Concept Design of Automation System for Installing Ceiling Glass

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ABSTRACT

Although construction materials are increasingly large and heavy, suitable construction equipment for these construction materials is lacking. In particular, the installation of heavy ceiling glass is very dangerous and laborious because of high-rise work. This paper discusses a conceptual design for a robot that installs heavy ceiling glass. The approach combines existing equipment, in order to achieve efficient effects with limited cost and time consumption. The design concept of a total robot system that installs heavy ceiling glass is expected to decrease the operator's danger and labour investment.

KEYWORDS: Concept design, Automation system, Ceiling glass

1. INTRODUCTION

Recently, the tendency in construction is to create high-rise buildings that maximize space utilization. The construction materials that offer efficiency and beauty have increased in size and weight, as described by Albus et al. (1986). The work involved to manage larger and heavier construction materials is a major cause for accidents and increased labour hours, since the number of skilled workers is limited at construction sites in developing countries, as expressed by Lee et al. (1991) and Kim et al. (2001). One interesting solution for these problems is in the design of construction automation systems and robotics, as described by Pablo et al. (2003), Roozbeh et al. (1991), and Choi et al. (2006).

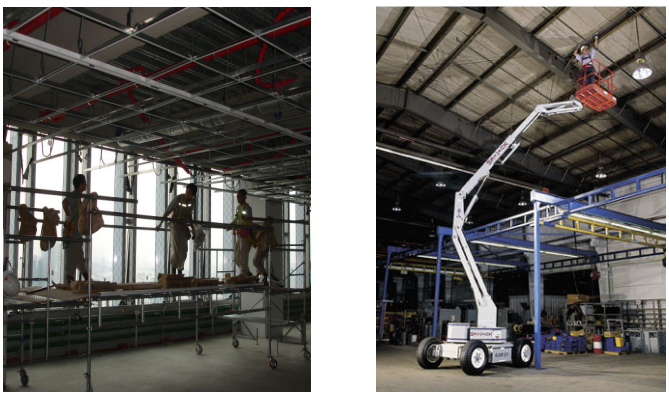


Figure 1. Examples of ceiling glass installation work


(a) RALF (England, GGR-UNIC) (b) HOMER (England, GGR-UNIC)

Figure 2. Example of installation robot

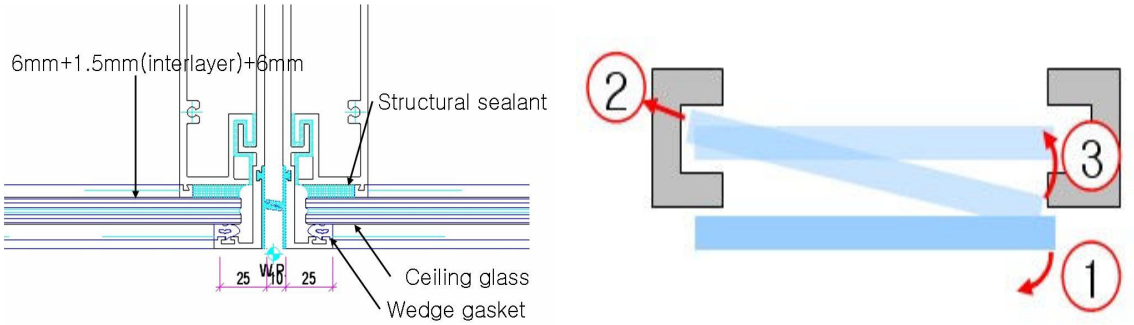
The installation of heavy ceiling materials is a dangerous environment for the operator. Also the installation process is complicated, often relying on existing equipment and a large number of operators, due to the lack of suitable construction equipment for heavy construction materials. In particular, heavy ceiling glass is susceptible to damage from collisions with other materials at construction sites. Generally, the installation of ceiling materials is executed as shown in figure. 1. One method involves using an aerial lift. This process has the danger of a falling accident or overthrow. This method is has restricted working heights and requires strong labour because the operator must directly handle the ceiling finish. Concentration, according to the incommodiousness of a worker's posture has fallen, which is connected to a productivity decrease and accuracy decrease of the establishment. Another method is to use scaffolding. This method has the problem of aerial lifts. Additionally, this method involves increased time for setup and removal of the scaffolding. The heavy glass installation robot has previously been developed and used in advanced countries. Figure 2 shows an example of an installation robot.
This paper suggests a concept design of a robot system that is expected to decrease labour and operator accidents.

2. ANALYSIS OF TARGET WORK

2.1 Target position of installation ceiling glass

Figure 3 shows a model of a building and its installation position. The sizes of the ceiling glass are 1500mm x 1350mm (16EA), 1500mm x 750mm (50EA), 1350mm x 1350mm (3EA), and 1350mm x 750mm (2EA). The weight of the ceiling glass ranges from 40kg to 80kg. The height of the installation is about 7.9m from the ground. The installation uses a 'Lay-in' method to put the ceiling


Figure 3. Installation position



(a) Module T&H bar (b) Lay-in

Figure 4. Installation method

glass on the frame, which is also called the 'Module T&H-bar' method of construction, as seen in figure 4. In order to apply the 'Lay-in' method to the robot system, the HRC (Human-Robot Cooperative) controller is applied, as described by Lee et al. (2007). The controller helps the glass move toward a desired operator safety direction. Only a scaled-down force is required for the operator using the controller.

2.2 Essential function of robot system

The essential function of the ceiling glass installation robot is drawn through spot analysis and existing methods, as shown in table 1. First, exclusive equipment that can transition through many operators is required to install large-sized ceiling glass safely. Also, the modus that is necessary for the worker's technology can be reflected as is during installation, in order to achieve consistent construction quality. The most suitable installation plan design for increased productivity and a countermeasure to prevent accidents with simulations and spot tests is required.

Table 1 Essential function

Requirements	Details
High–rise work	Working height : Approx. 7.9m
Support for high-rise work	Operator (Approx. 70kg) + Ceiling glass (Approx. 80kg×3EA) + Installation equipment (dependant)
Working range	32m × 22m
6-DOF manipulation	Lay-in operation after grip ceiling glass
Handling heavy materials	Affordable weight : approx. 100kg
Grip for ceiling glass	Optimization for handling ceiling glass
Intuitive control	Directly teaching by operator
Force augmentation	Handling heavy materials by relatively scaled down force
Force reflection	Feeling environmental force

3. CONCEPTUAL DESIGN

There is a need for a conceptual design to satisfy the essential functions provided in table 1 to develop the glass installation robot.

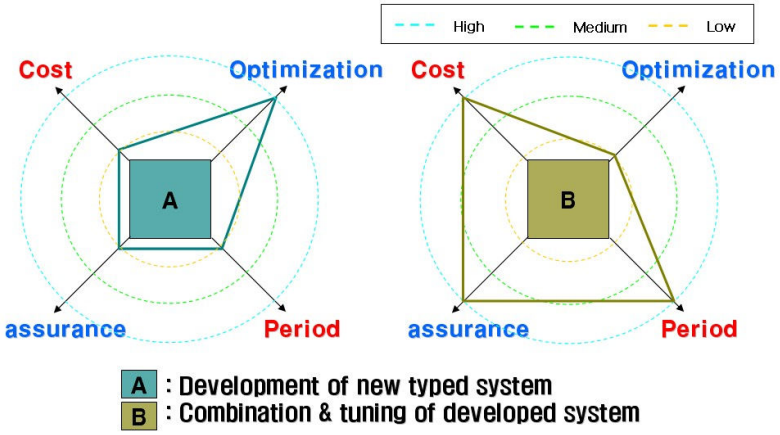


Figure 5. Merits and demerits of the approach to develop a robot

3.1 Approach to develop a robot

There is method to develop the new robot that can achieve the required work. There is method to propose a new system by collating the existing systems in comparison. A comparison of the merits and demerits of these two methods is provided in figure 5.
First, developing a new type of system is limiting in terms of expense and time. However, the advantage is that the system can be optimized to work as required. In the essence of time, the method of proposing a new system by utilizing existing systems is difficult to optimize for a target work load, but efficiency with limited cost and time allotment can be achieved. In addition, the authoritativeness of the product performance is of superior advantage. Therefore, the method of proposing a new system by utilizing existing systems was used to design the ceiling glass installation robot.

3.2 Proposal of ceiling glass installation robot

According to the essential functions determined by work analysis, the concept design of a finished installation robot is as follows.
1) An aerial lift is needed that can support an operator and the installation equipment with enough working range to reach about 7.9m height from the ground.
2) A multi-DOF manipulator is needed to install the heavy ceiling glass alternating through many operators. The robot has to be chosen according to the working space and payload.
3) This system is in semi-automation, in order to cope in a changing work environment. One operator

Table 2 Approach for requirements

Requirements	Section	Solution
High-rise work	H/W	Aerial lift
Support for high-rise work	H/W	Aerial lift
Movement covering working range	H/W	Wheel-typed aerial lift
Deck	H/W	Aerial lift reconstruction
Multi-DOF manipulation	H/W	Multi-DOF manipulator
Gripper for ceiling glass	H/W	Suction device
Force augmentation	H/W	Multi-DOF manipulator
	H/W	HRI device
	S/W	Human-Robot Cooperative control algorithm

Intuitive operation	S/W	Human-Robot Cooperative control algorithm
Force reflection		Human-Robot Cooperative control algorithm

gets into the deck of the aerial lift to operate a multi-DOF manipulator. The worker's judgment becomes the upper robot controller.

4) In order to reflect the worker's ability, external force information is used as the input signal for the robot exercise. The force information that uses the input signal needs to regulate freely according to the desired robot exercise and operator's age.
5) A vacuum suction device is used as an end-effect device to handle the glass. In preparation for variation of glass form, an end-effector is designed by modulation.
6) The deck of the aerial lift supports both the worker and robot. The design of the deck and work process must consider the worker's safety and productivity.

The essential functions found by work analysis are classified by hardware and software. Table 2 shows each requirement and approach method.
Figure 6 shows a conceptual design of the heavy ceiling glass installation robot. Both the hardware and software required to embody the essential functions are approached.

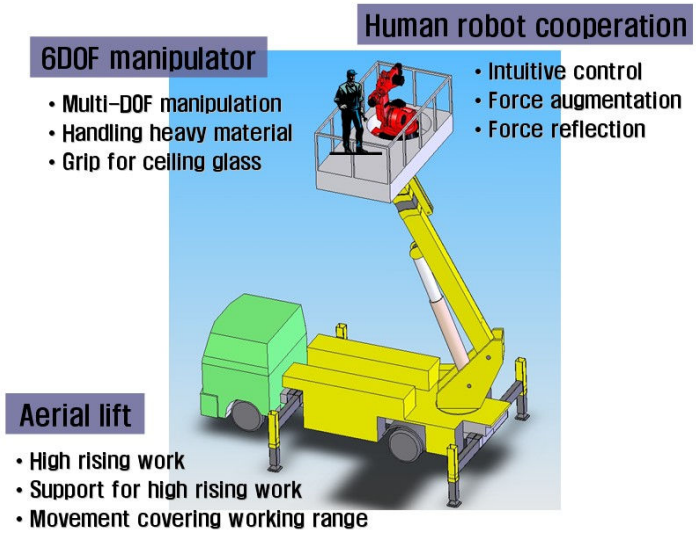


Figure 6. Concept design of glass ceiling glass installation robot

As shown in figure 6, the glass installation robot consists of a wheel-type aerial lift, multi-DOF manipulator, and human-robot cooperative control.

4. CONCLUSION

This paper presents a conceptual design of a heavy ceiling glass robot, in order to decrease an operator's labour and accident likelihood. In order to design this ceiling glass installation robot, existing methods were analyzed. In addition, an industrial robot and aerial lift were chosen for low cost and time constraints. Considering these conditions, the essential function elements (H/W, S/W) were determined. The conceptual design of the ceiling glass robot involved these elements. This robot will be developed and utilized at construction sites. Evaluation will be conducted.

5. CONCLUSION ACKNOWLEDGEMENT

This paper presents a conceptual design of a heavy ceiling glass robot, in order to decrease anThis study was supported by a grant from the SAMSUNG CONSTRUCTION and the international Mobile Telecommunications 2000 R&D Projects, Ministry of Information & Communication, Republic of Korea.

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