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Chapter 1

Introductory Chapter: Recent Development and Applications of Agricultural Robots

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1. Introduction

The robotics industry was originally developed to supplement or replace humans by doing dull, repetitive, dirty, or dangerous work [1]. Robot systems have broad application prospects in industry, agriculture, defense, and other fields. In the past decades, extensive research has been conducted on the applications of agricultural robots and automation to a variety of field and greenhouse operations, and technical fundamentals and their feasibility have been also widely demonstrated. Due to the unstructured environment, adverse interferences, as well as the complicated and diversified operation process, are the key in blocking its commercialization in robotic agricultural operations.

It is well known that the introduction of robotics in agriculture has not had the same success as it has in the manufacturing industry [2]. This is mainly due to the fact that the agricultural environment is much less structured, and the operating agricultural objects are flexible and vary in shape, size, and materials [3]. Consequently, it is more difficult to adopt robots in the automation of different agricultural processes.

As the development of automation techniques, smart sensors, and information techniques, some types of agricultural robot have achieved considerable success in recent years. Mapping and localization, navigation and guidance, robotic grasping, human-robot interaction, object recognition and location, and multi-robot systems and collaboration operation are the research hotspots in agricultural robots.

2. Hot research topics of agricultural robots

2.1. Object recognition for harvesting robots

In the latest decades, the use of robot systems in agriculture has seen a sharp increment [4]. Object recognition is the precondition for robot grasping. Today, harvesting robot mainly utilizes the methods based on computer vision to achieve recognition and location of objects. Actually, the key step of computer vision is the processing procedures of vision images which were acquired by visual sensors including our object. Not only the object but also many of useless and interferential information were present in the acquired image. These redundant information extremely may slow down the speed and accuracy of recognition. Thus, how to extract useful information while detecting the fruit or vegetable became the most important part.

In the past, researches gradually put forward the concept of feature engineering [5]. The available information in the object recognition is called feature. By extracting and using those features, the distinction between the object and their growing environment can be figured out. However, there are some uncontrollable and complex factories near the fruit and vegetable. The occlusion of leaves and stems, the illumination unevenness on fruit surface and the high variability of fruit color enhanced the difficulty of recognition and location. Therefore, a robust algorithm must be developed and applied to object recognition for harvesting robots.

2.2. Simultaneous localization and mapping for agricultural environments

Simultaneous localization and mapping (SLAM) is a critic problem in robotics automatic navigation and positioning, using multiple sensors to get external information, for the purpose of obtaining a consistent map of the environment and at the same time recognizing itself within this map [6]. From the choice of different sensors, the solutions to SLAM problem can be divided into three main fundamental categories: visual, lidar, and sensor fusion SLAM. Different kinds of SLAM algorithms have been in demand in many scenarios for a long time, such as VR/AR equipment, indoor autonomous mobile robots, and unmanned vehicle [7]. With the development and maturity of SLAM technology, SLAM has been applied to agriculture. It is a combination of traditional fields and new technologies. The most significant requirement for many applications in precision agriculture is the ability to accurately locate a moving vehicle [8]. By solving the problem of SLAM, the vehicle can map the targeted areas, locate itself, and fulfill tasks such as spraying, weeding, and mowing [8, 9]. As a consequence, the application of SLAM technology in agriculture can lighten framers' workload, complete dangerous tasks instead of human labor, and increase productivity [10]. Overall, SLAM technology has a bright prospect in the automation and intelligence of agriculture.

2.3. Agricultural product quality sensing for grading robots

Nowadays, fruits and vegetables have become an indispensable food in our daily life. Fruits and vegetables are not only important for people to adjust their taste but also rich in healthy vitamins, fiber, and trace elements. In recent years, consumer demand for fruits and vegetables tends to be diversified, and more attention has been paid to the external and internal quality of agricultural products [11]. Due to the ever-growing demand for food safety and security, the automated grading of agricultural products is playing an increasingly important role in agricultural field. The automatic robots are able to remove the need for human operators to carry out heavy, monotonous, and dangerous operations and give future generations the possibility to achieve economic sustainability in small high value farming operations. The principle of the automated grading robots is to apply machine vision to detect the external defects of the fruits and vegetables and to use spectral/hyperspectral imaging technology to measure the internal quality [12]. Therefore, it can be said that operations in grading system for fruits and vegetables became highly automated with the machine vision, near infrared, and robotics technologies. The automated grading robots of fruits and vegetables have been investigated over the past few years.

2.4. Robotic grippers and grasping control

Grasping and holding of objects are the fundamental capabilities and key tasks for robots and robotic manipulators. The grippers are the most important components of robots for many manipulation tasks, since they serve as mechanical interface between the robots and their environment. The fragile structure of the fruit or vegetable body makes them susceptible to bruising caused by the aggressiveness of harvest and postharvest processes. Grasping without damaging the fruits is a key barrier to the replacement of manual labor by robotic harvesting.

The agricultural tasks are always carried out in an outdoor unstructured environment [13]; the agricultural operations and sequence of motions are different from one task to the other; the manipulating objects of robots and grippers are flexible and damageable plants or fruits, and they are highly variable in shapes, sizes, and structures. The abovementioned factors put forward higher requirement to the machinery of robotic grippers, smart sensors, and grasping control strategy in agricultural tasks.

Robotic grippers design attempts to simulate the advantage aptitudes with the aim of grasping any kind of objects by copying human abilities such as sense of touch and visual perception [1]. By integrating various sensors, the robotic grippers can not only manipulate the workpiece but also analyze and the grippers can also conduct online decision-making based on the fusion sensory data. **Figure 1** shows the gripper development trend for sensors.

2.5. Other hot research topics

As the requirement of the agricultural robots, the research topics have been extended to very large areas, including precision farming, cloud computing, human-robot interaction, sensing and control, robot design and optimization, multi-robot systems and collaboration operation, weeding robots, fertilizing robots, transplanting robots, spraying robots, grafting robots, phenotyping robots, and unmanned aerial vehicles.

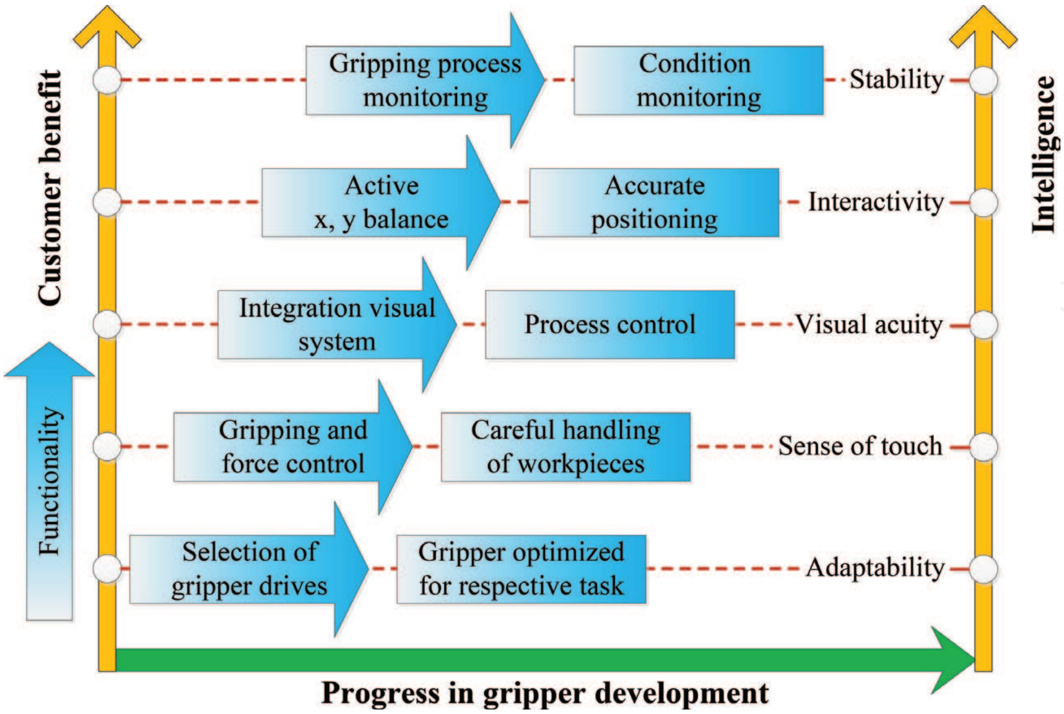

Figure 1. Gripper development trend for sensors.

3. Conclusions

With the motivation of high efficiency, high automatization, and increasing the value of the agricultural products to the consumer, worldwide research and development efforts in agricultural robot technology continue to be developed in the last 40 years. Many excellent research papers have been published focused on harvesting robots, weeding robots, fertilizing robots, transplanting robots, spraying robots, grading robots, grafting robots, phenotyping robots, unmanned aerial vehicles, etc.

This book intends to provide the reader with a comprehensive overview of the current state-of-the-art agricultural robots, fundamentals, and applications in robotic agricultural operations. The challenges and directions of agricultural robots for future research and development will be also reported and formulated in this book.

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