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On the Development of Robot based Automation System for Loading Cargo in Small and Medium Sub Terminals

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Abstract

The logistics market is continuously growing due to the development of technology and the growth of the online market. In addition, the social atmosphere that emphasizes non-face-to-face due to the pandemic situation is accelerating the growth of logistics. Delivery of goods ordered online requires delivery process through courier worker. In order for the courier worker to ship the product, the work of loading the product on the truck must be preceded. The accident caused by such delivery and loading work is increasing and it is emerging as a social problem. This study proposes a robot-based automated loading system to efficiently handle the increasing volume of courier service and to construct a more efficient and safe working environment by replacing the physical labor that was overloaded to courier workers. The proposed system replaces the loading of the courier worker and proposes the optimal loading function through the automation system.

1. Introduction

Recently, the Non-Connect culture has been settled due to the pandemic situation [1]. Non-Connect culture is a non-face-to-face form that minimizes contact with people [2], and the shipping service market is growing explosively [3]. In addition, the online market is growing beyond offline with the spread of mobile devices such as smartphones and technology related to the Fourth Industrial Revolution [4] [5] [6].

The courier market for delivering online ordered goods to customers is also growing together, and its size is rapidly increasing [7]. In order to deliver the ordered goods, delivery workers who transport the courier service must visit the delivery place in order [8]. Also, for delivery, the delivery worker should be preceded by loading the cargo in the truck [9]. The work of loading the cargo to be delivered to the courier truck is a physical burden because it requires the repetitive transfer of a large number of heavy cargoes. The death of the courier worker due to this work is emerging as a social problem [10].

This paper proposes a study on how to effectively load the cargo of courier service, which is increasing due to the change of non-Connect society due to pandemic and the growth of online market and logistics industry, to truck by minimizing the labor of workers. The purpose of this study is to improve safety and work efficiency with the aim of improving the courier environment where manpower-oriented work is being carried out in an advanced technology-oriented society.

The composition of this paper is as follows. In the introduction, the trend and necessity of social and research were presented. In the second chapter, the problems were defined through related research analysis. In chapter 3, the process of applying the identified elements to the design was performed and reflected in the results of the study. In chapter 4, the results of this study were summarized.

2. Definition of the problem

2.1 Limitations and problems of cargo loading work

The cargo delivered to the customer is classified by destination through the automation equipment and is loaded into the truck by the courier worker [11]. The courier worker performs the task of loading the classified cargo in the truck [12]. Before starting delivery, the worker moves the cargo to the truck and then arranges the cargo in order of delivery from inside the truck. All of the loading processes for delivery are carried out through the labor force of the courier worker. The number of cargoes that courier workers must ship per day is increasing every year [13], and the process of putting excessive burden on the body before delivery is preceded. Also, courier workers are inevitably working until nighttime for the day delivery, and the physical burden of walking for long driving and delivery is also increasing [14]. As a result, the number of cases of sudden death of courier workers is increasing [15]. Nine workers have died during delivery in the first half of 2020, such as Figure 1.
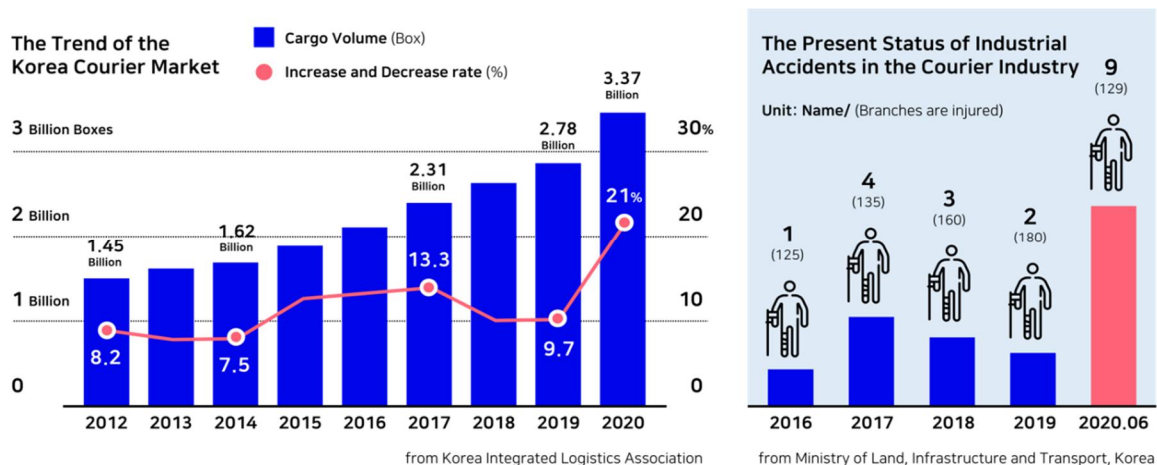

Figure 1. Growth of the Courier Market and Statistics of Industrial Accidents

All the related studies for delivery workers are focused on improving work efficiency and delivery service and improving competitiveness, and these studies cannot be fundamental solutions for delivery industry [16] [17] [18]. In addition, studies related to automation equipment for effectively handling increased courier cargo have been preceded, but no solution has been proposed to reduce the burden on workers in loading work [19] [20].

2.2 Development of an automated system for loading work

Various studies on automation equipment for effectively processing courier cargo have been preceded [21] [22]. In the case of large Hub terminals, the task is carried out using telescopic conveyor, an automation device for loading cargo. This can reduce the physical burden of the worker, but it still has the limitation that the worker should organize the cargo and can be applied only to large trucks [23].

The related patent technology was designed to be 'Autonomous truck loader and unloader', and the technology that can be connected with the conveyor and load the cargo using the robot arm inside the truck was proposed [24]. However, the recognition of cargo information and the delivery of environmental information were not considered, and it has a limitation that it is difficult to operate in a narrow space. The patent 'Robotics system with automated package registration mechanism and methods of operating the same' is connected to conveyor. The loading work of the cargo reflecting location by using all kinds of the sensors in the truck interior possible [25]. However, it is difficult to adjust the direction of the truck's loading box, and it has a limitation that it is less useful in the work environment. The patent 'Automated truck unloader for unloading/unpacking product from trailers and containers' is a technology that is connected to conveyors and can be adjusted by using various sensors inside a truck loading box [26]. However, the proposed technology does not provide a configuration for delivering environmental information, so it has limitations in its utilization.

The automated device studies involved are focused on loading cargo into trucks. In order to reduce the labor consumption of workers, the recognition technology for cargo recognition technology and loading environment should be considered together in automation devices. It is difficult to utilize the proposed system without considering the environment in which the device will be operated.
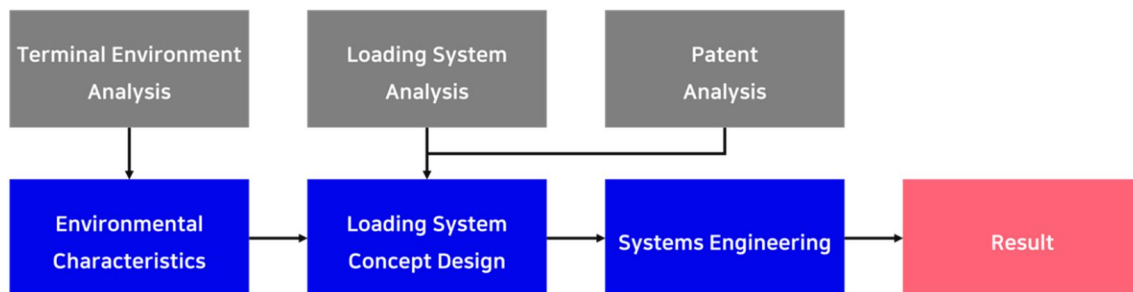

Figure 2. Objectives and Scope

2.3 Objectives and scope

This study proposes robot-based automation system technology like Figure 2. The proposed system aims to effectively handle courier cargo, which has increased due to the expansion of the pandemic era, the untapped culture, and the growth of the online market. The study proposes a loading automation system for sub-terminals and small trucks that can operate independently with last-mile-based retail-tech 4.0 technology and designs a concept that reflects environmental characteristics. The proposed loading automation system consists of an automation device system that does not utilize the labor force of courier workers. To this end, we derive the device design applying system engineering analysis and development process. The recognition about the

loading space and cargo possible with the automation through robot and artificial intelligence image recognition base system and the systematic task possible.

3. Development of a robot-based automation system for cargo loading

3.1. Design of cargo recognition concept reflecting sub-terminal characteristics

In order to load the courier cargo, it is necessary to recognize the cargo put into the device and to recognize the loading environment. For this purpose, cargo shape recognition algorithm and loading space arrangement algorithm are used, and each system is divided into a loading task management system and a loading decision making system. The loading task management system is proceeding the role of processing after the cargo information confirmation and fault cargo recognition. The loading decision making system performs the role of recognizing the cargo information base phase difference order, the position determination and loading cargo information. A depth camera sensor is used for spatial recognition, which enables a loading algorithm considering the size of the cargo to be operated. The algorithm derives simulation results based on the weight, volume, state, and distance of movement of cargo, and calculates optimal loading zone based on the dispatch vehicle and local information. Also, we derive the way point for cargo loading through the calculated result.

The recognition algorithm proposed through this study is applied to the sensor system to cope with various unexpected situations that may occur during the operation process. The cargo loading algorithm step of the robot-based automation system is the same as that of Table 1.

Table 1. Algorithm step of robot-based loading system

No	Step
1	Measurement of the Weight, Volume, State and Moving Distance of Cargo
2	Recognition information-based simulation result derivation
3	Calculation of Cargo Loading Zones based on Distributed Vehicles and Local Information
4	Optimal cargo loading way point derivation

3.2. Designs that reflect environmental characteristics and automation systems

Robot-based automation system for delivery cargo loading should be applied with design reflecting environmental characteristics. In the sub terminal, the process of classifying the cargo transported from the hub-terminal into the automation equipment and loading in the destination delivery truck is performed. In this process, automation equipment design should be applied to reduce labor consumption of courier workers and to improve work efficiency.

The proposed automation equipment is the same as Figure 3. The device comprises an extended conveyor for transferring cargo, an end effector for a loading space, an image recognizer for checking a loading state, a separator for managing a cargo order and a loading state, an image-based recognizer for checking a cargo state and tag information, and a sensor for sensing a cargo jam. For practical operation of the device, artificial intelligence-based loading operation management and loading decision-making software are used. The proposed device is configured to prevent the labor of courier workers from being done. Also, the shape and weight of the loaded cargo are recognized, and the loading order is determined, and finally the cargo is delivered to the end effector so that the cargo can be loaded in the determined order.
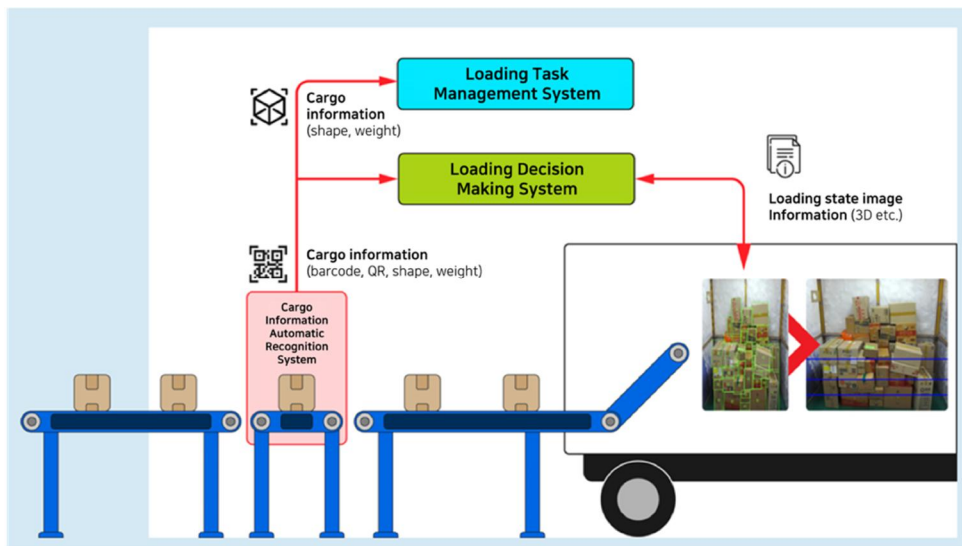
Figure 3. Robot based automation system concept

3.3. Design deduction of robot-based automated loading device

Figure 4 is the entire configuration of robot-based automation systems designed considering sub-terminal environments. The proposed system is designed to be applicable to small truck of 2.5 tons or less by identifying the relevant requirements based on Table 2. The robot-based automation system recognizes cargo and space based on the image recognition algorithm and the cargo loading possible it best suited. In addition, since the loading order is determined by reflecting the characteristics of the cargo, a waiting unit is formed to wait for the subordinated cargo. The cargo in which the loading order is delayed is transferred to the standby unit conveyor through the pivot sorter and it queues. If thereafter, order puts into the device and the loading is completed to the end effector. The proposed system can minimize the damage of cargo through the collision prevention device and high energy efficiency by applying the energy reduction conveyor device.
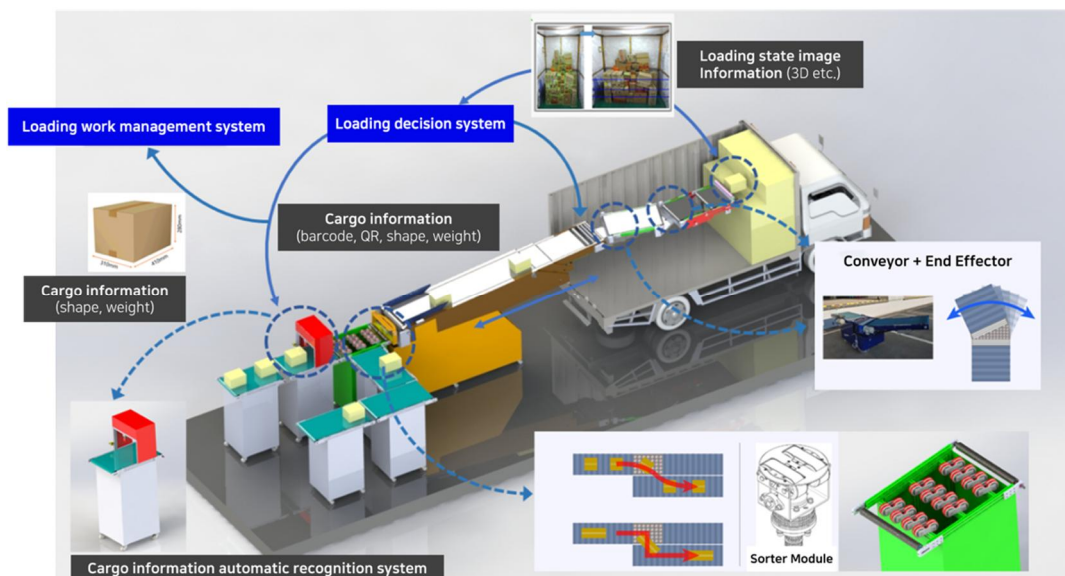

Figure 4. Design of a Logistics System based on Robot for Small Trucks

Table 2. Requirement and Specification based on Analysis Contents

Development Consideration	Requirement	Automated Specification
Environment Characteristics	To operate without a worker. Cargo must be transported and loaded. Cargo waiting platform must be configured.	Belt conveyor. Quarterly conveyor. Pivot sorter. Telescopic conveyor.
Loading System Concept Design	Cargo must be loaded by location. Cargo must be transported by location. Cargo breakage prevention technology is required.	End effector. Gripper for end effector. Impact reduction conveyor.
Cargo Recognition System Design	The recognition of cargo must be possible. Recognition of loading space should be possible.	Cargo recognition sensor. 3D depth camera sensor. Management system.

4. Conclusion

The proposed robot-based automation system is designed to replace the cargo loading work performed by the existing courier workers. The proposed system recognizes cargo through image recognition-based algorithm technology and enables optimal cargo loading by space recognition through depth camera sensor. In addition, the recognized result is configured to be operated through automation devices, so that the truck loading of the cargo injected into the device is smoothly performed. The technology proposed through the research enables the configuration of an environment that can prevent excessive labor consumption of courier workers and concentrate on delivery in the work of the car. The logistics market is continuously growing, and this trend is expected to accelerate according to the social atmosphere. In accordance with these changes, more efficient and sustainable work environment and structure should be achieved.

The purpose of this study is to reduce the physical burden of courier workers who were consumed unnecessarily by using the proposed technology and to contribute to the improvement of transportation efficiency and delivery service of courier logistics.

Acknowledgement

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