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Structure and Embedded System Design of Lettuce Intelligent Harvester

Zheng Zhou, Tao Wu, Xin Li
School of Mechanical and Automotive Engineering, Shanghai University of Engineering Science, China

Abstract
.Given the immaturity of automated lettuce-harvesting technology, we decided to develop a small-scale agricultural machine tailored for greenhouse lettuce. The harvester will be modeled and subjected to basic motion simulation in SolidWorks. After investigating the lettuce-cultivation conditions inside greenhouses, an appropriate drive chassis will be selected. Cutting blades will be chosen according to their performance in slicing lettuce, and, based on the post-cutting posture of the stalks, a suitable collection device will be designed. Once the prototype is built, field-cutting tests will be conducted to formulate an optimization plan and iteratively refine the machine.

Keywords: *Lettuce; Harvesting; Automation, Structural design*

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I. INTRODUCTION

At present, research and development of lettuce harvesters in China is still scarce, and most of it is carried out in universities. Almost no lettuce harvesters have been put into actual production. Shi Zhiming from Sichuan Agricultural University and others designed a single-row side-mounted lettuce harvester using the DF604-15F tractor as the driving power [1]; Liu Yuhao from Guangdong Vocational College of Science and Technology and others designed a lettuce planting machine that integrates harvesting and sowing [2]; Liu Changlin from East China University of Science and Technology and others designed a lettuce harvester [3]. We have learned from the existing experience of the above designs and focused on cutting and collecting to design a brand-new lettuce harvester.

II. OVERALL STRUCTURE DESIGN OF THE LETTUCE HARVESTER

Based on the manual lettuce-harvesting process, we divide the harvester into five modules: mobile chassis, defoliator, cutting head, conveyor, and collection bin. Because greenhouse lettuce is planted at high density with narrow aisles, the machine ‘s overall dimensions must be strictly limited; tractor-pulled harvesters [4] are clearly unsuitable for such conditions. To realize all required functions within this confined space, the structure must be extremely compact, and every module must cooperate precisely so that the entire lettuce-harvest task can be completed.

The overall structure Is shown In Fig 1.

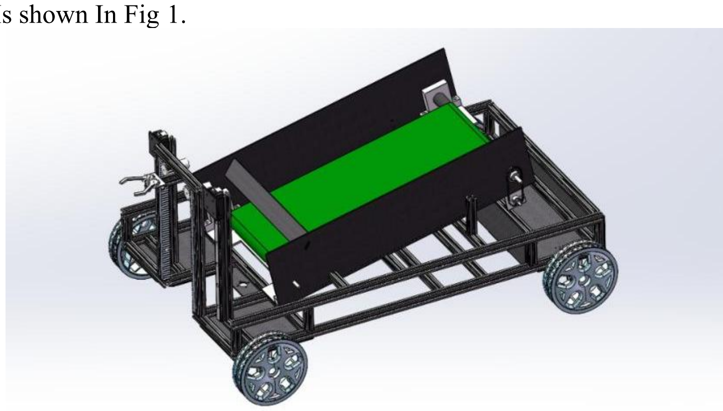

Figure 1:Diagram of the overall structure of the harvester

III. STRUCTURAL DESIGN OF THE MAIN FUNCTIONAL PART

3.1 Chassis structure design

The Based on our field survey of greenhouse lettuce cultivation, we identified three key characteristics:

1) The soil surface inside the greenhouse is relatively flat;

2) The soil moisture is high;

3) The planting density is large.

Taking these into account, we chose an aluminum-extrusion frame supported by four load-bearing wheels (Fig. 2). This layout guarantees smooth travel over the cultivated ground.

Joints between the extrusions are made with:

1) Corner brackets and transition plates where loads are light, because brackets are quick to install but offer limited rigidity;

2) Machined plates where higher strength is required, since they prevent relative movement between connected parts.

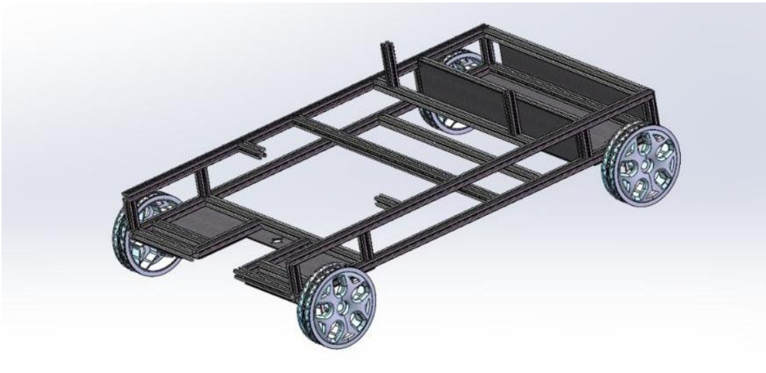

Figure 2: Harvester chassis structure

3.2 Structural design of defoliation device

For the gripping jaws of the defoliator, we adopt a “narrow-bottom, wide-top” profile whose lower rim is sharpened. As the motor drives the jaws downward, they easily shave off the leaf sheath from the lettuce surface (Fig. 3). The jaws also define a controllable clamping zone on the stem; this zone automatically adapts to stems of different diameters, so lettuces both thick and thin are stripped cleanly while excessive stem wobble during the operation is prevented.

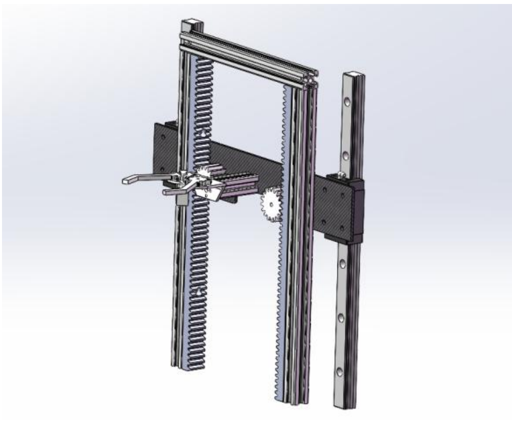

Figure 3: Dedefoliation mechanism

3.3 Structural design of excision device

The We first investigated the physical properties of lettuce stems. Literature shows that:

1. Moisture content ranges from 95.01 % to 98.00 %; the very high water content requires enhanced water- and corrosion-proofing of both the cutting and conveying units.

2. The maximum shear force required to cut a stem is 352.65 N, while the minimum compressive strength is 1.50 MPa. Consequently, the cutting device must deliver a shear force above 352.65 N, and the

clamping stress exerted by the conveyor must remain below 1.50 MPa [5]. These values provide the theoretical criteria for designing a reliable cutting mechanism.

In manual harvesting, a sickle is used to sever the plant at the root. Mimicking this action, we devised a cutting mechanism that automatically adapts to stems of different diameters. Mounted on the chassis as close to the ground as possible, it minimizes crop loss. Positioned beneath the chassis, the blade cuts the lettuce cleanly while remaining shielded from the operator, significantly improving operational safety.

3.4 Conveyor structure design

We opted for a belt conveyor. Guide plates are added to the belt to ensure that each lettuce enters the rear collection bin in the correct orientation. Because the cylindrical stems can roll off if friction is insufficient, we mounted cleats on the belt. Every cleat provides a supporting force that keeps the lettuce from falling and guarantees safe delivery into the bin.

3.5 Structural design of collection device

We used carbon-fiber panels for the four walls and the floor of the collection bin. These panels are light, easy to mount, and extremely strong, so they resist damage. The floor panel is tilted at a slight angle, allowing each lettuce to slide forward and maximizing the usable volume of the bin.

IV. EMBEDDED SYSTEM DESIGN

4.1 STM32 Embedded Main Controller

The embedded system uses the STM32F103C8T6 microcontroller as the main control chip. It is a 32-bit processor from the STM32 family built around an ARM Cortex-M core, offering 64 KB of Flash and 20 KB of SRAM together with a rich set of on-chip peripherals. Delivering solid performance at a very low price, it combines high capability, excellent cost-effectiveness, and low power consumption.

4.2 Chassis and Drive Control System

For the chassis and drive unit we selected a DC speed-regulated motor and use PWM (Pulse-Width Modulation) to control its motion. PWM regulates the signal by intelligently varying the duty cycle—the ratio of high-level to low-level time within a fixed period—thereby producing the desired average output. This dynamic adjustment gives PWM great flexibility and enables a wide range of output effects [6].

ADC motor itself operates at high efficiency under rated load. Although the reduction gearbox introduces some mechanical losses, the complete system works with a matched load, so electrical energy is converted efficiently into the required mechanical energy (high torque), avoiding the waste associated with an "over-sized motor driving an under-sized load."

4.3 Defoliation and Cutting Control System

For the defoliation and cutting unit, positional accuracy of the motor is essential. We therefore chose a stepper motor and drive it by a train of discrete pulses. Each pulse from the controller turns the motor a fixed, precise angle, giving the mechanism its high-resolution positioning capability.

4.4 Embedded Operating System

For the embedded operating system we selected FreeRTOS, an open-source, real-time kernel designed specifically for microcontrollers and small embedded systems. It brings multi-tasking to a single MCU, letting you run several tasks "simultaneously," much like running multiple programs on a PC. FreeRTOS offers preemptive scheduling, memory management, and inter-task communication, enabling more efficient and modular development of complex embedded applications while leaving ample room for future hardware and software iterations.

V. CONCLUSION

This paper presents a detailed description of every module of the lettuce harvester and its operating principles. With the close cooperation of all sub-systems, lettuce can be harvested smoothly and dropped accurately into the collection bin via the conveyor. Nevertheless, several improvements remain necessary; for instance, the current defoliator causes excessive damage to the stems and its leaf-removal performance still falls short of expectations—this will be the primary focus of our next optimization cycle.

ACKNOWLEDGMENT

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