Review on Robot for Remanufacturing

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Abstract: Remanufacturing plays an important part in solving wastes. Parts Disassembly is the first process of remanufacturing. However, this step is mainly carried by human labors. With the development of artificial intelligence and robot technology, scientists are trying to use robots to disassemble parts. However, there still exist some problems that should be solved, so that robots can work better. In this assignment, the remanufacturing robots are reviewed, including the process, development status, as well as challenges. Then, several thoughts combining with my dissertation project (hebbian learning) and previous research experience (mobile wireless sensor networks) are presented in this assignment. Finally, I summary what I have learnt in this assignment and think about future plan with robots.

Keywords: Remanufacturing; Robots; Hebbian Learning; Wireless sensor networks

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1. Introduction

Nowadays, remanufacturing technology is a key technology which is related to the country's sustainable development. Remanufacture is the process of rejuvenating old machines. It uses old machinery and equipment as the basis, adopts special technology, and carries out a new manufacturing based on the original materials [1]. Meanwhile, the re-manufactured products are no less than the original new products in terms of performance and quality. Product disassembly plays an important role in sustainable manufacturing. It is the first step in the remanufacturing process and also determines the efficiency and capacity of remanufacturing [2]. As intelligent manufacturing equipment, industrial robots, meet the characteristics of sustainable production with low energy consumption and high efficiency, and have begun to be applied to semi-automatic product disassembly. However, the current industrial robot disassembly process does not fully realize automatic production [3].

With the development of technology, robots play an important part in people's daily life. The application of AI robots overcome the problems of labors in time and space. For instance, it is easily to implement 24-hours working time per day by using robots in factory, and it can reduce the quality problems caused by manual production, which greatly improves the work productivity of the enterprise. Figure 1 shows several common application examples of industrial robots. Figure 1(a) shows a sorting robot in the process of sorting garbage; In order for robots to learn how to accomplish these tasks, they use a variety of machine learning techniques, including simulation, reinforcement learning, and collaborative learning. Every night, thousands of virtual robots practice garbage sorting in the virtual office in the cloud simulator. Then, they transferred the training to real robots to improve their classification capabilities. Then reintegrate this real-world training into the simulated training data and share it with other robots. (b) shows a handling robot for brick transportation; (c) shows an assembly robot for processing and assembling products on the production line; (d) shows the welding robots used for electrical welding of mechanical parts. The welding robot recognizes the solder joints by processing the images, so as to realize the work in the harsh environment.

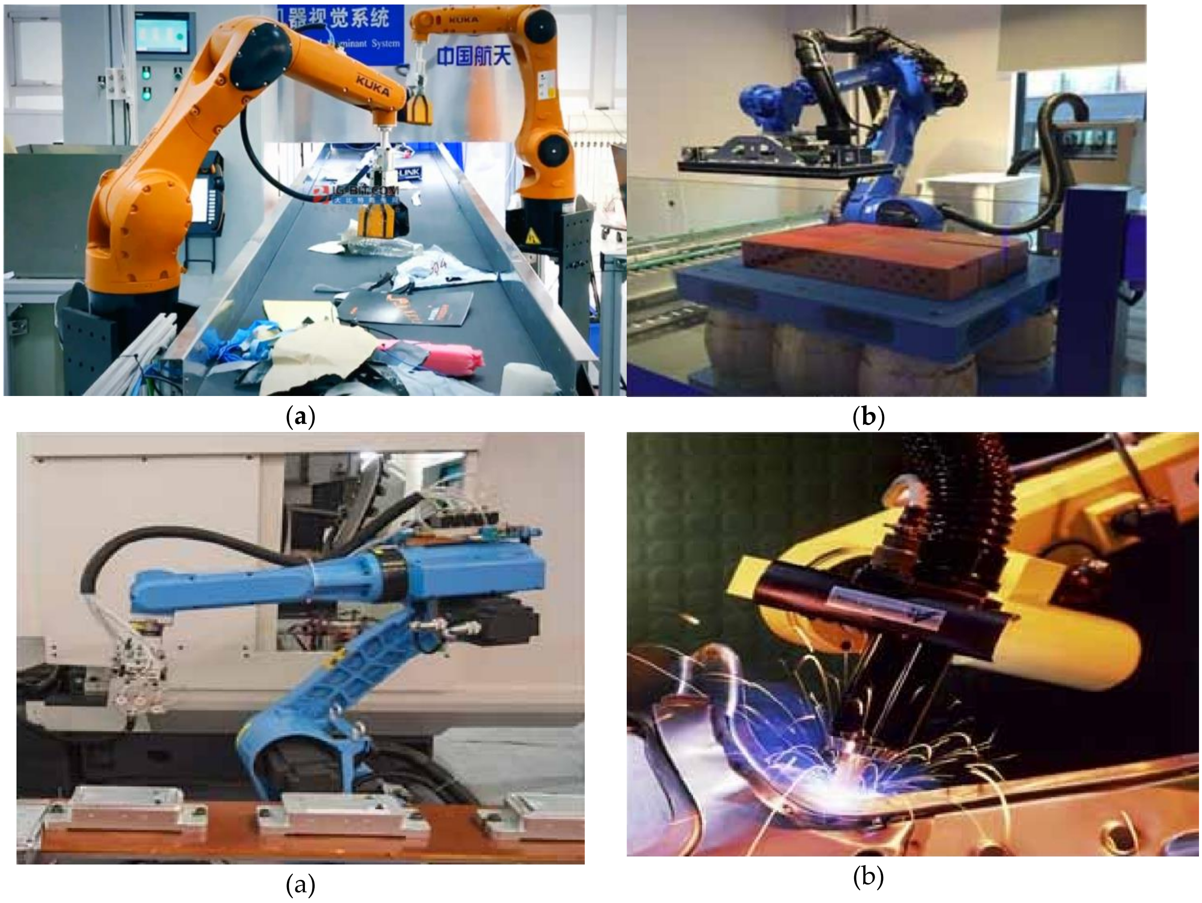

Figure 1. Application examples of machine vision in industrial robots

2. Definition of Remanufacturing

Remanufacturing refers to implement high-tech repair and transformation of waste products [4]. It is totally different with refurbish, because the performance of products from remanufacturing should be higher than previous model. Now, remanufacturing is regarded as the best method to solve waste products, since current product updating speed is accelerating. Judging from the latest global e-waste monitoring report [5] released by the International Telecommunication Union and United Nations University in 2020, the total amount of waste electrical and electronic products has risen sharply from 2013 to 2020. As of 2020, a total of 53.6 million tons of electronic waste products were produced globally, an increase of up to 32.3% compared to 2013, and it continues to grow at a relatively rapid rate.

3. Review on Robots in Remanufacturing

Specifically, different researchers have ever been made about robotic disassembly and remanufacturing. Manufacturing is the main pillar of the national economy, the main guarantee of national security, and an important manifestation of national competitiveness [6]. But manufacturing is also the largest resource consumer and environmental polluter. The amount of waste resources is staggering, and the utilization rate of traditional resource-based methods is low and pollution is high. The traditional way of dealing with waste resources is through recasting, which has low utilization rate, high energy consumption and serious secondary pollution. Therefore, in order to solve the environmental pollution problem of waste products, remanufacturing is an inevitable choice for green development [7].

Figure 2. Remanufacturing Process

Remanufacturing process is shown in Figure 2. One important part of remanufacturing is disassembly. Through disassembly, it is possible to successfully separate invalid parts, hazardous parts and recyclable parts, fully realize the classification and recycling of resources, explore the potential value of effective resources in waste products, and reduce waste incineration and landfill [3]. However, most tasks of disassembly are still performed by manual. In the operation process, people need to face complex and cumbersome disassembly objects. Excessive handling and removal work will put pressure on the human body and increase the body's burden. Simple and monotonous and repetitive disassembly operations can easily cause fatigue and drowsiness, and bury potential safety hazards. Disassembly objects with sharp edges or harmful substances, if the staff are not equipped with corresponding safety protection measures, are likely to cause injuries to the body. In this situation, robot is a perfect choice to solve this conflict, because we don't need to consider the safety of the robot, and the robot will not feel tired. The ideal working scenario is shown in Figure 3.

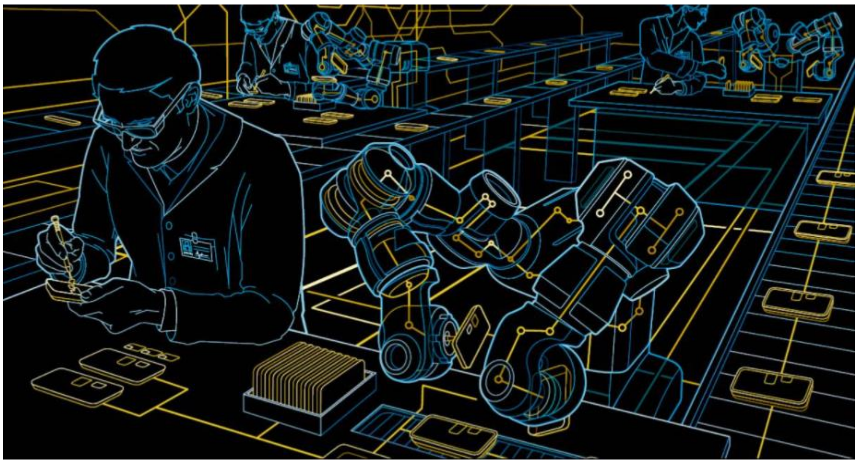

Figure 3. Ideal Working Scenario

Remanufacturing is a new concept that has emerged in recent years and it is forming a new emerging industry. The importance of this industry is self-evident. However, compared with other industries, the human resources crisis faced by this industry is more serious than other industries. There are two reasons for this. On the one hand, influenced by people's traditional ideas, the waste is attributed to the "waste recycling" industry, and it is dealing with "garbage", so young people are not willing to enter this business [8]. On the other hand, old products are often stupid and major mechanical products, and some of them are environmentally hazardous products, such as metallurgical industry, nuclear industry, heavy chemical industry and other equipment products [9]. It brings both high labor intensity and occupational disease threats. Under this situation, robots play an indispensable role in this industry and it can be justified without any exaggeration that remanufacturing requires robots more than other industries.

Remanufacturing has three important meanings. Firstly, remanufacturing can maximize the development and utilization of the value contained in waste mechanical and electrical products, and it is the preferred way of resource conservation and environmental protection. Research data shows that compared to manufacturing, remanufacturing can use only 10% of energy and 10% of raw materials, but it can reduce CO2 emissions by 80%. Secondly, remanufacturing has a wide range of applications and it can be applied to various fields, such as automobiles, aerospace, marine, medical equipment, industrial machinery, and IT. Thirdly, remanufacturing is an effective means of solving overcapacity in manufacturing.

To further improve disassembly efficiency, reduce production energy consumption, reduce production costs, optimize production tempo, and increase production flexibility, it is really necessary to uniformly describe and dynamically model the equipment capabilities of the disassembly process of industrial robots [10]. In addition, due to the lack of tools during the disassembly process, insufficient parts, unclear information, sequence turbulence or environmental changes occur from time to time. There is another big area about the application of robots in remanufacturing. Because remanufacturing is not only “repair the old products” but also need to “make full use of waste” which is the recycling of waste. However, the first step in recycling is disassembly and sorting. It is of great importance to separate the recyclable and non-recyclable, the metal material from the non-metal material, and the different metal materials. Without these separations, there is no recycling, let alone recycling. Obviously, human resources in this area are becoming more difficult. Despite the fact that the space for using robots is broad, but it also faces a huge challenge. Therefore, it is imperative to develop and implement automated processing equipment and build an automated system for waste recycling. The realization of full automation of system is completely possible if the garbage can be sorted from the source and the robot is introduced during the sorting phase.

So far, Scholars have made a lot of efforts on this idea and made many breakthroughs. Jiayi Liu, et al. designed a service platform for disassembly planning, the service platform for robots disassembly planning is presented in figure 4 [11]. Tao et al. proposed an algorithm for complex products disassembly sequence planning [12]. Jing Zhu et al. designed a set of visual recognition and positioning system for robot disassembly [13]. From my point of view, the core technology for this remanufacturing robots is computer vision and robot control. When the robot is working, the first job is to identify components installed on the products, which should be disassembled. As one of the important means of robot intelligent perception, machine vision technology has a history of decades of research. However, due to the complexity of the actual application scenarios of robots, industrial robots still have some difficulties and challenges in the classification and detection of objects. Then, after identifying objects, to achieve disassembly, the robot not only needs extremely high position accuracy but also extremely high force control. Even if it is just to remove a screw, there are still many problems that need to be solved.

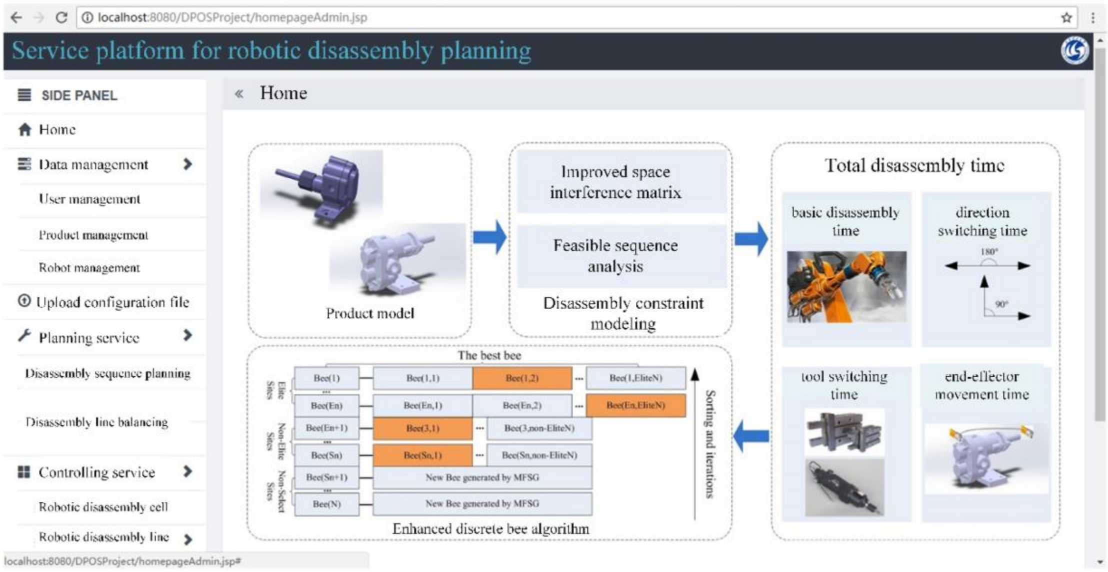

Figure 4. Robots disassembly planning platform interface

As shown in Figure 5, there are two main challenges that robots are facing. The first challenge is physical aspect. The robot obtains product images through the camera. In the process of image acquisition, the robot cannot correctly recognize parts due to changes in light intensity, changes in shooting angles, different shooting distances, material reflective deformation, or obstruction by other objects.

The second challenge is from category aspect. Firstly, there is a big difference within the class, that is, objects belonging to the same class have different manifestations. For example, the words "car" can cover cars, trucks, trains, tricycles, etc., with different appearances. Second, the difference between classes is small, that is, there are similarities between two or more different types of object instances, such as screws and studs. Finally, there is the interference of the environmental background. The detected target is very likely to appear in a more complicated and unclean background, which is easy to interfere with the classification and detection of the items we actually care about, which makes the identification difficult greatly.

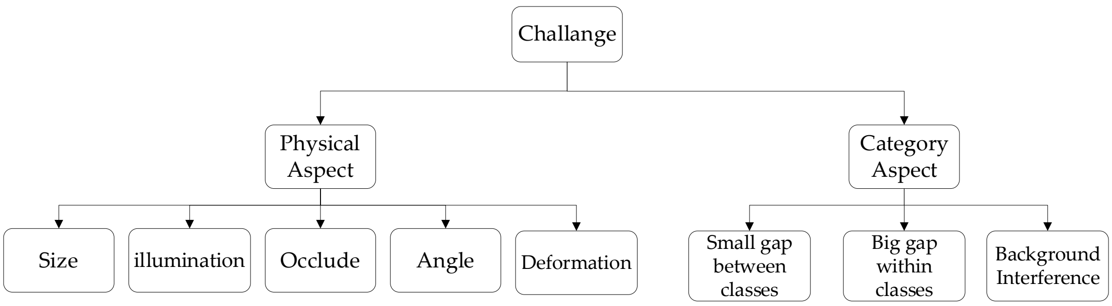

Figure 5. Difficulties and challenges in object detection.

4. Robots Target Detection Method

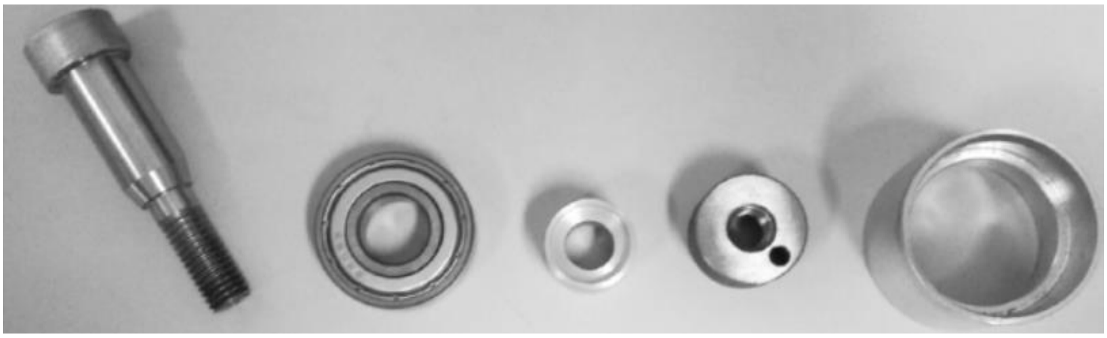

Figure 6. Input Features

Combing with my dissertation project, deep learning, this technology can be applied in remanufacturing robots. The first task to disassemble a part is to recognize. Deep learning can help robots to identify parts on recycled items. One method to realize this function is Convolutional Neural Network (CNN). The biggest advantage of CNN is that it can establish connections in different directions of pictures. For example, when the input picture is shown in Figure 6. From left to right are the central shaft, bearing, washer, nut, and sleeve. When robot is trying to identify these two items, robots can calculate the brightness value of one color in each pixel block. When the computer expands the value of each pixel of the image to obtain a column or row, the relationship between adjacent blocks in one direction (Horizontal or vertical) will be lost. But, CNN can solve this problem. The input data will take blocks of the same size as the convolution kernel from the upper left corner, and then the values in the blocks will be correspondingly multiplied and added to get the convolution result. In this way, the relationship between multiple dimensions of the picture can be trained. Now, CNN can gain more than 85% accuracy on CIFAR-10, which is a training dataset including airplane, automobile, bird, cat, etc. Similarly, this method can be used to train parts which should be identify on the raw material, so robots can identify their objective parts that should be disassembled.

At present, Hebbian learning is proposed in recent years. It simulates the transmission process of excitement between neurons. Comparing with other method, the training method of Hebbian learning is more plausible in biology. The first layer of Hebbian learning is completely unsupervised. The working process is presented in Figure 7. In Δw_1 refers to the updating weight of the first layer, and it is calculated by the input value and the hidden layer value, which represents the pre-synaptic and post-synaptic activations. Experiments have shown that Hebbian learning can achieve 94% accuracy on MNIST dataset and 46% on CIFAR-10. Now, I am trying to combine CNN with Hebbian learning to improve the accuracy. In my opinion, robots' recognition ability can be greatly boosted with the development of deep learning.

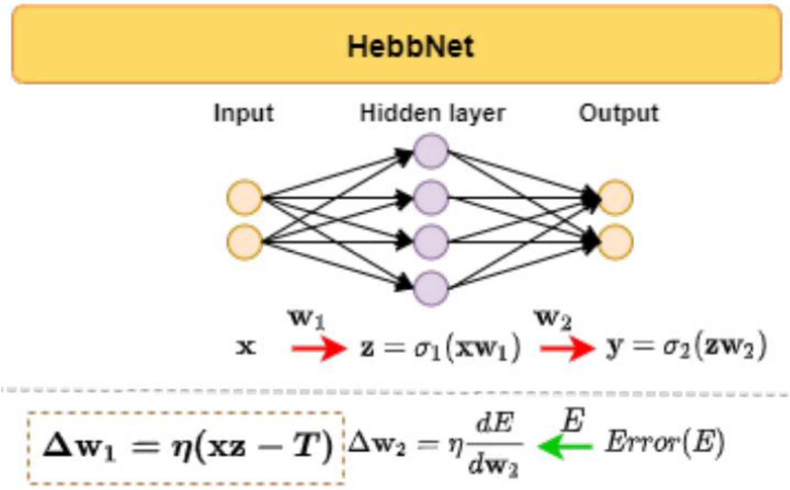

Figure 7. Conceptual working of Hebbian Learning

5. Robots with IoT

In my previous study experience about Internet of Things (IoT), and Wireless Sensor Networks (WSNs). These technologies can be combined with remanufacturing robots. First, implementing robots with could server, so that people can monitor robots working condition remotely. In addition, by revising hardware command, people can remote control their robots. Another advantage of combining cloud server with robots is that server can storage a large amount of data, and these data can be used to build a mathematical model. Then, this model can be used to help designing and repairing.

One of a problem in implementing mobile robots with IoT idea is routing process. With the development of technology, robots are required to move from one place to another place to do their jobs. For example, in industrial factories, the control center requires data interaction with the moving automated guided vehicle (AGV) to confirm the location of the vehicle and order the control instruction accurately. Therefore, the appropriate handling of the mobility of the mobile robots is very important. However, most routing protocols do not consider mobile scenarios, such as The IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL). In my previous study, I designed a distributed competition algorithm for RPL/6LoWPAN (DC-RPL), which can be used to manage mobility. The core idea is setting a timer to find the most preferred parent node to communicate by nodes' competition. The message interaction process of my design is shown in Figure 8. Suppose there are three routers that could be used as an alternative parent node within the communication range of the mobile node. Router 1 is the current parent node. When the threshold value is greater than the mobile node (MN)'s BARSSI, the MN multicasts DIS message with a mobile identifier to find a new preferred parent node. All routers could receive DIS messages. Router 1 would not reply to the MN because its RSSI is less than the threshold. Routers 2 and 3 would calculate their backoff time and activate the backoff timer according to a designed distributed competition algorithm. At the same time, they also listen to DIO messages in the network, which is sent to the MN. After a short time, router 2's backoff timer interrupts, and no DIO message is listened to, so router 2 replies with a DIO message to the MN, and router 2 is regarded as the new preferred parent node. When the timer of router 3 interrupts, router 3 will not send the DIO message to the MN because it listened for whether another router has already replied with a DIO message to the MN. Experiments show that my idea can greatly reduce power consumption, since the original protocol requires node to broadcast request message continuously. This method has been submitted to a journal, *Future Generation Computer System (FGCS)* last year, but it is still under review.

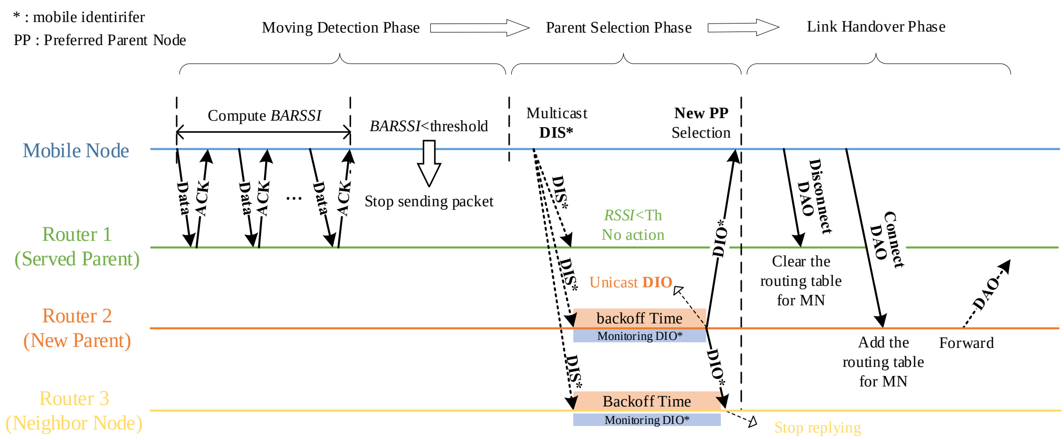

Figure 8. Message interaction process in DC-RPL.

6. What I have learned?

In this assignment, I review on the robots' application in (re)manufacturing. Firstly, the remanufacturing process and significancy have been studied. My undergraduate major is Mechanical Engineering, I have leant mechanical manufacturing and additive manufacturing. But I haven't heard about remanufacturing before, this concept that I study in this assignment greatly broaden my horizons. Secondly, by reading literatures, I understand the significance of remanufacturing and how robots can be applied in remanufacturing. In addition, I know about the robots' development trend and what things that robots can do and what cannot at present technology. Then, combining with my dissertation project, Hebbian learning, and previous research experience, WSN, I think about some idea that can be used to improve remanufacturing robots and mobile robots. This idea can help technology go out from lab to factory, which can help technologies to serve people better.

7. Future Plan

In this assignment, my understanding about robots improved a lot. Robot is a multidisciplinary technology, involving multiple disciplines such as mechanical design, computers, sensors, automatic control, human-computer interaction, and bionics. With the development of AI technology, Robots will become smarter and perform more complex tasks. I am very interested in working with robots, and that is why I choose *Computer Control and Automation* as my graduate major. In my opinion, robot technology has a good development prospect. In the future, I think most repetitive works will be replaced by robots, and I hope to contribute to the development of robots.

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