AN ADAPTIVE SYSTEM TO MODERNIZE CULINARY PRACTICES USING SEMI-AUTOMATION AND REAL-TIME DATA MONITORING

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ABSTRACT

The culinary industry, a vital component of the global economy, is increasingly challenged by job shortages and a resistance to automation. This paper addresses the growing tension between modernizing culinary practices through automation and preserving traditional cooking methods. To bridge this gap, we propose Auto Cook, a semi-automation tool that seamlessly integrates with existing kitchen infrastructure, enhancing efficiency without compromising the human touch in cooking. Auto Cook combines mechanical components, computational controls, and real-time data monitoring, enabling users to automate routine tasks while retaining creative control. Key challenges, such as adapting to diverse stove models, ensuring safety in hazardous kitchen environments, and managing power constraints, were effectively addressed through modular design, material innovation, and optimized power management. Experimental tests evaluated Auto Cook's response to sudden temperature fluctuations, demonstrating its capability to stabilize conditions with minimal intervention. The results highlight Auto Cook as a practical, cost-effective solution for modernizing kitchens, making it an essential tool for culinary professionals and enthusiasts alike.

KEYWORDS

Culinary Automation, Semi-Automation Technology, Kitchen Efficiency, Traditional Cooking Integration

1. INTRODUCTION

With the global economy as unstable as ever, job shortages are becoming a norm of the modern economy. Specifically, the culinary industry faces great challenges in terms of staffing, affecting both individual business and the industry as a whole, with more then one third of restaurants clasing in California [1]. More specifically, the sectors offering critical culinary services to those in need were hit the hardest by these changes. Lack of funding, lack of manpower, and overall disruption has highlighted the vulnerability of the industry in the modern world, with more than 110,000 restaurants shut down by the end of the crisis [2]. The industry is one of the most crucial sectors in the modern world. However, in today's world of advancing technology, there is a resistance against adoption of robotic and automation techniques in an effort to preserve tradition and the humanity of cooking. The key issue here is the difficulty of embracing two very different sides of the culinary world. One attempting to modernize alongside the rest of the world with the use of automation and other techniques, while the other focusing on the traditional techniques and the reliance of human labor. Such a change is another result of the pandemic, as the consumer seeks more efficient options of meals [3]. Both sides are key, and in the long run, the problem of the industry will stem from clashes from these two sides. The automation industry has invested in the culinary sector, a market growing by 16.6 percent year by year [4]. However, the average

David C. Wyld et al. (Eds): DSCC, AI&FL, SESBC, CSE– 2024
pp. 39-48, 2024. - CS & IT - CSCP 2024 DOI: 10.5121/csit.2024.141604

price of these machines or upgrades can range from the thousands [5]. Therefore, restaurants and organizations often face the decision of installing costly upgrades in order to increase efficiency that sacrifice the human connection to the kitchen and face a disruption in their operations from the installation process of new equipment.

While the Culinary world faces the crisis of shortstaffing and a struggle to adapt to automation, anotherissues troubles our society, the rising homeless crisis and the subsequent demand for food supplies for this growing population. More than half a million people experience homelessness in America and half of these are in California, this number is only growing [6]. Homelessness is like a disease, the average life expectancy for the homeless is 50, 78 for the average American, a significant difference [7]. This is due to many reasons, but one the major factors is the lack of proper nutrition [8]. A lack of proper nutrition will not only be detrimental to a person's physical health, but their mental helath as well, for a person in an already desperate situation, proper nutrition can be greatly helpful. Despite a 10 billion effort to combat the growing issue by the california goveronemnt, the problems continues to grow [9]. Before the pandemic, insisituions attempting to fix this gaping issue, such as homeless shelters or food banks, were able to rely on donations and volunteers to fund their efforts, however as a result of the pandemic, volunteering is down by 23.1 percent and donations along with it [10].

The increase in homelessness and the decrease in volunteering, increases demand and limiting kitchens' abilities to meet the increasing demand. The main issue here is manpower, and existing automations solutions in the culinary world are expansive, costly and time consuming to operate and train, and also not space efficient. A Solution to tackle the lack of manpower, is automation that can be used on existing equipment, require little to no cost to install, easy to train with and utilize, and drastically increase efficiency. To attract back not only the workers, but also volunteers, the kitchens of the world must modernize, not only to revitalize a growing industry, but also a society in need. To modernize cooking, means not only to focus solely on efficiency, but also the human experience of the culinary arts and embrace that connection while introducing technology.

In regards to similar methodology compared, the 3 chosen projects represent different aspects of AutoCook and the research behind our overall approach. First, the "Smart Chef" project by Vidya Deshmukh focused on demonstrating the usage of mechanical automation in a culinary setting. Despite its ability to complete tasks assigned to it, its lack of ability to gather data and analyze said data to provide suggestions or take action itself leaves room for development. On the other hand, the data focused project of Bhabendu Kumar Mohanta and Debasish Jena provided an intriguing perspective on the usage of data in a culinary setting, through its analysis of kitchen data, the project was able to offer data on safety and efficiency in the kitchen. The lack of mechanical components in this particular project means the inability to implement changes based on the data gathered. Lastly, the project by Haryanto et al showed a focus on a combination of data gathering sensors and communication with kitchen equipment to control a culinary environment, although the focus of kitchen fire prevention is different from the goals of Auto Cook, the approach is remarkably similar. The difference lies in the implementation of the mechanical component, instead of relying on the user to react to the data, AutoCook's design focuses on the ability to react to situations such as changes in temperature, a significant improvement.

My approach to this problem involves adapting to the challenges set by the culinary environment through a process of Semi-Automation. Instead of traditional automation processes which completely replace the role of a chef, our approach combines the power of web3 and automation to adapt existing culinary infrastructure into the world of modern cooking. Instead of requiring costly and complicated upgrades of the existing system, which is not only not affordable, but also

disruptive to the operation of an organization or restaurant. Instead, our approach, named AutoCook, utilizes the most basic existing kitchen appliance, the stove, for automation. The application comes in 3 parts, one the mechanical component, which is used to operate the stove automatically, two the computation component, handling controlling the automation component and handling data inputs, third the data component, allowing the user to monitor the progress of their dish through temperature data. Using the custom built app, the user is able to harness all three components of the project. With all three components, AutoCook reduces the stress brought by a modern kitchen and reduces the time and energy that is required for each dish, allowing for increased productivity, efficiency, and safety. But using safe and noticeable materials, AutoCook prevents automation from becoming a hazard in the kitchen, and through built in mechanisms, allows the user seamless control over their kitchen. The role of AutoCook is to take on the tedious tasks of a kitchen such as checking the temperature of a dish or monitoring temperature, allowing the user more freedom and time to express their creativity and love in the kitchen. Through this approach, the user is able to reap the benefits of automation through efficiency and connection to the modern world without the replacement of the traditional kitchen setting.

In order to test the reaction of the AutoCook system to drastic changes in temperature from the addition of new ingredients to a dish. To accomplish this, a pot of water is initially heated to an initial setup of 100°C, then with Autocook device set up and initial measurements taken, simultaneously, a thermometer is setup in order to verify the data recorded in the app..Once the setup is completed, the experiment begins with cold ingredients in the form of ice cubes are added to the pot. Then, observations are made to see how AutoCook responded to the changes in temperature, in terms of temperature data. Here it was observed that an initial lag with temperature drops from 100°C to 70°C in the app and an thermometer recorded drop of 100°C to 69°C. Then, AutoCook begins the temperature recovery stage, after 5 minutes, the temperature rose from 70°C to 98°C in the app and 69°C to 97°C on the Thermometer, with 5 more minutes the temperature on the app reached 100°C, and 5 more minutes later the same result was displayed on the thermometer. The testing highlighted both the advantages and the shortcomings of AutoCook, while there was a period of lag as the ingredients were added, the advantage of AutoCook is the lack of human intervention needed during the temperature adjustment. The lag is likely due to the code, and the response time period set, which can produce a lag in response. The slight difference in temperature between the app and the thermometer can be explained by equipment differences and the sensitivity of the electronic thermometer. Overall however, the experiment fully demonstrated the abilities of AutoCook as an effective tool in the kitchen.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. A culinary space

A particular challenge faced in the design of this project centers around the conditions of a culinary space. Due to the nature of cooking and the ingredients of many dishes, any device that aims to automate culinary equipment would face an environment with potential of liquid contact and other hazardous conditions. Due to this a design would need to have a focus on the protection of critical infrastructure of the project along with ensuring that the device would not disturb the flow of a culinary environment. Following this design will require a careful selection of materials with characteristics such as water and heat resistance. The project will further also be designed to ensure the protection of critical electronics.

2.2. Adapt different models of stove tops

The operation and success of the prototype also depends on its ability to adapt to different models of stove tops. Each stove model features distinct dimensions and configurations, posing a difficulty for standardized automation solutions. Addressing this means that the design of the mechanical component would have to be flexible to the needs of different scenarios. Therefore, when designing the prototype, a modular approach could be taken, allowing for different configurations. A possible way to test multiple different components would be to utilize 3d printing technology to create the ability needed. To account for space limitations in different kitchen environments, the space taken up by the prototype must also be considered.

2.3. Providing Power to the Equipment

Lastly, the issue of providing power to the equipment must be considered. There are many ways to approach this problem, but once the aforementioned issues are taken into consideration, the issue of power storage and maintenance must be considered. For one, the power storage often takes up the most of the space and mass budget of the prototype and has to be the center of the design. Moreover, powering the device is also the most sensitive part of the prototype, faced with the hot and humid conditions of a kitchen, options such as batteries must be protected, which limited space means that any device that required to be plugged in would struggle to find space.

3. SOLUTION

The provided code snippet is part of a temperature control system for a stove, where it regulates the temperature by adjusting the stove's knob using a stepper motor. The DS18B20 temperature sensor continuously measures the stove's temperature, which is stored in the variable temperature. This value is periodically checked every temperatureTimeDelay interval. If the elapsed time, stored in timeSinceLastChange, reaches 300, the code resets the counter and verifies if the current temperature is within the desired range, defined by targetTemperature and temperatureRange. If the temperature deviates from this range, the system identifies whether it is too high or too low. Based on this, the stepper motor, controlled by kit.stepper1, adjusts the stove's knob. It moves 500 steps backward if the temperature is too low, thereby increasing the heat, or 500 steps forward if the temperature is too high, reducing the heat.

This device is connected to an app via Bluetooth, which allows real-time monitoring and control. The Bluetooth module on the device communicates with the app, sending the current temperature readings to be displayed on the user's smartphone. Additionally, the app enables users to set the target temperature. When the user inputs a new target temperature, this value is transmitted back to the stove's control system via Bluetooth, updating the targetTemperature variable. This integration ensures that users can effortlessly monitor and adjust the stove's temperature, maintaining precise control over their cooking environment. This system combines automated temperature regulation with user-friendly remote control, enhancing convenience and safety in the kitchen.

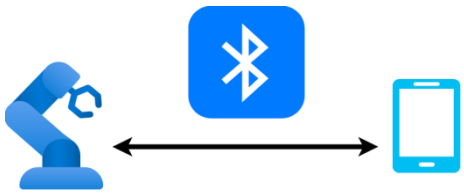


Figure 1. Overview of the solution

The device uses a DS18B20 sensor to monitor the stove's temperature and a stepper motor to adjust the stove's knob. When the temperature deviates from the set range, the motor moves the knob to increase or decrease the heat, maintaining the desired temperature.

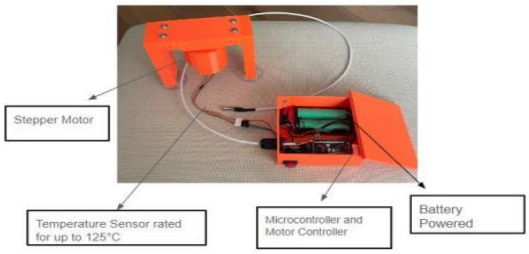


Figure 2. Component

```
temperature = ds18b20.temperature
timeSinceLastChange += temperatureTimeDelay
if(timeSinceLastChange == 300)
    timeSinceLastChange = 0
    if((temperature >= (targetTemperature + temperatureRange)) or (temperature <= (targetTemperature -temperatureRange))):
        print("not in range")
        if(temperature < targetTemperature):
            for i in range(500):
                kit.stepper1.onestep(direction=stepper.BACKWARD)
            print("moved")
        elif(temperature > targetTemperature):
            for i in range(500):
                kit.stepper1.onestep()
            print("moved")
```

Figure 3. Screenshot of code 1

This code monitors and adjusts the temperature using a stepper motor. First, it reads the current temperature from a DS18B20 sensor and increments a time Since Last Change variable by temperature Time Delay. When time Since Last Change reaches 300, it resets to 0. The code then checks if the temperature is within a specified range (target Temperature ± temperature Range). If the temperature is outside this range, it prints "not in range". If the temperature is below the target, it moves the stepper motor backward by 500 steps, indicating some action to increase the temperature, and prints "moved". If the temperature is above the target, it moves the stepper motor forward by 500 steps to decrease the temperature, also printing "moved". This ensures the system maintains the target temperature by making adjustments when deviations are detected.

The app sends temperature adjustment messages via Bluetooth by checking for a writable UART service. It converts the target temperature to bytes and writes these bytes to the Bluetooth characteristic, either increasing or decreasing the temperature, ensuring no concurrent operations with a bluetoothWriting flag.

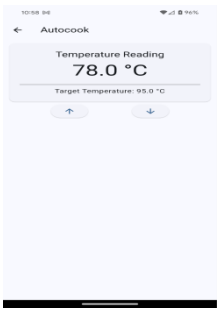


Figure 4. Screenshot of temperature page

```
void increaseTemperature() async{
if (bluetoothWriting){ return; }
bluetoothWriting = true;
if (uartService != null){
  print("uartService set");
  for(BluetoothCharacteristic c in uartService!.characteristics){
    if(c.properties.write){
      int temp = targetTemp.floor() + 1;
      List<int> bytes = integerToBytes(temp);
      print("sending $temp : $bytes");
      await c.write(bytes);
    }
  }
}
else{
  print("not uartService set");
}
bluetoothWriting = false;
}

void lowerTemperature() async{
bluetoothWriting = false;
print("bluetoothWriting $bluetoothWriting");
if (bluetoothWriting){ return; }
bluetoothWriting = true;
if (uartService != null){
  print("uartService set");
  for(BluetoothCharacteristic c in uartService!.characteristics){
    if(c.properties.write){
      int temp = targetTemp.floor() - 1;
      List<int> bytes = integerToBytes(temp);
      print("sending $temp : $bytes");
      await c.write(bytes);
    }
  }
}
else{
  print("not uartService set");
}
bluetoothWriting = false;
}
```

Figure 5. Screenshot of code 2

This code provides functions to increase and decrease the temperature via Bluetooth communication with a UART service. The increaseTemperature function first checks if bluetoothWriting is true, indicating an ongoing Bluetooth operation. If not, it sets bluetoothWriting to true and proceeds. If the uartService is available, it iterates through its characteristics to find one that supports writing. It then increments the targetTemp by one, converts this new temperature to bytes using integerToBytes, and sends these bytes via the characteristic. After writing, bluetoothWriting is reset to false. The lowerTemperature function works similarly but decreases the targetTemp by one instead. Both functions ensure that no simultaneous Bluetooth operations occur, preventing potential conflicts. They also provide debug prints to indicate the operations performed, including whether the uartService is set and the temperature being sent. This setup ensures controlled and sequential temperature adjustments through Bluetooth, maintaining communication integrity with the connected device.

To connect an app to the Bluetooth microcontroller using BLE, start by enabling Bluetooth and scanning for devices. Use a BLE library to discover and list available devices. Select the desired microcontroller, connect, and access its services and characteristics. Implement reading, writing, and notifications for communication.

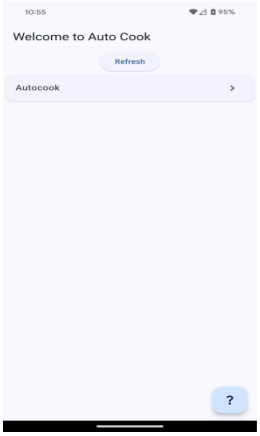


Figure 6. Screenshot of autocook page

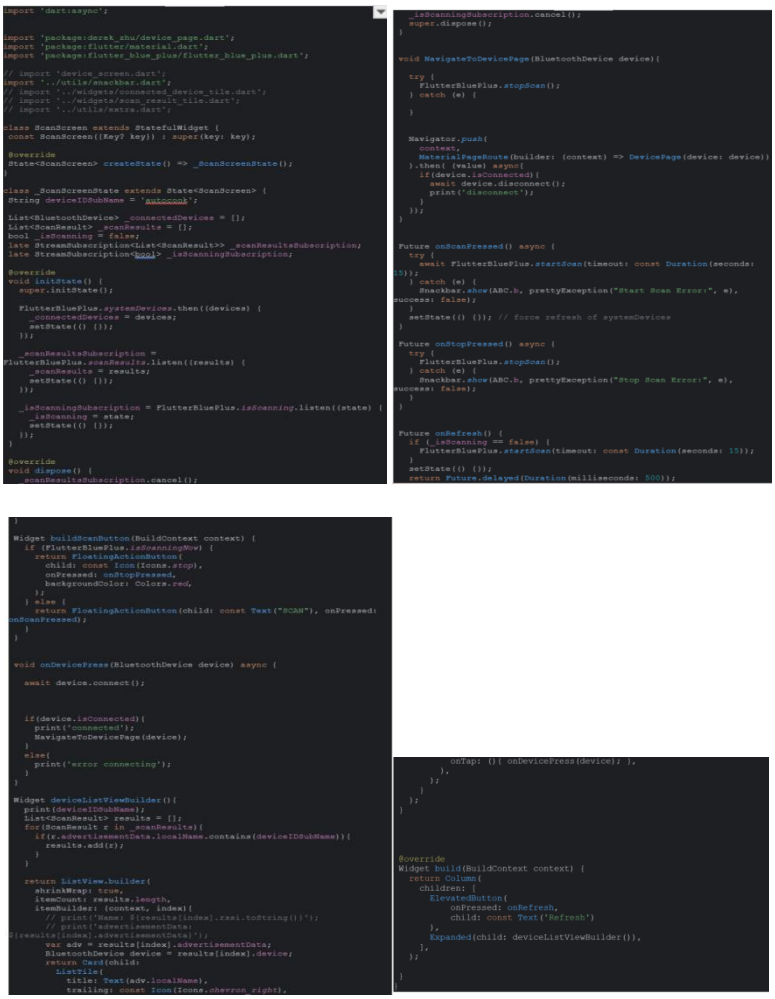


Figure 7. Screenshot of code 3

This code defines a Flutter widget for scanning and connecting to Bluetooth devices using the flutter_blue_plus package. The ScanScreen widget initiates Bluetooth scanning, displays available devices, and allows connection to a selected device.

In ScanScreen, the initState method initializes the scanning process by subscribing to scan results and scanning state streams. It also fetches currently connected devices. The _scanResultsSubscription listens for scan results, updating _scanResults and refreshing the UI. The _isScanningSubscription monitors the scanning state, updating _isScanning accordingly.
The NavigateToDevicePage method stops the scan and navigates to a new page (DevicePage) when a device is selected. If the device is still connected upon returning, it disconnects. The onScanPressed and onStopPressed methods start and stop the scanning process, respectively, handling any errors using a Snackbar.

The onRefresh method restarts scanning if it's not already in progress, and the buildScanButton method displays a button to start or stop scanning, depending on the current state. The onDevicePress method attempts to connect to a selected device, and upon successful connection, navigates to the device page.

The device List View Builder method filters scan results based on a substring (device ID SubName) in the device's local name, and builds a list view of these filtered devices. Each list item shows the device's name and a button to connect.

The build method constructs the UI, including a refresh button and the device list view. The code provides a comprehensive Bluetooth scanning and connection interface within a Flutter app.

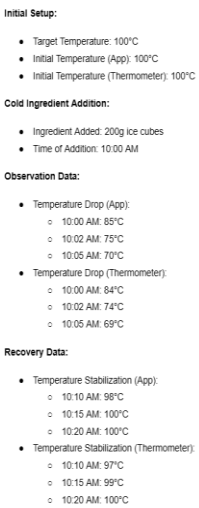
4. EXPERIMENT

A blind spot to test is the AutoCooker's response to sudden temperature drops, like when cold ingredients are added, to see how quickly and accurately it stabilizes the temperature.

Objective: To evaluate the AutoCooker's ability to stabilize temperature after a sudden drop caused by adding cold ingredients.
Procedure:

1. Initial Setup: Heat water in the AutoCooker to a target temperature (e.g., 100°C).
2. Baseline Measurement: Record the temperature using the app and an independent thermometer.
3. Cold Ingredient Addition: Quickly add a cold ingredient (e.g., ice cubes) to the water.
4. Observation: Monitor the AutoCooker's response using the app and thermometer, noting the temperature drop and recovery time.
5. Recording: Document temperature changes and the time taken to return to the target temperature.

Data Analysis: Assess how effectively and quickly the AutoCooker compensates for the sudden temperature drop.



Initial Setup:

- Target Temperature: 100°C
- Initial Temperature (App): 100°C
- Initial Temperature (Thermometer): 100°C

Cold Ingredient Addition:

- Ingredient Added: 200g ice cubes
- Time of Addition: 10:00 AM

Observation Data:

- Temperature Drop (App):
  - 10:00 AM: 85°C
  - 10:02 AM: 75°C
  - 10:05 AM: 70°C
- Temperature Drop (Thermometer):
  - 10:00 AM: 84°C
  - 10:02 AM: 74°C
  - 10:05 AM: 69°C

Recovery Data:

- Temperature Stabilization (App):
  - 10:10 AM: 98°C
  - 10:15 AM: 100°C
  - 10:20 AM: 100°C
- Temperature Stabilization (Thermometer):
  - 10:10 AM: 97°C
  - 10:15 AM: 99°C
  - 10:20 AM: 100°C

Figure 8. Figure of experiment 1

The experiment assessed the AutoCooker's response to sudden temperature drops when cold ingredients were added. Initially, the device maintained the target temperature of 100°C, as indicated by both the app and the independent thermometer. Upon adding 200g of ice cubes at 10:00 AM, a significant temperature drop occurred, with the app recording a decrease to 70°C and the thermometer to 69°C within three minutes. This drop indicates the AutoCooker's initial lag in compensating for rapid changes.

Recovery analysis showed that the AutoCooker took approximately 10 minutes to stabilize the temperature, with the app reaching 98°C at 10:10 AM and 100°C by 10:15 AM. The thermometer readings were slightly lower but closely aligned, stabilizing at 100°C by 10:20 AM. The data suggests that while the AutoCooker effectively returns to the target temperature, there is a brief lag period where the device adjusts to sudden changes. Future improvements could focus on reducing this response time to enhance cooking accuracy.

5. RELATED WORK

In a similar project by Vidya Deshmukh, called 'Smart Chef" the robotic arm was used to cook certain foods [11]. The solution was able to follow recipes in the form of directions, but lacked the ability to exert its own judgment due to the fact it lacked any sensory input. However, the use of existing culinary equipment in the form of a stove and pan is similar to our approach. It however limited the human involvement in the process and lacked the ability to allow for control through a mobile platform, preventing it from accessing the advantages of Internet of Things technology, something we thought to improve with AutoCook. The space that the solution took up could also be an issue in the cramped kitchen environment, something AutoCook seeked to minimize.

Managing the kitchen environment through the management of collectable data is a matter investigated by Bhabendu Kumar Mohanta and Debasish Jena [12]. In their research, a clear path for how to collect data in a kitchen and use said data to manage both safety and efficiency was established. While offering the user data for monitoring purposes is an important aspect of our project, the difference stands in allowing the user to interact and control the system remotely. Through automation, the amount of control a user can exert on a system increases through the combination of data and action. AutoCook was able to leverage both aspects to combine for an elevated user experience.

Lastly, our focus for the development with a focus on a Internet of Things model in the kitchen is shared with a similar project by Haryanto et al [13]. The difference between the two projects is the end goal, while AutoCook is focused on the operation aspect of a kitchen, their project focuses on the utilization of gathered data in a kitchen for detection of fire and other incidents. This difference means that while Haryanto's project has less mechanical parts then AutoCook, it is able to rely on the information gathered through sensors to control the stove. However, in order for this application to operate, a "smart stove" is needed, as connection between servers and the stove is necessary for user control. AutoCook avoids this requirement by enabling any stove to be utilized in the AutoCook system, an improvement that allows for the adaptation of the technology without costly upgrades and equipment replacements.

6. CONCLUSIONS

The limitations of AutoCook mostly concerns its inability to operate and accomplish sophisticated dishes beyond changes in temperature. The lack of ability to interact with dishes beyond the temperature does limit the use cases of AutoCook to a certain degree in its current stage. As development continues, we aim to develop AutoCook from a culinary tool to a Culinary Assistant. Following this line of thinking, continued development will see improvements in both the data gathering and mechanical area. Expanding the ability of AutoCook to contribute in the kitchen while still following the original goal of offering affordable automation in kitchens would be challenging, but doable. Implementing the ability to stir for example will truly unlock a new dimension in the project, while implementing computer vision is a possible route to consider for further data gathering. Moreover, new materials are being tested for better performance over a

long period of time, and once implemented can elevate the project to another level. Moreover, other possible use cases can also be considered for the project, the need to limit food waste in the culinary world can present AutoCook was another task to consider [14]. Along with the effort to keep cost and space down, the effectiveness of the project over a long period of time may be affected. However, despite this, the use of 3d printing technology allows for quick replacement of parts [15].

Overall, the project provided a new approach to considering automation not only in culinary, but possible areas of exploration. Moreover, the approach of adapting automation to existing infrastructure can open many doors in terms of future development. Through more trials, the validity of this approach in other settings will be tested, opening many more possible venues and ideas to be explored and the potential to be unlocked to benefit society.

REFERENCES

[1] Brizek, Michael G., et al. "Independent restaurant operator perspectives in the wake of the COVID-19 pandemic." International Journal of Hospitality Management 93 (2021): 102766.
[2] Jacob, Rachel. "Visualising global pandemic: A content analysis of infographics on COVID-19." Journal of Content, Community and Communication 11.6 (2020): 116-123.
[3] Gaffar, Vanessa, et al. "Unfolding the impacts of a prolonged COVID-19 pandemic on the sustainability of culinary tourism: Some insights from micro and small street food vendors." Sustainability 14.1 (2022): 497.
[4] Berezina, Katerina, Olena Ciftci, and Cihan Cobanoglu. "Robots, artificial intelligence, and service automation in restaurants." Robots, artificial intelligence, and service automation in travel, tourism and hospitality. Emerald Publishing Limited, 2019. 185-219.
[5] Spence, Charles. "Robots in gastronomy: Psychological and financial considerations." International Journal of Gastronomy and Food Science 32 (2023): 100707.
[6] Cunningham, Mary. Preventing and ending homelessness: Next steps. Washington, DC: Urban Institute, 2009.
[7] Cunningham, Mary. Preventing and ending homelessness: Next steps. Washington, DC: Urban Institute, 2009.
[8] Swartz, Natalie, et al. "“Sick and tired of being sick and tired”: Exploring initiation of medications for opioid use disorder among people experiencing homelessness." Journal of Substance Abuse Treatment 138 (2022): 108752.
[9] Theroux, Mary LG, et al. "Beyond Homeless: Good Intentions, Bad Outcomes, Transformative Solutions." Independent Institute, November 10 (2021).
[10] Postigo, Hector. "Emerging sources of labor on the Internet: The case of America online volunteers." International review of social History 48.S11 (2003): 205-223.
[11] Deshmukh, Vidya, et al. "Smart Chef: Automated Cooking System with Robotic Arm." JOURNAL OF TECHNICAL EDUCATION: 195.
[12] Rao, Vidya, and K. V. Prema. "Internet-of-things based smart temperature monitoring system." 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT). IEEE, 2018.
[13] Anifah, L., et al. "Smart controlling system for kitchen fire protection based internet of things." IOP Conference Series: Materials Science and Engineering. Vol. 1125. No. 1. IOP Publishing, 2021.
[14] Spence, Charles. "Robots in gastronomy: Psychological and financial considerations." International Journal of Gastronomy and Food Science 32 (2023): 100707.
[15] Iftekar, Syed Fouzan, et al. "Advancements and limitations in 3D printing materials and technologies: a critical review." Polymers 15.11 (2023): 2519.