

*Scientific Paper*Doi: <http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v42n4e20200198/2022>**DESIGN OF AUTOMATIC PACKING SYSTEM FOR PIPETTE SUCTION HEADS****Lixiang Sun<sup>1\*</sup>, Kun Yang<sup>1</sup>, Xinyi Zhai<sup>1</sup>, Liangwu Zheng<sup>1</sup>**<sup>1\*</sup>Corresponding author. Yancheng Polytechnic College/Yancheng, China.E-mail: [15151079025@163.com](mailto:15151079025@163.com) | ORCID ID: <https://orcid.org/0000-0002-8030-1131>**KEYWORDS**

pipette tips, automatic packing, mechanical design, hardware and software design, improve efficiency.

**ABSTRACT**

Among the shortcomings of the existing pipette cartoning technology, first, it needs a lot of manpower and time to complete by hand; second, it is based on a semi-automatic equipment for loading the suction heads, which cannot ensure that the suction head is upright (bottom tip down) or avoid the phenomenon of suction head overlapping. Based on this, an automatic system for packing pipette suction heads is proposed. Firstly, the research status of pipette cartoning is analyzed; secondly, the mechanical design of the automatic cartoning system for pipette suction heads is given; thirdly, the hardware structure diagram and software flow of the automatic cartoning system are given. Finally, the system is applied to a pipette suction head box in a school laboratory. After many times of practice, it is proved that the system can realize the automatic pipette suction head box, and has the advantages of stable performance, accurate positioning and intuitive display, which improves the efficiency of the pipette suction head box in the laboratory.

**INTRODUCTION**

A micropipette suction head (or gun head) is commonly used in chemical, biological, environmental, food and pharmaceutical laboratories. Before use, the suction head generally needs to be loaded into the suction box to enable the micropipette to take the suction head. At present, most of the work of loading the suction heads into the suction head box is done manually, which requires a large amount of manpower and time (Wei et al., 2018; Xu et al., 2019). There are also some automatic or semi-automatic loading equipments for the suction heads, such as patent CN201521133770.X, which discloses an automatic loading device of a portable liquid pipette gun head, which can quickly and accurately insert the whole row of gun heads into the gun head box. In order to avoid the overlapping of the gun heads, a group of curling blades are added, but the equipment is more complicated and the suction heads may be damaged by extrusion. The direction of the gun head is adjusted by setting thin metal thin metal strips to ensure that the bottom tip of the gun head is downward, so the effect of this scheme is difficult to guarantee (He et al., 2019). The technical difficulties of the automatic or semi-automatic suction head loading equipment mainly include: 1) ensuring that the suction head is upright (the bottom tip is downward);

2) avoiding the phenomenon of suction head overlapping. However, with a large number of the suction head loading equipments employed so far, it is difficult to overcome the above defects, so a more reliable scheme is needed now. In view of the shortcomings of the existing technology, this paper puts forward a new kind of automatic packing equipment for pipette suction heads (Zhang et al., 2019).

**MATERIAL AND METHODS****Mechanical structure of automatic packing equipment for pipette suction heads**

The automatic packing equipment for pipette suction heads proposed in this paper is shown in Figure 1, which includes: a feeding–sorting mechanism, reclaiming mechanism and suction head storage box. The feeding–sorting mechanism includes a feeding device and a sorting device; the feeding device includes a storage bin for storing the suction heads and an impeller feeding component for conveying the suction heads to the storage bin and making the suction heads enter the sorting device in an upright posture with the bottom downward; the sorting device is arranged on the discharge port, and the sorting device receives the conveying of the feeding device. The sorting device is also provided with a fixed mechanism to

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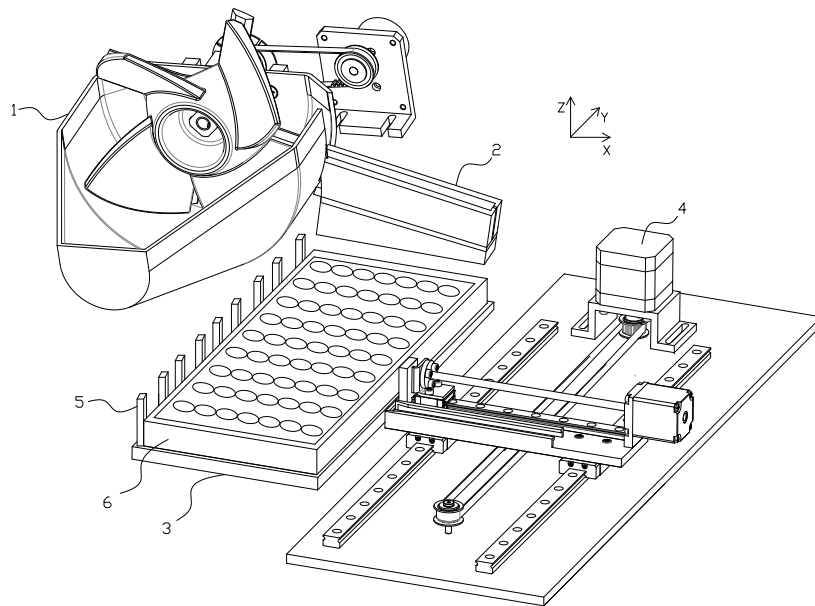
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keep the sorting groove fixed in order to fix the suction head in the sorting groove (Sun et al., 2016; Szymkowicz & Benajes, 2018). The reclaiming mechanism includes a tray for storing the suction head storage box and a two-dimensional handling device for transporting the tray to the lower part of the sorting device (Vipavanich et al., 2018).

The tray is provided with a discharging mechanism for releasing the fixing of the sorting slot to the suction head so that the suction head can fall freely from the sorting groove. A number of discharge suction head storage holes are arranged on the suction head storage box for storing the suction heads (Wang et al., 2018).



1. Feeding device; 2. Sorting device; 3. Tray; 4. Two-dimensional handling device; 5. Discharging mechanism; 6. Suction head storage box

FIGURE 1. Structural diagram of pipette suction head automatic packing equipment.

The principle of the equipment is as follows: the storage bin and the impeller feeding assembly are arranged horizontally. The impeller feeding component carries the suction head from the storage bin to the discharge port by rotating, and when the suction head reaches the discharge port, it keeps the bottom downward upright posture (hereinafter referred to as upright), and then enters the inclined sorting slot, and arranges a single row vertically in the sorting slot, eventually filling the whole sorting slot side by side (Xie et al., 2017; Zhao et al., 2018; Zhao et al., 2019). At this time, the impeller feeding component is suspended. The tray and the tip storage box on the tray are transported to the bottom of the sorting slot. When the tray reaches the working position (that is, the unlocking position: the first empty tip storage hole is directly below the sorting slot), the discharging mechanism on the tray releases the fixing of the sorting slot to the suction head stored therein, and the suction head falls down into the corresponding position on the suction head storage box. Then the tray moves forward along the y-axis to the empty position (the middle position of the two rows of suction head storage holes is directly below the sorting slot), and the fixing mechanism makes the sorting groove recover the fixation of the suction head stored in the sorting slot; the impeller

feeding assembly works again, and the suction head is transported to the sorting slot again; the impeller feeding assembly stops working once it is full, and the two-dimensional handling device moves the suction head storage box into the sorting slot again. The second empty suction head storage hole is transported to the lower part of the sorting tank to fill the second empty suction head storage hole; the feeding, discharging and filling actions are cycled, so that each row of suction head storage holes on the suction head storage box is filled with suction heads in order to complete the automatic suction head packing operation (Lu & Li, 2018; Ji et al., 2018; Guan et al., 2017).

### Hardware design of automatic packing equipment for pipette suction heads

The core of the hardware design of this system is a single-chip microcomputer, which mainly controls the driving of the x-axis motor, impeller motor and y-axis motor, the detection of the position of the moving mechanism, the display of the movement mechanism when it changes, and the display of the indicator light when a fault occurs (Fang et al., 2020). The hardware structure of the system is shown in Figure 2.

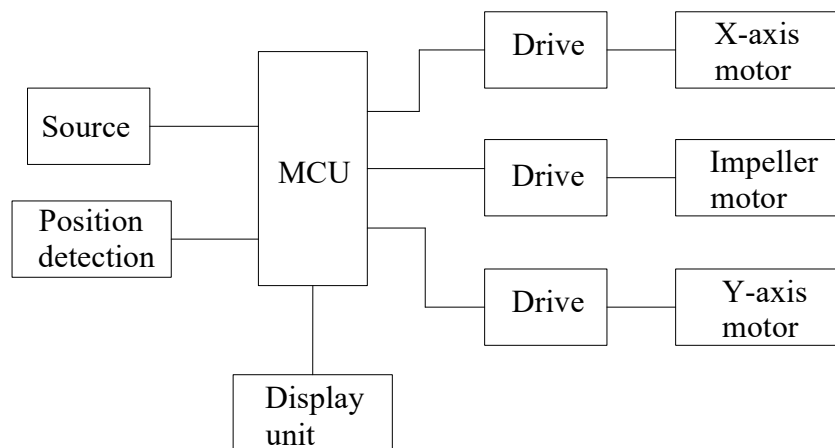


FIGURE 2. Schematic diagram of hardware structure.

### Software design of automatic packing equipment for pipette suction heads

The main functions of the system software include drive control, fault detection and position detection of the x-axis motor, impeller motor and y-axis motor. The main program flow chart is shown in Fig. 3. Referring to Fig. 1 and 2, the overall working process of the automatic packing device for pipette suction heads is as follows: First, the suction head storage box is put into the tray and fixed, and the x-axis handling mechanism works to realise the x-axis direction in place. Second, the production suction head is dropped into the storage bin, the impeller motor works, and the suction head is transported to the sorting tank until the sorting tank is full of suction heads, and the impeller motor stops working. Third, when the y-axis handling mechanism works, the photoelectric switch reaches the first unlocking position, the unlocking column reaches the unlocking

position, the y-axis motor stops working for 1-4 seconds, the sorting slot opens, and the suction head falls into the storage hole in the first row. Fourth, the y-axis motor continues to work, the photoelectric switch reaches the first empty position, the y-axis motor stops working, the unlocking column crosses the sorting device, waiting for feeding, the sorting slot returns to the initial state, keeps the fixed suction head, and the impeller motor returns to work to feed the sorting slot (Pei et al., 2019). Fifth, after the sorting slot is filled with suction heads again, the impeller motor stops working; then the above steps are repeated, and the photoelectric switch successively reaches the second unlocking position, the second vacant position, the ninth unlocking position and the ninth vacant position; the second, third and ninth rows of suction head storage holes are filled one by one, and finally the filling of the suction head storage box is completed (Sun et al., 2020; Xu et al., 2018).

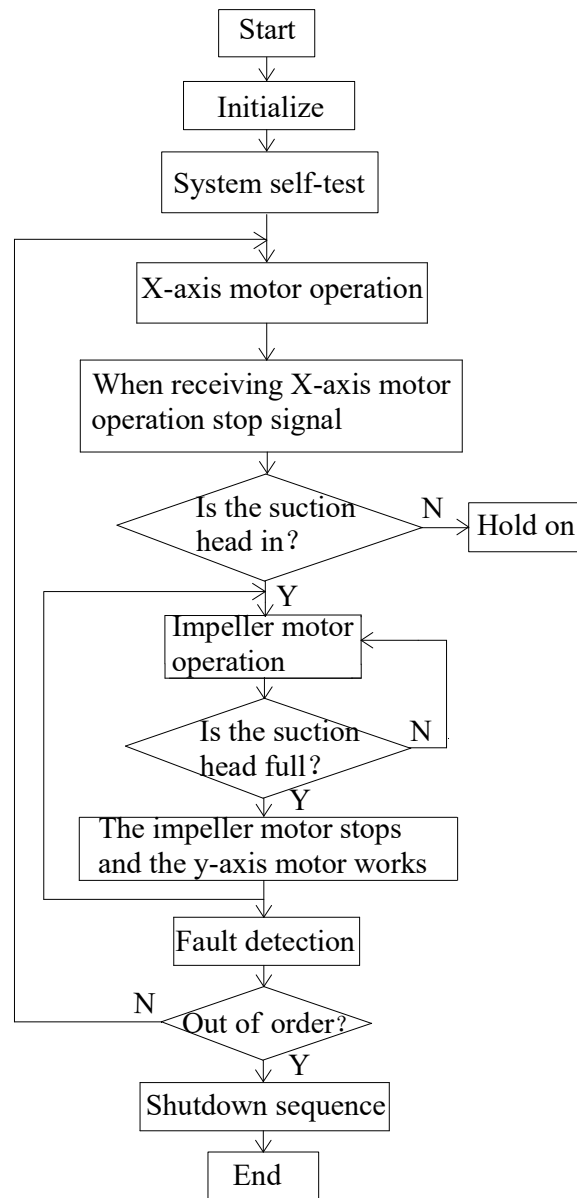


FIGURE 3. Main program flow chart.

## RESULTS AND DISCUSSION

### System experiment

When the system is powered on and running normally, the feeding of the suction head box and the automatic feeding of the suction heads can be completed in advance within the packing time of the cartoning station, so the feeding time cannot be considered when calculating the packing time of the cartoning station, and the assembly time is mainly determined by the speed of the cylinder. Because the cylinder stroke is short, the speed of the selected cylinder to complete the operation is the same as that of the empty stroke. In this paper, the speed of the lower lifting cylinder is selected as 60 mm/s. The time consumed by other automation devices in the system mainly includes the response time of each cylinder action and the movement time of the boxed components. Generally, the scanning period of micro-programmable logic controllers (Micro PLC) is tens of milliseconds, plus the loss time of the transmission signal. Therefore, this paper takes the loss time of each

cylinder as 0.1 s. Through repeated experiments, the time required to fill

a box of suction heads is about 44 s, and there are 9 rows of suction heads in a box. Therefore, the average period of filling a row of suction heads is only 4.89 s. However, the time for manually filling a row of suction heads measured by the test is at least 10 s (Xu & Lu, 2019). It can be seen that the efficiency of the automatic packing system is double the manual alternative. In addition, from the human point of view, it also eliminates the weariness of manual packing (Ding et al., 2019).

### CONCLUSIONS

The experiment shows that the system can realise the automatic packing of pipette suction heads. It has the advantages of stable performance, accurate positioning and intuitive display, and improves the efficiency of pipette suction head packing in the laboratory. The system also has some shortcomings. On the one hand, it can only achieve single row packing. If it can achieve double row or even

multi row automatic packing, the efficiency will be greatly improved; on the other hand, there is a lack of monitoring of the system. These two aspects will be the focus of the next research.

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