling the system and also performing other functions. It recognizes ID and IL from packet of panels, from specifications in project documentation 3 which is received by said computer as 3D model said computer recognizes the location where the panel should be assembled on actual building shell. Further, from digital snapshot of actual main construction 4 the computer recognizes actual main axes and possible disagreements of main construction or dimensions of the objects with plans which need to be taken into account during assembly.

[0016] The apparatus for automated assembly comprises micromanipulator — ("MM") 5 and micromanipulator — ("mM") 6. MM 5 is the system for rough coordination and movement of mM 6 in environment. Function of mM 6 is gripping of the panel, positioning, fine regulation of slants and adaptation to deformation and tolerances of construction as well as attaching of said panel onto essentially precise location in the building shell.

[0017] In preferred embodiment MM 5 is adapted mobile crane with chassis 501, the first full rotation R1 of upper moveable part 502 on which there is a control (cabin) with crane arm 503 with rotation in vertical direction R2 and telescopic movement L1. At the end of crane arm there are three additional devices enabling rotation in three directions. The first of these three devices 505 enables rotation R3 at the end of crane arm in direction up-down (rotation around x axis). The second device 506 enables rotation R4 in direction left-right (or up and down around y axis). The third device 507 enables rotation R5 of mM 6 in horizontal direction around z axis. All rotations and translations are controlled by sensors and limited. The limitations are programmed in order to prevent collision (contact) mM 6 or panel with MM 5 frame. The range of operation is quite wide and is limited with reach of crane arm, width of the building and heights up to 30 m.

[0018] Micromanipulator mM6 is designed to provide for all necessary functions of grip, positioning, drilling and bolting or other form of attaching (fastening) in its range of operation. It is comprised of frame 601 onto which grip systems are attached, in preferred embodiment two vacuum gripping units 602 having in addition to basic function of holding the panel during transport to the location also moveable mechanism 603 for approaching the panel on the floor or approaching of the panel to the assembly position on building construction. The system of vacuum gripping units is attached using attaching element 604 which provides that vacuum gripping units 602 adapt dur-

ing positioning on the panel to smaller errors connected to accuracy of positioning, bending due to different weights and possible non-symmetry of the panel etc. Between both vacuum units there is system of correcting vacuum grippers 605 attached to the frame, these having function of leveling o panel due to deformations usual for the panels before assembly due to difference in temperature of outer and inner metal sheet. The panel should be essentially level in order to be inserted into junction of previously attached panel on building shell.

[0019] Nest to gripping vacuum units 602 there are moveable stabilization vacuum units 606 with moving mechanism 607, said stabilization vacuum units 606 attaching to previous panel right before final positioning of the panel in order to provide for stabilization and smooth movements of other mechanism without large deviations and swinging. After stabilization vacuum units 606 are attached gripping vacuum units 602 are positioned closer to sub-frame. In case that vertical movement is needed this is provided by mechanism of vertical movement of gripping vacuum units 608.

[0020] On frame mM 601 there are guides 609 on which the cart of the robot 610 is driven, onto which at least one SCARA (expression known in state of the art standing for «Selective Compliance Assembly Robot Arm») robot 611 is attached, and further drilling - bolting unit 612 attached onto it. SCARA robot 611 provides for movements toward panel attachment position where in embodiment drilling - bolting unit 612 provides for drilling and bolting. In this area there is a container containing bolts and reserve drill 613. The system can have more than one, for example two robots or guided 3 axis units providing for operation of assembly and attaching on left and right side simultaneously for horizontal assembly or up and down in case of vertical assembly. More robots can be attached or used. In preferred embodiment the single SCARA robot 612 is used moving on the frame of mM 601 to position of drilling and bolting regardless of said position being on the end of the panel or along the panel.

[0021] The solution using MM 5 and mM 6 can be adapted for high rise building and buildings with 3D shell. In such cases the platform of the crane is replaced with guided chassis/cart in three directions following main construction or sub-frame of building shell. Micromanipulator can (similarly to telescopic arm) adapt and perform operations of positioning and attaching. Such system can even increase accuracy as crane arm MM 6 can be supported by main construction or sub-frame.

[0022] The principle of operation of whole system as presented in this application is as follows: The control unit 7 receives needed data related to object (building) 4, project 3, and panels 1 through input/output units such as readers, cameras, and transfer of 3D model. In preferred embodiment a worker manipulates packet with panels 2 in such a way that on the building site he or she prepares unloading platform or similar place for unloading said packet with panels 2 and removes the packaging

from the packet. Then the operator of the system comprised of MM 5 and attached mM 6 using input/output devices such as touch screen or some other technologically equivalent system determines position where packet with panels 2 is and guides the crane arm to the position of the first packet. This can be upgraded by establishing fixed unloading dock and automatizing the whole operation including taking of the first panel.

[0023] MM 5 is moving under controlled conditions in space. Subject of this invention is also method of control of control unit 7 of whole system which provides for all operations from attaching the panel 1 until its final attachment to the building to form part of the building shell. The control unit repeats these operations adapted to new panels and new locations. The control unit 7 by means of sensors each of movement axis provides for high accuracy and repeatability in wider range of operation. In principle the shortest trajectory is selected, however different trajectory can be entered in due to obstacles on building site or on the building itself. In such case the whole system avoids said obstacle taking into account geometry of mM 6 and the panel carried at the time. The setting of the first panel is important as it is reference point. This reference point can be introduced by operator via input/output devices such as touch screen or joystick or other form of I/O device 8 meant for manual mode of operation. The whole system is wholly automated and is controlled in a way of example via screen 701 or video cameras 702.

[0024] The control unit 7 can communicate via link 702 which can communicate directly with manufacturer of the panels for (in a way of example) ordering of future panels in sequence or with accounting department for providing debit notes or other forms needed for payment or reporting, or for other purposes such as specifications of assembly on facades or parts of the building

Claims

1. Apparatus for assembly of building shell elements for essentially automated assembly of building shell, **characterized in that** it comprises a macromanipulator (5) and a micromanipulator (6) whereby the macromanipulator (5) is meant for rough coordination and directed moving of micromanipulator (6) in environment, and further the function of micromanipulator (6) comprises gripping of the panel, positioning, fine regulation of slopes and adjusting to deformations and tolerances of construction as well as attachment of panel (1) on predetermined location in building shell.
2. Apparatus according to claim 1, **characterized in that** the manipulator (6) comprises of frame (601) at least one gripping vacuum unit (602) for gripping the panel (1) during transport, moving mechanism (603) for approach of panel (1) in the packet (2) on the

floor or approach of panel to the assembly position on the construction, at least one stabilizing vacuum unit (606) with moving mechanism (607) which attaches to previous panel right before final positioning of the panel (1) onto position in building shell.

3. Apparatus according to any of the previous claims, **characterized in that** the micromanipulator (6) further comprises guides (609) on which the cart of the robot (610) onto which at least one SCARA robot (611) is attached, to which drilling-bolting unit (612) is attached.
4. Apparatus according to any of the previous claims, **characterized in that** the macromanipulator (5) comprises of mobile crane with chassis (501), the first full rotation R1 of upper moveable part (502) on which there is a control (cabin) with crane arm (5)03 with rotation in vertical direction R2 and telescopic movement L1, and further at the end of crane arm there are three additional devices enabling rotation in three directions, namely device (505) for rotation R3 at the end of crane arm in direction up-down (rotation around x axis), further device (506) rotation R4 in direction left-right (or up and down around y axis), and device (507) enabling rotation R5 of micromanipulator (6) in horizontal direction around z axis.
5. Method for assembly of building shell elements comprising the following steps:
 - a. virtual assembly of building shell;
 - b. identification of particular panel ID (101);
 - c. identification of location of particular panel IL (102),
 - d. de-construction of building shell marking of each particular element by the designer and assigns it to packet P;
 - e. stacking of particular packet P and transport of the packet P to building;
 - f. assembly of particular building shell element with macromanipulator (5) and micromanipulator (6).
6. Method for assembly of building shell elements according to claim 5, **characterized in that** it further comprises step of marking the panels with identification of particular panel (ID), identification of particular panel in packet (IL), step of stacking of panels (1) in order of assembly, from the first assembled panel (IL1) to last assembled panel in packet in either this or reverse order, further comprising recognizing of specification of particular panel from project documentation (3) in 3D model, and comparison of digital snapshot of main construction (4) with 3D model from project documentation (3).

7. The method according to any of claims 5 or 6, **characterized in that** the identification ID (101) comprises data on geometry, properties, attachment to sub frame, batch (color) of materials, technological properties, sequence and time of manufacturing. 5
8. Method according to any of claims 5 to 7 **characterized in that** the control unit (7) receives all necessary data on object (4), project (3), and panels (1) by means of input/output units, preferably readers, cameras (702) and/or transfer of 3D model. 10
9. Method according to any of claims 5 to 8, **characterized in that** it comprises steps for de-construction of assembled building shell, in reverse order as steps for assembly. 15

20

25

30

35

40

45

50

55

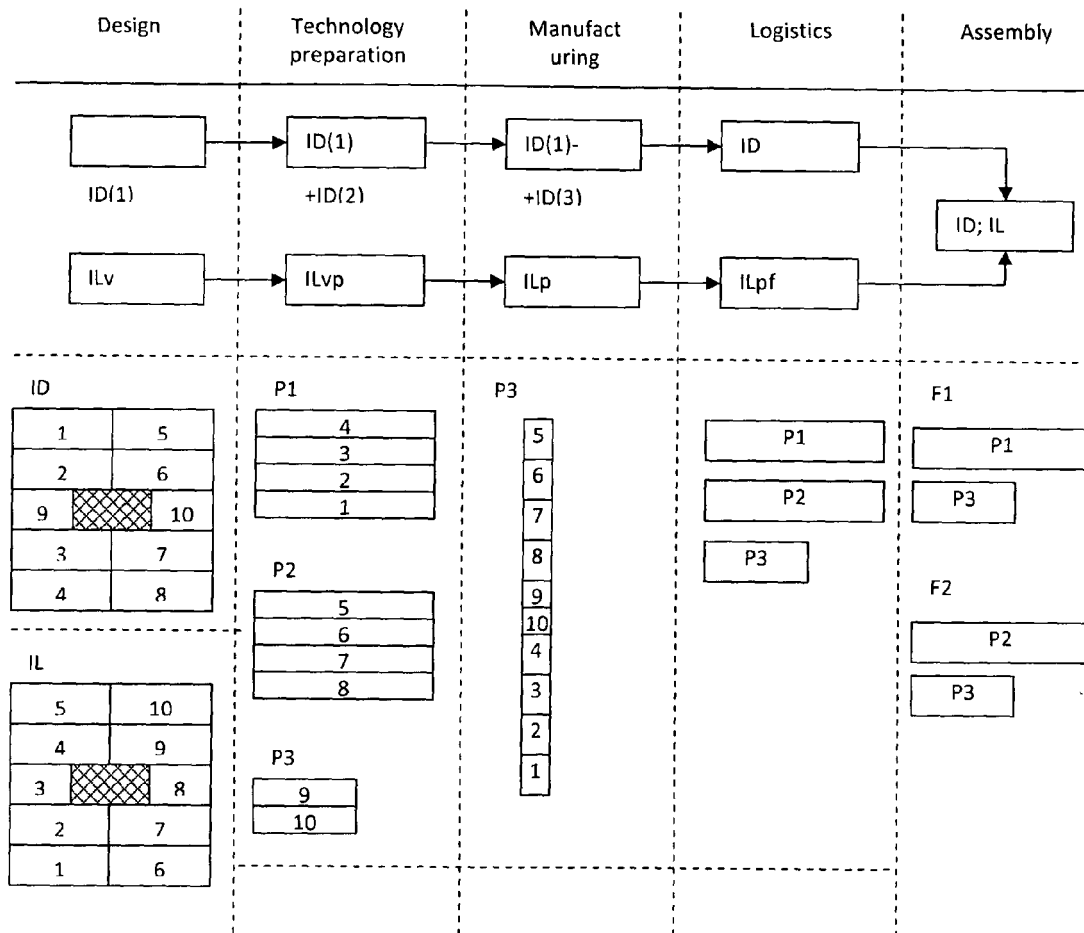


Fig. 1

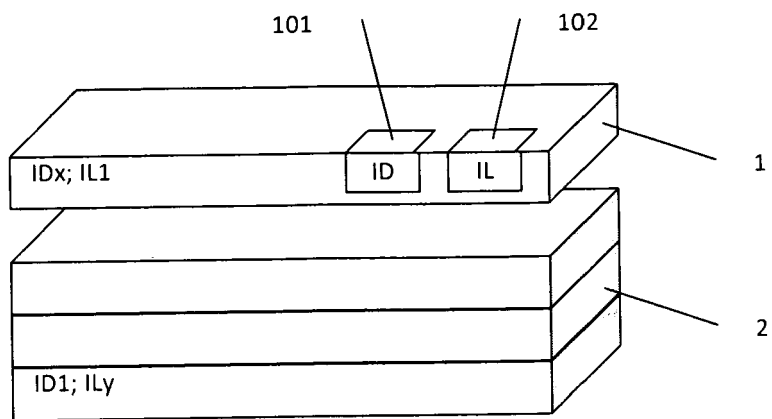


Fig. 2

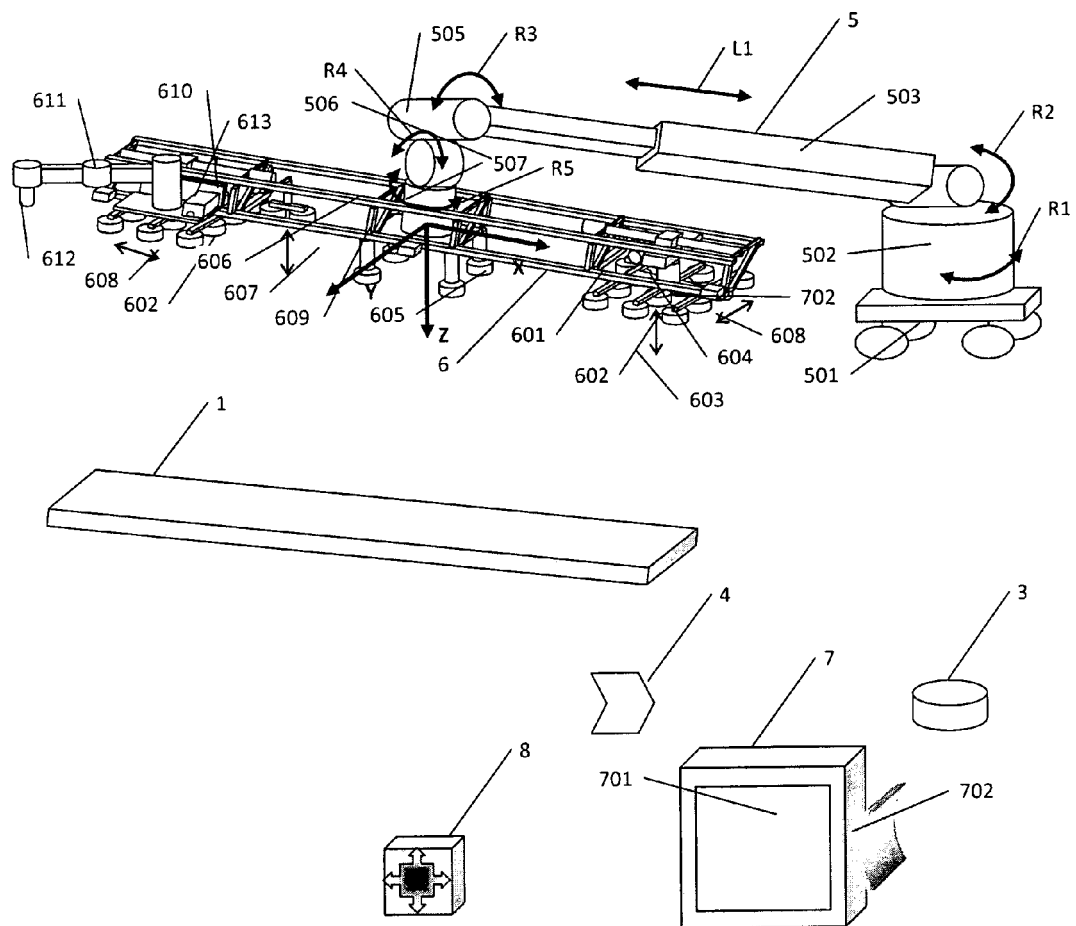


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 11 00 0780

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/133917 A1 (CLARK JEFFREY A [US] ET AL) 22 June 2006 (2006-06-22) * the whole document *	1,2,4-9	INV. B66C1/02 B65G47/00 B65G61/00
X	US 5 984 623 A (SMITH SCOTT R [US] ET AL) 16 November 1999 (1999-11-16) * the whole document *	1,2,5-9	
X	US 5 015 145 A (ANGELL MICKEY A [US] ET AL) 14 May 1991 (1991-05-14) * abstract; figures * * column 2, line 33 - column 5, line 7 *	1-3,5-9	
X	GB 2 268 536 A (WURTH PAUL SA [LU]; ARBED [LU]) 12 January 1994 (1994-01-12) * abstract *	1,2,5-9	
A	* line 9 - page 12, line 28 * * page 21, line 23 - page 24 *	4	
A	WO 2008/133974 A2 (PACE INNOVATIONS L C [US]; HJORNET PREBEN K [DK]) 6 November 2008 (2008-11-06) * abstract; figures *	1-9	TECHNICAL FIELDS SEARCHED (IPC)
A	WO 2004/028754 A1 (CONSEJO SUPERIOR INVESTIGACION [ES]; GONZALEZ DE SANTOS PABLO [ES]; JI) 8 April 2004 (2004-04-08) * abstract; figures 1-6 *	1-9	B66C B65G B25J
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 16 May 2011	Examiner Verheul, Omiros
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 2
EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 00 0780

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-05-2011

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2006133917	A1	22-06-2006	CA 2527243 A1	22-06-2006
			US 2007119123 A1	31-05-2007

US 5984623	A	16-11-1999	NONE	

US 5015145	A	14-05-1991	NONE	

GB 2268536	A	12-01-1994	AU 669174 B2	30-05-1996
			AU 4178093 A	13-01-1994
			BE 1006857 A3	10-01-1995
			CA 2099961 A1	08-01-1994
			DE 4321299 A1	13-01-1994
			ES 2069480 A2	01-05-1995
			FR 2694955 A1	25-02-1994
			IT 1264642 B1	04-10-1996
			JP 6074663 A	18-03-1994
			LU 88144 A1	01-04-1994
			NL 9301088 A	01-02-1994
			SE 9302336 A	08-01-1994
			US 5419669 A	30-05-1995

WO 2008133974	A2	06-11-2008	AU 2008246203 A1	06-11-2008
			CA 2685274 A1	06-11-2008
			EP 2146821 A2	27-01-2010
			JP 2010524712 T	22-07-2010
			KR 20100017393 A	16-02-2010
			US 2010135760 A1	03-06-2010
			ZA 200908340 A	25-08-2010

WO 2004028754	A1	08-04-2004	AU 2003268956 A1	19-04-2004
			ES 2206038 A1	01-05-2004

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82