A Fully Automatic Fresh Apple Juicer: Peeling, Coring, Slicing and Juicing

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Abstract. With the fresh apple juice as an example, a fully automatic and intelligent juicer prototype was built via the integrated application of servo positioning modules, human-machine interface, image vision sensor system and 3D printing. All steps including peeling, coring, slicing and juicing were achieved automatically. The challenging technical problems about the identification and orientation of apple core, and adaptive peeling were settled creatively. The trial operation results illustrated that the fresh apple juice can be produced without manual intervention and the system has potential application in the crowded sites, such as mall, school, restaurant and hospital.
Keywords: Fresh apple juice, machine vision, removal of apple core, servo positioning.

1 Introduction

Generally, fresh fruit juice is full of nutrition and active to people health. Meanwhile, the process of squeezing juice is almost transparent and timely without any additive and decaying fruits. Therefore，fresh fruit juice has become the flavour of drink market. However unlike sodas and concentrated juice, the fresh juice is unsuitable for batch production due to the short shelf life and demanding procedure. Production of fresh fruit juice first need to select perfect fruits and usually also need to peel and core, namely "just squeeze -just sale-just drink". Hence the production of fresh juice belongs to individualized on-demanding production. Currently, at the level of domestic or personal juicer, manual operation is essential within loading, peeling, coring, slicing and such operations. The fully automatic fresh apple juicer still is a gap in the market.

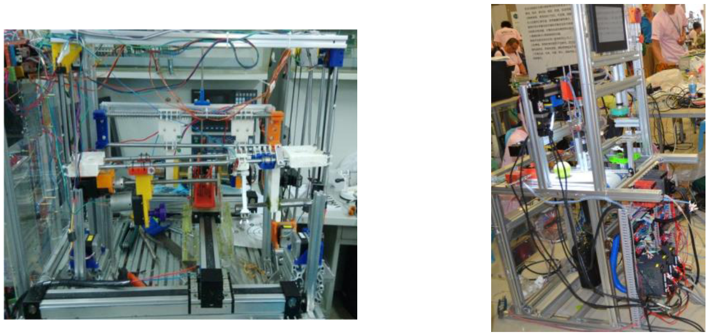
Certainly, there are several kinds of fresh fruit juicer in the market, such as orange juicer. But it does not peel the orange before juicing. Thereby this may lead to doubts and hesitations: what about the surface clearness, what about the wax residues, etc. For instance, the apple juicer in the market may achieve automatic peeling, but the coring automation is not implemented. Zeng et al [1] presented a principle solution using the spinning copying cutter to peel the apple. Bai et al [2] put forward an automatic system including the processes of conveying, location of apple core, peeling, and coring.

Briefly, there are two core difficult issues when developing a fully automatic fresh apple juicer. First, it is the adaptive peeling of apple. The nutrition or detriment of apple peel is always a highly controversial topic. It is better to peel for ensuring the flavour and safety. However, there are no two identical apples in the world. The apples have irregular shapes, dents of stalk and calyx. These factors lead to big difficulties for complete peeling. And the second problem is automatic coring problem. Since the apple core contains little cyanide which does not benefit our health, it is better to core when juicing. However, how to identify the position and orientation of the core and to separate it from flesh is another problem for fresh juicing [3]. To develop a fully automatic fresh apple juicer, the two key issues mentioned above must be settled.

In this paper, we put forward a fully automatic juicing concept at the level of domestic or commercial environment rather than the industrial environment. And we have developed a fully automatic fresh apple juicer prototype in laboratory environment based on a creative solution using machine vision system.

2 Solution presentation

Figure 1 has shown the main configuration of the presented system as two generation prototypes. The basic working procedure includes seven steps: loading apples using robot, cutting the end, identification of core, wedging, peeling, slicing and coring, squeezing.



(a) The first-generation prototype (b) The second-generation prototype

Fig. 1. Structure of the system

Two generation of automatic fresh apple juicer system are made. The first generation of the system (Figure 1a), making a bit rough, is in the exploratory stage to find reasonable workflow and some problems. In the first juicer system, the problems are that the force inserting the apple is underestimated leading to system instability as well as motor power shortage. The core position of the apple is not accurate without utilizing the vision system. In the second generation juicer system (Figure 1b), more powerful motors and profiles are introduced to the system. Vision systems are adopted to identify the accurate position of the apple core. The full automatic fresh apple juicer system' s performs using procedure presented on Figure 2 as the following:

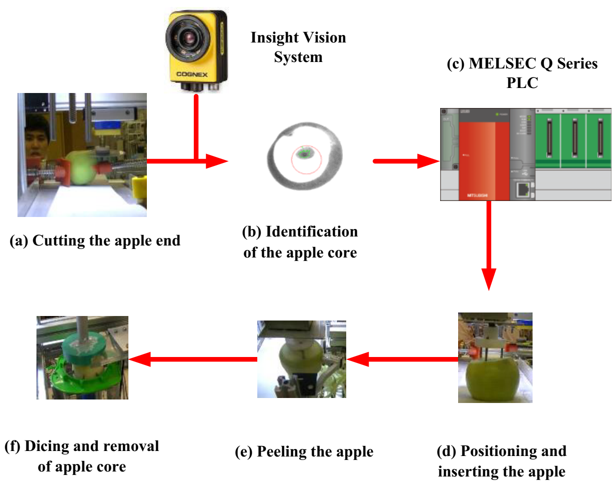


Fig. 2. Automatic fresh apple juicer work procedure

- *Loading*: The industrial robot picks the apple from the storing box and places it onto the conveyors. Here, the basic assumption is that apples in storing box have been washed.
- *End cutting*: When the apple was transmitted to the position at the center of the clamp device, it would be held on. Then under the drive of the linear slide module, the spinning cutter would cut off the ride of the apple end, as shown in the Figure 2. The flesh of apple end would come out, and its colour is in total contrast to the black apple base. This can lay the foundations for the identification of apple core in next process. Meanwhile, this work is equivalent to removing the peel on the apple base. The peel on the apple base is usually difficult to be removed when adaptive peeling.
- *Identification of apple core*: We identified the position of apple core using the machine vision camera. As illustrated in Figure 2, the core is viewed as "spot" and then is identified by the vision tool of spot detection. First in the vision area, the camera sensor roughly determines the core position. Second, in the obtained area, the black spot would be obtained exactly。After two times detection, the apple core can be exactly confirmed and its position coordinates (x_d, y_d) or offsets from the reference axis can be calculated.
- *Wedging:* The COGNEX vision system can be connected directly on the Ethernet port on the Q-series PLC using Ethernet based on the seamless message protocol (SLMP) or MELSEC communication (MC) protocol.

Consequently, the apple core position parameters would be transmitted from vision camera to the programmable logic controller (PLC). PLC would drive the line slide module and bring the wedging pins to the target position. In the Z direction, the wedging pins plate moves down driven by screw motor and plugs into the flesh (Figure 3).

- *Adaptive peeling:* After the insertion of wedging pins plate into the flesh, the apple would move to the peeling position with the drive of linear slide module. Then the wedging pins plate start rotating and moves down along Z direction. Though the apple has irregular shape, the spring at the peeling cutter bar can make it close with the peeling cutter. Hence, the adaptive peeling of apple can be achieved as shown in Figure 2. Maybe this mechanical method of peeling has lower efficiency than the lye corrosion method [4]. But it can avoid steeping and washing processes. Therefore mechanical peeling method has priority for the personal commercial juicer.
- *Slicing and coring*: After peeling, the apple the apple would further move to the below the pushing plate. The pushing plate driven by screw motor would push the apple into the slicing and coring cutter, and the core is removed and the flesh is cut into slices (Figure 2). The core slides into the hopper of the juicer through the slide way, and the removed core drops into the collector through soft pipe.
- *Juicing:* Here, the domestic juicer is directly used to squeeze the apple slices without further improvement.

Through the sequential process above, the system first solved two key issues: adaptive peeling and coring. This realized the possibility of fully automatic juicing without manual intervention. Particularly, the process of cutting end made the identification of apple core very easy via the machine vision, and also removed the peel on the apple base. It is shoot two hawks with one arrow. Thirdly, the system used servo positioning technology and ensured the precision requirement of every shift position.

3 System establishment

Next we discussed the integration and connection strategies of the whole system. Since the PLC, touch screen, motion module, servo drive, servomotor and industrial robot are chosen from Mitsubishi Electric Corporation, they naturally have good compatibility and easy communication interfaces. Therefore, we mainly described the servo positioning system configuration, as well as the communication between the CONGEX camera and the Q series PLC.

The COGNEX vision system can be connected directly on the Ethernet port on the Q-series PLC using Ethernet based on the seamless message protocol (SLMP) or MELSEC communication (MC) protocol [5,6]. Thereby, the SLMP/MC protocol communication enables COGNEX vision system to communicate directly with Mitsubishi PLCs without requiring ladder logic. COGNEX vision can read and write many different data types via SLMP/MC protocol, including tool results, data strings and tolerances. The following diagram (Figure 3) illustrates the communication method between In-Sight and Q-Series PLCs using MC Protocol.

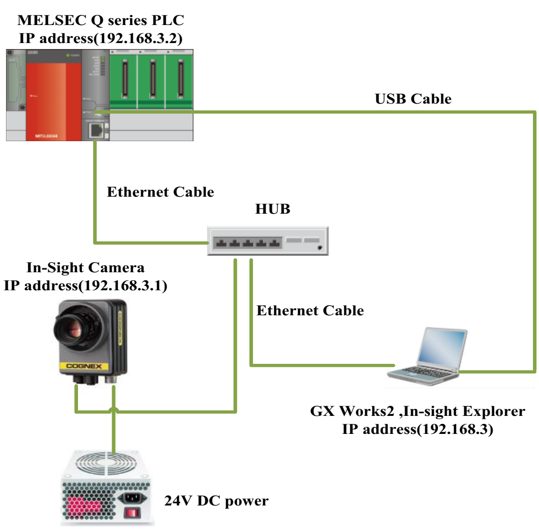


Fig. 3. Connection configuration for the vision system

4 Conclusion

In the present work, we put forward the fully automatic juicing concept at the level of domestic or commercial environment rather than the industrial environment. And we have developed a fully automatic fresh apple juicer in laboratory environment. The system synthetically used the technologies of image sensor, servo positioning, PLC as well as additive manufacturing. The whole processes of peeling, coring, slicing and juicing can be achieved automatically

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without manual intervention. This potential application spots of the system embraced the crowded sites, such as mall, school, restaurant and hospital. Obviously, this system prototype had many aspects that can be improved, for instance, industrial design, operation reliability etc. Further research is required to completely build a full product type and more simple system.

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