Journal of Engineering Science and Technology Review 9 (1) (2016) 95-101

JOURNAL OF
Engineering Science and Technology Review

Research Article

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Design of an ARM-based Automatic Rice-Selling Machine for Cafeterias

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Received 12 November 2015; Accepted 19 February 2016

Abstract

To address the problems of low selling efficiency, poor sanitation conditions, labor-intensive requirement, and quick rice cooling speed in manual rice selling in cafeterias, especially in colleges and secondary schools, this paper presented an Advanced RISC Machines (ARM) microprocessor-based rice-selling machine for cafeterias. The machines consisted of a funnel-shaped rice bin, a thermal insulation box, and a conveying and scattering mechanism. Moreover, this machine exerts fuzzy control over stepper motor rpm, and the motor drives the conveyor belt with a scraper to scatter rice, deliver it, and keep it warm. Apart from an external 4*4 keyboard, a point of sale (POS) machine, an ARM process and a pressure sensor, the machine is also equipped with card swiping and weighting mechanisms to achieve functions of card swiping payment and precise measurement, respectively. In addition, detection of the right amount of rice and the alarm function are achieved using an ultrasonic sensor and a beeper, respectively. The presence of the rice container on the rice outlet is detected by an optoelectronic switch. Results show that this rice-selling machine achieves precise measurement, quick card swiping, fast rice selling, stable operation, and good rice heat preservation. Therefore, the mechanical design enables the machine to achieve its goals.

Keywords: Advanced RISC Machine, Automatic rice- selling machine, Fuzzy control, Precise measurement, Point of sale machine

1 Introduction

Most cafeterias in colleges and organizations sell meals manually. In these places, the rice being sold is exposed in an open environment throughout the selling process, turns cold easily, and may become contaminated resulting from its contact with meal sellers or with flies. In addition, high intensity and complex meal taking action easy to make sellers be fatigue and result in uneven rice selling amount. Many students in colleges and secondary schools take their meals at peak hours, resulting in long queues for rice.

Many types of rice-selling machines, such as automatic instant rice production machines and automatic rice fillers; are commercially available; however, these are bulky, consume high amount of energy, and cannot select the amount of rice to dispense [1-3]. Chang Junran et al. designed a rice-selling machine that sells rice by volume according to the principle of a vending machine; this machine dispenses cube-shaped rice portions with affecting the taste as it uses mess tins of fixed specifications. However, this kind of machine does not easily meet the requirement of random dining in cafeterias [4-6]. To solve the abovementioned problems and conditions, we developed an automatic rice-selling machine for cafeterias in the current study.

2 Overall Scheme of the Proposed Automatic Rice-Selling Machine for Cafeterias

The automatic rice-selling machine designed consists of three parts: the input layer, the processing layer, and the execution layer. Fig. 1 shows the schematic of this system. The input layer consists of a 4*4 keyboard, an optoelectronic switch, an ultrasonic probe, and a pressure sensor. The quantity of rice is selected using the keyboard; the optoelectronic switch determines whether the holding vessel on the weighing mechanism contains rice, and the pressure sensor measures the weight of rice to be dispenses. The processing layer comprises Advanced RISC Machines (ARM) microprocessor, HY-SRF05 and HX711, which carries out Analog/Digital(A/D) conversion to signals of the input layer and inputs the converted signals into ARM directly or after amplification for use in the application program and then to output signals to achieve the control function. The execution layer manifests the output signals of the processing layer involving the rotating and stopping of the motor, displaying of rice weight and remaining amount, and sounding of the beeper alarm.

3 Hardware Design

The hardware design of the automatic rice-selling machine includes a circuit design and a mechanical system design. The signals of the ultrasonic sensor, pressure sensor, optoelectronic switch, and keyboard are inputted into the ARM microprocessor directly or after processing in order to control the mechanical equipment and perform the corresponding action.

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ISSN: 1791-2377

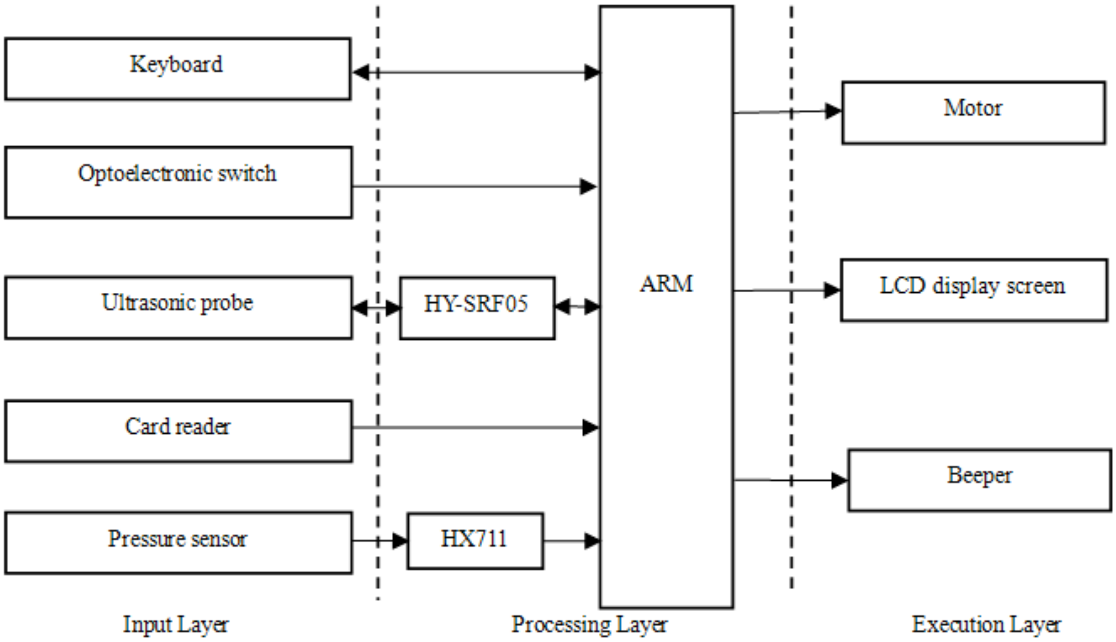


Fig. 1. Integral structure of system

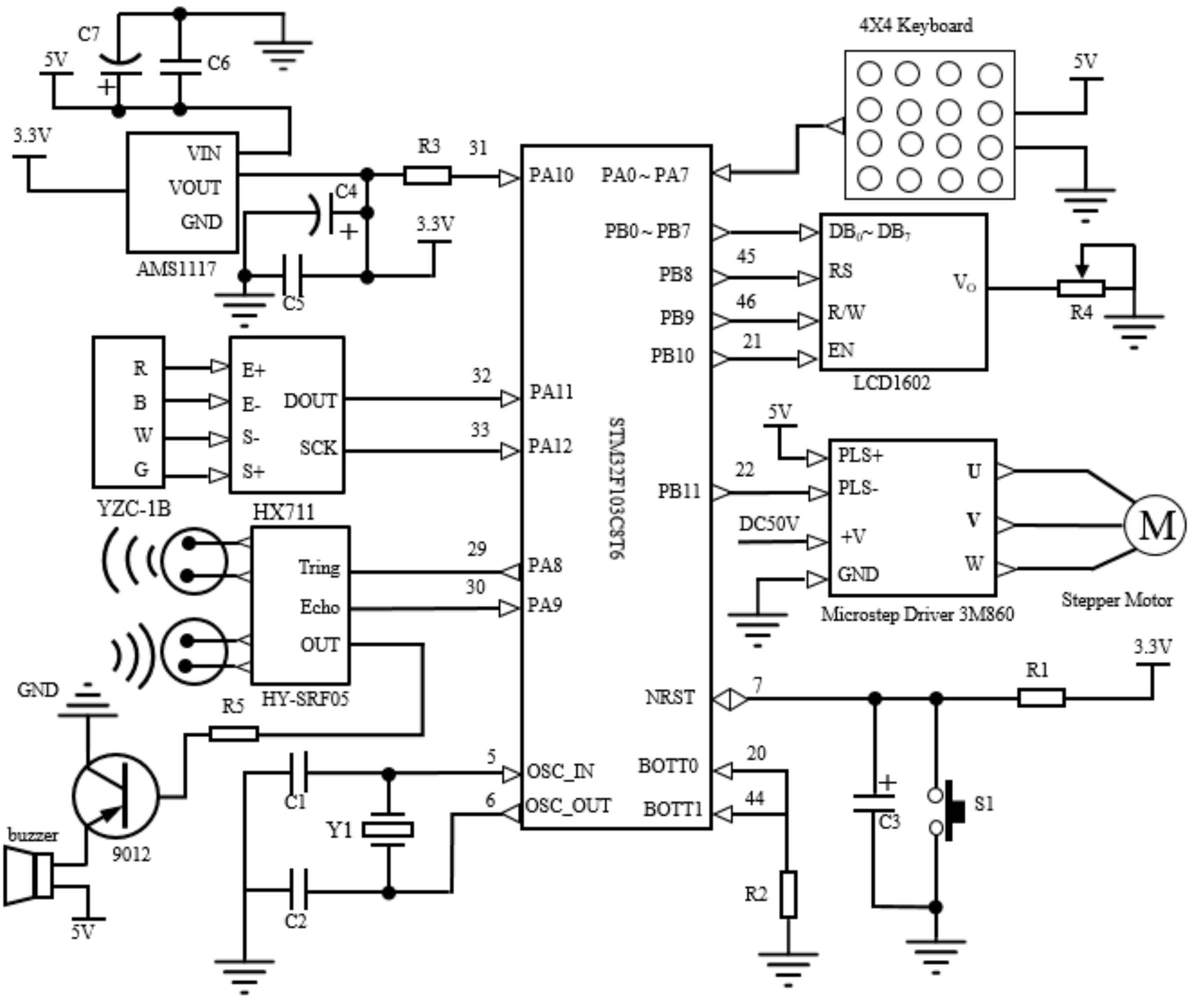


Fig. 2. Circuit of automatic rice selling machine

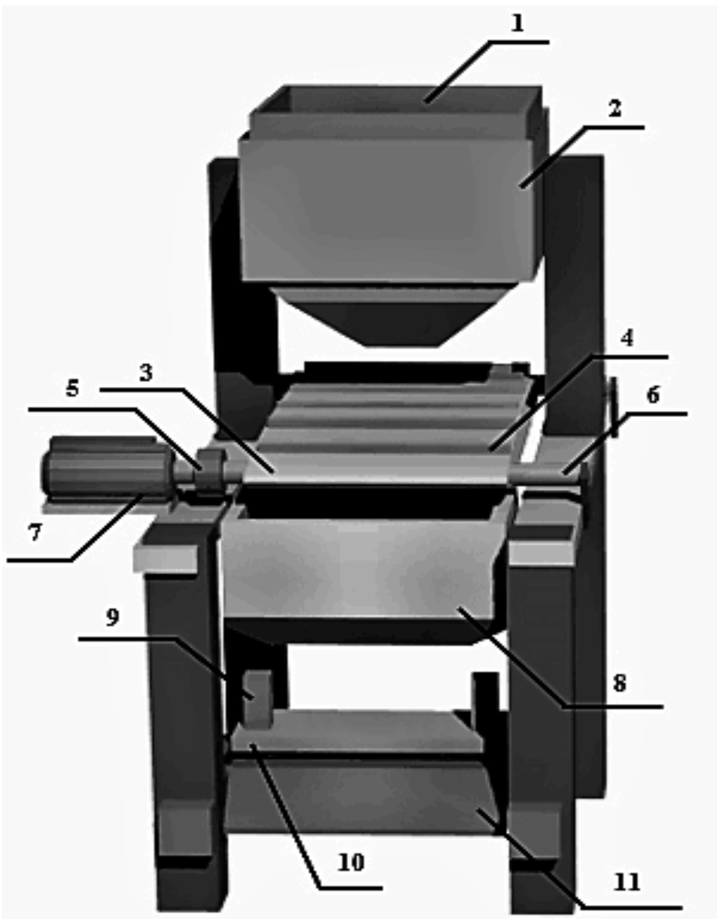
3.1 Circuit Design

This paper adopts the ARM Cortex-M3 kernel-based enhanced microprocessor STM32F103C8, which is manufactured by ST Corporation, as the core unit of the system. This low-cost microprocessor exhibits high performance and low power consumption. Meanwhile, HX711 is a 24-bit A/D converter chip especially designed for high-precision electronic scale. This chip integrates peripheral circuit (including regulated power supply and on-chip clock oscillator), which is required by the other chips of the same variety. The high level of integration, fast response speed, and high anti-interference performance of this chip guarantees hardware accuracy for rice measurement.

Fig. 2 shows the hardware circuit of the proposed automatic rice-selling machine. The 4*4 keyboard encodes in the rank scanning mode and is connected to eight continuous input/output (I/O) ports (PA0–PA7) of the microprocessor as well as to the button port of the POS. The two probes (ultrasound transmitting and receiving) carry out A/D conversion by HY-SRF05, and they are connected to PA8 and PA9of the microprocessor, respectively, through the Trig and Echo ports. The OUT end is connected to the beeper to produce the alarm. Four pieces of colored signal lines (red, black, white, and green) of the resistor strain type sensor are respectively connected to E+, E−, A+, and A− of the module HX711 for A/D conversion and amplification. Moreover, the PA11 and PA12 of the ARM microprocessor are respectively connected to the pin SCK (Serial clock input) and DOUT (Digital signal output) of HX711 for reading the weighting signals. The receiving end of the optoelectronic switch is connected to one I/O port of the microprocessor so that the ARM processor can determine whether rice is contained in the holding vessel. LCD1602 is also connected to 11 I/O pins of STM32F103C8 to display the button signal, the weighing signal, the operation state and time, the ground through the potentiometer at pin V0 of LCD1602, and the changes in the brightness of Liquid Crystal Display (LCD). The PA pin of STM32F103C8 is connected to the impulse input end of stepper motor driver 3M860 for ARM to control motor operation.

3.2 Mechanical Design

The mechanical part of the automatic rice-selling machine consists of rice storage, thermal insulation, conveying and scattering, and weighing mechanisms. Fig. 3 shows the mechanical design of the machine. The rice storage mechanism is a funnel-shaped rice bin made from the austenitic stainless steel 0Cr19Ni9 and is located on top of the frame, the upper part of which is a 30 cm*30 cm*20 cm (length × width × height) cuboid shape; the lower part is in 30 cm H* 15 cm bottom closing up width * 11 cm width funnel shape. The outer layer of the thermal insulation mechanism is a sealed box with the following dimensions: 4 cm thickness*20 cm height*30 cm internal length*30 cm internal width, and is made of the stainless steel 0Cr25Ni20. The box is wrapped from outside to inside with thermal insulation board, reflective film, and electric heating film. The scattering and conveying mechanism consists of a conveyor belt (25 cm in width, 48 cm in perimeter), scrapers (25 cm long, 1 cm high, 3 cm spacing), two rollers (2.5 cm in radius), and a stepper motor. The 86BYG350-150 motor is also used. The weighing mechanism consists of a 25 cm*31 cm metal plate, a YZC-1B pressure sensor, and an M12 optoelectronic switch.



Note: 1. Rice storage mechanism 2. Thermal insulation mechanism 3. conveying belt 4. Scrapper 5. Connecting shaft 6. Roller 7. Motor 8. Rice outlet 9. Optoelectronic switch 10. Metal platform 11. Pressure sensor

Fig. 3. Mechanical structure drawing

4 Software Design

Fig. 4 shows that the ARM microprocessor first performs program initialization, including variable initialization, module HX711 program segment initialization, and LCD program initialization. The presence of a rice-holding vessel is detected by the optoelectronic switch placed on both sides of the weighing mechanism. In the absence of the vessel, the ARM microprocessor will read the amount of residual rice in the rice bin through ultrasonic wave signals; if the amount of residual rice is too low, it will produce an alarm and perform program initialization again. When a card swiping signal is received and a rice is contained in the holding vessel, the machine determines whether the quantity of rice is selected; otherwise, it waits. To improve the speed and accuracy of rice delivery, fuzzy algorithm is employed to control the pulse output frequency; this pulse is sent into the driving circuit to control motor rotation for rice scattering and delivery. When the weighing mechanism detects the desired amount of rice weight is reached, the motor will stop running and completes rice delivery.

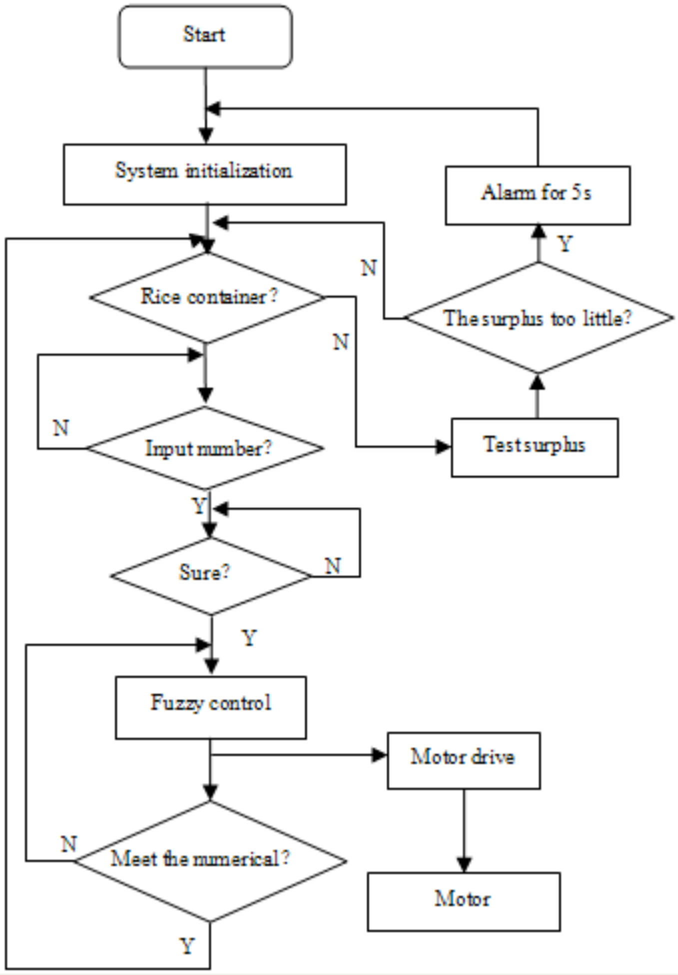


Fig. 4. Control system flowchart

Being an open loop control motor, the stepper motor cannot determine non-synchronization during operation, and the weight of delivered rice varies every time[7-11]. The traditional stepper motor is controlled in two ways: (1) either the speed is constant and the stepping and step pitch are adjusted by section, or (2) the speed, stepping, and step pitch are all adjusted by section. These two control methods are realized by calculating the steps passed by from the original point. The weight of rice on the conveyor belt varies each time; thus, the weight of rice cannot be determined by fixing the advancing distance. When the difference between the entered value in the fuzzy controller and the practical weight is positive, the stepper motor operates one step pitch in one operation cycle and realizes the integral control of motor rpm by continuously monitoring the weighting signals [12-18] .The motor stops running when the difference between the entered value and the practical weight is zero.

The fuzzy control rule of the stepper motor speed Sd is expressed as

$$if\ P_e = Ai\ and\ Pec = Bi,\ then\ S_d\ is\ Ci \quad (1)$$

where Ai, Bi, and Ci represent weight difference Pe, change rate of weight difference Pec, and value of motor linguistic variable Sd, respectively. In fuzzy control rules, the linguistic variable values of Pe take “zero(ZO),” “positive small (PS),” “positive medium (PM),” “positive big (PB),” and “positive big big (PBB);” those of Pec take “negative big big (NBB),” “negative big (NB),” “negative medium (NM),” “negative small (NS),” and “ZO;” and those of Sd take “ZO,” “positive small small (PSS),” “PS,” “PM,” “PB,” and “PBB.” All membership functions of Pe, Pec, and Sd are triangle.

The determination of control rules is described by the following:

(1) When the weight difference Pe is PB and the change rate Pec is NS, Sd shall select large speed to accelerate the speed delivery. When the change rate is NBB, Sd shall select medium or low speed.

(2) When the weight difference Pe is PM, the motor speed vSd is reduced; when the change rate Pec is NB, the speed Sd is further reduced.

(3) To ensure the delivery of rice with precise weight, the motor speed Sd shall be reduced to prevent overstriking when the weight difference Pe is PS .

(4) When the weight difference Pe is not zero but the change rate Pec is ZO, the motor will run at low speed because no rice is available for delivery and the weight is unchanged. Table 1 shows the control rules.

Table 1. Fuzzy control rules

Pe	Pec				
	NBB	NB	NM	NS	ZO
PBB	PM	PB	PB	PBB	PSS
PB	PM	PM	PB	PBB	PSS
PM	PS	PM	PM	PB	PSS
PS	PSS	PS	PM	PM	PSS
ZO	ZO	ZO	ZO	ZO	ZO

Using Matlab software, the membership functions of all variables and control rules are written into new.fis of fuzzy algorithm tool kit when performing Mamdani fuzzy inference and defuzzies using the centroid method[19-20]. This process is done to obtain the fuzzy controller model (Fig. 5).

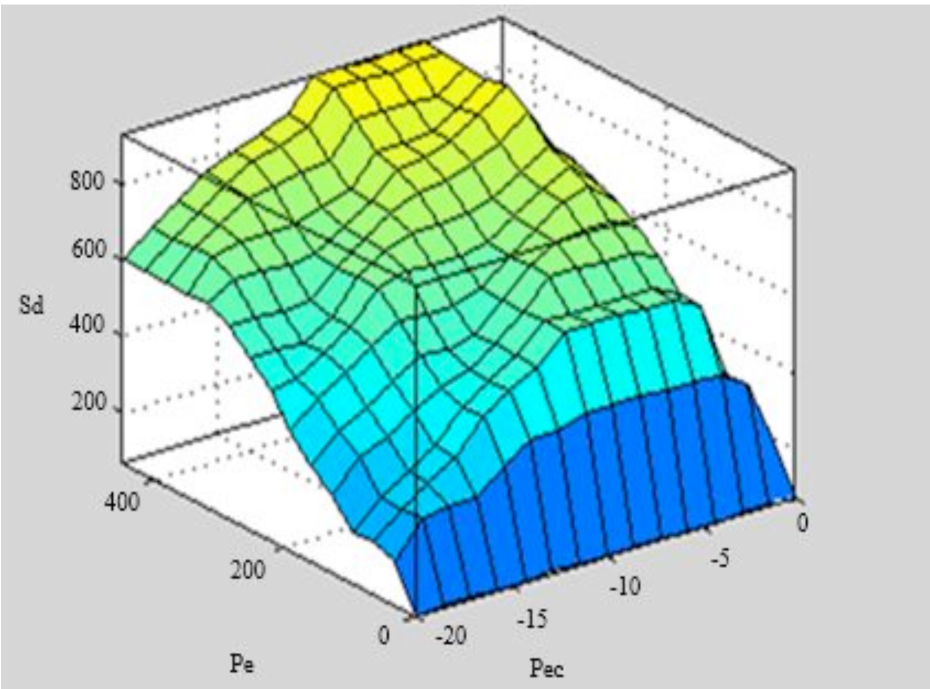


Fig. 5. Model of the fuzzy controller

5 System testing

Fig. 6 shows the trial production of the automatic rice-selling machine for cafeterias according to the design scheme.

Table 2 shows all of the parameters of the automatic rice-selling machine for cafeterias. Practical control adjustment is performed to the integral system after designing the hardware and software presented above. Finally, the step pitch of the stepper motor is determined as 2000 steps/revolution according to the fuzzy algorithm and mechanical size. The motor runs stably with low noise.

The operation of the proposed automatic rice-selling machine for cafeterias is tested. The testing range for weight is 100g to 400g. The weight test started at 100g, which is then increased at 50g increment. We compared the rice selling time and precision of the machine with that of manual labor in the student cafeteria of Sichuan Agricultural University. Each rice weight is tested 50 times and then averaged. The test results are shown in Fig. 7 and Table 3.

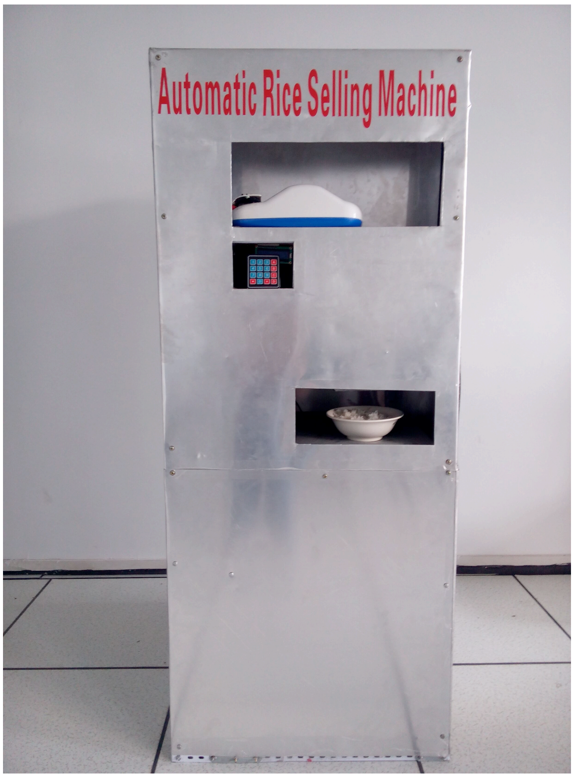


Fig. 6. the prototype of the automatic rice- selling machine for cafeteria

Table. 2. Whole parameters

Net weight of the whole machine (kg)	88.5	Dimensions of the whole machine(cm)	64*77*150
Power of the whole machine(W)	1050	Motor torque (NW)	7
Step pitch of stepper motor (S/R)	2000	Capacity of the rice storage mechanism(L)	32.5
Temperature of the sold rice(˚C)	45-55	Average rice selling time(S)	3.3

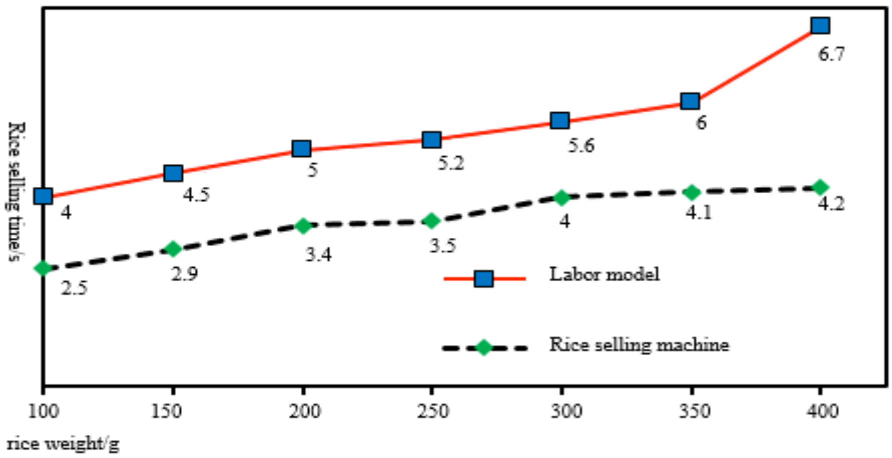


Fig. 7. Rice selling time comparison

Fig. 7 shows that the rice selling time of the automatic rice-selling machine designed is 1s to 2 s shorter than the manual selling. Manual selling often requires two to three rounds of scooping to fill the dish of the diner, thereby significantly prolonging the rice selling time. Moreover, the rice-selling efficiency diminishes resulting from fatigue caused by prolonged and continuous working of the laborers.

Table 3 shows that the maximum error in the rice-selling weight of the automatic machine is 5% at 100g, and the error increasingly decreases with increasing rice weight. The precision of manual selling is much lower than that of the automatic rice-selling machine. Moreover, manual selling fully depends on experience and is easily influenced by the environment and customer and is thus affected by random error.

Card swiping and deduction are possible with the machine, and no mistake in money deduction occurred during testing. Moreover, the temperature of the sold rice is detected every 10 min and then compared. At an ambient temperature of 22 °C, the temperature of the rice exposed to air drops by 5 °C to 6 °C, whereas that of the rice sold by the automatic rice-selling machine is maintained owing to the thermal insulation device of the machine.

Table 3. Rice selling precision comparison

Set value of rice weight(g)		100	150	200	250	300	350	400
Labor model	**Weight(g)**	156	173	175	216	339	455	486
	Error(g)	56	23	-25	-34	39	105	86
	Error	56.00%	15.33%	12.50%	13.60%	13.00%	30.00%	21.50%
Rice-selling machine	**Weight(g)**	105	157	209	248	306	355	405
	Error(g)	5	7	9	-2	6	5	5
	Error	5.00%	4.67%	4.50%	0.80%	2.00%	1.43%	1.25%

6 Conclusions

To address the problems of low selling efficiency, poor sanitation, great labor intensity, and quick rice cooling speed in manual rice selling in cafeterias, especially in colleges and secondary schools, we innovatively designed an ARM microprocessor-based automatic rice-selling machine that sells rice by weight and is able to charge via card swiping. The main functions of this automatic machine include rice scattering, precise measuring, charging via card, rice delivery at constant speed, and residual amount detection. Owing to the ease of operation precise and measurement, this automatic machine can automate rice selling and has a wide-ranging application. This machine will greatly reduce labor cost, increase labor efficiency and make rice selling orderly in cafeterias. The automatic rice-selling machine is suitable to the fast pace and high efficiency of the present life and ensures food safety. Moreover, this machine greatly reduces the operation costs, as well as the need for labor force.

Acknowledgements
The study was supported by the key project in Sichuan Province Department of Education (Grant No. 035Z1021).

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