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Smart Building Devices

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MAJOR QUALIFYING PROJECT

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SMART BUILDING DEVICES

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Abstract

The purpose of this Major Qualifying Project is to develop a prototype of a face detection smart device to be used in the prevention of domestic kitchen stove top fires. To develop a device that can accomplish this task, an OpenMV7 component with an attached camera and microcontroller was used to detect faces in the kitchen area. Presumably, the built-in face recognition software will help reduce the number of kitchen fires caused by unattended stovetops. Specifically, the device, through communication with an STMF1 microcontroller, recognizes a hazardous time interval of the stove being unattended, and will sound an alarm when the hazard is detected.

Acknowledgements

I would like to thank Professor Jianyu Liang for her guidance in creating this project. Dr. Liang was crucial in leading the team before, during, and after the project. Her, along with Professors and students from Wuhan University of Technology, made this project possible through the merged project center of WUT and WPI students. Also, Yanru Peng, Chengyu Jiang, Yang Liu, Andrew Scheuller, and several other WUT students had contributing roles in the creation of the device. In addition, I would like to thank students from Beijing University of Chemical Technology and from Tsinghua University for their supporting role in guiding my travels in China, I country I had never visited before and did not know the language. Lastly, I would like to thank Mahdi Elhousni from WPI whose preliminary device idea brought this project to fruition.

TABLE OF CONTENTS:

LIST OF FIGURES

Chapter 1: Introduction

Domestic stovetop kitchen fires are the leading cause of injury, death, and property destruction in the kitchen area. From 2010-2015, cooking equipment was the cause of 47% of fires in the household, 20% of civilian deaths due to household fire, and 45% of civilian injuries due to household fires (Ahrens 2017) Out of all cooking equipment fires, equipment being unattended led to 33% of these fires, 43% of civilian deaths, and 45% of civilian injuries (Ahrens 2018) Additionally, cooking equipment being unintentionally turned on, or not turned off, led to 8% of cooking equipment fires, 8% of civilian deaths due to cooking equipment, and 8% of civilian injuries due to cooking equipment (Ahrens 2018). The purpose of this Major Qualifying Project is to build a prototype of a device that can prevent these fires from occurring, by building a face detection device that recognizes hazards due to unoccupied stovetops and sounds an alarm when the hazard is noticed.

1.1 Problem statement

The primary concern that our device attempts to solve is the misuse of stovetops, which leads to dangerous fire ignition. Specifically, a lack of attendance to stovetops is a leading cause of fires in households and in kitchens. This problem has become more relevant in today's age of technology with electric stovetops, which do not emit a visible light or sound when in operation. Because of this, electric stovetops are more likely to be unattended for hazardous periods of time than gas powered ones.

1.2 Main Objective

The objective of this project is to develop a prototype face detection device that will be used for fire prevention in domestic electric stovetop fires through face detection software to notice an unattended stovetop and a timed alarm that rings when the operated stovetop is unattended for a hazardous time interval. This project was accomplished by students from Worcester Polytechnic Institute and Wuhan University of Technology. This group of interdisciplinary students chose the device components and software. A mechanical engineering major and a robotics engineering major from WPI, and an automation major and materials student from WUT, with help from several computer science majors from WUT worked together in a interdisciplinary, cross cultural group to build the device. The group used their strengths in group management, control theory, electronics, coding, and electrical engineering with dedicated teamwork to achieve the objective of the project. This device will use temperature readings, face detection, a countdown timer, and an alarm to alert home occupants when a stovetop fire has been left unattended or accidentally left on.

The four components of the device were built, and these were: stovetop operation detection software, face detection software, resettable timer, alarm.

The stovetop operation detection software recognizes when the stovetop is being used for cooking, through detection of high temperatures via an infrared temperature sensor. This component of the device is useful to recognize when a stovetop is on. When the stovetop is recognized to be on, it communicates with the face detection software.

The face detection software, which communicates with the stovetop operation detection software, uses an OpenMV7 camera/microcontroller to detect faces via OpenMV IDE software. While the stovetop is detected to be in operation, the face detection software searches for faces in the kitchen. A camera that is pointed towards the front of the stovetop, for maximum visibility, is used for this aspect of the device system. The face detection software searches for faces, but if it does not recognize any faces for a hazardous time interval, it works in conjunction with a countdown timer to recognize a hazard.

The countdown timer will sound the alarm component of the device when the hazard has been recognized. However, the timer will reset when the face detection software recognizes a face.

To prevent the ignition of flames, this device will ring an alarm when a hazardous period of time of stovetop non-attendance has been detected. The alarm will notify the occupants of the house of the unattended stovetop via a loud bell, and an able bodied individual will then act accordingly by either turning off the stove or removing the food from the stove before a fire ignites. If the individual cannot reach the stove in time, or a fire has already been ignited, then the individual must not attempt to extinguish the fire and should instead call 911 or allow the smoke alarm to alert the fire department.

This can be used in conjunction with smoke detectors. When an uncontrollable fire occurs while the stove is being operated, then the smoke detector will alarm the fire department.

1.3 Background Research

Inspiration for the smart building device came from prior research by Mahdi Elhousni, an Electrical Engineering Graduate Student at Worcester Polytechnic Institute. Background research by him on fire prevention systems led to the creation of this project. A pre-ignition detection system was a project that had previous research, but needed to be built. The MQP group worked on researching and designing the device over a span of three months.

The pre-ignition device was chosen to solve a dangerous problem faced by households with electric stovetops. From 2011-2015, 47% of home structure fires were caused by cooking equipment, and the leading cause of these fires was unattended cooking (Ahrens 2017). Accordingly, this project will focus on preventing cooking equipment fires, through detection of the equipment being unattended. This project, and the device, was completed with electric stovetops in mind, although this prototype device may be used for other kinds of indoor cooking equipment such as fryers, toaster ovens, etc. This is done through detection of high temperatures that can lead to property damage or personal injury.

Temperature sensors are used to detect hazardous temperatures, which detect temperature changes in the environment and communicate with the STMF1 microcontroller to read voltage changes that are linearly related to temperature change (STM32F103x8). In order to prevent fires from occurring, the device will sound an alarm to the home occupants when it notices no human movement near the stove for a hazardous amount of time.

The team was also given inspiration for this device by the principles of tea kettles. When the desired temperature is reached on a tea kettle, the kettle whistles indicating the water inside is ready for preparation. In a similar fashion, fire prevention device creates a noise when the device is simultaneously at a hazardous time and temperature threshold. In both the tea kettle and the smart fire prevention device, a sounds alerts the home occupants of a temperature threshold being reached.

Thus, this project was given inspiration from the general concept behind preventing hazards via alerting others. The temperature sensor and face detection software is efficient at accomplishing its goal of recognizing hazards and alerting home occupants. However, the original idea of the project involved using infrared thermal cameras to detect stovetop operation. In this design idea, the stove would automatically shut off when the infrared thermal cameras detected a lack of stovetop attendance. However, this idea required significant amounts of programming and research.

In addition, infrared thermal cameras and current methods of fire detection largely rely on flame detection. Infrared thermal cameras are more reliable in detecting ignited fires rather than specific temperatures. The temperature sensor used in the final device was more reliable and less expensive for the purpose of temperature reading. Temperature sensors were used rather than infrared thermal cameras because of the ease of code implementability at the students level of programming experience, and because of time restrictions due to a seven-week project. Lastly, the final device differs from the preliminary device due to the action performed as the device detects a hazard. Rather than turning off the stove, the final device instead sounds an alarm. Similarly to the reasons behind using temperature sensors, the implementation of an alarm rather than an automatic shut-off is more time and money efficient as well as more easily implementable regarding programming experience of the students involved.

Another technological method used for fire prevention is smart phone based applications that allow users to shut off electrical equipment through their smartphone. This method was disregarded for our project, since the required coding and electrical equipment necessary is not easily implementable by mechanical engineering students.

Also, the required time for such a device, including testing, was outside the time allotted for the project. In addition, a simple device that does not require internet signal was more appropriate for the purpose of operation. The underlying principle of stove top non-attendance is that the user does not remember when the stovetop is on. The solution proposed by the smartphone application does not readily solve this problem, since it requires users to remember they left the stove on.

Chapter 2: Literature review and Background Research

In order to solve the problem of fires starting in the kitchen due to a lack of presence, then the onset of these fires can be prevented much more easily and also much earlier. In today's current state of technology, most methods of fire protection involve detecting fires that have been ignited. There are fewer devices that can prevent the onset of a fire, rather than detecting one. These devices are far and few between, and have not seen wide implementation due to the novelty and lack of awareness about them.

2.1 Home cooking fires

Most fires that start in the kitchen are caused by unattended electric stove tops (Ahrens). Since electric stove tops do not have the obvious features of a gas stove top such as a noticeable flame or a hissing noise, they are left unattended much more frequently. Electric stove tops left unattended cause fires when they create too much heat, and burn the pan with food, which ignites the cooking oil and starts a fire. In addition, it is difficult to fight fires, which have been ignited, and also very dangerous if not properly trained.

2.1.1 Stovetop fires

If one were to prevent the root problem of lack of attention to the stove top, then properties and people will be much safer. This project will allow our group to create a prototype for a device that will prevent unnecessary property and personal damage from occurring.

2.1.2 Cost of household fires

In 2014, fires caused $13.2 billion worth of property loss (Ahrens 2017). These fires were preventable, and the design for the device could have saved money due to damages. In principle, if fires were never started, then the property damage would never have occured. By preventing the onset of a fire, rather than detecting it, hundreds of millions of dollars can be saved.

Additionally, these preventative measures can be done through a relatively simple and inexpensive device.

2.2 Fire safety devices

Today, most households in the United States rely on a flame or smoke detector to notify the home occupants of a fire in the household. A flame detector is a sensor designed to detect and respond to the presence of a flame or fire. Response to a detected flame depends on the installation, but can include ringing an alarm, shutting off a fuel line, or activating a fire sprinkler system. A flame detector can often respond faster and more accurately than a smoke detector or heat detector due to the mechanisms it uses to detect the flame.

2.2.1 Flame Detection Technology

Infrared/ultraviolet flame detectors are used to detect fires in hydrogen stations, gas-fueled cookers, industrial heating and drying systems, domestic heating systems, and industrial gas turbines.

For instance, flame detectors utilize optical technologies to detect flames. Flames emit electromagnetic radiation in the infrared, visible light, and ultraviolet wavelengths depending on the fuel source. Because of this, optical flame sensing technologies have been developed utilizing such technologies. These products rely on line-of-site detection, as well as detection of radiation emitted.

2.2.2 Infrared Thermal Cameras

Infrared cameras can be used for detection to prevent fires from occurring. These are sensed using a specialized fire-fighting thermal imaging camera, a type of thermographic camera.

A problem with these devices is false alarms. False alarms can be caused by other hot surfaces and background thermal radiation in the area. Also, water on the detector's lens will greatly reduce the accuracy of the detector, as will exposure to direct sunlight.

Almost all radiation can be absorbed by water or water vapor, particularly in the 4-.3-4 µm region. From approx. 3.5 µm and higher the absorption by water or ice is practically 100%. This makes infrared sensors for use in outdoor applications unresponsive to fires.

Most IR detectors are designed to ignore constant background IR radiation, which is present in all environments. Instead they are designed to detect suddenly changing or increasing sources of the radiation. When exposed to changing patterns of non-flame infrared radiation, infrared detectors become more prone to false alarms.

2.2.3 Thermocouple flame detection

Thermocouples are used to monitor flame presence in combustion heating systems and gas cookers. This technique is often used in conjunction with supply shut-off technology. The purpose of this is to prevent unburned fuel from accumulating, and to prevent fuel from being added to the fire. This is helpful for once the fire has occurred, but not very useful in creating an early prevention signal.

2.2.4 Temperature sensors

Temperature sensors run on the principle of outputting a voltage proportional to the Celsius temperature reading. The TMP36 Infrared sensor used in the device does not require calibration, and outputs data with accuracies of ±1°C at ±1°C at +25°C (Low voltage temperature sensors). Additionally, it has accuracies of ±2°C at −40°C to +125°C. The voltage output uses scale factors of 10 mV/°C.

2.3 Smart Fire Prevention Devices

Smart fire prevention devices use novel techniques using the latest technology in order to innovate the fire protection field. By using innovative methods to protect households, these devices helped inspire this project. Additionally, these devices use a wide range of technological devices that are more geared towards fire prevention rather than fire detection. These smart devices use the principle of shutting the stove off to prevent fires, but they do not assist the user in recognizing a fire hazard due to a lack of attendance. For these devices, the user must remember they have left the cooking equipment unattended.

2.3.1 WallFlower smart monitor

Several fire prevention devices exist today. For example, the "WallFlower Smart Monitor for Electric Stovetops" uses smart technologies to prevent a fire from occurring. By plugging the stove power cord into this device, and then into the electric outlet, the user can use the WallFlower smart phone application to shut off the stove entirely. The device also notifies the user when they travel over 1000 feet away from the stove, and whether the stove has been left on for an extended period of time according to the user's personal preferences (Jablokov).

This device allows for the flexible usage of fire prevention. Although stove fires are considered hazardous if let unattended, sometimes an unattended stove is not hazardous. Just one example would be a family leaving a big pot of spaghetti sauce on the stove for a long period of time on low heat to allow it to slowly simmer. In this situation, the stove is left unattended but it is safe to be left unattended because of the low temperature.

However, the disadvantage of this device is that people without smartphones will not be able to use it, and must rely on family members or housemates that do have smartphones.

2.3.2 Automatic stove shut-off device:

Another device that implements smart technologies to prevent fires is the "Automatic Stove Shutoff" by FireAvert. This device works similarly to the WallFlower device, because they both use plug-in device systems. The Automatic Stove Shutoff device differs from the Wallflower because it uses the smoke detector alarm noise to turn off the plug-in device 6]. When the smoke detector senses smoke, it rings an alarm, which is then processed by the Automatic shut-off device. As this device notices the sound of the smoke detector, it then sends a signal to the device to shut off the stove. This is helpful for older people and those with Alzheimer's according to FireAvert (Stove Fire Prevention I Fire Avert I Alzstore.).

The problem with this device is that the smoke detector must sound an alarm before the device can shut off. This can cause fire stations to react to the scene without their being an actual fire, and this will waste the fire station's time. Further preventative measures would be ideal, as it will create a safer and less bothersome situation for everyone.

2.3.3 Belkin WeMo Switch:

Lastly, a third smart fire prevention device is the "Belkin WeMo Switch," which allows the user to use their smartphone to control the power to any device in the house (The Belkin WeMo Switch and Motion 7). This is useful for powering off the stove, if you remember that you left it on. However, it does nothing for a forgotten, unattended stove. In addition, it uses motion sensors to control the power to any device as well. For instance, users can set up the device to turn on the porch lights whenever someone walks by sensors in a different room in the house.

This device is useful for fire prevention, but it is more focused on user comfort rather than fire prevention. In addition, it shares the issue of the Wallflower device, in that it requires a smartphone to be used.

These three devices all have their niche target audience, but our project will focus on creating a prevention device before the smoke detector is needed.

To create a device that accomplishes this task, our group research various technologies, such as sensors, that are used in flame detection. Our group did not focus on creating an outlet device, due

CHAPTER 3: DEVICE CONSIDERATION

The considerations for this device include using technology and innovative solutions in order to prevent fires from occurring in the kitchen due to the lack of attendance to a stovetop. Therefore, the device must be able to recognize when the stovetop has been left unattended, and when the stovetop is under operation. Without the former, the device cannot be of much use in preventing this problem of stovetop non-attendance. Without the latter, the device will create false alarms that recognize the stovetop is unattended, even during inappropriate times such as when the stovetop is not in use. Therefore, the device was built with these two main goals, of detecting non-attendance and detecting stove top usage.

3.1 Price

The students were allocated $250 to create a device. Therefore, inexpensive parts were chosen.

3.2 Time constraints

The students had 7 weeks in China to complete the project. Consequently, a simple device was created that did not require advanced technology or sophisticated programs.

3.3 Student ability

The students who primarily worked on the project were mechanical engineering students, who had little previous programming experience. Students at WUT assisted the WPI students in writing robust code.

CHAPTER 4: FINAL COMPONENT SELECTION

The efficiency of the device was evident in the design, as demonstrated in its simple yet effective component design. The individual instruments that were considered each had strengths and weaknesses that were thoroughly considered, and the instruments were chosen after a close examination of the desired outputs. The details of the components were considered after research was done on each individual considered component. Instrument specifications were secondary to the final outcome that was to be created. Therefore, instruments that were not necessarily ideal for the device were chosen because of their low cost, ease of building, and timely implementation. For instance, instruments that serve multiple purposes were chosen in order to efficiently save resources. The two major components of the device, the STM32 circuit board, and the OpenMV camera, each had multiple design features that allowed for integrated use of the built-in features.

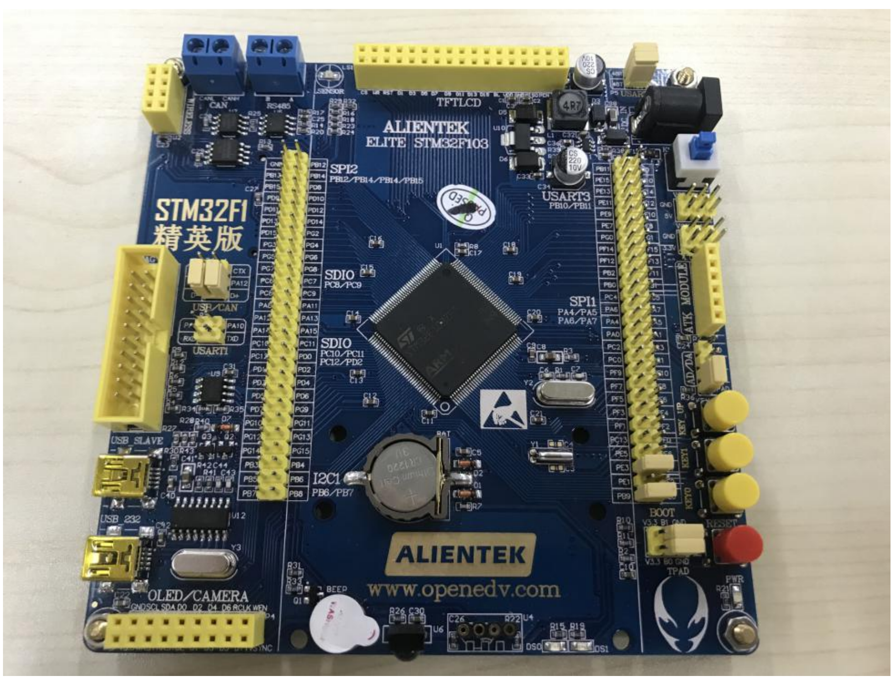

Figure 1: STM Circuit board.

In the above figure, the circuit board used in the device is shown. The pins are shown, which are used for communication, via wires, with the OpenMV Camera.

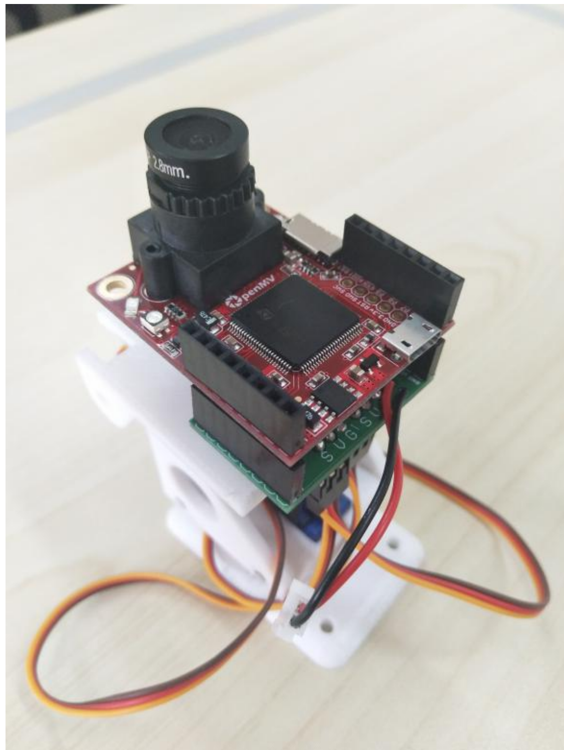

Figure 2: Picture of the OpenMV Camera

In the above figure, the OpenMV Camera is shown. The black plastic pieces on the red circuit board are used for communication, via wires, with the STM circuit board.

Similarly to the chosen instruments, simplicity of the system was considered, in terms of ease of programming the control system. Because the device required a program, the instruments were chosen to implement the device in the most time and cost effective manner possible. A simple device idea was used for this reason. Rather than spending lots of time and money on a more complicated device that required more complex and expensive equipment, the device that was built contained simple, relatively inexpensive components. These components, however, still allowed the device to accomplish its main purpose successfully.

The idea of the face detecting device with a timed alarm was discussed, and was chosen as the device to complete our goal of creating a fire prevention device. Concrete advice from Professors at the Wuhan University of Technology, as well as from students, was implemented due to the constraints on purchasing the instrumentation in China. The device components were purchased through online Chinese electronic retailers and at local electronic hobbyist stores nearby the university. All device components were capable of being constructed by the students in the project.

Each of the boards has individual codes configured into it, and each had separate roles in the device system. The OpenMV board's code was written to not only detect faces, but also to begin a timer, and additionally to send analog signals through ASCII communication to the STM board. The STM board's code's purpose is to read the outputted ASCII signal from the OpenMV board, and then ring the alarm connected to the board when the signal is received. The STM board also read the infrared temperature readings from the infrared sensor (DS18B20 - Temperature Sensor IC, Programmable Resolution) Theses code written on the two boards enabled the device to operate smoothly.

Figure 3: The temperature sensor used in the device

usart.c | usart.h | main.c* | startup_stm32f10x_hd.s | ds18b20.c | delay.c

```
while(DS18B20_Init())
{
  delay_ms(200);
  delay_ms(200);
}
while(1)
{

  if(t%10==0)
  {
      t = 0;
      temperature=DS18B20_Get_Temp();
// printf("%d\n",temperature);
      if(temperature>280 && send_flag == 0) //temperature in C
      {


        int i = 0;
        send_flag = 1;
        for (i = 0; i<3; i++)
        {
          Uart1_Put_Char(hotout[i]);
        }

        // Uart1_Put_Char(messages.HOT);
       // printf("1\n");
      }
      else if(send_flag == 1 && temperature<=280)
      {

          int i = 0;
          send_flag = 0;
          for (i=0; i<3; i++)
          {
            Uart1_Put_Char(coldout[i]);
          }
        // printf("0\n");
      }
```

Figure 4: Code for the STM circuit board, which reads the temperature sensor and sends the respective data to the OpenMV.

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

  }
```

Figure 5: Code for the STM circuit board, that reads the data sent from the OpenMV camera, to create a beep.

CHAPTER 5: CONTROL SYSTEM AND ENGINEERING DESIGN DIAGRAM OF THE DEVICE

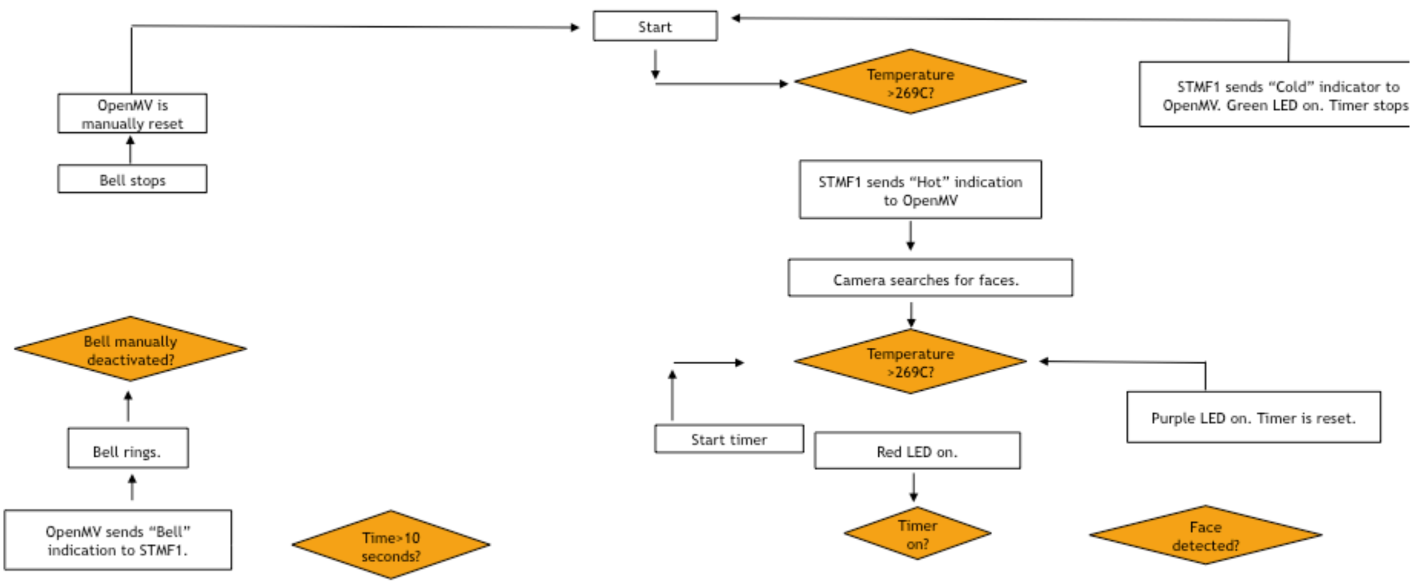

Figure 6: Control system of the Smart Building Device

The design of smart build device will be run by a number of modern and state of the art equipment including a temperature sensor, an OpenMV CamM7 devices, an STMF1 microcontroller, and a bell used as an alarm to notify the home occupants. (STM32F103x8) (OpenMV Cam M7)

Specifically, the OpenMV CamM7 device stores the STM32 device for signal analysis, and the camera for face detection. In addition, the OpenMV M7 will be mounted on a rotating camera mount that allow for enhanced range of vision. The temperature sensor will signal the STMF1 microcontroller to run, which will send a signal to the OpenMV cam to begin searching for faces. When the time interval has been passed with high temperature and no face detection, the OpenMV communicates with the STMF1 board, with a built-in bell, to signal the ringing of the bell.

One important aspect of the control system is the detection of a high stovetop temperature. For environment monitoring of stove operation through face detection, the STM circuit board must first be turned on. This resets the circuit board as well as the OpenMV face detection camera. Resetting the board and OpenMV is necessary for the previous program to stop running, and for the board and OpenMV to properly communicate with one another. This is because of the way in which the analog communication works. The communication between the two is written in ASCII characters, which is the characters in which serial communication is written. A "resetted" program is the most reliable method of running the device.

5.1 STMF301 Circuit board and Keil software

Specifically, the STM31 circuit board utilized the Keil development environment, which was written primarily in C++ programming 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 systems. (www.embeddedindia.com)

Code written onto the two boards allowed for the entire operation of the device system. Besides the obvious features that can be seen during operation, additional code was written that allowed for serial communication between the two instruments. This was done by wiring the output pins of one device to the input pins of the other device.

5.2 Temperature sensor

The specific infrared temperature sensor works by detecting and processing temperature data that can be read by the STM31 board. This standalone component could accurately detect temperatures to the nearest degree Celsius.

Next, the device searches for high temperature. It does this through temperature sensors that are wired to the STM circuit board. The IR sensor monitors the environment for high temperature readings. When this high temperature threshold is reached, the STM board sends an, "H" character in ASCII characters to the OpenMV board. When this occurs,

5.3 OpenMV camera and OpenMV IDE

Additionally, the OpenMV camera utilized the OpenMV integrated development environment, which is written in Python programming language. This development environment made use of a text editor, debugging terminal, and a frame buffer viewer (OpenMV Cam M711) Included in this IDE was face detection software. Through coding additional features onto the built-in code on the instrument, it was possible to detect faces accurately from a distance of around 3 meters.

The running OpenMV code turns on the face detection software, and searches for faces. Also, this signal adjusts the camera's mount to be faced directly forward. The gears on the mount are powered to a specific state, and return to this state regardless of its state before powering. In addition to the camera and mount gears being powered, the signal from the STM circuit board also starts a timer on the OpenMV camera. This only shuts off when the camera is turned off, or when the IR sensor reads a low temperature that surpasses the cold threshold temperature. When this occurs, the STM board sends a, "C" character in ASCII characters to the OpenMV board. After the OpenMV camera reads the, "C" character, the face detection software stops running.

The timer on the OpenMV board creates a countdown, with an adjustable time allocation. This timer can be reset, and shut off, depending on the inputs that are received from the OpenMV and the STM instruments. When the OpenMV camera detects a face in front of the stovetop, indicating that the stovetop is being attended to, the program on the instrument will automatically reset the timer back to the allocated time given to it. As long as there is a face being detected, the OpenMV code will stop the timer. The timer starts again when no faces are detected by the camera. When this timer completes its allotted time, the OpenMV will send an analog communication signal, a "B" ASCII character to the circuit board that turns on the alarm. When the STM board reads a, "B" character, the bell is signalled to start ringing. This louding ringing alarm can only be shut off manually, through shutting off the STM circuit board.

CHAPTER 6: TESTING AND MANUFACTURING

As the components became available, experiments were run at each step of the building of the device. Several iterations and trial runs were necessary for proper testing and operation. Throughout construction of the preliminary iterations of the device, several constructions were completed that were useful for testing individual components of the device, and were relevant for these purposes solely. Test trials of the face detection software, the bell, the timer, and the communication between devices were all individual aspects of the device that were completed to identify the reliability of the respective parts. With each successful component being constructed and tested, the next step in the device's system was added onto the previously built segment. This process was successful in efficiently allotting time into the devices construction, and successfully testing each device along the way in order to ensure that each instrument worked properly.

The infrared sensor is capable of detecting fires, as it was tested for up to 300 degrees Celcius by holding a Bic lighter next to the sensor. The purpose of this was to measure the rate of change in the temperature readings read by the STM board. This was useful in testing the device, as it was shown that the infrared sensor can detect small changes in temperature. Holding the Bic light was used to streamline the process of testing the temperature readings. Initially, these temperature readings were done by holding the infrared sensor itself, and allowing the warm temperature of a hand to raise the temperature. However, this was shown to be too long of a process, as it was less time efficient and also less reliable of a method to raise the temperature readings.

Because not all stovetop fire temperatures are considered dangerous, the device ideally should only check for the dangerous temperatures. However, for the purpose of testing the device, a lower temperature threshold was used. The temperature threshold can be changed through the STM board code.

For instance, analog communication between the STM circuit board and the OpenMV camera required several days of research, testing, and coding, in order to properly allow for communication between the two boards.

Configuring the OpenMV board and the STM32 board together required used of two different programming languages, Python and C++. Configuring the two boards also included wiring the boards together, through utilizing the analog pins on each device so the output of one device was read through the input pins of the other. This communication between the two boards was a critical component of the device, as it allows for serial communication between devices. Using serial communication allows the device to utilized the two boards as well. This is important because using two devices allowed for more features on the device.

CHAPTER 7: RESULTS AND CONCLUSIONS

However, the current device is reliable in accurately detecting faces. The OpenMV camera is very useful in detecting these faces, and can communicate very reliably with the STM board. The code on the OpenMV has been tested multiple times and is very accurate at detecting faces directly in front of the camera. This assumes that people nearby the stove will be directly in front of the camera itself. While this may not be a reasonable assumption for all scenarios, this was another constraint on the usefulness of the device in actual scenarios. This limitation can be counteracted by writing additional code onto the device, that moves the direction the camera points in order to more accurately detect faces nearby the stove that may not be directly in front of the starting position. This is just one way to face this challenge. When the OpenMV wants to move the way it points its camera, it must be powered by a battery connected to the gears on the mount.

From several test trials that simulated stovetop operation scenarios, it was shown that the device was capable of alerting users of a potential hazardous fire in the kitchen. This would be useful in preventing fires before they can start. In addition, this was done with very little cost, and with little false alarms. The device was not built to be used in actual operations, so it is not a fire prevention device, but rather a prototype for such a device in the future.

CHAPTER 8: IDEAS FOR THE FUTURE

Our project will be a step forward in preventing home fires, and the fire prevention field. In the future, this project can be a foundation for preventative detection systems not just for fire, but also for hazardous gases in private, industrial, and public settings as well. Other researchers interested in this project can continue building on our project as well, and perhaps program the device to shut the stove off rather than simply ringing an alarm.

These temperature readings from the infrared sensor are useful in monitoring hazardous conditions due to the range of accurate readings it can observe. Because temperature above 300 degree Celsius are considered dangerous, as this is the autoignition temperature of oil, and thus this temperature is a good threshold for the upper limit of a, "safe" temperature. Since the infrared sensor on the device could monitor this temperature, this shows that our device has potential to be used for detection of potentially hazardous stovetop conditions.

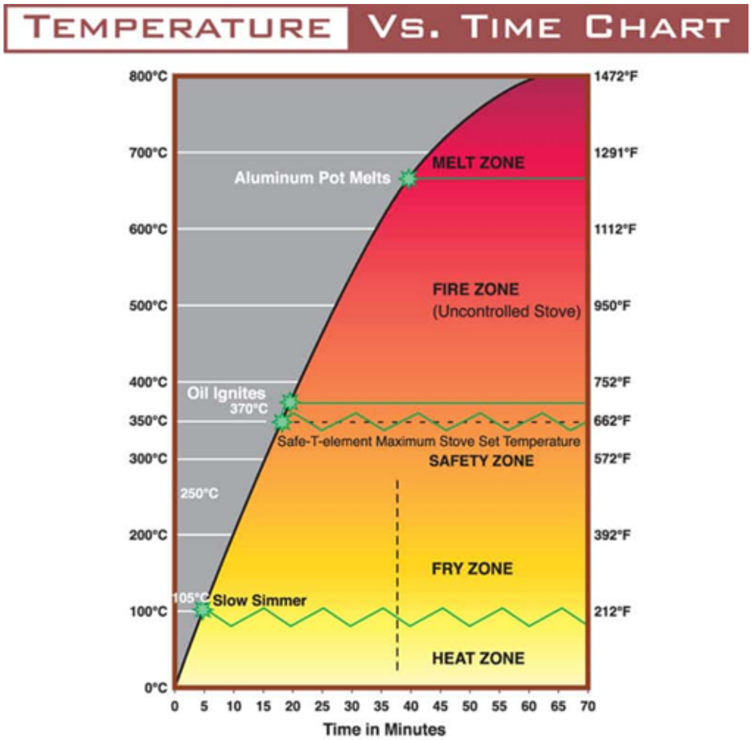

Figure 7: Temperature vs. Time chart

This temperature is helpful for detecting the beginning of hazardous conditions on a stovetop. In addition, the temperature readings of the infrared sensor also decrease as the stovetop conditions lower to a safer temperature. This is helpful to prevent false alarms from occurring, which can be used for after the stovetop is powered off. However, the infrared sensor takes longer to cool down than does the air surrounding it, so the timer must accommodate for this. Without the timer being set properly for actual use of fire prevention, then the infrared sensor will read high temperatures while the air temperature and thus the stovetop temperature are lower than the dangerous threshold temperature.

Also, the timer can run consistently under all scenarios, and rings the alarm on the STM board. However, the time set on the timer must be accurately changed from the current time on the prototype. The current timer is not a long enough time interval for accurate preventative measures. Therefore, the time on the timer must be increased to make the device more accurately detect temperatures. In addition, this time set on the timer must be chosen after research is done on how long the stovetop can be unattended, without a danger being present. Then, the timer must also consider the interval between resetting of the timer from the face detection software, while taking into account the time interval of the high stove temperature. When the stovetop is on a high temperature for a significant amount of time, multiple face detections resetting the timer may not be safe. Because the temperature of the stovetop may be high for a longer amount of time under these conditions, the device may not be able to detect a potential hazard. This is one limitation of the device that was not considered during the seven week span of our project, due to time and skill constraints on completing the necessary programs.

The purpose of pointing the camera in different directions, if implemented, would improve visibility in front of the stovetop which also reduces false alarms due to lack of face detection. This idea was tested, but was not implemented in the final device due to time constraints. Setting the rotational speed on the gears was the most challenging task for the students programming the OpenMV code. Perhaps, redirecting the camera in different directions would be done after a certain time has elapsed without face detection.

Another aspect of the device is the bell alarm that rings when the allotted time has passed by. This was coded onto both devices, and rings a high-pitched noise that is difficult to ignore in a room. This bell is currently set to ring when the timer runs out of time, and does not stop until the STM board is powered off manually, through pressing the red button on the device. This was done in order to ensure the users of the device are aware of the danger, and physically move to the stovetop where the device is placed onto. In addition, the STM board is turned off when this occurs. This causes the OpenMV, if being powered by a battery, to run improperly, and it must be manually reset by unplugging and plugging the battery. This is useful in preventing fires on the stovetop because users must be physically near the device, and must notice the stovetop and attend to it if necessary at this point.

The bell connected to the STM board is just one way that the device design was shown to have been built with simplicity in mind. Because the bell was connected to the STM board to begin with, it was relatively easy to code this component into our device. In addition, connecting an alarm to the device was one of the original objectives, and the STM board we chose was able to compactly include this component.

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