

Structural and Control System Design of an Automatic Cooking Robot

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Abstract: With the rapid development of electronics, household kitchen appliances are gradually becoming intelligent. To improve the wellbeing of office workers and address challenges such as limited time for cooking rice, this paper proposes the structure and control system of a cooking robot. The system uses an STM32 microcontroller as its core and integrates IoT and other new technologies to enable interaction among the smartphone, cloud, and the cooking robot. It supports remote control and monitoring via a mobile app, and ondevice monitoring of the operating status or the cooking curve through a touch screen. Experimental tests show that the robot can automatically complete a series of operations, including rice metering, rice washing, and rice cooking, making the system more userfriendly and intelligent.

Keywords: Cooking robot; Internet of things (IoT); STM32; Control system; Cloud platform

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1. Introduction

In recent years, within the smallappliance manufacturing industry, rice cookers have enjoyed a strong sales advantage. To expand the market and meet diverse needs, ricecooker manufacturers have continuously innovated and upgraded, resulting in significant improvements in performance and operability. Temperature control during cooking has evolved from the previously used magnetic temperature limiter to microcomputer control, and the heating method has expanded from traditional resistive heating to electromagnetic heating^[1]. Market surveys indicate that commonly used highend rice cookers adopt IH (induction heating), enabling functions such as rice cooking, soup making, and steaming; however, there is still no household cooking robot on the market that integrates automatic rice dispensing, automatic rice washing, automatic rice cooking, and remote operation. To further raise the level of intelligence in rice cookers and move China's brands closer to the ranks of worldclass brands, this paper proposes a controlsystem design for a cooking robot that automatically performs rice fetching, rice washing, rice dispensing, water addition, and cooking, making rice preparation

convenient, fast, and within easy reach, thereby improving quality of life ^[2].

2. Overall structural design of the cooking robot

2.1. Rice storage & metering-dispensing mechanism and working principle

The rice storage and metering unit consists of: rice storage hopper (1), remaining quantity detection sensor (2), rice inlet of the metering device (3), spherical rice metering cup (4), mounting bushing for the metering device (5), mounting bracket (6), rice outlet (7), coupling (8), stepper motor (9), and rotating shaft of the spherical metering device (10), as shown in **Figure 1**.

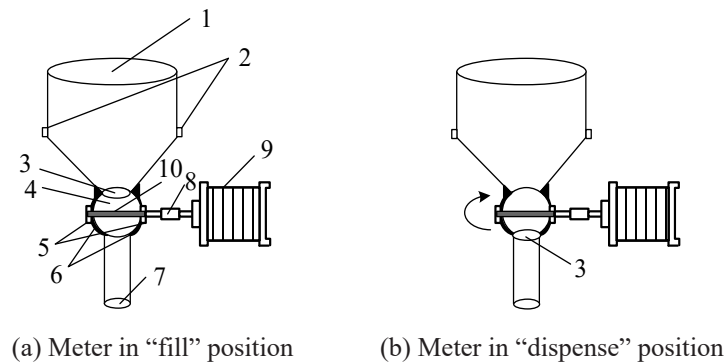


Figure 1. Structure of the rice storage and metering unit.

The storage hopper adopts a funnel shape to realize first-in-first-out (FIFO), solving issues such as stale rice accumulation, moisture, and insect infestation in traditional bins. A spherical metering cup (4) is installed at the lower end of the hopper (1). The cup is spherical with a rice inlet (3) at the top. According to the requirement, the spherical cup (4) is designed with a fixed volume—for example, the maximum amount per fill is 3 liang (150 g) per cup. A rotating shaft (10), aligned horizontally with the inlet (3), is fixed to the spherical cup (4). Supported by the mounting bushing (5) and bracket (6), the entire metering device is mounted beneath the hopper (1).

During metering, the inlet faces vertically upward so rice flows smoothly from the hopper into the spherical cup (**Figure 1a**). When dispensing is required, the stepper motor drives the cup, via the coupling, to rotate clockwise by 180° (as indicated in **Figure 1b**), turning the inlet vertically downward (**Figure 1b**) so that one cup (3 liang) of rice exits through the outlet into the washing bucket. After dispensing, the motor rotates the cup another 180° clockwise to return to the fill position. If more rice is needed, the action repeats. A rice level sensor is installed at one-third of the hopper capacity. Comprising a photoemitter and photoreceiver, it detects “sufficient” when light is blocked by rice above the 1/3 level, and when the level falls below 1/3, the photoreceiver senses light from the emitter; the MCU then issues a refill reminder. The hopper level can also be monitored via a mobile app to implement low-level alerts.

2.2. Ricewashing and water dosing mechanism & working principle

In the ricewashing and water dosing unit, a three-dimensional hydrojet washing method is used to simulate agitator stirring, removing debris from the rice while better preserving nutrients. This 3D hydrojet approach eliminates the need for a mechanical agitator and motor, reducing the washer’s size and simplifying both

mechanics and control. Coordinated with the sprinkler rings to actuate the pushdown rice valve, which prevents rice adhesion and improves reliability. The overall structure is shown in **Figure 2** ^[3].

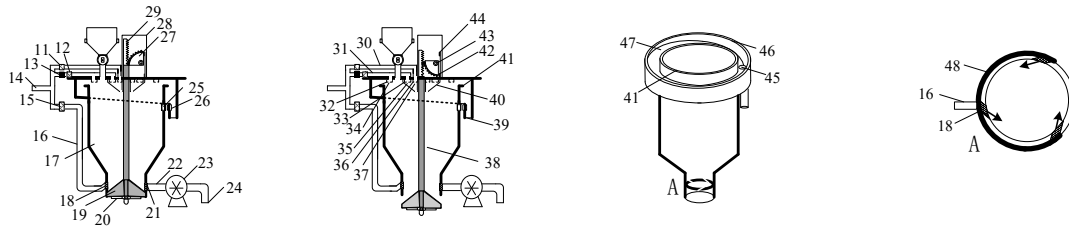


Figure 2. Overall structure of the washing unit. (a) Rice valve closed (b) Rice valve open (c) Structure of the washing bucket (d) Structure at location A.

The washing unit mainly comprises: solenoid valve for floatingdebris removal (11), watervolume solenoid valve (12), flow sensor (13), water inlet port (14), washing solenoid valve (15), washing water inlet pipe (16), washing bucket (17), filter screen (18), ricedischarging valve (19), valve fixing gasket (20), drain filter mesh (21), drain pipe (22), selfpriming drain pump (23), drain outlet (24), bucket waterlevel sensor (25), overflow detection sensor (26), lift cam (27), protective cover (28), mainshaft lift control rack (29), inlet pipe for the first spray ring (30), inlet pipe for the second and third spray rings (31), third spray ring (32), second spray ring (33), spray holes of the third ring (34), spray holes of the second ring (35), first spray ring (36), spray holes of the first ring (37), pushpull rod (38), lower drain outlet of the bucket (39), water collector (40), bucket overflow port (41), “downpush inplace” switch for the rice valve (42), controlmotor main shaft (43), “uppull inplace” switch for the rice valve (44), upper drain outlet of the bucket (45), outer waterblocking ring of the drain channel (46), annular drain channel (47), and annular washer (48). The height of the bucket’s overflow port is lower than that of the outer waterblocking ring.

When a washing command is received, the unit operates as follows:

2.2.1. Automatic water addition and rice loading

Upon receiving the command, a geared motor rotates the lift cam clockwise to drive the pushpull rod upward; as it rises, the rice valve is pulled up. When the cam edge triggers the “uppull inplace” switch, lifting stops, and the rice outlet is closed. The MCU energizes the watervolume relay to open the watervolume solenoid; water passes the flow sensor and is sprayed into the bucket via the second and third spray rings. When the preset volume is reached, the solenoid is deenergized to stop inflow. To prevent adhesion to the bucket wall, water is added before rice so the grains enter water and are wetted and loosened. After the first water addition, the storage/dispensing unit adds rice according to the set quantity.

2.2.2. Automatic washing and removal of floaters

After rice loading, the MCU energizes the washing solenoid; water entering the annular washer moves upward in a helical direction, washing the rice in 3D. When the level reaches the bucketlevel sensor, spraying stops to avoid overflow. Rice settles while floaters remain on the surface. The MCU then opens the floaterremoval solenoid; water from the first spray ring is sprayed downward 360° around the pushpull rod, raising the water level. When it exceeds the overflow port, the flow carries floaters into the annular drain channel. Because this channel is circumferentially sloped and equipped with an overflow sensor at the

discharge end, once overflow is detected, the MCU delays around 5 s, then closes the solenoid and stops inflow. Next, the drain pump empties the bucket, completing the first wash. The second wash repeats the spraying until the level sensor is reached, then drains again. The unit then proceeds to water dosing and rice discharge^[4].

2.2.3. Automatic water dosing and rice discharge

The flow sensor, containing a rotor/impeller and a Hall sensor, is in series with the inlet solenoid to measure throughflow. With the inlet energized (valve open), the impeller's magnet rotates at a speed proportional to flow; the Hall sensor outputs pulses counted by the control circuit to estimate volume^[5]. This method achieves high dosing accuracy, especially for small portions (e.g., 150 g rice with 250 mL water).

Typically, the ricetowater ratio is 1:1.2–1.4. Experiments show that, for small volumes, adhesion at the rice piston/outlet can occur. To avoid sticking and ensure smooth discharge into the cooker's inner pot, the MCU first doses twothirds of the required water to prewet the rice surface, then rapidly drives the rice valve downward while spraying the remaining onethird via the second and third spray rings: 360° onto the bucket's inner wall and downward along the pushpull rod onto the top of the rice valve. This disperses the grains evenly into the inner pot without needing manual leveling and prevents adhesion.

2.2.4. Automatic selfcleaning

The MCU raises the pushpull rod to close the rice valve and enter cleaning. Water from the three bottom inlets rises in a swirling motion to flush the bucket, rice valve, and rod. When the level exceeds the overflow port and flows to the floater discharge, the overflow sensor signals the MCU, which delays around 5 s, then stops inflow and runs the drain pump to empty the bucket, completing cleaning. If the unit will be idle after cooking, the MCU lowers the pushpull rod to standby and opens the rice valve to ventilate and prevent odors.

2.3. Cooking mechanism

A cooking mechanism is arranged beneath the washing and dosing unit. After washing and dosing are completed, the riceandwater mixture is discharged into the robot's inner pot. The control circuit then starts the cooking program, putting the robot into the cooking state.

3. Control system design of the cooking robot

The cooking robot provides the following functions: automatic rice fetching, automatic water addition, automatic rice washing, automatic water dosing, automatic cooking, and remote monitoring/control via a mobile app. A block diagram of the control system is shown in **Figure 3**. The hardware consists of an STM32 core module, WiFi circuitry, ricequantity metering and control circuits, waterquantity metering and control circuits, drain control circuitry, washing control circuitry, cooking control circuitry, temperaturesensing circuitry, and a touchscreen display/input module^[6]. The core board adopts the STM32F103C8T6, featuring 64 K Flash, 20 K RAM, up to 72 MHz clock, 32 generalpurpose I/Os, and a 12bit synchronous ADC (two groups, ten channels). It carries an onboard 24C04 EEPROM and supports oneclick downloading via USBtserial, meeting the system requirements^[7]. During operation, the MCU receives commands for rice quantity and cooking mode via the touch screen or WiFi module; the LCDs display the rice quantity, cooking mode, and process information. The flow sensors, watervolume relay, and drain relay in the washing/

discharging/drainage mechanisms control washing water and drainage. After washing, the ricedischarging mechanism meters and sends rice into the cooker’s inner pot. Under the control of the cooking unit—using lid and bottom temperature sensors and the heating main control circuit—the robot performs automatic cooking.

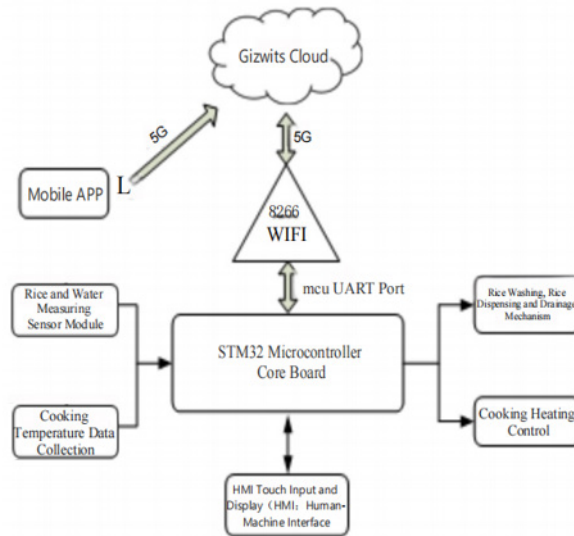


Figure 3. Block diagram of the cooking robot control system.

3.1. Mobile-app remote control and monitoring

For appbased control, the system uses an ESP8266 WiFi module in conjunction with the OneNET cloud platform [8]. Once the device is registered on OneNET, the robot connects via the WiFi module using the EDP protocol specified by OneNET: it composes a data packet and sends a connection request to the cloud. Upon success, the platform shows the device as online, and the mobile client can query the device status by calling methods from the OneNET API with the corresponding device ID. Since the robot is programmed to send a connectionrequest packet at powerup, the app indicates online whenever the device is powered; if power is lost, it shows offline. Only when the device is online are the app’s full functions enabled [9].

During cooking, the app can monitor parameters in real time: lid (top) temperature, bottom temperature, relay actuation states, and the stages of the cooking process, such as preheating, water absorption, heating, boiling, simmering, and keepwarm.

3.2. Touch-screen HMI functions

For human–machine interaction, a serial HMI touch screen is used [10,11]. The HMI display module communicates with the STM32 MCU via UART. The display interface is created with PCside configuration software, while the MCU only needs to exchange commands over the serial link to display the robot’s operating status in real time and to handle ricedischarge/cooking control, status display, and alerts. The touchscreen interface supports: ricequantity display, ricequantity categories, cookingprocess display, time display, and parameter adjustment.

4. Workflow of the cooking robot

When cooking is needed, the user can control the system remotely via the mobile app or operate it through the robot’s touch screen. After setting the rice quantity and issuing the command, the robot starts operating according to the workflow shown in **Figure 4**.

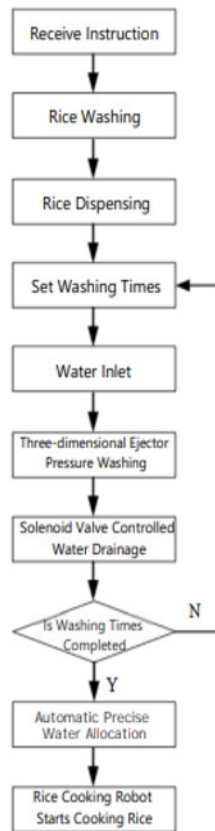


Figure 4. System workflow diagram.

5. System testing

After system debugging, tests were conducted on rice quantity, waterdosing volume, and ricewashing time. Method: start the washing process; use a stopwatch to record the time from the start to completion (as described); open the lid and pour the water from the inner pot into a measuring cup; record the values. The results are shown in **Table 1**.

Table 1. Tests of rice mass, water volume, and washing time

| Rice mass (g) | Measured water (mL) | Designed water (mL) | Washing time (min) |
|---------------|---------------------|---------------------|--------------------|
| 150 | 245 | 250 | 3 |
| 300 | 415 | 400 | 6 |
| 450 | 525 | 550 | 9 |
| 600 | 715 | 700 | 12 |
| 750 | 850 | 850 | 15 |

6. Conclusion

Future household kitchen appliances should evolve toward greater intelligence, ease of use, style, and energy efficiency. Given its smart, energysaving, and ecofriendly characteristics, the ricecooking robot is destined to become a promising direction. Based on the design and experiments, this paper proposes a structural and controlsystem scheme that implements water storage, rice storage, automatic rice discharge, automatic rice washing, automatic water addition, automatic water dosing, and automatic cooking. Leveraging IoT technology enables interaction among the smartphone, the cloud, and the robot. With a userfriendly interface, it provides heating curves and selectable taste/texture options, and also allows remote cooking control and parameter tuning via the app, as well as realtime monitoring of bottom/lid temperatures and cooking time during the cooking stages, thereby enhancing the robot's intelligence.

Disclosure statement

The authors declare no conflict of interest.

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