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A novel automatic cooking robot for Chinese dishes

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SUMMARY
Up to now, most people are still cooking in the kitchen, which makes them feel fatigued and also makes the air polluted. With the development of the numerical control technology, it becomes more and more urgent to apply the related technology to the automatic cooking field. In this paper, the cooking technique for the Chinese dishes is introduced and China's first cooking robot, named AI Cooking Robot (AIC), is presented. The robot mainly consists of four parts: the wok mechanism, the stirring-fry and dispersing mechanism, the feeding mechanism, and the mechanism of leaving the material in the middle process. In order to adjust the temperature, the fire control system is also given in this paper. Experiments show that the new robot will be a milestone in the cooking automation science because of its cooking technique.

KEYWORDS: Automatic cooking robot; Cooking Principle; Chinese dishes.

1. Introduction

Chinese cooking technique is the most complicated of the three cuisine systems in the world (Chinese cuisine, French cuisine and Turkish cuisine). The cooking equipments available now can only make simple cooking processes such as heating with the microwave oven, baking with the roaster, boiling with an electric kettle and broiling with the frying pan. They cannot complete the core part of the Chinese cooking processes such as pan-frying, stir-frying, burst-frying, quick-frying and re-frying without the related automated operations.

Chinese dishes are very famous,[1] but their cuisine makes cooks tired. During the traditional cooking process, cooks often work hard in the hot kitchen.[2] In this case, it is not surprising that the taste of most of the dishes are not as good as desired. Furthermore, the high pressure of the modern life makes people spend less time in cooking, as the Chinese cooking is complicated. So, it is urgent matter to design a robot for cooking, which can take the place of people in the kitchen.[3–6]

The automatic cooking robot for Chinese dishes is a new robot with the following functions:

1. It can put the raw materials into the wok automatically.
2. It can make the food in the wok heated evenly.
3. It can finish the basic Chinese cooking technique.
4. It can clean itself.

It should also be easy to be operated by people, and the dishes that are cooked by the automatic cooking robot should be delicious. The Chinese cuisine has its own features, and understanding the principle of Chinese cuisine is necessary for the design of the automatic cooking robot. This paper is organised as follows: in Section 2, the essential Cuisine principle of Chinese foods is introduced; in Section 3, the system of the Chinese foods cooking robot AIC is introduced; in Section 4, the experiments are introduced.

2. The Essential Cuisine Principle of Chinese Foods

The cooking method of Chinese foods is different from that of western foods. According to different cooking process, Chinese foods can be divided into five types. The cooking steps of each type are showed in Table 1.

As shown in Table 1, we divide the actions of cooking the Chinese foods into five parts: add the oil, add ingredients, pan-fry and stir-fry, stir, and pour the oil or water. As the pan-fry, stir-fry and stir are all achieved by the pancake turner. For the cooking robot is impossible to achieve different action by using different mechanism such that mechanism will be extremely complicated. By synthesizing the characteristics of various actions, we can divide the process of cooking into four parts: feeding module, the module of leaving the material out in the middle process, cooking module and fire-controlling module. Each module can achieve some special functions. Table 2 shows the functions of each module.

The materials of the dishes are arranged according to the traditional Chinese technique, and the motion information every dishes are produced by Chinese cuisine experts using the robotic method of "teach-in and playback". Based on the essential cuisine principle of Chinese foods, we can design a new cooking robot system for Chinese foods.

3. The System of the Chinese Foods Cooking Robot AIC

3.1. The essential mechanisms of the system

The cook is playing the primary role in the cooking process that is finished by manual work. He can decide when to add the ingredients, how much to add and how to operate

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Table 1. The steps of cooking for Chinese foods.

No.	Type	The steps of cooking
1	Stir-fry dishes series	Add the oil, add the major ingredients, add seasoning, pan-fry and stir-fry, add water and starch, stir, serve and finish
2	Braise and stew dishes series	Add the oil, add the major ingredients, turn and stir-fry, add water, add seasoning, shakes the wok, serve and finish
3	Pan-fry and deep-fry dishes series	Add the oil, add the major ingredients, shovel the ingredients, add seasoning, pour the oil, serve and finish
4	Saute dishes series	Add the oil, add the major ingredients, turn the ingredients, add seasoning, pour oil, add seasoning juice, add water and ingredients, add the ingredients, stir, serve and finish
5	Soup series	Add stock, add the major ingredients, add seasoning, take away the spume, add water and starch, drench the oil, serve and finish

in order to make the food taste better. However, the robot is limited in flexibility as it is impossible to imitate people in cooking completely. It must coordinate various movements of mechanisms in order to fulfil the requirement of manual cooking.

As shown in Table 2, the structure of the Chinese cooking robot AIC consists of four essential parts: feeding mechanism, the mechanism of leaving the material out in the middle process, wok movement mechanism and stirring-fry and dispersing mechanism. The cooperation of these four parts can fulfil the movement showed in Table 2. In other words, the feeding mechanism can put the right ingredients into the wok accurately. The wok movement mechanism

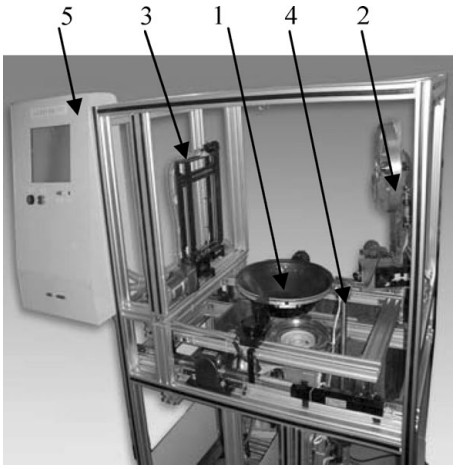

Fig. 1. The structure of Chinese foods automatic cooking robot AIC. 1—The wok mechanism, 2—stirring-fry and dispersing mechanism, 3—The feeding mechanism, 4—the mechanism of leaving the material out in the middle process, 5—The control system.

and stirring-fry and dispersing mechanism can accomplish nearly all the cooking methods, and can drain the oil with the mechanism of leaving the material in the middle process. The stirring-fry and dispersing mechanism is propitious to the cooking of soup. In the mean time, the automatic cleaning mechanism will be designed into the stirring-fry and dispersing mechanism. The fire-control system is closely related to the wok movement mechanism, the fire-control should be performed in the whole cooking process.

The whole structure of this robot is shown in Fig. 1, the overall size is: 1000 mm (length) × 600 mm (width) × 1500 mm (height). Let's analyse the mechanism and the function in the following sections.

3.1.1. Wok movement mechanism. The wok movement mechanism is the core mechanism of the automatic cooking robot. The wok is shook and leaned by hand, when this work

Table 2. The main functions for different modules.

No.	Module	Function	
1	Feeding module	Add the ingredients into the wok accurately	
2	The module of leaving the material out in the middle process	1) Pour	Get the ingredients out of the wok completely
		2) Drain the oil	Extract water and oil from the ingredients that treated after drained by oil.
		3) Back to the wok	After the ingredients been drained of oil, they will be put back to the wok
3	Cooking module	1) Even stirring	Mix the ingredients and heat them evenly
		2) Stir-fry and disperse	Separate the ingredients immediately and heat evenly.
		3) Gathers together	Gather the ingredients into the bottom of the wok
		4) Turn another side	invert the ingredients completely (Heating surface and relative non-heating surface inversion)
		5) Guards against sticks	Prevent the conglutination of the ingredients with the wok in order to avoid burning
		6) Crack	Crack the ingredients conglomerated by heating into pieces (separate)
		7) Drench	Let the stock cover or soak the ingredients
4	Fire-control module	Control the switch of cooking range and the size of fire	

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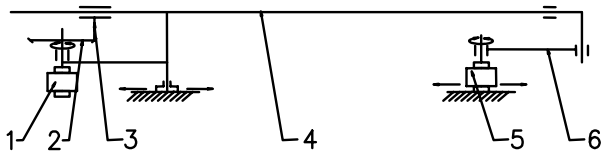

Fig. 2. The principle of the wok mechanism. 1—motor1, 2—conic-gear1, 3—conic-gear2, 4—rocker, 5—motor2, 6—rank.

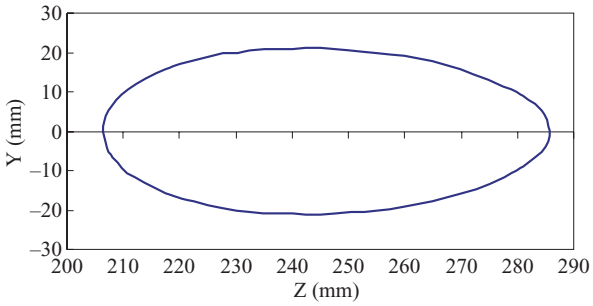

Fig. 3. The curve of wok-center position.

is finished manually. So the design of the wok movement mechanism is the key for the robot. The functions are shown in the following:

1. Heat the ingredients evenly.
2. Cooperate with the stir-fry and dispersing mechanism.
3. Cooperate with the mechanism of leaving material out in the middle process.
4. Make the agglomerate ingredients in the wok turn over fully or partly.
5. Pour the used oil or water into the oil tank or waste trough.

Figure 2 shows the schematic diagram of the wok movement mechanism, which can achieve three different movements: level moving, shaking and turning. These movements can implement the actions bellow:

1. Level moving can move the wok center along the curve in Fig. 3. In different positions, the wok can cooperate with others to add ingredients and put the material out in the middle process.
2. Shaking the wok is the basic movement of Chinese cuisine, which can make the food heated evenly, and also can fully turn over the agglomerate ingredients in the wok by changing the velocity and acceleration. The velocity of shaking the wok should not be too fast as the ingredients may be thrown out.

Given the velocity of shaking, $\omega = 150$ r/min, then the acceleration of the center point in wok is

$$\vec{\alpha}_C = \vec{\alpha}_B + \vec{\alpha}_{C/B} \tag{1}$$

$$\vec{\alpha}_B = \vec{\alpha}_B^{\tau} + \vec{\alpha}_B^{n} \tag{2}$$

where $\vec{\alpha}_B^{\tau} = 0$ and $\vec{\alpha}_B^{n} = \omega^2 r$. Substituting the rotational velocity and acceleration of the wok mechanism given in Eq. (2) into Eq. (1) yields the accelerations of the wok-center showed in Fig. 4.

As the shifting of velocity and turning of the ingredients depend on the friction of the surface of the wok, it is

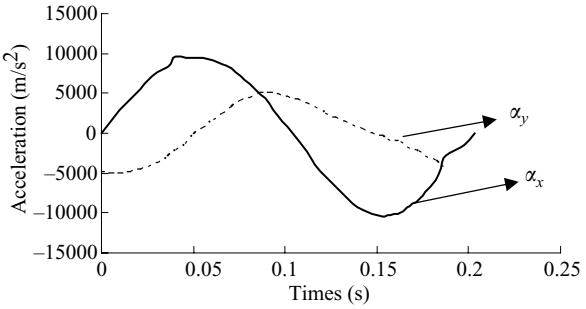

Fig. 4. The accelerations of the wok-center.

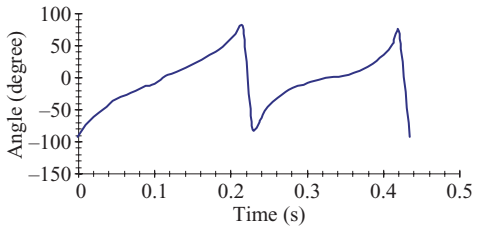

Fig. 5. The angle of acceleration.

necessary to analyse the direction of the acceleration of the wok. Figure 4 shows the accelerations of the wok in the x and y directions. Therefore, we can obtain θ, the angle of acceleration of point c with the direction x.

$$\tan(\theta) = \frac{\alpha_y}{\alpha_x} \tag{3}$$

The angle curve of acceleration in the direction x is shown in Fig. 5. It is noted that the wok will make shift of velocity and rotation movement even though the shaking makes uniform motion. Moreover, there is always a time when the acceleration changes most greatly in one period of motion. At that moment, the force applied to the ingredients is the biggest, and the state of motion change is also the most obvious.

3. Turning movement not only can throw the oil or waste water out of the wok, but also can help to pour and accelerate the turning of the ingredients by the mechanism of leaving the material in the middle process in order to heat the ingredients evenly.

3.1.2. The stirring-fry and dispersing mechanism. This mechanism plays the important role in the process of cooking Chinese foods. It is composed of comb-shaped stirrer used for stirring-fry and dispersing and the cover is used for gathering together (see Fig. 6). In order to simplify the entire mechanism, we should install the nozzles inside the cover to achieve the function of cleaning.

1. To save water, six small nozzles are separately installed in the cover of the wok in different positions such that the wok can be cleaned with less water.
2. The function of stirring is to make the sticky ingredients heated evenly, so that it prevents the phenomenon of dishes sticking to the wok.

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Fig. 6. The 3D drawing of the cover mechanism.

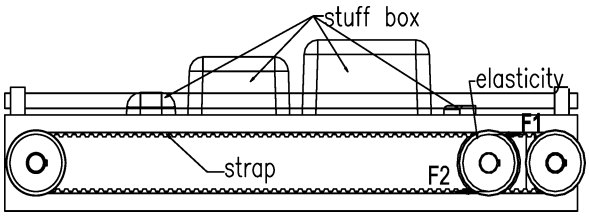

Fig. 7. The structure of feeding mechanism.

3.1.3. The feeding mechanism. For automatic cooking robot, there will be a standard menu in which the kinds and rates of ingredients have been determined. So this mechanism just needs to send the various ingredients into the wok accurately at the pre-arranged time. According to the steps of cooking in Table 1, we can divide the feeding box into four parts for keeping oil, major ingredients, minor ingredients and seasoning separately in each parts, and then sealing them with the film.

Figure 7 shows the structure of the feeding mechanism: Front of the film sealed in the box is clamped in the elastic axis. When the driving wheel rotates clockwise, force F1 and F2 will make the elastic axis rotate clockwise and move parallel in x direction, thus, tearing out the film such that the ingredients will drop into the wok that has already been moved accurately under it. So the function of feeding ingredients is automatically achieved.

3.1.4. The mechanism of leaving the material in the middle process. This mechanism will cooperate with the wok movement mechanism to achieve the following motions when deep-frying the food: pouring out of the wok, draining the oil and baking the wok. This mechanism needs two motions: moving up and down and turning over. Figure 8 shows the working processes, taking the fried meatball as an example. This mechanism is called as leaving mechanism for short in Fig. 8.

3.2. The control system of automatic cooking robot

As a household appliance, the automatic cooking robot should be convenient and reliable. So, when we design the software of the robot, we use the method of modularization and object-oriented processing. It mainly includes monitor module, movement module, fire-control module and the human–robot interface (HMI). As the former two parts need

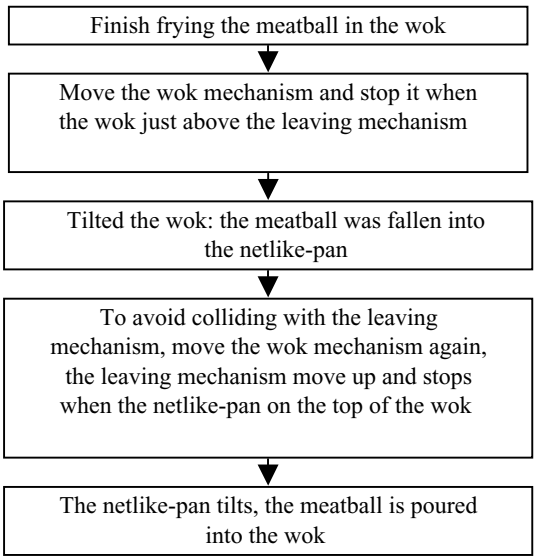

Fig. 8. The process of leaving the material.

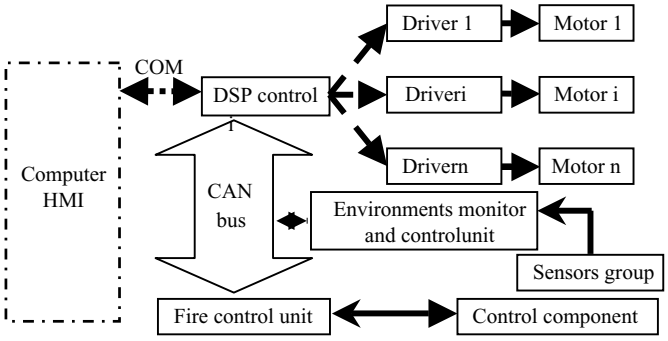

Fig. 9. The control system frame.

to exchange information, we adopted the controller area network (CAN) bus communication module to ensure the stability and reliability.

Figure 9 shows the control system diagram of the automatic cooking robot. The monitor module is an important part of the automatic cooking robot. This module includes the functions as follows:

1. Identify the bar coded of box semi-manufactured ingredients produced by vegetable preparing center to affirm the name of the dish to be cooked.
2. Environment monitoring (the temperature, the density of CO in air and so on).

To realize the three-dimensional (3D) real-time display of the working condition, we use C++ programming language calling 3D OpenGL API library functions, combined with the interface functions on the teach-in instrument, synchronously displaying the status of each part of the robot in real time.

3.3. The fire control system

The fire control is the key and also the difficult point for automatic cooking robot to imitate the real cooking methods. It aims at achieving intelligent step-less nonlinear control of

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the cooking power according to different dishes and flow rate of flammable gases in different area.

The fire control unit consists of the micro-processor controlling part, the action performing part, the temperature closed-loop part and the safety monitoring part.

3.3.1. The micro-processor controlling. We use the micro-processor MC56F8322 deal with the signal processing, the temperature closed-loop control, safety monitoring and the control of different valves. These tasks require wide temperature adaptation and high operation speed. We can also run the corresponding real-time operation system to insure the accuracy, and consequently, implement multi-tasks parallel processing and promote the operation efficiency.

3.3.2. Action performing. The executing objects of the entire cooking-power auto-control system includes: cooking-power intensity valve control, security valve control and ignition coil control and so on.

Cooking-power intensity control is the key of the entire cooking-power controlling system. The flow rate can be regulated through mechanic or electric methods. Together with temperature and thermal-radiation real-time monitoring, the autonomous closed-loop feedback cooperative control can be achieved.

The security valve control is the important part for the cooking-power control, as the complete cooking-power control unit should achieve the gas appliances safety certification. So, when the cooking-power intensity controlling part cannot fully cut down the gas, the security valve, using relay or power device to perform reliable control should perform the shutdown action to insure the safety of the system.

As illustrated in the Fig. 10, the high voltage coil is controlled to discharge, igniting the flammable gases. By usual means, relay is used to control the charging of the battery and the discharging of the high voltage coil. As the high electromagnetic fields, generated by high voltage may interfere the stability of the storage and the processing device, reliable earthing or shielding can evade the affection of the electromagnetic field interference, and we can also get rid of changing batteries by using super capacitor to implement the ignition.

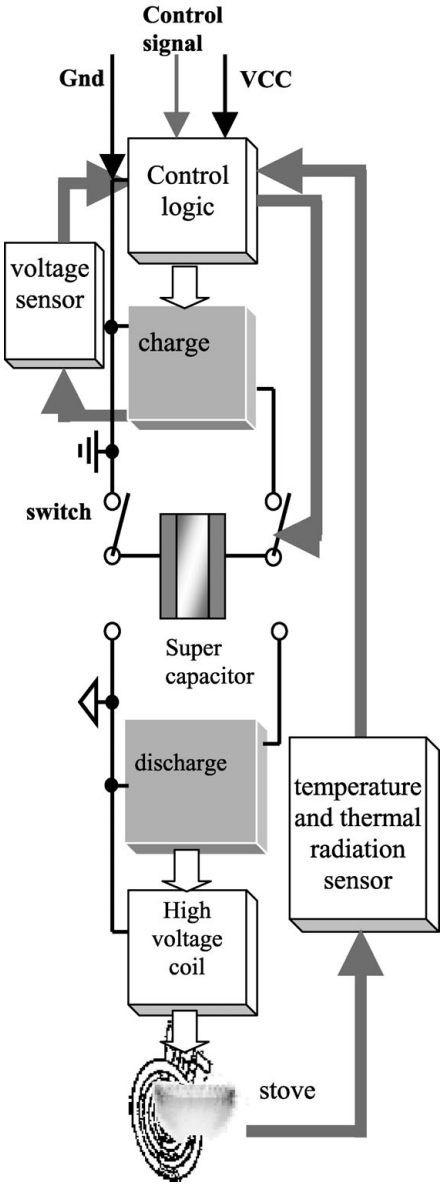

Fig. 10. The ignition control frame.

3.3.3. Temperature closed-loop. Temperature closed-loop control can be achieved by detecting temperature at fixed positions. Because wide temperature adaptation is required, we can choose the thermal radiation sensor and platinum resistance by means of difference amplifying and nonlinear revising to get reliable temperature measurement.

Temperature measured at fixed positions is not only a reference for the cooking-power control but also a feedback of the control effect. So, the key point is the determination of reliable measuring points. The temperature measuring can monitor the cooking power. With repeated linear fittings having been made and parameter compensated in formal simulation, we can make accurate calculation of the cooking-power intensity.

3.3.4. The safety monitoring. As it concerns the flow-rate control of flammable gases and gas appliances should reach the safety certification standards, the security of the system is especially important. CO concentration sensors are used for safety monitoring, and the flow rate of flammable gas is controlled by the security valve. Safety alarm can be made by the cooking-power intensity controlling system and the main controlling system, which require timely maintenance.

4. Experiments

China's first cooking robot (See Fig. 11), named AI Cooking Robot, has been successfully exhibited in 2006 Shenzhen High technology exhibition. In order to validate the function of the cooking robot, experiments are performed. By the automatic cooking of several kinds of dishes such as Shredded Pork with Garlic Sauce, Curry Pinion of Chicken, Bean Curd Home Style and Double Cooked Pork, the robot can cook delicious foods automatically and achieve the anticipated effect (see Fig. 12).

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Fig. 11. AIC robot.

Fig. 12. The dishes auto-cooked by the robot.

Table 3. The final score for the four typical Chinese dishes by Chinese cuisine experts.

No	Name	Colour	Scent	Sapor	Meaning	Shape	Nutrition
1	Shredded pork with garlic sauce	E	G	E	E	G	E
2	Curry pinion of chicken	G	E	E	E	G	E
3	Bean curd home style	E	G	E	E	G	E
4	Double cooked pork	E	E	E	E	G	E

E—excellent. G—good. F—fair.

Table 3 shows the final score for the four typical Chinese dishes by Chinese cuisine experts. We can see from above table, the score for the shape for these dishes is only G, because they are placed by the operator himself. Except for the score of the shape, others are almost excellent. Experimental results prove that the new automatic cooking robot for Chinese dishes is effective, stable and convenient.

5. Conclusion

Chinese cuisine is the most difficult cooking method in the world. At present, cooking labor is the main part in social activity. Based on Chinese cooking technique, a novel automatic cooking robot for Chinese dishes is developed in this paper. Though it looks like a huge refrigerator, it is a fully automated robot that may provide solutions for the Chinese fast food industry. The robot is able to cook Chinese food in different regional flavors, including that of Shandong, Jiangsu, Guangdong and Sichuan, which are famous for their spicy food and hot pot. We have translated standardized human cooking actions into machine language in this paper. By analyzing the system requirements, the function and characteristics of the robot, the paper designs the mechanisms of the robot as four parts: feeding mechanism, the mechanism of leaving the material in the middle process, wok movement mechanism and stirring-fry and dispersing mechanism. Experiments proved that the cooperation of these four parts can fulfil automatic cooking of most Chinese foods, especially the stir-fry dish series. Meanwhile, it also provides upgrading space for promoting the system. Experiment results show that the robot has already realized Chinese cooking techniques and achieved perfect effects in color, scent, sapor, meaning, shape and nutrition. Because the new cooking robot produce different dishes under the different digital files without any help from human beings, in the meantime of the cooking process, the efficiency of the cooking robot can be greatly improved.

Acknowledgements

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