Designing an Artificial Cooking Machine for Enhanced Cooking Experience

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Abstract: Eating plays a vital role in people's lives, but the demands of a fast-paced lifestyle often hinder individuals, especially the elderly, from cooking nutritious meals at home. To address this issue, an intelligent self-cooking robotic arm can be designed to automate the process of cutting vegetables and frying dishes, providing a convenient solution for individuals who are not present in the kitchen. This paper draws inspiration from existing cooking robots to propose a more advanced robotic arm capable of performing various cooking methods with increased efficiency and convenience. The design focuses on creating a mechanical product that caters to the needs of the modern population, aiming to enhance their cooking experience. The paper discusses the structural framework and internal system required for the development of this intelligent cooking robot.

1 INTRODUCTION

The impact of automation and robotics has significantly permeated the kitchen landscape as socio-economic factors, changing work patterns, and recent global events like the COVID-19 pandemic have driven the need for more efficient and contactless cooking solutions. As individuals grapple with balancing work-from-home arrangements and household chores, the demand for automated kitchen appliances, including cooking robots, has surged. The current market for cooking robots is varied, with brands offering models that range from basic cooking functions to more sophisticated units capable of replicating intricate culinary techniques. Brands like Moley Robotics, Nymble, and Thermomix are paving the way in this burgeoning industry. However, while these models offer a promise of convenience, they often come with limitations such as high price points, bulky sizes, and complex user interfaces (Singh et al 2021).

1.1 Basic Situations

The evolution of cooking robots can be traced back to rudimentary devices that performed simple tasks such as stirring and basic chopping. These initial versions of cooking robots were limited in their capabilities, primarily designed to automate routine tasks and reduce human effort in the kitchen (Garcia-Haro et al 2020). Their functions were often programmable but relied heavily on manual user input and had limited adaptability. Still, they represented the first steps toward the automation of cooking processes, providing a foundation for the more advanced models we see today.

Over time, the capabilities of cooking robots have expanded significantly due to advancements in technology and a better understanding of user needs and expectations. Today's cooking robots come equipped with advanced features such as ingredient recognition and programmed recipes (Pereira, Bozzato et al 2022). These robots are capable of performing more complex tasks, such as measuring ingredients, stirring at different speeds, and even following a pre-programmed recipe to create a dish from start to finish (Pereira, Pra et al 2022).

However, despite these advancements, contemporary cooking robots often encounter challenges when it comes to tasks requiring finer motor skills or judgment calls. For example, adjusting cooking times based on the size or amount of ingredients is a task that most current models struggle with. Similarly, tasks like finely chopping vegetables, carefully stirring delicate ingredients, or assessing when a dish is perfectly cooked, are still outside the reach of many cooking robots (Ramirez-Alpizar et al 2021). These areas highlight the limitations of current

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technology and provide a clear direction for further improvements.

Livinsa *et al.* made a significant contribution to the field of cooking automation with their proposed model of a cooking robot (Livinsa et al 2021). This model uses the Arduino Mega platform for complete automation, providing a high degree of control and programmability (Kusriyanto and Putra 2018). The robot is capable of performing a variety of kitchen tasks, including ingredient pumping, stirring, and cooking. By automating these tasks, the robot vastly reduces the time and effort required from the user, making the cooking process more efficient and less labor-intensive. This model represents a substantial leap forward in cooking automation. However, it's not without its shortcomings. Aspects such as the user interface could be improved to provide a more intuitive and user-friendly experience. Currently, users may find the interface complex and difficult to navigate, which can lead to frustration and a reluctance to utilize the robot's full capabilities. Furthermore, while the robot offers a degree of flexibility in cooking methods, there is scope for further enhancement. A wider range of programmable cooking techniques would allow the robot to cater to a broader array of cuisines and recipes, greatly increasing its versatility and appeal (Wang et al 2019). Finally, the integration of the robot with smart home systems represents another area for improvement. As smart homes become increasingly common, the ability to seamlessly integrate with other devices and systems in the home could greatly enhance the robot's functionality and user-friendliness (Wilson et al 2019).

In summary, while the Livinsa *et al.* model represents a significant advancement in the field of cooking robots, there is still considerable potential for further improvement and innovation. With ongoing research and development, future models will undoubtedly continue to push the boundaries of what is possible in cooking automation.

1.2 Future Opportunities

In the contemporary fast-paced society, the number of individuals engaged in office work or other demanding professional sectors has seen a steep rise. The hectic schedules and demanding lifestyle often leave these individuals with little or no time to engage in cooking. This scarcity of time, coupled with limited cooking skills in some instances, has led to an increased reliance on outside food. However, this dependence on commercially prepared meals is not without its health implications. Commercially prepared meals often contain high levels of salt, oil, and sugar, along with various food additives. The excessive intake of these substances can have adverse effects on health, placing undue strain on several vital body systems (Nadathur et al 2016). For instance, high salt content can contribute to hypertension and strain the cardiovascular system. Excessive oil, especially if it is saturated or trans fats, can lead to obesity and cardiovascular diseases. High sugar content can lead to insulin resistance and eventual diabetes. Moreover, various additives commonly used in commercial meals can affect the digestive system, leading to various intestinal issues.

Recognizing these health concerns and the need to overcome time constraints and limited cooking skills, the kitchen appliance industry has made significant strides. A variety of innovative appliances have been introduced to facilitate home cooking without requiring significant time or culinary expertise. For instance, multi-function cooking machines, as discussed by Livinsa *et al.*, have emerged as a popular solution (Livinsa et al 2021). These machines combine the functions of several kitchen appliances, capable of weighing, chopping, cooking, grinding, and stirring. This multi-functionality not only saves space in the kitchen but also simplifies the cooking process, making it more accessible to those who might be intimidated by traditional cooking methods.

Another promising development in this space is the advent of mobile cooking robots (Yamamoto et al 2019). These robots can perform a range of cooking tasks, significantly reducing the time and effort required for cooking. By automating the cooking process, these robots allow individuals to use their time more effectively, freeing them from the need to spend extended periods in the kitchen. Automated cooking robots represent a convenient and efficient solution for home cooking. By improving the quality of dishes and reducing the labor burden, these robots bring the joy of delicious, home-cooked meals to those with busy schedules. They offer a hassle-free cooking experience, allowing individuals to enjoy nutritious and personalized meals without having to compromise their health or their time. In essence, these innovations are bridging the gap between convenience and health, providing a viable alternative to the over-reliance on commercially prepared meals.

2 CLASSIFICATION AND SOLUTIONS FOR COOKING ROBOTS

2.1 Classification of Cooking Robots

In the realm of cooking automation, robots are primarily classified into two types: fully automated and semi-automatic cooking robots (Bock et al 2019).

Fully automated cooking robots, such as the Moley Robotic Kitchen, are designed to handle the entire cooking process independently, from prepping ingredients to cooking and even cleaning up. These robots are typically integrated into a kitchen set-up and include robotic arms, an oven, a stove, and other necessary appliances. They offer a luxurious, hands-off cooking experience ideal for individuals who prefer minimal involvement in the kitchen. However, their high cost and complex installation requirements limit their widespread adoption.

Semi-automatic cooking robots, on the other hand, like the Thermomix TM6, are compact countertop devices that can perform multiple cooking tasks. While they cannot operate entirely independently, they provide substantial aid in the kitchen, performing functions like chopping, stirring, and cooking. These robots are popular due to their affordability, ease of use, and versatility in cooking a wide range of dishes.

In terms of mixing methods, cooking robots can employ several techniques depending on the specific requirements of the dish. Active stirring is a common method used in robots designed for dishes that need uniform stirring, such as fried rice and stir-fried noodles. For example, the HomeCooker from Philips uses active stirring to ensure even cooking. Passive stirring, on the other hand, is a method often seen in appliances like the Tefal Actifry. It uses a stirring paddle that moves with the pan, somewhat like a washing machine. This method is advantageous for dishes that require specific mixing techniques, such as stir-frying seasonings or gently tossing ingredients without breaking them.

Other robots, like the June Oven, use a different approach altogether, employing convection heat and internal cameras to cook and monitor the food, eliminating the need for stirring. As the field of cooking automation continues to evolve, we can anticipate the emergence of more sophisticated mixing methods and cooking techniques, providing a richer and more convenient cooking experience.

2.2 Specific Solutions

Optimizing the rotation angle and angular speed of the cooking robots' arm or stirring mechanism is key to achieving efficient and effective cooking. This optimization can be approached through control theory principles and kinematic analysis. For example, the rotational motion of the robot arm can be described using the equation 1 (used in Figure 1):

$$\theta = \theta_0 + \omega_0 t + 0.5\alpha t^2 \qquad (1)$$

where θ is the rotation angle, θ_0 is the initial rotation angle, ω_0 is the initial angular speed, α is the angular acceleration, and t is the time. By adjusting the angular speed (ω_0) and the angular acceleration (α), the robot can adapt its rotation angle (θ) effectively to the required cooking task.

To identify and manipulate food items, a Simultaneous Localization and Mapping (SLAM) system can be employed (see Figure 2) (Stachniss et al 2016). This technology is often used in autonomous vehicles and drones for navigation. In the context of cooking robots, a SLAM system can perform object recognition, allowing the robot to identify different food items. The SLAM system uses a combination of sensors (like LiDAR or sonar) and cameras to create a map of the environment and track the robot's location within it. Machine learning algorithms can be trained on a dataset of food images to enable the robot to identify different ingredients.

However, the use of SLAM in cooking robots comes with its limitations. It requires a significant amount of processing power and a large, high-quality dataset for reliable food recognition. Lighting conditions and the appearance of food items can vary greatly, complicating the task of accurate identification. Additionally, the system may struggle with identifying and manipulating food items that have similar colors or shapes. As technology advances, these limitations can be mitigated through improved sensor technology, more powerful processors, and more sophisticated machine learning algorithms.

Figure 1: The models of smart cooking stir-fry machines on the market.

Figure 2: The sensors that used to identify food via taking photos and maps in real time.

2.3 Challenges and Safety Considerations

Despite the promise of convenience, cooking robots, like any other automated system, are not devoid of safety incidents. For example, in 2016, a Thermomix TM31 unit reportedly caused several burn incidents due to a faulty sealing ring that allowed hot food and steam to escape. Safety considerations in the design and operation of cooking robots are paramount to prevent such incidents. These safety measures can be broadly categorized into hardware safety features and algorithmic safety features.

Hardware safety features include design elements such as robust sealing systems, sturdy build quality, and safety locks (Anderson 2020). These features are designed to prevent physical accidents like burns, cuts, and spills. Additionally, overheat protection measures, such as temperature sensors and automatic shut-off features, can prevent overheating, a common issue in kitchen appliances.

Algorithmic safety features refer to the software-level safety measures implemented in the machine's operating system (Fernández et al 2021). One such feature could be a fall-back mechanism in the control system that stops the robot's operation if it detects an anomaly. This could be achieved using a watchdog timer, a common safety feature in embedded systems. If the system does not reset the watchdog timer within a certain period (indicating that it's operating correctly), the timer triggers a system reset or a safe shutdown.

Another algorithmic safety measure could be an emergency stop (E-Stop) feature, which allows the user or the system itself to halt operations immediately in case of a perceived risk. This could be a physical button on the robot or a command in the user interface. Algorithmic safety features would also include error detection and fault tolerance methods. For example, the robot could be programmed to recognize when a cooking pot is not correctly placed, preventing it from starting a cooking process that could lead to a spill or burn.

As cooking robots continue to evolve, the integration of advanced sensor technology and machine learning can significantly enhance safety. For instance, predictive analytics could be used to anticipate potential hazards and proactively address them, leading to safer and more reliable cooking experiences.

3 CONCLUSION

The proposed design of an advanced robotic arm for cooking automation differentiates itself from existing solutions by focusing on user-centric design, flexibility in cooking methods, and seamless integration with smart home systems. While current solutions offer a range of functionalities, they often fall short in terms of intuitive user interfaces and versatility in cooking techniques. The proposed design seeks to address these gaps, providing a more personalized and engaging cooking experience. By optimizing the rotation angle and angular speed of the robot arm, the system can adapt to a wide range of cooking techniques, allowing for more diverse and complex dishes. Additionally, the use of a SLAM system for ingredient recognition opens up possibilities for more intelligent and autonomous cooking processes.

Safety is a paramount concern in the proposed design. By incorporating both hardware and algorithmic safety measures, the system aims to provide a secure cooking environment that minimizes the risk of accidents. This focus on safety, combined with user-friendly design characteristics, sets the proposed solution apart from existing market offerings. The potential impact of this proposed solution is multifaceted. For users, it promises a more convenient and enjoyable cooking experience, with the added benefit of healthier, home-cooked meals. For the elderly or those with physical disabilities, the proposed design could provide invaluable assistance, making cooking more accessible. On the market level, this innovative approach could stimulate further advancements in the field of cooking automation, leading to products that are even more intelligent, versatile, and user-friendly. As consumer expectations evolve, there will be an increasing demand for solutions that not only automate cooking but also make it an engaging and personalized experience. The proposed design aims to meet this demand, paving the way for the next generation of cooking robots.

In conclusion, while there are challenges to overcome, the potential benefits of an advanced cooking robot as proposed in this paper are significant. With further research and development, we can move closer to a future where cooking is not a chore, but a seamless and enjoyable part of our daily lives.

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