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Smart Fire Prevention Device

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Smart Building Device

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Abstract

House fire is mainly caused by stovetop of the kitchen. According to the research done by the NFPA, equipment unattended has become the leading factor in cooking fires and cooking fire casualties. The main idea of this project is to develop a prototype that can detect stovetop fire at the first place. To achieve the goal, the device uses temperature sensor to detect temperature on the stovetop and uses OpenMV camera to search human's faces to determine whether there are people attendant and operating the Stovetop or not, meanwhile a timer will start to count down once the OpenMV determine that there is no one attendants front of stove. After a certain time period with no one in the kitchen, the timer will send signal and trigger the alarm. The alarm will notify people to return to the kitchen and operate the cooktop, making sure situation is still under control.

Acknowledgements

We would like to thank Professor Jianyu Liang for her guidance in creating this project. Dr. Liang was crucial in leading the team both before, during, and after the project. Her, along with Professor Chen and students from Wuhan University of Technology and Tsing Hua University, made this project possible by provide us the rooms and technical support to develop our prototype in WUT. Also, Yanru Peng, David Cardoza, Yang Liu, Andrew Scheuller, and several other WUT students had contributing roles in the creation of the device. In addition, we would like to thank students from Beijing University of Chemical Technology for supporting my staying in Beijing, a city that I'm not familiar with and it is away from my hometown. Lastly, I would like to thank Mahdi Elhousni from WPI who help us to develop our first idea about this project and keep working on this project until this project is completed.

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Chapter 1: Introduction

According to the research conducted by the National Fire Protection Association (NFPA) in two thousand eleven through two thousand fifteen, compared to the other areas in the house, the kitchen, or cooking area, is the most dangerous place in the house in United States. Cooking equipment was one of the leading causes of 47% of house structure fires and home fire injuries, and the second leading cause of home fire deaths. Twenty percent of home fire deaths resulted from fires beginning with cooking equipment. After the number of home kitchen fires declined for couple years, reported home kitchen fires increased and reached the new high in 2012 to 2015. After 2016, the number of reported home fire dropped slightly but kitchen fire still takes a huge part of in domestic fire.

Additionally, unattended cooking was far leading factor among cooking fires and cooking fire casualties. Abandoned or discarded material, which also may be related to unattended cooking equipment, rank second in factor of home kitchen fire and third place in home kitchen fire deaths and injuries.

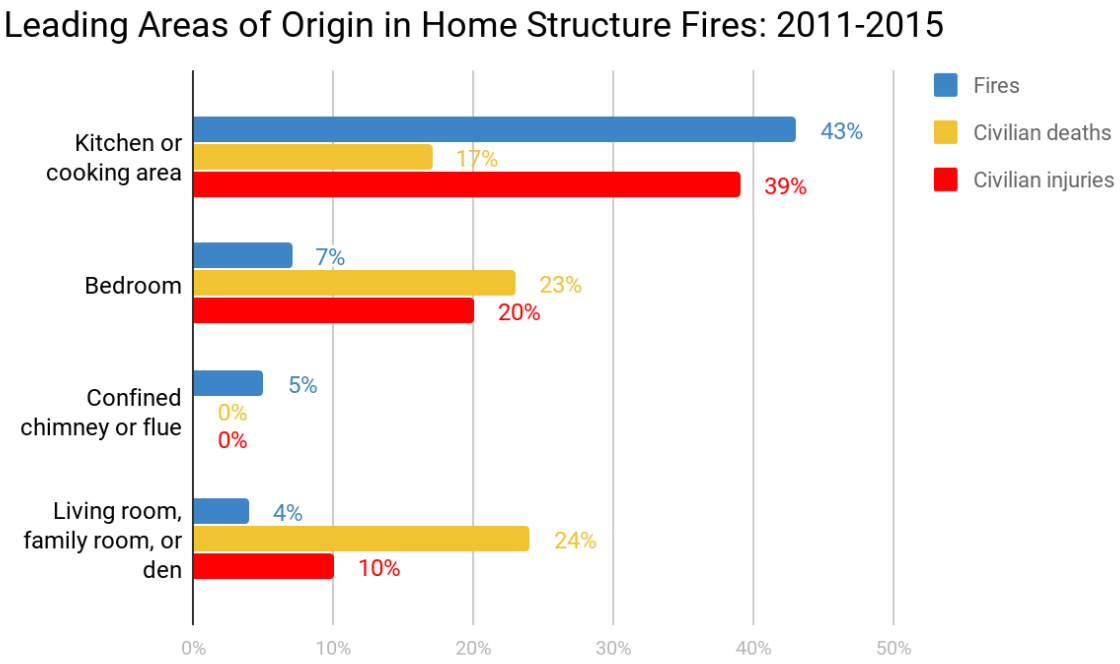

Figure 1 Leading Areas of Origin in Home Structure Fires: 2011-2015

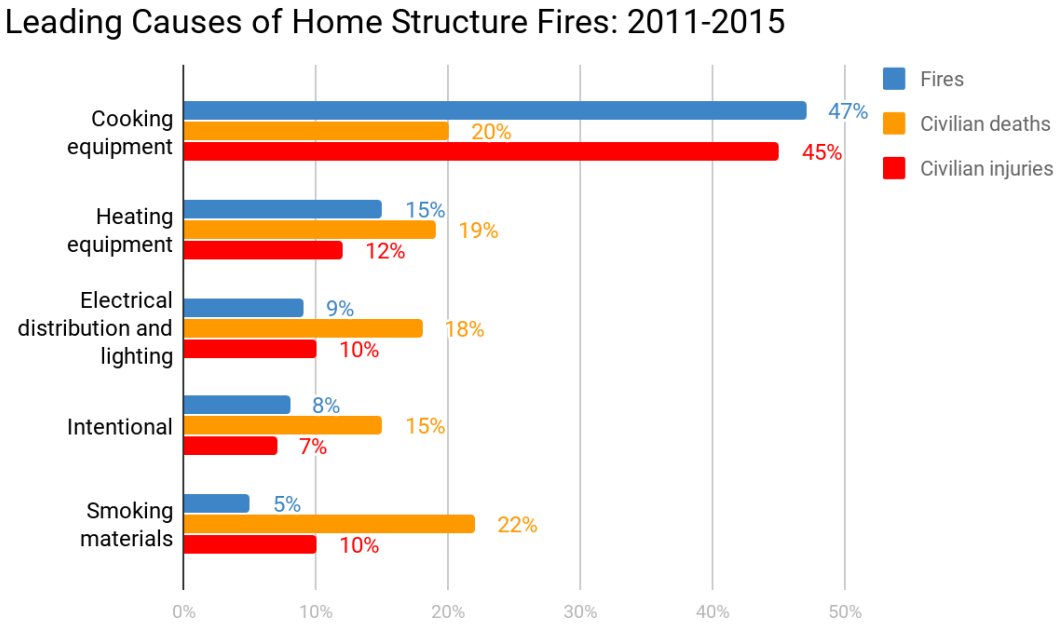

Figure 2 Leading Causes of Home Structure Fires: 2011-2015

Senior citizens face a higher risk of dying in a fire than do young people. This is mostly because people sometimes forget the stove is still operating. Although most families will equip at

least one smoke alarm, problems still exist like alarms not operating properly, or was not being present in the area. So, this project will focus on building a smart device that can help people especially old adults to detect fires. Because the situation in China is different from United States, this project will mainly focus on the kitchen in United States instead of China.

1.1Problem Statement

In this project, our device is primary to prevent the fire cause by the un-attendant kitchen which is the leading factor of national home fire. This problem is more relevant in nowadays technology with electric stovetops, which aim to operate without actual fire. So, the electric stovetop would be no visible light or sound during its operation. Due to all these statements mentioned, elderly person become easier to forget.

1.2 Main Object:

The main idea of this project is to develop a prototype that can detect stovetop fire at the first place. To achieve the goal the device uses temperature sensor to detect temperature on the stovetop and OpenMV camera to search human's face to determine whether there are people attendant and operating the Stovetop, meanwhile a timer will start to count down once the OpenMV determine that the stovetop is unattended. After a certain time period with no one in the kitchen, the timer will send signal and trigger the alarm. The alarm will notify people to return to the kitchen and operate the cooktop, make sure situation is still under control.

This project was accomplished by students from Worcester Polytechnic Institute and Wuhan University of Technology. This team of students chose the component and software to operate the prototype. This team includes two mechanical engineering major students and a robotics engineering major student from Worcester Polytechnic Institute, and an electrical computer engineering and a material science student from Wuhan University of Technology, with help from several computer science major students Wuhan University of Technology worked together to develop this prototype. Team members used their strengths in control theory, electronics, coding and electrical engineering with hard teamwork to achieve the goal of this project. The final prototype includes temperature reading, facial recognition, timer, and alarm to notify home occupants when the cooktop is operated without attendance for a long period.

The cooktop operation detection system is able to recognize whether the cooktop is being operated or not via an infrared temperature sensor. The temperature sensor would work functional

when the power is plugin. Once the temperature detected a high temperature around the cooktop, it would send a message to the facial recognition camera.

When the camera received the message, it would be turned on and search for human face in a certain region. An OpenMV7 camera/microcontroller selected to detect the human face in the kitchen area via OpenMV7 IDE software. This camera is placed in front of the cooktop, for its maximum visibility, to search human face movement. The OpenMV7 camera is connection with a timer in order to determine the time. The timer will automatically reset when there OpenMV7 camera detects there are human face appeared. After the countdown is over and Camera can't detect human movement in the kitchen, a message will send to the alarm and trigger the alarm.

If occupants of the house return to the kitchen and the camera has capture his/her face, the alarm will automatically shut down and the timer will reset as well. If the situation is already out of control when the occupants return to the kitchen and he/she is not able to return to the kitchen, he/she must not attempt to extinguish the fire himself/herself and instead, he/she should contact the emergency center (911) and the emergency center will be able to contact the local fire department.

1.3 Background Research

The idea of building a smart device is came from prior research done by a Worcester Polytechnic Institute Electrical Engineering graduate student Mahdi Elhousni. He was inspired by the background research and came out with the idea of building a fire prevention system. The MQP team worked on researching based on Mahdi Elhousni's idea and designed a prototype to prove this idea during the summer in 2018.

After meeting with Mahdi Elhousni and Professor Liang in WPI for couple times, the MQP team came out with an idea of building a smart pre-ignition device to prevent fire even before smoke was generated. According to the research, smoke is always considered as the first sign of fire. Based on the information was found, most of the house in United States are built by wood or other inflammable material, so it only takes a few minutes for the fire spread out. Once the fire is spread out, the situation would be out of control. Property damage, injuries or even death would be unavoidable. Therefore, this project aims to design a smart device to detect whether the kitchen is attended or not when the stovetop is operated. In this project, students aim to build a prototype

that focus on electric stovetop only, although it could also be used for other purposes based on the situations like oven, fryers, etc.

Although the temperature sensor used in this project has a small detection range, but it could always switch to a more accurate temperature sensor. The temperature sensor is used to detect a certain temperature range and communicate with the system board STM-F1 to read voltage changes. The system board STM-F1 will trigger the alarm when stovetop is left without human movement for a time period, which is to prevent the kitchen fire occurring.

Another idea that was considered during the design process was the connection with the smart phone through an application. Ideally, this phone application would be able to allow the house occupants to shut down the stovetop though the phone. However, this idea was not being able to accomplish since it required coding experiments which would be a huge challenge for mechanical engineering students.

Chapter 2 Literature and Background Research

2.1 Main Ideas:

The main idea of this project is to develop a prototype that can detect stovetop fire at the first place. To achieve the goal the device uses temperature sensor to detect temperature on the stovetop and OpenMV camera to search human's face to determine whether there are people attendant and operating the Stovetop, meanwhile a timer will start to count down once the OpenMV determine that the stovetop is unattended. After a certain time period with no one in the kitchen, the timer will send signal and trigger the alarm. The alarm will notify people to return to the kitchen and operate the cooktop to make sure situation is still under control.

2.2 Trends in Cooking Fires and Fire Deaths

According to the research done by National Fire Protection Association, after declining for couple years, reported home kitchen fires increase and hit the new high in 2012 to 2015. After 2016, number of reports dropped slightly.

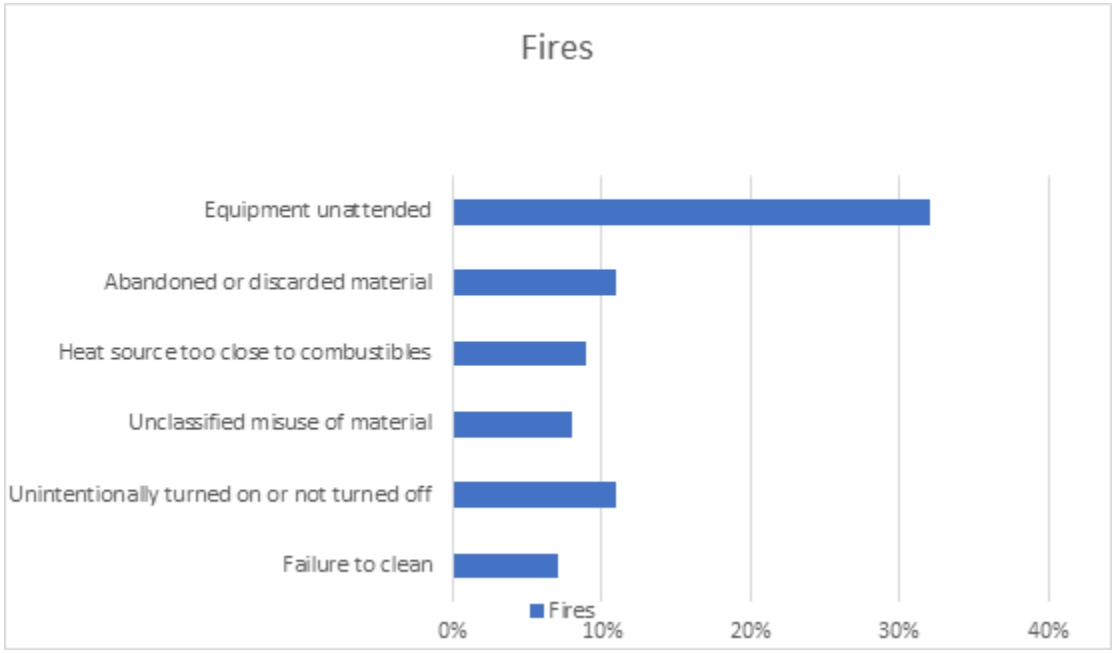

Figure 3 Leading Factors in Home Cooking Fires and Cooking Fire Deaths: 2012-2016

2. 3 Motion and Temperature Sensor

Motion detector is a device that moving object particularly human movement. Motion detector is often integrated as a component of a system with automatically function or alerts users in a certain area. It could almost be any types of camera even the laptop front camera with codes.

2.3.1 Photoelectric sensor

Photoelectric sensor is type of equipment that transfer light signal to electric. It detects object, changes in surface, and other items through a variety of optical properties. A Photoelectric sensor consists primarily of an emitter from emitting light and a receiver for receiving light. There are ways to use photoelectric sensor include: through-beam sensors, retro-reflective sensors and diffuse- reflective sensors.

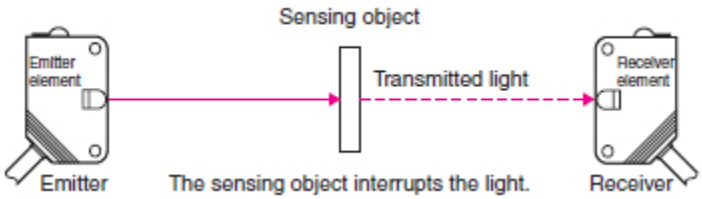

Figure 4 Through-beam Sensors

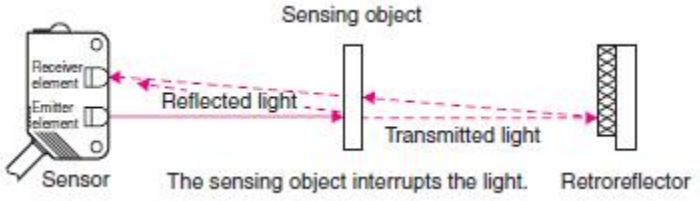

Figure 5 Retro-reflective Sensors

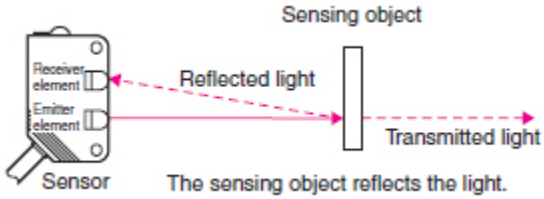

Figure 6 Diffuse-reflective Sensors

As a widely use sensor nowadays, photoelectric sensors have some unique features that other sensors can't replace which include: Long Sensing Distance, Virtually No Sensing Object Restrictions, Fast Response Time, High Resolution, Non-contact Sensing, Color Identification and Easy Adjustment. All these features mentioned above can be used to help the team to detect the attendance of the kitchen.

2.3.2 Facial recognition camera

Facial recognition camera is able to recognize, identify or verify a person. In this project, OpenMV7 is consider for the facial recognition system because the facial recognition program is already be written and tested by the merchant.

2.3.3 Temperature sensor

A temperature sensor is a device typically, a thermocouple or RTD, that provides for temperature measurement through an electrical signal. In this project, the temperature range for the temperature sensor that was used is -55 to +125

2.3.4 Infrared sensor

An infrared sensor is an electric instrument that is used to sense certain characteristics of its surrounding. It does this either emitting or detecting infrared radiation.

2.3.5 System board

A motherboard is the main printed circuit board found in general purpose computers and other expandable system. In this project, the MQP group considered to use STM-32 as the system board. STM-32 is one type of the 32-bit microcontroller integrated circuit by STMicroelectronics.

2.4.1 WallFlower Smart Monitor

Smart fire prevention devices are well developed nowdays. Smart devices developed by WallFlower is a good example using modern technologies to prevent stove fire. The idea of WallFlower smart monitor is to plug in the stove power cord into the monitor and then the monitor into the electric outlet. The system notifies users that the stove top is left operating without attendance though phone application. The device will notify users when users is 1000 feet away from the stovetop. The system also allows users to shut off the stove top through the phone application.

This device allows users to get notifications when hazardous activity is detected. Although unattendant cooktop is considered to be a main factor causing kitchen fire, unattended cooktop is not a potential safety hazard from time to time. For instance, soup cooking in Chinese cuisine sometimes take more than two to three hours or even longer time period to be finished. In this example, cooktop need to operate for a long period without attendant, but this activity is considered to be safe since temperature that required is low and water inside the soup pot can prevent cooktop fire to happen.

Based on our research, we found out that senior is facing a high risk in kitchen fire and most of the elderly people are not familiar with smart phone or might have difficulties using the smart phone application. So, we believed that it would be a better idea to develop a device that require less smart operating skill.

Figure 7 WallFlower Smart Monitor for electric stove

2.4.2 Automatic stove shut-off device

Another stove fire prevention smart device we found during the research is automatic stove shut-off device develop by FireAvert. This device has same functionality as WallFlower smart monitor as we mentioned. These two devices both used plug-in system to detect cooktop status. The only difference is that automatic stove shut-off device would unplug the power supply once the smoke alarm noise. When the FireAvert unit detects the cooktop is operating and the smoke sensor detected smoke in the kitchen, FireAvert will shut-off the cooktop by turning off the power supply. According to FireAvert, this product can help especially elderly people with Alzheimer issue to prevent kitchen fire.

The disadvantage of this product is that FireAvert cannot detect smoke or fire but have to depend on smoke alarm. Smoke alarm has a high percentage of mistrigger by the smoke that generated by oil and smoke alarm would sent the wrong signal to FireAvert. It is also possible that

smoke alarm might not be functional then FireAvert would fail to receive the signal and fail to notify users.

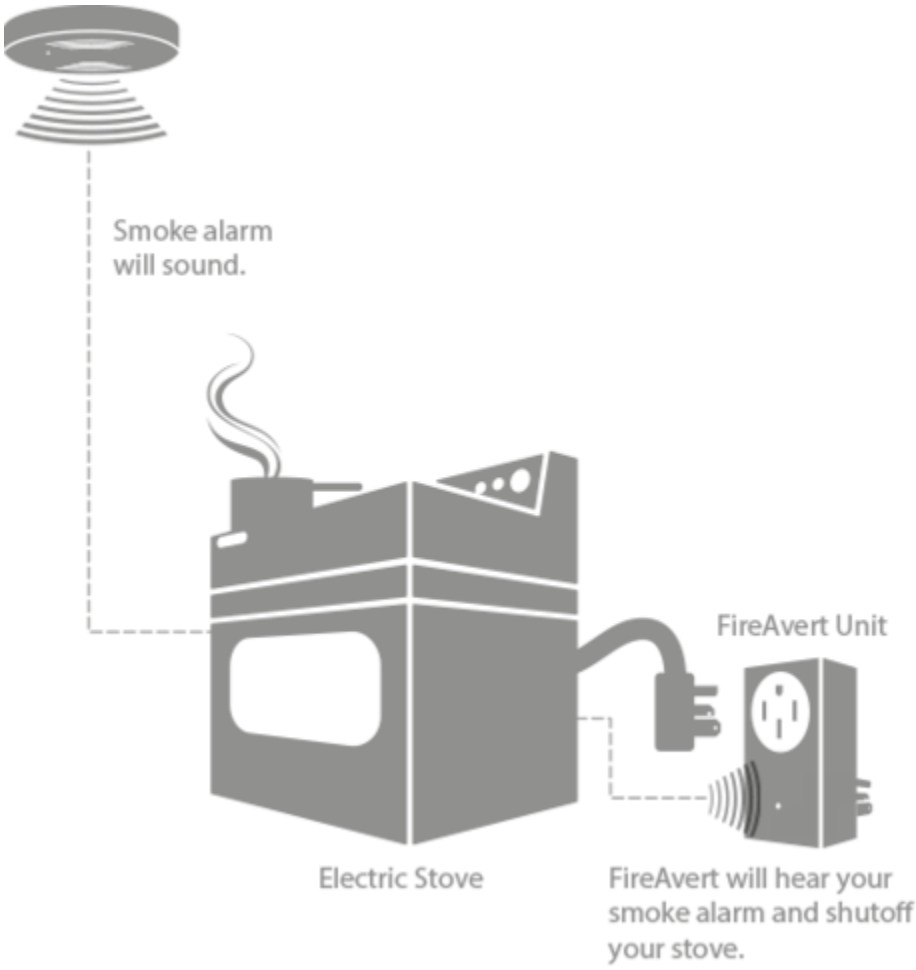

Figure 8 Automatic stove shut-off device.

3. Device Consideration

After the group is done with the research, we believe that nowadays technology is well developed, and all the fire detective devices are efficiency and functional. We believe that the biggest problem with nowadays devices is none of these devices have the multi-detect ability. Therefore, we are suggested that it would be more efficiency if the devices from nowadays can be combined and utilized in some way.

3.1 Budget

According to the school policy, this project was allocated $250 to build a device. Because of the budget limitation, we can only afford the inexpensive part to create our prototype. However, due to the price of commodities in China is less expensive than United States and Professors from WUT were able to give us support. Our final purchase is a small price for a good article.

3.2 Time Constraints

The team was offered 7 weeks to complete this project. Consequently, we've built a simple prototype to prove this idea is accessible which did not include advanced technology or complex codes.

3.3 Student Background Knowledge

The two-team members who primarily worked on this project were mechanical engineering students who were not robotic concentration and had little computer science background or programming experience. Several electric computer engineering students from WUT and a robotic engineering from WPI assist the WPI team in building and programing the prototype.

Chapter 4: Final Component Selection

Throughout the component selection process, several components are considered and the individual instruments that were selected to be the final component had strengths and weaknesses. Due to the budget limitation, timely implementation and the ease of building, the final component selection is not necessarily ideal for the device options for the future development.

The first idea for human activity detection in kitchen is using motion sensor. The team first plan to place the motion sensor in the kitchen where allows the camera to cover most of the area to detect human activity. This idea allows the system to detect most of the place in the kitchen and would be able to capture human activity accurately.

Professor Chen from Wuhan University of Technology suggested us to change to motion sensor idea to photoelectric sensor which could also detect human activity and required less coding experiment. The theory of using photoelectric sensor is similar to the human activity detection theory of elevator door. Once human trigger both the photoelectric sensor and temperature sensor, a message of stovetop is being operated with attended would send to the system and once the human trigger the photoelectric sensor again, another message about stovetop is being operated unattended would send to the timer and start to countdown. The system would sound the alarm to notify house occupant when the countdown is over. Compare to the motion sensor design, this idea require less computer science background knowledge and is also able to detect human activity accurately. The disadvantage of this idea is that most kitchen in United States are design as an open kitchen which means the kitchen doesn't have a door or have more than one door. Open kitchen would increase the difficulty of installing the photoelectric sensor. This idea was not being able to be accomplished because by the time when professor Chen found the MQP team, most of the component was purchased and the facial recognition program is already completed.

STM board was not selected at the beginning when the group started to build this device because the OpenMV7 is a camera develop on a single chip. However, during the developing other part on the OpenMV7, we found out that if all the program is developed on the single chip of the OpenMV7, it would be overload operation be the OpenMV7. The facial recognition program is complex program for OpenMV7 to run and serious problems might come out if programs run at the same time.

After fully consideration, MQP group selected STM-32 circuit board as the system board to connect all components. In the figure above, the STM-32 is used as the system board in developing the device. The STM-32 communicates with the OpenMV Camera via wires.

In the figure above, the OpenMV camera is shown. The black plastic piece on the circuit board is used for the communication between the OpenMV camera and the STM-32 via wires.

Same as choosing the component for the system, simplicity is the main object in terms of ease of coding the whole system. Instead of spending lots of time and budget on a high-technology device that required more complex equipment, the final prototype is built with simple, functional and effective components. These components, however, still allowed the device to complete the main purpose of this project.

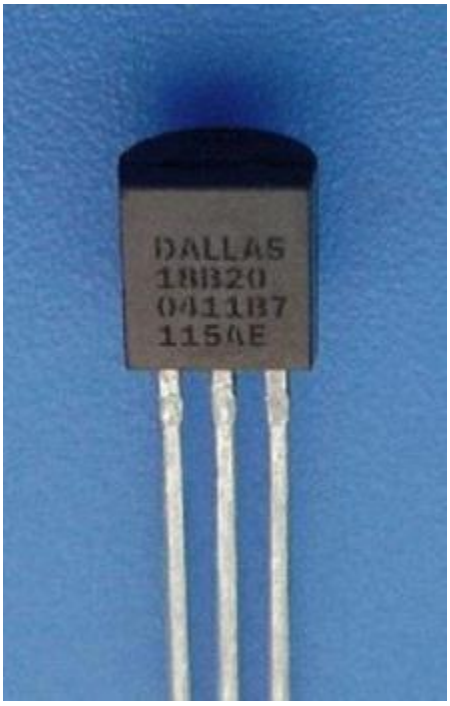

Figure 9 The Temperature sensor used in the device

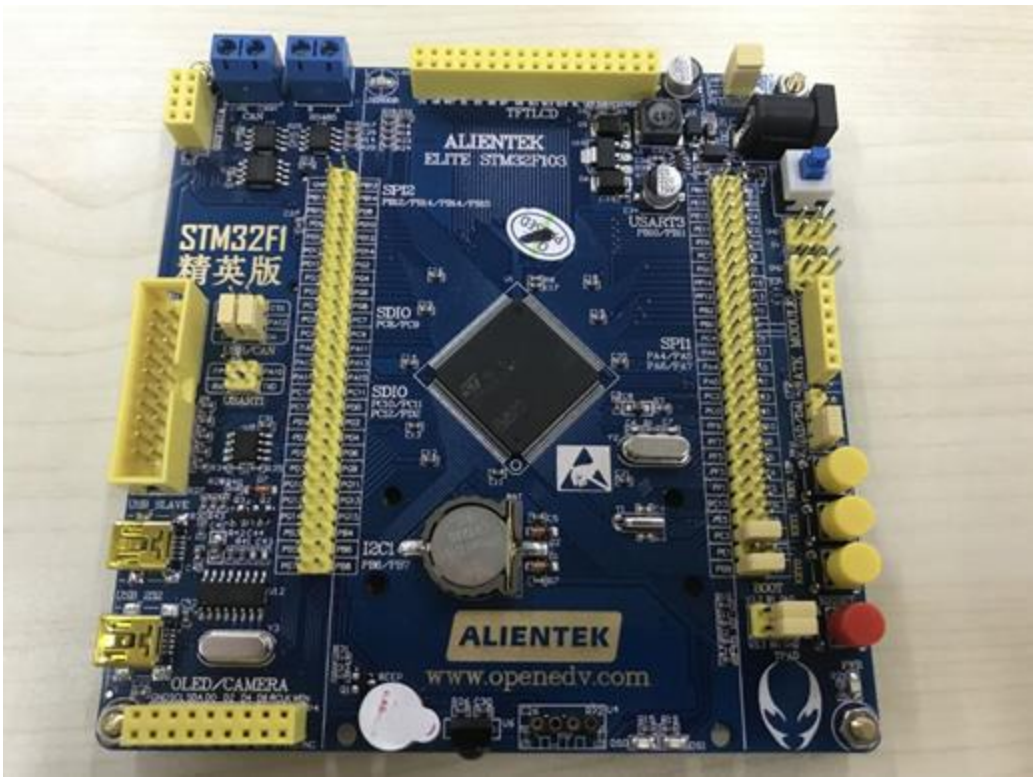

Figure 10 STM32F103 Integrated Circuit

```
        if(Res=='B')
        {
          BEEP=1;
        //  printf("TEXT");
        }
        else if (Res=='O')
        {
          BEEP=0;
        }
    }
    delay_ms(100);
    t++;

}
```

Figure 11 Codes for the STM circuit board that received the data sent by OpenMV camera and sound the beep

Figure 12 Code for STM circuit board, which reads the temperature sensor and sends the respective data to the OpenMV

Chapter 5: Control System and Engineering Design Diagram of the Device

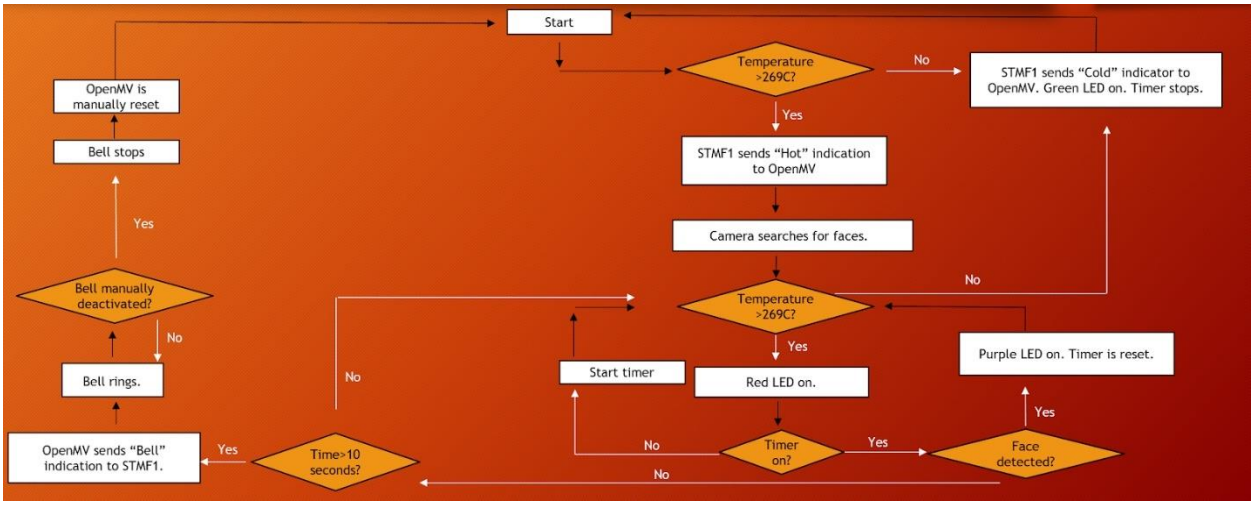

Figure 13 Control Systems of the Smart Building Device

The project of building a smart fire prevention device will run by numbers of units including a temperature sensor, an OpenMV7 devices, an STMF1 microcontroller, and a bell. (STM32F103x8) (OpenMV Cam M7)

Specifically, the OpenMV CamM7 device stores the STM32 device for signal analysis, and the camera for face detection. More to mention, OpenMV camera is placed on a rotating stage which enhanced the range of vision. The temperature sensor will send signal and wake STMF1 to run. Then OpenMV will turn on by STMF1 and start to search faces in certain range. When the time limit has reached, and no faces are being detected, OpenMV will send the signal back to the STMF1 board and trigger the alarm and ring the bell.

Basically, the temperature will signal the STMF1 microcontroller to run, and then STMF1 microcontroller will send a signal to the OpenMV camera to begin search faces. When faces cannot be detected for a time period with cooktop being operated, a signal will be sent to the bell and trigger the alarm.

5.1 STM301 Circuit board and Keil software

STM301 Circuit board use Keil to develop its program which was primarily written in C++ program language. Keil allowed the use of ASCII communication that could be read by

the OpenMV camera. In addition, it also provides development tools like debuggers library management and real time operating system. (www.embeddedindia.com)

The entire system codes were written in different program language and was written on tow different board. Addition code was written in order to ensure that two boards are capable of communicate with each other. This was done by wiring the output pins of one device to the input pins of the other device.

Figure 14 Keil

5.2 Temperature Sensor

The temperature is connected to the STM32F1 board to read and process data. STM32F1 board provide power supply and deliver signal to other units. When temperature detect heat source, “H” character in ASCII characters would be sent by the STM32F1 board. When this occurs, the STM32F1 board would turn on the OpenMV camera.

5.3 OpenMV camera and OpenMV IDE

The OpenMV camera utilized the OpenMV integrated development environment which is written in Python programming language. OpenMV camera was possible to detect faces about 2.5 meters when the faces were placed in front of the camera. Any angles would fail the detection process.

When low temperature is detected by the temperature sensor, STM32F1 board would send a “C” character in ASCII characters to OpenMV board. When this occurs, faces detection process would not run. When OpenMV board receive “H” character in ASCII character, the facial recognition program will start to run.

Figure 15 OpenMV IDE

Chapter 6: Testing and Manufacturing

Experiments and tests were run step by step before building the final prototype as all components arrived. In order to make sure each component is functional and is able to work properly, trial runs were necessary for proper operation. Test trials of facial recognition camera, temperature, the bell was all tested to identify the reliability of the respective parts.

Because of the time limitation, we didn't have enough time to calibrate the temperature. Also, because the model we built is only a prototype to prove the idea of building a smart fire prevention device, actual cooktop temperature might damage the units that were used in this prototype. Temperature sensor is capable of detecting fires. Cooktop was replaced by lighter.

Ideally, an environment similar to kitchen in United States should be created to test our prototype. However, due to the time limit and budget limit, we could not test our device in such an environment. Also, since our temperature is not suitable for high temperature, we chose to test the prototype with a Bic lighter in a Computer Laboratory provided by Wuhan University of Technology.

Chapter 7: Results and conclusions

The idea of this project is to build a smart fire prevention device that alter users when cooktop is left without attendance for a period of time. According to the research done by National Fire Prevention Association, kitchen is the leading area of origin in home structure fires and unattended cooktop is the leading factor of home fire in United States. Once a fire is happened in kitchen, situation will out of control within minutes because wood is the most common material that was used in house building. Property damage or even injured and death will be unavoidable once the fire is happened. However, we believed that this problem could be solved if we could build a smart device that could notify people when it detected fire might happen in kitchen area. Although fire prevention devices nowadays are well developed, most of the fire prevention devices can only detect fire when smoke is already generated. In these situations, property damage is already happened. The idea of building a smart fire prevention device was proposed and we spent 7 weeks in China to build the prototype to prove this idea.

As a result, the prototype is working functional which has proven the idea of building pre-ignition device to prevent fire. The OpenMV is very functional in detecting human face when the camera is placed right above the cooktop and the face detection system code in fully functional and accurate after the multiply time tests. We assumed that the users would operate in front of the kitchen so that the OpenMV would be able to capture their faces, although this assumption is not reasonable in real life. OpenMV could only detect faces in front of the camera and if the faces were not facing directly, OpenMV would fail to recognize the faces. The maximum detect distance of OpenMV camera is within 2.5 meters. As we expect, the STM-32 performed well in handling and delivering signal between each unit.

From several test trials that stimulated the stovetop operation, the prototype has shown that each unit of the device was capable of communicate and alter users when potential danger is detected. However, since the temperature sensor that was used in building this prototype is not design for high temperature, electric stove top was not used in the tests trial and light was the heat source instead. Because of the temperature sensor selection, temperature calibration was not done in this project and the number 269 in the program is only a number.

The idea of building a smart fire prevention device was proven to be executable. However, this device is only a prototype to prove this idea. The final prototype was finally built cannot reset

automatically and would need manually operation to restart once the alarm is triggered. This device was not built for actual operation, so it is not a fire prevention device but a prototype for similar device in future.

Chapter 8: Future Development

8.1Internet & smart devices connection

In 21 century, smart devices, especially smart phone, are highly developed. Smart phone has been developed more and more functions that the team believe it would be a huge improvement if smart phone can be involved in this project. The motherboard that we use in developing this prototype has the access to connect Wi-Fi.

Connection with internet or user through Bluetooth or Wi-Fi. One of the reasons that we choose STM-32 as our motherboard is that STM-32 has the ability to connect with other devices through Bluetooth or Wi-Fi. Connecting to internet can increase the accuracy of the device and can notify more people about the situations.

8.2Communication with fire department

Once the device is connected to the internet, fire department can be noticed before the situation is out of control. Fire fight can make decision based on the situation and more professional actions will be made. Property damage and government budget will be reduced if the fire is being noticed and extinguished in the first place.

8.3Connection with cooktop.

The idea of this project is to prevent fire at the very beginning. According to our research, the first sign of fire would be smoke. Connection with stovetop would ideally stop the fire. Once the device detected that the cooktop is be operated without attendance for a period of time, the device will shut down the cooktop automatically. If the device can control or even shut down the cooktop once the device detected the cooktop is unattended for a time period, the percentage of fire will be happened can be reduced significantly. Numbers of death and property damage would drop rapidly.

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