A New Look at The Supply Chain: Challenges and Opportunities of Warehouse Robotics

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Abstract — **Robots are changing the structure of the entire supply chain, especially in warehouses and distribution centers. Due to the advancement of AI algorithms and sensor technology, warehouse robots already have mature technical solutions and a market with potential. However, the widespread use of warehouse robots still faces commercial and technical issues. If technicians and related companies can make breakthroughs in these areas, warehouse robots will appear in more places closely related to people's lives in the future. This paper will give a general description of the challenges facing warehouse robots at this stage and explore new areas where warehouse robots can be applied after overcoming these challenges.**

I. INTRODUCTION

In the last decade, online retail giants have begun to look for smarter, more efficient solutions to help them manage their busy distribution centers. Imagine that warehouses of Amazon processes and packs incoming orders at all times, and they urgently need a group of elves to help them with their work while they are asleep. Now, engineers and capitalists have found better helpers than elves. Today, more than 200,000 mobile robots in Amazon's warehouse are working day and night [1]. According to existing reports [2], the global market for warehouse robots has reached $ 2,442 million in 2016 and is expected to reach $ 5,186 million in 2023. Market analysts believe [3] that this rapid industry growth has benefited from the development of AI and sensor technology in recent years, allowing robots to run autonomously in warehouses. These robots work with hundreds of thousands of warehouse employees to cope with the rapid increase in the number of online orders. In China, Alibaba has deployed similar robots. JD.com (similar to Amazon) even built the first humanless warehouse in the world [4].

A. Warehouse Robots

In fact, robots have been used in the supply chain for a long time. George Devol and his company produced the first industrial robot for material handling in 1956 [5]. For a long time after that, robots were mainly used to replace those high-risk and heavy tasks. Until the retail industry has a new need for efficient solutions. Today, there are many different types of robots that play an important role in the warehouse [6]. People may already be familiar with goods-to-person robots, flat robots that shuttle quickly across the warehouse floor. This is the largest proportion of warehouse robots. In an Amazon show video, these Automated guided vehicles (AGVs) travel freely at high speed in a warehouse. But there seems to be some regular behavior between them. Dozens of robots move the shelves efficiently without collision.

Figure. 1 A group of shelf robots from GreyOrange are working in the warehouse [7]

This technology has made tremendous progress in the past decade [6], mainly from breakthroughs in AI algorithms and sensing technology. Improvements in the algorithm allow the software to direct a large number of robots to work together. The path sensor of AGVs has also been changed from earlier surface marks to laser guidance [8]. The same technology is also applied to self-driving forklifts and automated storage systems, which are other types of robots in automated warehouses [9].

B. How They Changed Warehouse

There are two main purposes for using robots in warehouses: to improve efficiency and to reduce labor costs.

You may have heard that Amazon fulfillment center employees complete a marathon in warehouses every day. Although this statement is a bit exaggerated, they need to walk 12-20 miles per day. Now, their daily walking distance has been greatly reduced. Warehouse robots can deliver shelves directly to the sorters without the need for them to find them in person. In Alibaba's warehouse, robots have already replaced people with 70% of their work [1]. This sorting method improves efficiency while reducing labor costs.

In addition to the work of porters, robots are now also assisting people in packing and counting inventory [10].

II. CHALLENGES

One thing people can easily focus on: why is it 70%? Since JD.com built the world's first unmanned warehouse in Shanghai, no second has yet appeared. Although JD.com claims that the entire warehouse only needs five robot maintenance personnel, it can be found in actual inspections that there are still many work steps that have to rely on manual labor. This reveals some of the technical obstacles that warehouse robots currently face. These obstacles are thought to prevent unmanned warehouses from being widely used in the next decade [11]. Although the related technologies of mob Picking can hardly be considered a difficult task. After all, anyone can complete any picking job after simple training. robots have matured, the realization of unmanned warehouses requires other breakthroughs.

A. Picking

Picking can hardly be considered a difficult task. After all, anyone can complete any picking job after simple training. But this is because of the excellent performance of the human brain, eyes, and hands. For robots, identifying apples from a pile of fruits only with optical devices and grabbing them with a robotic hand is still a challenge. When the range of recognition objects is expanded to over one million, it becomes a big one. On the other hand, the implementation of the picking action will also be difficult due to the different objects. Designing a robot that can accurately pick up hundreds of items with different shapes and weights is not an easy task. From the market point of view, there are many companies using mobile robots to provide automated warehouse solutions. Some large

companies have even wholly acquired related companies to provide technical support for them. But most companies that develop picking robots are still in the financing stage.
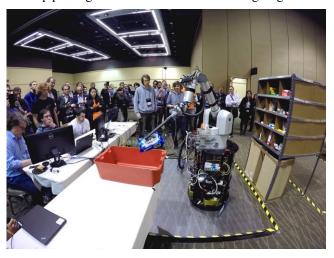

Figure. 2 Team from TU Berlin won the first Amazon Picking Challenge in 2015 [12]

In order to fill the gaps in related technologies, and more importantly, to replace the remaining 30% of the labor force in the warehouse, Amazon has been hosting a technology competition called "Amazon Picking Challenge" since 2015 [13]. The competition is fierce. Despite gathering the smartest engineers in the world together, only half of the team able to successfully identify the target product and move it into the cargo box during the first challenge. Of course, in recent years, the robots of the participating teams have greatly improved their recognition accuracy and picking speed. There are also teams or members who have achieved good results started to operate as a company. If mature picking robots can begin to be widely used, then the manual works still in the warehouse, such as picking and packaging, will be replaced by robots. So as to achieve a real unmanned warehouse.

B. More general deployment conditions

This is another challenge that warehouse robots need to overcome to expand their applications area. Although autonomous mobile robots and AGVs have improved a lot in terms of speed and accuracy, they still need specific working environments in order to ensure operating efficiency. This includes a complete set of management software, maintenance program and a specially designed warehouse layout. These supporting facilities increase the cost of the entire warehouse system, so that the economic

benefits of the warehouse robot can only serve companies with a large number of goods in circulation. These supporting facilities increase the cost of the entire warehouse system, so that the economic benefits of the warehouse robot can only serve companies with a large number of goods in circulation. High construction costs and strict deployment conditions are one of the reasons why warehouse robots have not been adopted by small and medium enterprises and other industries.

Figure. 3 A mobile piece picking robot working in a storehouse [14]

Mobile piece picking robots are considered the next step for warehouse robots [14]. By integrating the functions of movement and picking, this robot can be deployed in a traditional warehouse without changing the layout. Although this conceive faces greater technical challenges than current warehouse robots [15]. But to be sure, this robot is more likely to be used by small and medium-sized enterprises than large automated warehouse systems. In addition, this robot helper has a wider range of applications. They can help supermarket employees replenish shelves and can even be used in the service industry.

III. OPPORTUNITIES

Once the warehouse robot technology can overcome the above challenges, their application scope will be extended to the entire modern logistics system and even the tertiary industry.

A. Service Industry

From the point view of the process, the task of warehouse and service industry have some similarities. Picking, moving and delivering. Robots have long been thought to replace most people's jobs in the future. Relevant technologies have now matured. Interactive interfaces equipped with AI are also being used on various devices. These technologies make robot waiters, robot bartenders, and robot shopping guides possible. Although these ideas still face security and cost issues, they are no longer as impractical as science fiction.

B. Medical Care

After the rapid spread of COVID-19 worldwide, people have witnessed some dilemmas faced by modern medical systems. Lack of medical staff and secondary infections in the care process are among the top issues. Most countries have to mobilize retirees and medical students to fill vacancies in the medical system. Medical care robots are considered one of the feasible solutions [16]. Although they are not yet capable of performing complex tasks like surgery, they have outstanding advantages in caring for patients with infectious diseases. They can help nurses do most of care works and reduce the threat of infectious diseases to medical staff. In addition, they are also capable of doing daily drug distribution just like the same work in warehouses.

C. Last-Mile Delivery

Retail giants have been hoping to deploy their investment in robotics into their entire logistics system to reduce all unnecessary human resources [1]. The last-mile delivery problem is the current technical difficulty. This involves shipping issues from the distribution center to the shipping address. Although Amazon has long ago proposed the idea of using drone delivery. But anyone can find that this idea is currently too expensive, inefficient, and faces many issues such as theft and security. Some research teams have currently proposed some intelligent centralized delivery designs, such as setting up centralized extraction cabinets in major communities and apartments and centrally delivering packages by drones. To be sure, this will be the next promising market for robots in logistics.

IV. CONCLUSION

Warehouse robots are the fastest growing robot industry in recent years. It is also one of the few robots that is beginning to show economic benefits. Their related technologies are also beginning to be used in other industries than logistics. It is believed that when the current technical

challenges are solved, we will be able to see more robots appear in people's daily lives.

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