PARENTS OF THE FUTURE

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ECE 445 Design Document

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1. INTRODUCTION

1.1 Problem and solution overview

A lot of times, both parents (or the only parent, in case of single parents) of the household tend to be working for some number of hours a day, and have to leave their children alone at home. A study [1] commissioned by “Visit Anaheim”, stated that families spend only about 37 minutes of quality time on weekdays and 2 hrs and 40 minutes of quality time on weekends, mainly due to parents’ hectic work schedule. This time should be spent on emotional bonding, and should not be cut short by parents having to tell their children to do things that children can easily do while their parents are away, such as household chores. Hence, we would like to build something that would allow parents to track their children’s progress on a set of household chores, namely doing the laundry, doing the dishes, and taking out the trash.

Although there are several apps [2] that keep track of children doing their chores, most of them depend on the children logging completion of their chores on their smartphone apps, or parents having to check manually. Our solution employs sensors and algorithms that monitor chores in real time and themselves check for task completion, which provides reliability and saves the parents’ time.

There are also several home surveillance and security systems [3] available in today’s market; however, none of them can decide whether or not tasks have been completed, but rather, can only record video data that the parents will have to manually track. Our solution overcomes the shortcomings of both the aforementioned pre-existing solutions.

The original project that we are referencing sought to build an IoT based system that would help parents monitor the chores done by their children, using pressure and ultrasonic sensors in the sink, the trash can and the laundry bin, and building a local network between the sensors and the parents’ computers. We would like to implement the functionality of this project by removing the pressure sensors and adding visual surveillance to the already existing solution, by adding vision sensors or cameras, and placing them near the doors or rooms where the chores (laundry, trash and dishes) are to be carried, and connecting their output to a laptop, which would run computer vision algorithms to detect whether a task has been completed, which would then be transmitted as an update to the apps on the parents’ devices.

1.2 Visual Aid

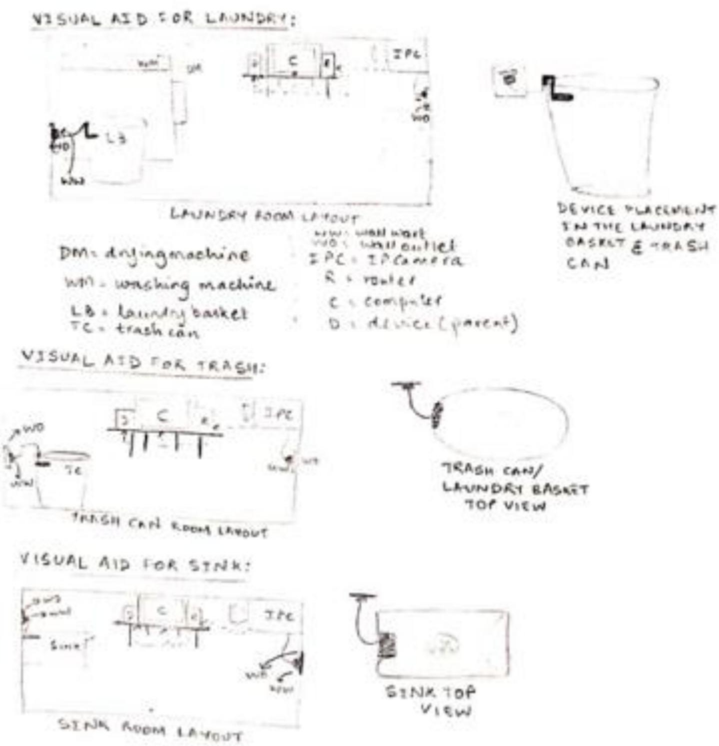

Figure 1: Visual Aid

The above visual aid presents the placement of each component in the project. The laundry room layout, trash can room layout and sink room layout show the respective regions in which the chores are carried out the left, and an IP camera for each task plugging into the wall at the right of the room layout. The middle part of each layout contains a pictorial representation of the Wi-Fi router, the main computer and a client device; but these three components can be placed anywhere in the home (client devices can even be outside the home), since the internet connection does not require the devices to all be present in the same room. The diagram also shows the top view and side view of the physical device (including the sensors and microcontrollers) and how they will be plugged into the wall.

1.3 High Level Requirements

The high-level requirements of the system will be as follows:

1. The system should recognize the children as they enter the field of view of a video camera
2. The system should recognize that the task has been completed using the sensors and camera
3. The system should update the information to the parents' device apps every time a task is started or completed

2. DESIGN

2.1 Block Diagram

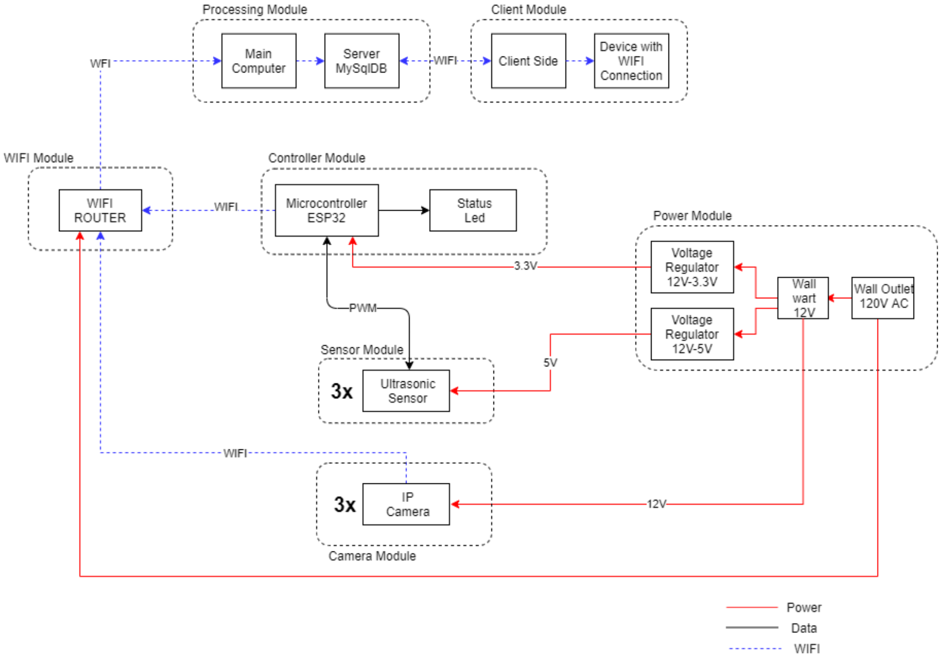

Figure 2: Block Diagram

(a) Power Module: this will consist of the home power outlets used to connect the system components to electricity, the wall wart and required connectors that will step down the main outlet voltage to 12 V, wires where required for electrical connections, and voltage regulators for stepping battery voltage down to 3.3V and 5V for the microcontrollers and the sensors respectively.

(b) Control Module: this will be made up of the microcontroller and the LEDs status. The microcontroller will receive data from the ultrasonic sensor using the PWM method, and transmit them to the processing module via the inbuilt Wi-Fi chip on the ESP32 microcontroller. This module will fit on the PCB.

(c) Sensor Module: this will consist of three ultrasonic sensors, in the same rooms as the cameras, and will be used to collect data such as the amount of clothes or garbage or dishes collected in the laundry basket or trash can or kitchen sink respectively. They will be placed on the top of the containers, pointing down to it.

(d) Wireless Camera Module: this will consist of 3 wireless cameras placed at certain locations in the home, such as in the kitchen, in the laundry room, and the room containing the trash, which will collect video data that will then be processed by the computer. This data will be transmitted to the processing subsystem directly by the camera over Wi-Fi (the Xiaomi IP camera has built in Wi-Fi capabilities.

(e) Wi-Fi Module: this will consist of the Wi-Fi the router for sending information from the Wi-Fi chip for each of the PCBs, as well as the cameras to the main computer, and for providing internet connectivity between the computer and client devices when present inside the home.

(f) Processing Module: this will consist of the main computer present in the home which will run video and image processing algorithms to detect objects and people in the apartment, and track task completion. The main computer will take in camera input via Wi-Fi, and will also generate the signals to be updated on the apps on the parents' laptops, tablets or smartphones (complete and incomplete chores, and chore progress). It will also have a server, which will have a database (MySQL DB) to store all the processed data. The software module running on the computer will contain a main python program to extract data from the database, to run the Python-OpenCV library to make use of computer vision algorithms to generate data, and to print out HTML, CSS and JavaScript code to update the website that will be accessed by the client devices.

This is the actual "brain" of the project, and will be used to fulfil all the high-level requirements of the project. However, the system will also rely on the other components of the project to get the job done.

(g) Client Module: this pertains to every parent device that the parents would like to use to access the chore monitoring system app.

2.2 Physical Design

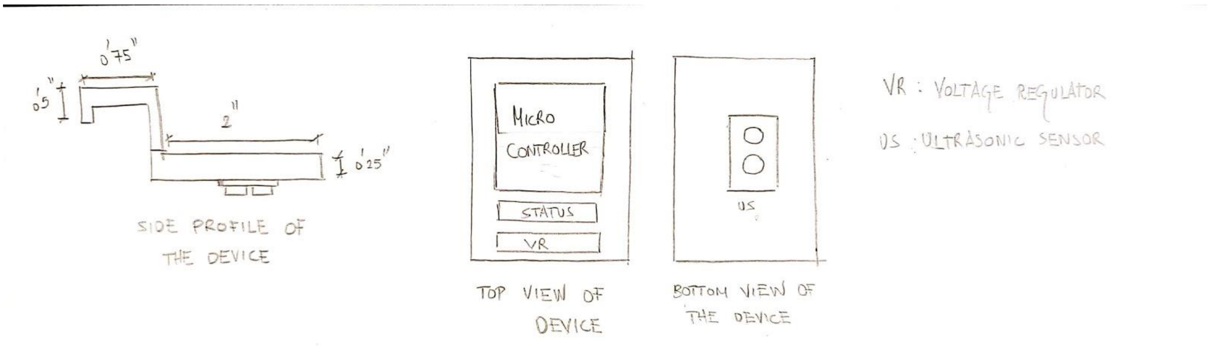

Figure 3: Physical Design

Apart from the cameras that are going to be mounted at a chosen location in the room as shown in the visual aid, the sensor portion of the device will be built on a small metallic plate like body, with dimensions as shown in the diagram above to the left. All the components of the control module and sensor module will be placed on it, as well as the voltage regulators. Since the ultrasonic sensor will only be required to detect how full or empty the sink/garbage can/laundry basket, we will be placing it at the bottom of the device to give it better access to the contents of the aforementioned chore sites.

2.3 Power module

Our project is going to be connected to the wall outlet, and this is how all the PCBs, router and cameras are going to be powered. The cameras that we are going to use already have their plug in with their own wall wart, Each PCB will be powered at 12 V, but it will have two Voltage Regulators inside each PCB so it can match 3.3V needed for the microcontroller and 5V needed for the sensors.

2.3.1 Wall Wart

We made the decision of using wall warts to power the PCB because they are more environmentally friendly as compared to lithium batteries and because they are more convenient for clients in case of a long term set up, since they do not have to be recharged, like Lithium batteries would have to be.

Requirements	Verification
The output should be 12V +/0.6 V	With a voltmeter connected to the output of the voltage regulator in parallel, the voltage should be between 11.4V and 12.6V.

Table 1: R&V Wall Wart

2.3.2 Voltage regulator 3.3V

This voltage regulator is going to be connected exclusively to the microcontroller, which needs at least 0.5mA and 3.3V+/-0.3V to work.

Requirements	Verification
The 12V from the wall wart should reach 3.3V+/-0.3V	With a voltmeter connected in parallel to the output of the voltage regulator, the voltage should be between 3V and 3.6V.
There should be at least 0.5 mA for the microcontroller to work	An ohm resistor will be connected at the output. An ammeter will be connected in series to the output terminal, and the output current measured should be more than 0.5mA

Table 2: R&V Voltage regulator 3.3V

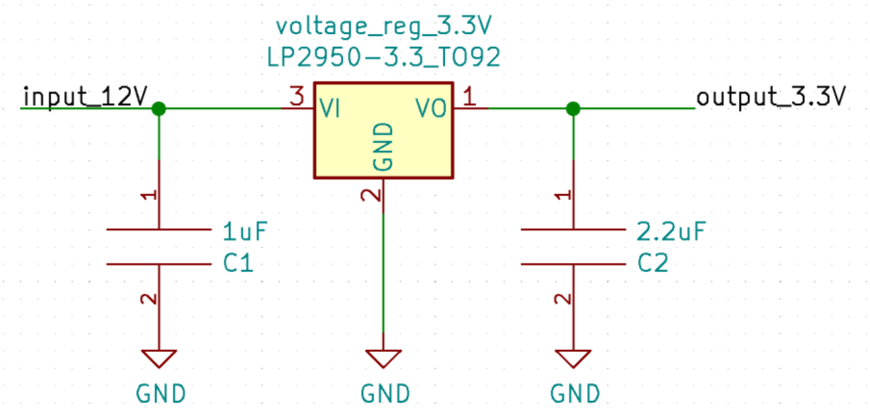

Figure X: Schematic for Voltage regulator 3.3V

2.3.3 Voltage regulator 5V

This voltage regulator is going to be connected to the sensor and the microcontroller. The minimum current through each of them is 15mA (ultrasonic sensor).

Requirements	Verification
The 12V from the wall wart should reach 5V+/-0.5V	With a voltmeter connected to the output of the voltage regulator, the voltage should be between 4.5V and 5.5V.
There should be at least 15 mA for the ultrasonic sensor and microcontroller to work	An ohm resistor will be connected at the output. An ammeter will be connected in series to the output terminal, so the outputted current measured is greater than or equal to 15mA

Table 3: R&V Voltage regulator 5V

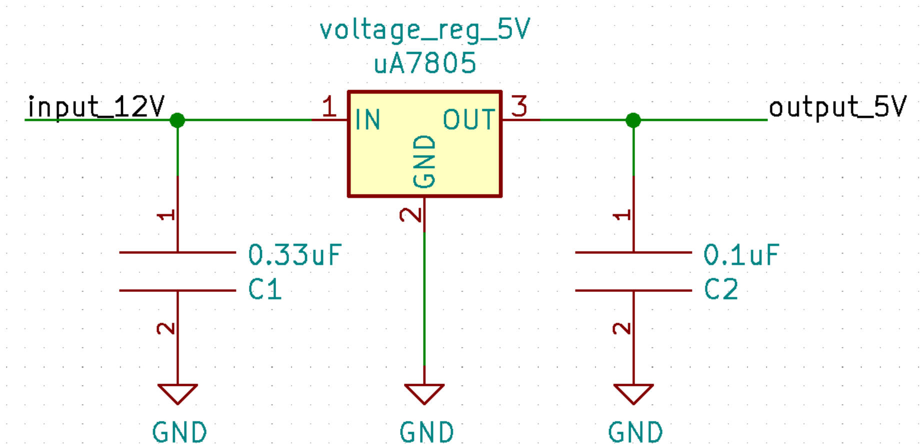

Figure 4: Schematic for Voltage regulator 5V

2.4 Control Module

This module is made up of two parts, namely the microcontroller and the status LED's. The microcontroller will be powered with the 3.3 V from the 3.3 V voltage regulator and LEDs will work with signals provided by the microcontroller. The ESP32 will be responsible for processing the data from the ultrasonic sensors and transfer the data to the main computer over Wi-Fi using the inbuilt Wi-Fi chip.

2.4.1 Microcontroller

For this project, the microcontrollers that are going to be used are going to be the ESP32, which will be low cost and enough for the devices that we need to connect to the microcontroller. We were looking for a cheap microcontroller, because we are going to use three of them and with the wireless cameras our project price is going to rise. This microcontroller also has Bluetooth and Wi-Fi connections integrated.

The microcontroller will be powered with a 3.3V voltage regulator. The ultrasonic sensor will be connected to the ESP32 through the Digital PWM input pins, as well as the Analog Input pins.

Requirements	Verification
When providing an input voltage of 3.3 V and the frequency being 20 MHz, the supply current should be approximately around 12 mA with a percent error of 10%	With an ammeter connected in series a resistor and the output terminal, so the outputted current measured is around 12mA (10% error)

Wi-fi pin must correctly receive and send 5 bytes of data from the microcontroller to the database.	This can be verified using dummy tests by transmitting random data over Wi-Fi once the PCB with microcontroller is connected.

Table 4: R&V Microcontroller

2.4.2 LEDs status

These LEDs will be located on the PCB and their aim is to indicate the user if the microcontroller is currently being powered or not. the children if they have to work on it or not. The LED will be connected to a standard PWM Digital Input pin and depending on whether the device is powered, it will be on or off.

Requirements	Verification
When the ESP-32 is correctly powered with an input voltage of 3.3V and receiving data from the Ultrasonic sensor the LED should power on.	When the power module is connected to the PCB, the sensors are connected to ESP-32, the LED should be held in the high position. This will be verified through the use of a multimeter.

Table 5: R&V LEDs status

2.5 Sensor Module

2.5.1 Ultrasonic Sensor

The sensor that will be used is HC-SR04 ultrasonic sensor. It will be used for determining in the container is full. When a container is full, the distance between the top and bottom part of the container is detected as less, because there are obstacles in the middle. The sensor should be able to send a signal indicating the container is full when the measure is 7 inches.

This sensor works by emitting a 40kHz ultrasound wave which will bounce on the object and come back to the sensor. The sensor will measure the time that it takes for the wave to come back, and depending on the time, the obstacle is closer or further. We will send 10 signals in order to make sure that the object is not falling, but it is staying in the pile of stuff. In Figure X there's an explanation of how it works internally.

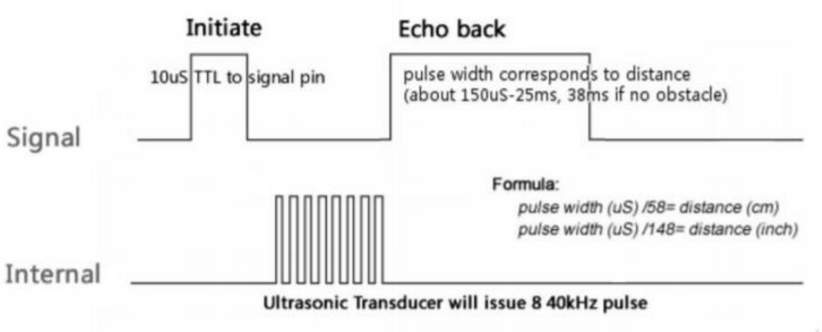

Figure 5: Ultrasonic Sensor Timing Diagram

The sensor will be receiving power from the voltage regulator and the TRIG and ECHO pins on the sensor will be connected to the PWM (Pulse Width Modulation) pins on the ESP32 [4] .

Requirements	Verification
The sensor must be able to measure the distance from 1.5 feet to 7 inches.	The sensor will be tried by measuring distances that are already measured with a measuring tape.

Table 6: R&V Ultrasonic sensor

The sensor must be able to work with the measures, but what we really want from the sensor is to be able to detect whenever the distance is 7 inches or less. For that purpose, the algorithm used will be as shown in Figure 6:

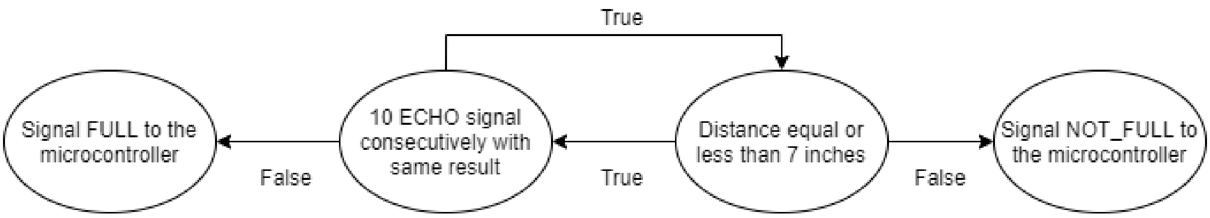

Figure 6: Ultrasonic Sensor Algorithm Flowchart

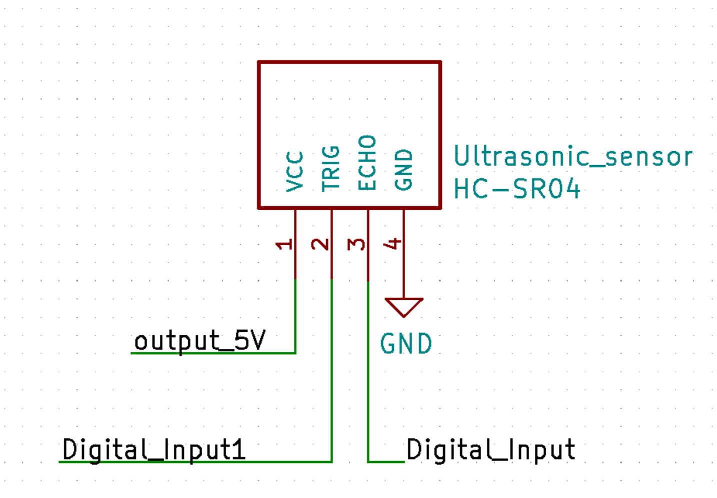

Figure 7: Schematic for Ultrasonic Sensor

2.6 Camera Module

2.6.1. IP Camera

The cameras that are going to be used need to be IP cameras. They don't necessarily need to be wireless, because they don't have to be moved, but they must be able to connect via Wi-Fi to the computer (with a router). These cameras need to have enough quality so our code can successfully identify a person.

Requirements	Verification

The camera must be capable of recording at an angle of at least 120 degrees	Once the camera is working, two different objects will be placed within 120 degrees, and we will prove that both objects are detected by the camera by sending video data to the computer over Wi-Fi and viewing it on the computer screen.
2. The camera must send data at a rate of at least 20 fps	To test the camera, we will set it up to connect with the power and Wi-Fi, and

Table 7: R&V IP Camera

2.7 Wi-Fi Module

2.7.1 Router

The router will be used to connect the IP cameras and the microcontroller to the main computer, and send information back and forth between them. This won't have to be bought, because the camera should work with the router device in any apartment. This router must be able to receive 6 different signals.

Requirements	Verification
It must be able to receive 6 different signals (3 from the sensors and 3 from the cameras) and send them to the computer.	This can be verified with test runs by sending dummy data from the 3 sensors and 3 cameras to the computer and verifying that they are received after everything is settled up.

Table 8: R&V Router

2.8 Processing Module

2.8.1 Main Computer

The computer will be responsible for processing all the data coming from the camera, via Wi-Fi, and all the sensor information, that is also transmitted via Wi-Fi. It will run video and image processing algorithms to detect the unwanted objects, happenings or people in the apartment. This computer will be also responsible for running the script (HTML, CSS, JavaScript) which will hold all the Client-Server communications, acting as a back end.

Requirements	Verification
1. The computer must have enough processing power to run and process all the video data by running image processing algorithms (4.9 GHz frequency and 8 GB RAM minimum)	1. Check if our main PC components have enough processing power and RAM available by checking the specifications on a laptop running a reliable processor, such as Intel i7
2. The computer must be able to connect to the internet so it can receive all the data from the microcontroller and the video from the IP Cameras.	2. Check if our main PC is able to connect to the internet by connecting to different webpages, after completing the required Wi-Fi setup.

Table 9: R&V Main Computer

2.8.2 Server

The server will hold all the database access and handle all the database requestss from the client side. The database will be updated every time a task is completed, and it will be updated from the main computer we talked before

Requirements	Verification
Minimum disk space of 2GB The server should be secure and all information should be protected	1. Buy enough memory or verify that the computer has it already. Use passwords in order to access the server.

Table 10: R&V Server

2.8.3 MySQL Database

The database acts as storage for all of the data coming from the sensors. Via Wi-Fi, an Arduino based microcontroller can directly push data to a database. Databases are a method of organizing data records and SQL is an implementation of the former that allows a user to obtain many records with a single command. SQL is attractive to a large array of problems due to this functionality, and is essential for our goal of visualizing statistical information.

Requirements	Verification
The database must be able to either receive or send at least 15 bytes (mean length of a human name 15 chars)	1. We will test this with a computer by sending requests to the server.

Table 11: R&V MySQL Database

2.9 Client Module

2.9.1 User Device (Client Side)

This will consist of every device with an internet connection that will access the web page. The updates will be made on the back-end side, and will be shown on this side (front-end).

Requirements	Verification
The devices need to have Wi-Fi on them and they have to be able to connect to the internet.	1. We will check this by loading a simple web page (eg: google.com) on the devices

Table 12: R&V User device

2. 9 Tolerance Analysis

The most critical features of our project are the camera module and the computer. This is because the main task of detecting the completion of the task will be carried out by the Vision algorithms on the computer, with the data that is collected from the cameras set up for each task. This data needs to be sent over Wi-Fi. In order to prove that our design will be able to function despite the limited accuracy of the sensors, we need to show that our current requirements will be satisfied even if there are fluctuations in the given data within the tolerance ranges of the components involved.

Beginning with the camera, we see that it is required to have a 120-degree field of vision, as well as be able to generate data of at least 20 frames per second. The camera that we have chosen is a commercial camera, and we do not have access to its data sheet since it is a commercial product and not a sensor; we will have to test it when we get the device delivered in order to measure the tolerance range. For now, we will assume an error of 5%, because we are using a well-developed commercial product, from which we can expect good quality. Our camera has a listed field of view of 130 degrees, and so we will get 130 degrees+/-6.5 degrees, which will be somewhere between 123.5 degrees to 136.5 degrees, which will ensure that the vision angle parameter is met.

We can also assume a 5% error in frame rate, which will put the camera frame rate within the range of 19-21 frames per second. However this will not be a problem either, since we are planning to use vision algorithms for OpenCV, on an i7 processor, which will be able to handle this frame rate, in terms of computational performance (the processor will be able to process the data and generate results to be updated on the back end of the server.)

Since this system is to be deployed in the USA, where there is reliable electricity and internet in most places; therefore, the components of the power module and the Wi-Fi module have not been taken into consideration in the tolerance analysis.

Since all the above requirements have been met, the project will be able to operate successfully.

3. PROJECT DIFFERENCES

3.1 Overview

The previous project chose to check whether or not a task was complete based on the readings of pairs of sensors that are updated to a website, which parents and students can access. There is a reward system for children to get rewarded or penalized within the app, based on whether or not they complete the tasks. The children can use their version of the nap to mark as unread.

Our project makes use of a camera to collect video data, and then runs computer vision algorithms on that data, which determines whether or not a task has been completed. If the task has been completed, the user front end of the website gets updated automatically. Otherwise, the website does not get updated, and the task remains marked incomplete. We also have ultrasonic sensors (to determine how full the containers and sink are are, much like the last project did, but most of our processing is done via computer vision and the sensors are only there to create redundancy.

Our solution offers an improvement over the previous one because it is a lot more reliable. For example, there can be instances in which someone throws something in the trash can or laundry basket which gets suspended from the edge of the container, giving the false illusion to the sensors that the container is full, and throwing the reported website numbers off. However, this situation can be avoided if a camera is used, because it can assess that the trash/cloth has not landed all the way at the bottom of the container atop the given container contents.

Our solution is more reliable also because the website data about task progress and completion can only be updated by the computer algorithms, and not by the children, who might not always be able to correctly assess whether a given task has been completed to satisfaction or not, whereas the algorithms will.

However, the only trade-off is that although this system will be a lot more accurate, it will also be more expensive to create than the previous design. However, this trade-off is worth making due to the added accuracy and reliability of the system.

3.2 Analysis

The previous solution sought to monitor tasks by checking the data for each chore generated by pressure sensors and ultrasonic sensors. The ultrasonic sensor detected objects that were 7” or less away from the sensor. The pressure sensor had a range of 0.1 kg to 10 kg, and the original project used it to detect a part of the weight of the garbage instead of the full can, since it was only 2”x2”, and only sent a “full” signal when the weight of the garbage/laundry was over 4 kg.

Our solution did away with the pressure sensor in the original design since it was redundant in the case of the chore of doing dishes, since it would be extremely unsafe to have a sensor with electrical components present near water. We kept the ultrasonic sensor to add a redundancy to our main computer vision system, and to perform sanity checks on and calibrate our camera data.

Our solution will be an improvement since our cameras will be able to not only track two states of the track, complete and incomplete, but also be able to track progress. For example, the algorithms will be able to recognize how full the garbage can/sink/laundry basket are, and help parents decide whether they want each to fill up, or to assign a task to the children right away (in case there are going to be guests, or in case there are not enough people at home to fill up the sink, and the parents don’t want the dishes to sit for that long).

4. COST AND SCHEDULE

4.1 Cost Analysis

- Labour: our goal is that we all work the same number of hours and optimize the time in the best possible way. For this, it will be necessary to build a previous distribution of tasks that make our work a place for a complete project and in which the high-level requirements are met. As we are assuming that for the project we are working as engineers without experience, a reasonable salary should be 30$/hour. Assuming we are going to work for 10 weeks from now and we’ve been working for 4 weeks, that’s a total of 14 weeks, 15hours/week.

Total cost = 3 *2.5*14*30*15 = **47,250 $** for Labour cost

- Parts: Table# below includes all the parts that need to be bought to build the robot.

Description	Manufacturer	Quantity	Cost/unit ($)	Total cost ($)
Microcontroller ESP32	Espressif Systems	3	2.20	6.60
ATMEGA328P	Microchip Technology	3	1.98	5.94
Ultrasonic Ranging Module	Sparkfun	3	3.84	11.52
Voltage regulator 5V (UA7805CKCT)	Texas instrument	3	0.58	1.74
Voltage regulator 3.3V (LP2950-3.3_T092)	Texas Instrument	3	1.08	3.24
Wall Wart 12V	Jameco Valuepro	3	7.95	23.85

Mi Home Security Camera Basic 1080P	Xiaomi	3	20	60
TOTAL				$112.89

Table 13: Total Cost for the Parts

- Sum of cost:

Total for the Labor	$47,250
Total for the Parts	$112.89
Overall cost	**$47,362.89**

Table 14: Total Cost Analysis

4.2. Schedule

Week	Nacho	Nishqa	Belén
Week 1	Order the parts and start working with the image processing	Machine shop, and explain our physical design	Improve the schematics and send the first version of PCB
Week 2	Image processing	Program Client web	Second version of PCB
Week 3	Facial recognition	Facial recognition	Start working on the code for programming the sensors
Week 4	Image processing	Program ESP-32	Assemble PCB and soldering
Week 5	Image processing	Start programming ESP-32	Verify requirements and verifications
Week 6	Program ATmega328p	Continue programming ESP-32	Verify requirements and verifications
Week 7	Verify requirements and verifications for the processing module	Finish programming ESP-32	Program ESP-32

Week 8	Assemble the modules	Verify requirements and verification for client module	Assemble the modules
Week 9	MOCK PRESENTATION	MOCK PRESENTATION	MOCK PRESENTATION
Week 10	FINAL PAPER	FINAL PAPER	FINAL PAPER

Table 15: Schedule

5. DISCUSSION OF ETHICS AND SAFETY

One major issue that this project could face is that the video data could be intercepted by malicious third-party content, which would be a violation of sections 1.2 and 1.6 of the ACM code of ethics [5], titled "Avoid Harm" and "Privacy" respectively. To avoid this, we could encrypt the data from end to end, so that it cannot be used maliciously even if the system is intercepted.

Moreover, if intercepted, this data could be used to determine whether the children are home alone or not, which could cause a lot of damage. In order to effectively deal with this, all the cameras should be kept out of places in the home where privacy is expected, such as bedrooms, bathrooms and changing rooms. Also, the field of view of the camera should be limited to the bare necessary minimum required to assess whether or not the task has been completed.

Although there are not many codes and laws for camera surveillance, every state in USA has their own laws about what is and isn't legal to do, and customers can contact their attorney to confirm them [6].

Since this project is heavily reliant on electricity, several electric safety measures will have to be followed, to avoid causing injury or harm to the members of the household or guests who may come in contact with it, in order to be in line with the IEEE code of ethics [2], entry 9. We will make sure to ground each electrical component, and also place it on rubber or wood in order to insulate it.

5. CITATIONS

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