EE/SE/CPRE 491
MAY 1631
DESIGN DOCUMENT VERSION 2

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ISU Electrical & Computer Engineering

Project Title
Automated Tool Monitoring System

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Executive Summary

The goal of this project is to track down and secure the tools that are taken out from the toolbox. Often the tools missing are not because it has been stolen but because students forget to put them back to their original spot. Thus we are committed to create a system that can keep track of changes happen within the toolbox and eventually solve the issues of missing tools.

Project Statement

Due to the tools used in the ECPE machine shop often get missing or do not get returned, our group will try to solve the problem by creating a system called Automated Tool Monitoring System to secure and track down those tools borrowed by students. The system will allow access to the toolbox by the swipe of a student, staff or faculty member's ID card. Once opened, the system will keep video records of tools removed and returned. The system will also need to interface with the lock system of the existing toolbox.

Ideally our system will utilize a single board computer called Raspberry Pi to handle the workload. As Raspberry Pi is capable of doing everything like a desktop computer do, we will connect a camera and user input components, which are magnetic card reader and keyboard, through USB port. User input components will allow the user to swipe their card or enter their ID card number. High resolution camera will be used to record a 1080p video. Servo will be used to unlock the tool drawer while the sensor will be used to detect which drawer is opened. All the videos recorded will be sent to dropbox for image analysis and comparison before go to the database. Also, the system will use a 7’ monitor as user interface.

System Level Design

System Requirements

The system created for this project will meet the following requirements:

- The user with valid access should able to open the tool machine by using their ISU card or by entering their ID number using numpad.

- The camera for Main Control Unit should able to record 480p video for more than **3 minutes**
- The camera for Image Processing Unit should able to capture 1080p image for image analysis.
- The Image Processing Unit should able to detect which tool is taken or returned at more than **80% accuracy.**
- The Dropbox should have enough storage to store videos for 1 week assuming the number of tool transaction per day is less than 20.
    - 20 transaction * 7 days = 140 transaction
    - Each transaction take at most 3 minutes of video = 420 minute worth of 480p video.
    - 1 minute 480p video requires approximately 50 MB storage
    - 420 minute * 50 MB = **21 GB of video storage**
- The sensors on each drawer should able to detect if a drawer is open at **100% accuracy.**
- Warning alarm should be activated when more than one drawer is opened at the same time
- The validation process from MySQL database should take **less than 2 second.**
- The Raspberry Pi should able to be accessed remotely from any computer using SSH for configuration and troubleshooting.
- The tool box must be physically locked.

Functional Decomposition

- Authorization
    - Read the identification number of the card swiped
    - Parse the identification number
    - Authorize the identification number with database

- Record Video
    - Activate camera
    - Record video
    - Upload video to Dropbox
    - Get a share link for the uploaded video

- Unlock Tool Box
    - Signal the servo
    - Unlock the key

- Image Processing
    - Capture images
    - Feed the image to the Image Processing Unit (MyRIO)
    - Detect missing or returned tools
    - Send the data to Main Control Unit

- Detect Drawer
    - Get signal from sensors installed in each drawers
    - Send the data to database

- Admin Web Application
    - Add new user for access
    - Remove user
    - Monitor users
    - Monitor users' activities
    - Monitor tools availability

System Analysis

- Main Control Unit (Raspberry Pi)

  Raspberry Pi plays an important role in this system. Raspberry Pi is a credit card sized single board computer that basically can do anything that a normal computer can do. In this system, Raspberry Pi acts as a central processing unit that handles all the input from Magnetic Card Reader and Keyboard, run the main program and handle interaction with Dropbox and MySQL database. It will also will interact other output component like monitor, speaker, camera and servo.

- ## User Input

  The two input component for this system are the magnetic card reader and keyboard. The magnetic card reader should able to read the card number for validation. In case of card read failed, user can enter their card number manually using keyboard.

- ## Camera

  The camera is used to record activity for every transaction of taking tools or returning tools. It also used to capture image for further image processing and comparing to detect which tool is taken or returned. Camera that will going to be used for this project Logitech Webcam.

- ## Lock Mechanism

  Servo is the main component for the tool box lock mechanism. Since there are two lock for each compartment of the tool box, there will be two servo used in the system. Each drawer of the tool box will be installed with sensor to detect whether it is opened or not. If more than one drawer is opened in the same time, the system will sound the alarm to give warning to the user.

- ## Image Processing Unit (MyRio)

  The system will be able to detect which tool is taken or returned by user. For that purpose, we used National Instruments MyRIO as the Image Processing Unit for our system. a few images will be captured by the camera and will be feed to the MyRIO embedded program and Vision Assistant script for image analysis. The result then will be sent back to the Main Control Unit for further processing.

  In Vision Assistant Script, we used two functionality to detect which tools is missing from the drawer which are Color Pattern Matching and Shape Detection Matching. As for Color Pattern Matching, we give it a template that is going to be used to compare with our image captured and it will return the position where it find the similar color pattern. To get a more accurate result, we will also use Shape Detection function where we detect circular shape in our image and it will return the location and the radius of the circles. Therefore by using this vision script we are able to pin-point the x and y position of where this special circle pattern is found in the image. This data will be send to the Main Control Unit for

further analysis so that we can determine which tools is missing or returned in which drawer.

- Admin Web Application

  Admin will be able to see all the transaction records through this web application. It also enable admin to add new user to the system, remove user from the system, contact user and update database. Furthermore, both admin and users will be able to see the list of tools in the toolbox and their availability.

Block Diagrams of the Concept

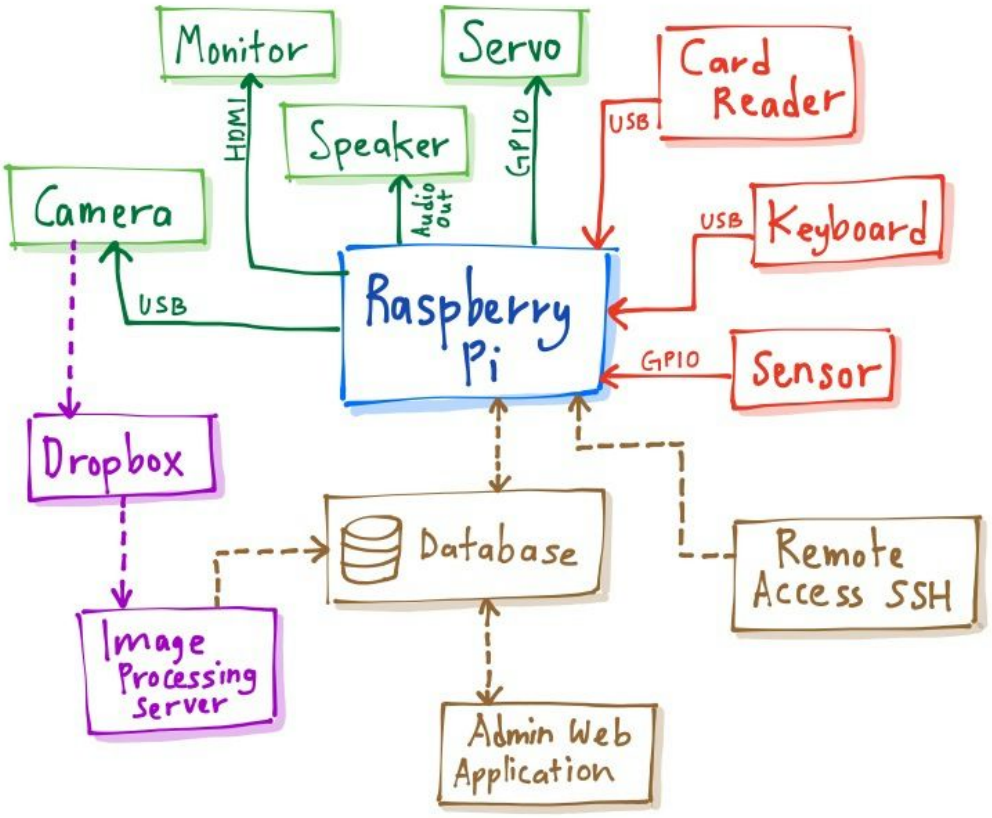

Figure 1 : First Draft Concept Sketch

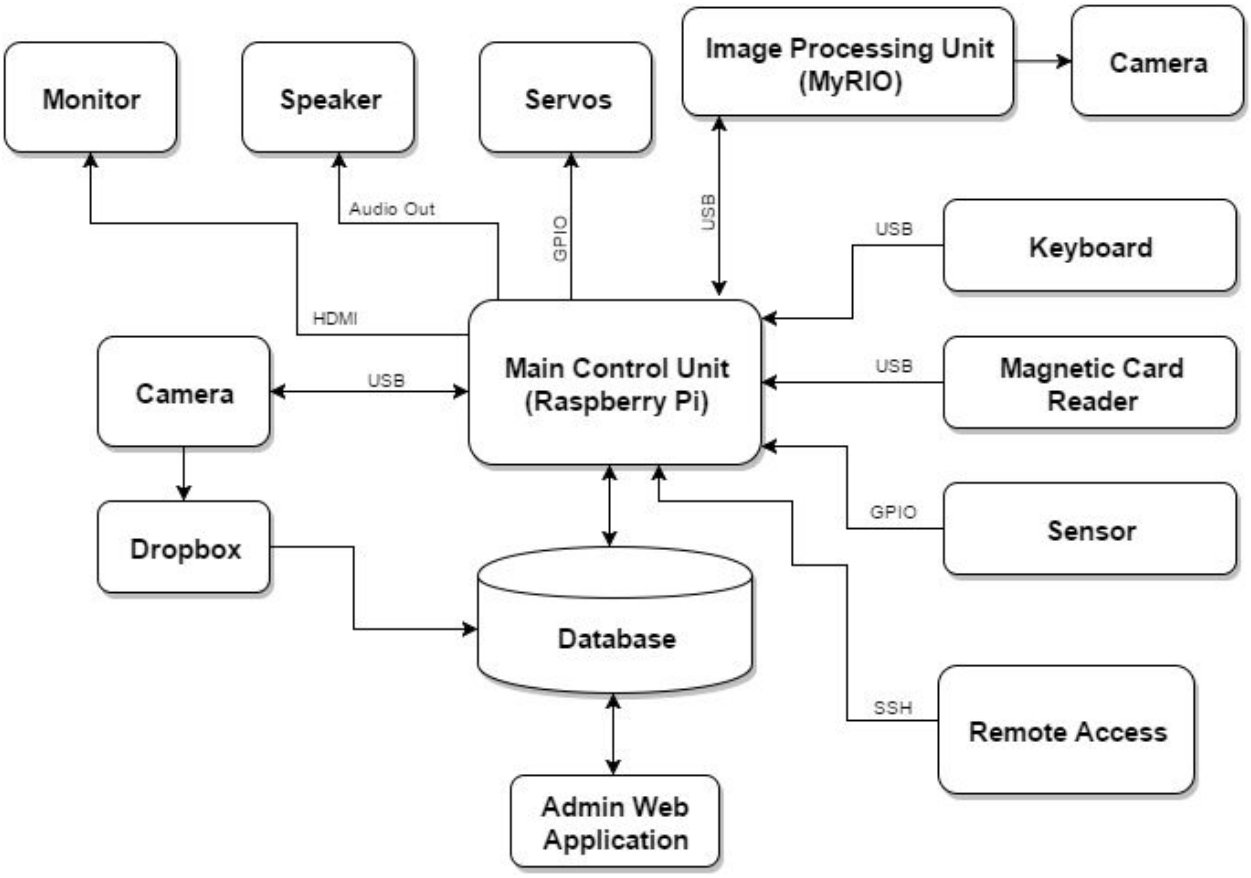

Figure 2 : Final Block Diagram

Detailed Implementation

I/O Specification

The input and generated output for our system is explained below:

Input:

- Magnetic Strip ISU Card Reader
    - Takes in the student/faculty ID number to log them into the Tool Checkout System

- Numpad
    - Alternative to enter the ID number to log into the system.

- Camera
    - Once the user has been authorized, the camera will be activated and record the user's activity.

Output:

- Sounding alarm
    - When user has more than one tool drawer open an alarm will sound to notify the user to only have one drawer open at a time
    - This is due to safety concerning due to a potential tipping over of the cabinet, should the weight be offset

- Servo Locks
    - After the user has logged into the system and are approved to remove tools from the cabinet, tool cabinet will unlock

- LED Monitor
    - WIll display login screen as well as additional relevant information

User Interface Specifications

Our system interface shall be designed with human-usability in mind. The user will just simply swipe the id card to unlock the tool box. Onced swiped and approved access, our system will do the rest. Additionally, the Main Control Unit shall be constructed in such a way that the keyboard is easily accessible and typable. Besides, the screen will be set to have a large enough text to increase readability. The LCD interface itself shall be as simple as one input field for ID number, as well as relevant success/fail messages.

Hardware Specifications

- ### Raspberry Pi

  Raspberry Pi of model B, which comes with 512MB of RAM, 2 USB ports, an ethernet port, and composite video will be used for the project as the Main Control Unit. The processing speed and the RAM available has been tested and verified to be sufficient for the process to get done. Additionally, a 16GB micro-sd card will be used to store any additional relevant data(if any), and a usb splitter

will also be integrated on one of the USB port to connect the keyboard, USB camera, and the magnetic card-reader.

- NI MyRIO

  We use National Instrument MyRIO model 1900 as the Image Processing Unit for our system. MyRIO has dual-core ARM® Cortex™-A9 real-time processing and Xilinx FPGA customizable I/O. It has a powerful processing power that is very essential to run a highly performance process like image processing and analysis.

- Servo Motor

  The motor being used to control the locking and unlocking of the lock is a Parallax Standard Servo (#900-00005). This servo has interface capability with PWM capable devices and can hold any position from 0 to 180 degrees. The servo can apply 38 oz-in torque at 6VDC and can operate in the range of 4-6V. The servo also has a maximum current draw of 140+/-50mA at 6VDC and draws 15mA under static conditions. The I/O of the servo motor is connected to the Raspberry Pi. The I/O of the servo is controlled by the Raspberry Pi. The servo is powered from 6V batteries, through a transistor, to conserve power. When the Raspberry Pi sends a signal to move the position of the servo, the increase in voltage causes the transistor to turn the servo on and move it to its desired angle. When the servo does not receive a signal from the Raspberry Pi, it stays at its current location and operates under static current conditions. The servo is independently powered from an external 6V battery source in an order to avoid current spikes.

- Magnetic Card Reader

  The magnetic card reader that will be used is Yasoo®New 3 Magnetic Card Reader. it is a new USB 3 Track Magnetic Card Reader fully plug&play compliant. It means that it will act like a keyboard. It is very light, and could be operated at a low temperature of 0 degree Celsius and as high as 40 degree Celsius. It is a USB powered device and didn't draw high current and voltage.

- Magnetic Sensor

  MC 38 Wired Door Window Sensor Magnetic Switch will be used for the project. It is a small magnetic sensor with a distance accuracy of 15-25mm. The sensor is easily to be programmed. It consist of two wires which one is already defined to be connected to ground. The other wire will be connected to I/O port and the

send signals to inform the Raspberry pi about the status of the drawer. Magnets will be placed on the drawer so that when one drawer is open, the magnet will be far and the sensor will inform Raspberry pi that the drawer is now open.

- Lock

  The Lock mechanism that will be used is the original lock that has already been installed on the drawer. We have decided to keep the lock mechanism the same as the original because when there is power outage or the system fails to work, the drawer could be resetted and operated manually. However, the lock mechanism will be integrated with servo so that when the system is operating, servo will act like a key to lock and unlock the drawers. The servo will be connected to a custom made rod. One end of the rod then will be connected to the original lock mechanism so that when the servo moves to a desired angle, it push the rod to lock and unlock positions.

- Camera

  Main Control Unit

  - For the Main Control Unit, we used Raspberry PI 5MP Camera Board Module. It has a capability of 5 mega pixel native resolution sensor-capable of 2592 x 1944 pixel static images and supports 1080p30, 720p30 and 640x480p60.90 video. And this camera also supported in the latest version of Raspbian, Raspberry Pi's preferred operating system

  Image Processing Unit

  - For the Image Processing Unit, we have used a Pro HD Webcam 1080P. It is a USB powered camera. It can record 10800p HD videos at 30 frames per second. It has a 78 degree wide view which is good for close range image or videos capturing. The USB powered camera also equipped with two stereo microphones(additional features that might or might not needed). For this project, we found that this camera would work perfectly with our system. it could be programmed easily, it could record videos and take pictures with high resolution, also it requires low voltage and current to be operated.

Software Specifications

- ### Raspberry Pi Software Specification

  The Raspberry Pi is loaded with Raspbian Operating System which has a similar environment with Linux OS. This allow us to write new code in the Pi text editor and compiled using Terminal. Raspberry Pi runs on the Broadcom BCM2835 system on a chip(SoC), which includes an ARM1176JZF-S 700 MHz processor and VideoCore IV GPU.

- ### Main Control Unit (MCU) Software Specification

  Most of the code for the MCU is written in C and Python. The main program is written in C and it will execute other Python program to interface with input and output component. The programs imports several **libraries and modules** and runs several functions for the LCU to function correctly.

  Libraries and Modules

  - bcm2835 1.46
    - To access General Purpose Input Output (GPIO) on Raspberry Pi board

  - avconv
    - To interface with the camera

  - MySQL-python 1.2.5
    - To interface with the database

- ### Admin Web Application Specification

  Client Side

  - The client side of the web application is created using Laravel 5 framework which make used of HTML, CSS and PHP script along with Blade templating.

Server Side

- For the server side that is used to communicate with the MySQL database, we used PHP scripting language.

- Image Processing Unit (IPU) Software Specification

  The image analysis program that is deployed into the MyRIO is created using National Instrument LabView and Vision Assistant.

Simulation and modeling

As for now, we are in the process of creating the first prototype of Automated Tool Monitoring System. We will assemble all the sub-components into one system. To simulate the system, we will first ran each sub-component of our system through a series of simulations on breadboard while connecting with Raspberry Pi.

First, we simulate and test the camera to record a good quality of video that can capture in about 3 minutes period and upload them to Dropbox without having any troubles.
Then, we simulate the Raspberry Pi sending Python command using pulse-width modulation to control the servo and unlock the lock. During the simulation we are checking to see if the servo is moving in a smooth manner (no jittery behavior) and accurate angle as instructed. In order to create an efficient system, we simulate the magnetic door sensor connected to GPIO pin of Raspberry Pi to make sure any movement can be detected effectively. We also simulate the student ID card swiped on the magnetic strip reader and student ID number manually inserted through keyboard. We will see if we are able to open the drawer of toolbox after integrating with servo.

Implementation Issues Challenges

The biggest implementation challenge for our system is to find the best way to detect the missing and replaced tools in the tool box. The initial plan is to used image processing and analysis to implement the tools detection functionality. However the problem with this implementation is that there are probability where the image taken is blurry if the it is taken when drawer is moving. Besides, there also chances that the content of the drawer is blocked by the user which would make the system fail to detect the tools in the image.

Other than that, another issue that we have is how to integrate the servo with the lock mechanism for the tool box. The existed lock system for the tool box is quite mechanically complicated and none of our team members have much experience with mechanical lock system.

Testing Procedures and Specifications

- ### Electrical Component Testing/Procedures/Specifications

  All electrical components such as servo and magnetic sensors will be tested on breadboard first and then it will be implemented into PCB layout. The voltage supply for the servo also will be tested so that we know how much power it needed in order to work perfectly. Besides, the sensors also will be tested its minimum and maximum distance of detection before the signal is sent to the Raspberry Pi.

- ### Hardware Component Testing/Procedures/Specifications

  All hardware components will be tested to ensure that they meet our high level system requirements. First, the servo will be tested by sending a signal from the Raspberry Pi to rotate a corresponding number of degrees. Next, we will verify that the servo did move the intended number of degrees. Then the magnetic sensor will be tested by making sure that the Raspberry Pi will get the open and close signal from the the sensor. We also will verify that the camera did record a minimum length of 3 minute video and capture images at the same time.

- ### Software Component Testing/Procedures/Specifications

  All software for this project will be tested thoroughly including the Main Control Unit software, the Image Processing Unit software and web application. In particular, specific emphasis will be given to testing security and secure information transfer from the system and database. This testing will ensure that no outside user will be able to get into our system, and gain unauthorized access. As for the image processing unit, we feed in different images into our Vision Assistant script and see if the script able to detect all the pattern in the images accurately. We also vary the distance of camera when we capturing the images.

Additional Information

PCB Issues

When testing the electronic parts individually, we have encountered zero difficulties/issues except for the anomalous behavior of the parallax servo when leave static at 0 degree. We haven't face much difficulties maybe because we are still at the testing stage where what we do right now is just to make sure everything is working before assemble them as a system. In the future, we expected ourself to face a lot of unexpected difficulties/issues to get the project done.

Software/Firmware Design Documents

- Raspberry Pi User Guide
  http://www.cs.unca.edu/~bruce/Fall14/360/RPiUsersGuide.pdf
- NI myRIO Vision Essential Guide
  http://www.ni.com/white-paper/52475/en/
- NI myRIO Project Essential Guide
  http://www.ni.com/tutorial/14621/en/

Conclusion

Our main goal is to create a system that would benefit others. We are creating this system with the hope that anyone who take tools from the department`s tools drawers will feel responsible to return the tools back to where it belong so that it could be used again by others. As our work will be focusing on creating a security for the tools, we will be creating a system to monitor who took what and when. Also, we will record a video of them taking the tools out from the drawer. By using the camera provided, we will also try to make an image comparing software to detect what tools were taken out so that we could record and store all the necessary information in our database. Also, we will be focusing on delivering a working final product that meet the required specifications. We do noticed that the system is already existed in the market. However, we hope that we could create a working product that function the same as the one in the market at a

lower price. Thus, the product usage that we will be making could be expanded more throughout the campus as it requires lower cost to be implemented. With all the knowledge we learn at the Iowa State University, we are looking forward to make this project a success.