Software Formalization

Year: 2019 **Semester:** Spring **Team:** 2 **Project:** Guard DAWG System
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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Third Party Software		x2		
Description of Components		X3		
Testing Plan		x3		
Software Component Diagram		x4		
Writing-Specific Items				
Spelling and Grammar		x2		
Formatting and Citations		x1		
Figures and Graphs		x2		
Technical Writing Style		x3		
Total Score				

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

General Comments:
Relevant overall comments about the paper will be included here

1.0 Utilization of Third Party Software

Previously in your Software Overview you discussed algorithms and data structures to be used in the software/firmware of your ECE477 team project. In this section, explicitly list out all of the third party software you intend to use for your project (a table may be a very useful way of conveying this information). Provide citations to source material, a description of the software being used, and a brief description of what your team intends to use it for. Also include any relevant licensing information for the software and any steps necessary to use the software (such as paying a royalty for licensing commercial software, or attribution requirements for open source software)

Name	License	Description	Use
[1] MSP432/HC-05 UART Driver	-	Module to connect MSP432 to HC-05 through UART	Reference code
[2] Face Recognition	MIT License	Recognize and manipulate faces from Python or from the command line with the world's simplest face recognition library. Built using dlib's state-of-the-art face recognition built with deep learning. The model has an accuracy of 99.38% on the Labeled Faces in the Wild benchmark.	Map faces to verified users
[3] DLib	Boost Software License	Dlib is a modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to	Used by Face Recognition to implement algorithm

		solve real world problems. It is used in both industry and academia in a wide range of domains including robotics, embedded devices, mobile phones, and large high performance computing environments. Dlib's open source licensing allows you to use it in any application, free of charge.	
[4] OpenCV	BSD License	A cross-platform library focusing on image processing, video analysis, and face and object detection for real-time computer vision applications	Used by face_recognition and
[5] NumPy	NumPy Developers	A python library built in C/C++, offering fast computational capabilities for multi-dimensional arrays and matrices, with a variety of optimized mathematical operations found useful in a wide variety of applications.	Used by DLib and OpenCV for various calculations, for speed and efficiency that Python alone couldn't reach.
[6] PyBluez	GNU General Public License	A python extension module for Bluetooth built to allow python applications to use	Used by the Raspberry Pi to communicate with the Bluetooth chip

		Bluetooth resources in GNU/Linux and Windows XP	connected to the MSP432
[7] PiCamera	BSD License	A pure Python interface to the Raspberry Pi camera	The image streaming process
[8] Raspbian	Oracle Binary Code License Agreement	An operating system optimized for the Raspberry Pi hardware	Image streaming, Bluetooth with the Micro

2.0 Description of Software Components

Define the software/firmware components of your design (i.e. functions, objects, etc.). Differentiate between components being developed by your team, components that are being ported to your project, and components that you intend to use as-is from previous projects or third-party vendors (a table may be a very useful way to convey this information). The use of a function call structure or software component diagram is strongly recommended here.

The software for the lock can be divided into two major functional blocks: the low-level embedded software and the Raspberry Pi/Facial Recognition high-level server code. The embedded software is responsible for initializing the lock/unlock sequence, reading in data from UART from the Bluetooth Module, reading in number presses from the keypad, and sending signals to the power electronics to dog/undog the motor though a timer interface. The Raspberry Pi reads in the image data from the Pi Camera, and sends it to a server through WiFi, which detects the faces in the image, and runs the largest one through the Facial Recognition algorithm to determine whether or not it corresponds to a verified user.

Embedded:

2.1 Code Structure

The software on the MSP432 includes data structures for receiving information from peripherals, interrupts to handle events, and functions to initialize system components. The micro will be in a defined state and will only leave that state when an interrupt is triggered such as the door opening or receiving a message from the Raspberry Pi over UART. Having the system be interrupt driven allows the micro to be efficient and . The following are the main software components. Smaller components like functions for the Hall effect sensor and LEDs are not listed as they require much less complexity.

2.2 UART

- data packet structure: Data packets will be sent a byte at a time allowing for fast transactions and minimal latency. A single byte can represent 256 decoded responses and should accommodate a defined language between the micro and the Raspberry Pi. Each byte the micro receives will be decoded and contain information such as the Raspberry Pi is configured and ready, or a registered face was successfully detected.
- uart_send(char*): This function will attempt to send a request to the Raspberry Pi. There is an internal buffer for data requests that the input character is added to and will be sent out when all other requests have been handled.
- uart_recieve(): This function is an interrupt and will receive a byte packet over UART which will be decoded and used to determine the next state of the micro.

2.3 Keypad

- keypad_pressed(): This is an interrupt that is triggered when a button on the keypad is pressed. The function will decode the keypad by polling GPIO pins to see exactly which row and column the button was pressed on. Once decoded, the micro will continue
- special_key_pressed(): The button to begin facial recognition was pressed and the micro needs to send information to the Raspberry Pi over UART.
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2.4 Timer

- timer(): A timer interrupt function will be used to assess when to reset states in our system. This occurs when the Raspberry Pi becomes unresponsive, or when no one presses the keypad after initially starting to enter a code.

Bluetooth/Server:

2.5 PiCamera

- The PiCamera is the name of both a hardware component, as well as the Python code that comes with it for easy interfacing. The software allows for the camera to be set to a specific resolution and framerate, and then frames can be captured through a capture_sequence() function call that streams frames to a passed receiver, which for us is the agent responsible for passing the frames to the server over WiFi.

2.6 Bluetooth Socket

- The bluetooth socket connection is made using the PyBluez python library, which aims to give a python interface with the Bluetooth functionalities of Linux machines and Windows XP. Since Raspbian runs a Linux terminal, it also allows the connection to the Raspberry Pi's bluetooth capabilities as well.
- On a socket connection, a discover_devices() function call can be made to dynamically discover a bluetooth device by name if the MAC address isn't already known.
- Whether pre-encoded or dynamically found, the bluetooth connection allows for a simple send() function call to send a text string byte by byte to the connected device, which is the slave HC-05 in our current design.
- To receive data, a recv() call is made with an integer passed for the maximum amount of bytes to accept from the party on the other end of the socket. The resulting message is a bytes string, which can be decoded through a UTF-8 format to get the original string message, via Python's String.decode('utf-8') functionality.

2.7 Facial Recognition/Image Transformation

- The facial recognition algorithm is made through the face_recognition [2] open source library meant to provide a simple interface for facial recognition to python applications.
- Once an image is loaded into a numpy array, a simple call to face_locations() provides the bounding box for the face and an easy way to calculate the area of the picture taken up by the chosen face. The (bottom - top) * (right - left) area calculation is what we use to estimate the largest face in the image and designate them as the current user for the process.
- Once the face is selected, the face_encodings() function call is made to pull out the 128 feature vector for that respective face, and it is then compared to all the known, pre-found features of all registered users to see how many images of each known user matches each frame, and the resulting matches are summed and normalized.
- To compare one frame's feature vector against the collective list of features for one known user, the compare_faces() function call compares a single feature vector against a list of known features in an optimized manner. The result is an array of True/False values, one per known vector, to state whether there was a match by a predetermined threshold or not. The True values are summed and normalized for each respective user, and then the overall normalized result is passed back to the bigger application to send back to the Raspberry Pi as a JSON message.

3.0 Testing Plan

Each of the modules will need their own stress-testing, since they involve using several external resources. Below lists how we plan on testing our various software components in our system. A numerical component has been assigned to each indicating the level of importance for successfully verification with 1 being the utmost importance, and 5 being the least.

Raspberry Pi
Facial Size Recognition (3)
1. Have 1 verified person in frame, stationary 2. Unable to recognize verified user (1 person in frame) 3. Have no face in frame 4. Have 2 people, 1 verified, in frame, stationary, standing side-by-side 5. Have 2 verified people in frame, stationary, with one in the foreground and one in background 6. Have 3+ people, 1 verified, standing in frame, stationary 7. Unable to recognize verified user (2 people in frame) 8. Have 1 verified person in frame, in motion 9. Have 2 people, 1 verified, in frame, in motion, with one in the foreground and one in the background

Facial Feature Encoding (2)
1. Recognize an authorized user 2. Recognize an unauthorized user 3. Recognize "over-authorized" user? (matches 2+ profiles, may need twins/close siblings)
Bluetooth Functionality (1)
1. Send packet to microcontroller 2. Receive packet from microcontroller 3. Stream packets to microcontroller 4. Receive stream packets from microcontroller 5. Test packet overflow
Microcontroller
High-Level Driver Functionality (4)
1. Connect to Raspberry Pi through UART on power-up, Pi ON 2. Connect to Raspberry Pi through UART on power-up, Pi OFF 3. Dog/Undog motor
UART Read/Parse (1)
1. Read a character from UART 2. Read a stream of characters from UART 3. Split stream of characters from UART with end of packet character
Timer (3)
1. Enable timer on startup 2. When enabling lock, set timer to check for initialization button press
Keypad (2)
1. Press and hold button, test for button debouncing 2. Press several buttons in series 3. Press button in rapid succession, test for button debouncing
Override Buttons (3)
1. Test lock/unlock switch override functionality when idle 2. Test lock/unlock switch override functionality when reading from keypad 3. Test lock/unlock switch override functionality when reading packet from UART
Hall-Effect Sensor/Door Lock (3)

1. Determine threshold of signal for opened/closed door 2. Test closed/open 3. Test almost closed
HC-05/06 Bluetooth Module
UART Interface
1. Send characters through TX 2. Read characters through RX 3. Unable to connect to microcontroller 4. Unable to connect to Raspberry Pi 5. Invalid UART command from microcontroller

4.0 Sources Cited:

[1] Martinez, A. (2019). *MSP432-HC-05*. [online] GitHub. Available at: https://github.com/amartinezacosta/MSP432-HC-05 [Accessed 17 Feb. 2019].

[2] Geitgey, A. (2019). *face_recognition*. [online] PyPI. Available at: https://pypi.org/project/face_recognition/ [Accessed 17 Feb. 2019].

[3] King, D. (2019). *Dlib-ml: A Machine Learning Toolkit*. [online] Dlib.net. Available at: http://dlib.net/ [Accessed 17 Feb. 2019].

[4] Bradski, G. (2019). *The OpenCV library*. [online] Opencv.org. Available at: https://opencv.org/ [Accessed 17 Feb. 2019].

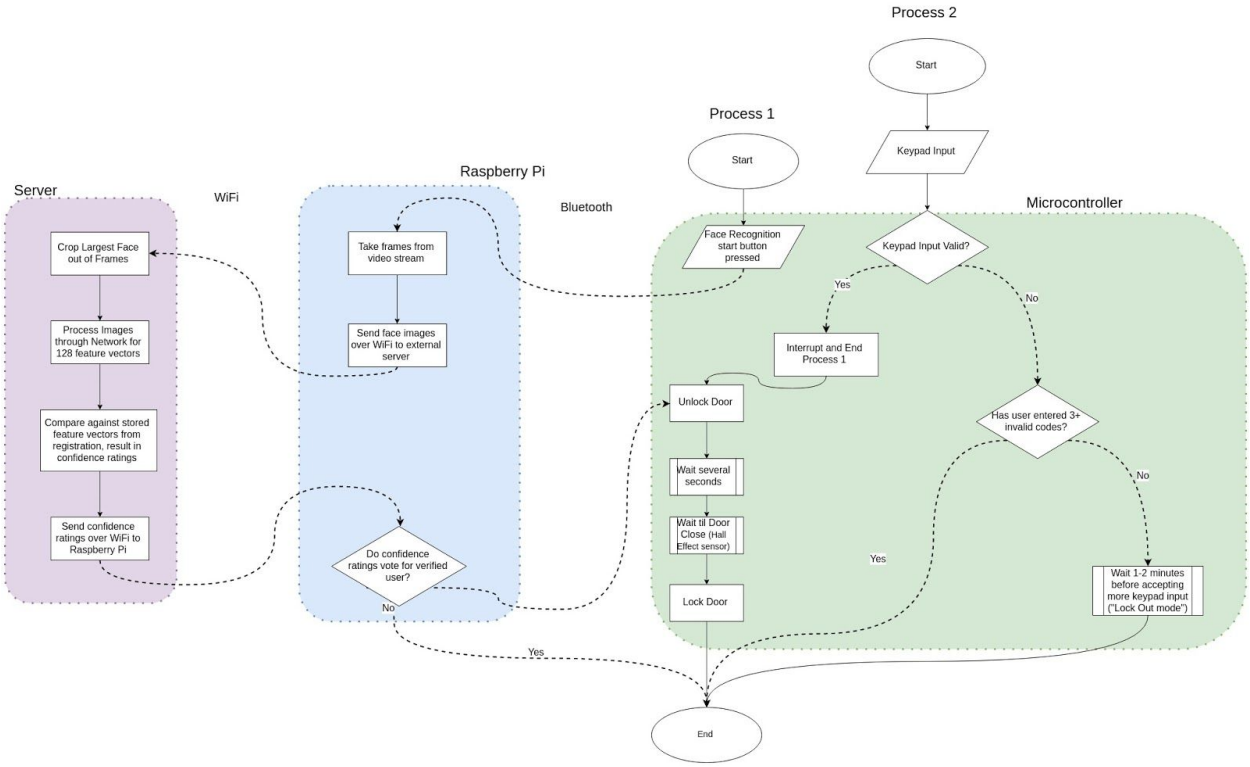
[5] Oliphant, T. (2019). *A guide to NumPy*. [online] Numpy.org. Available at: http://www.numpy.org/ [Accessed 17 Feb. 2019].

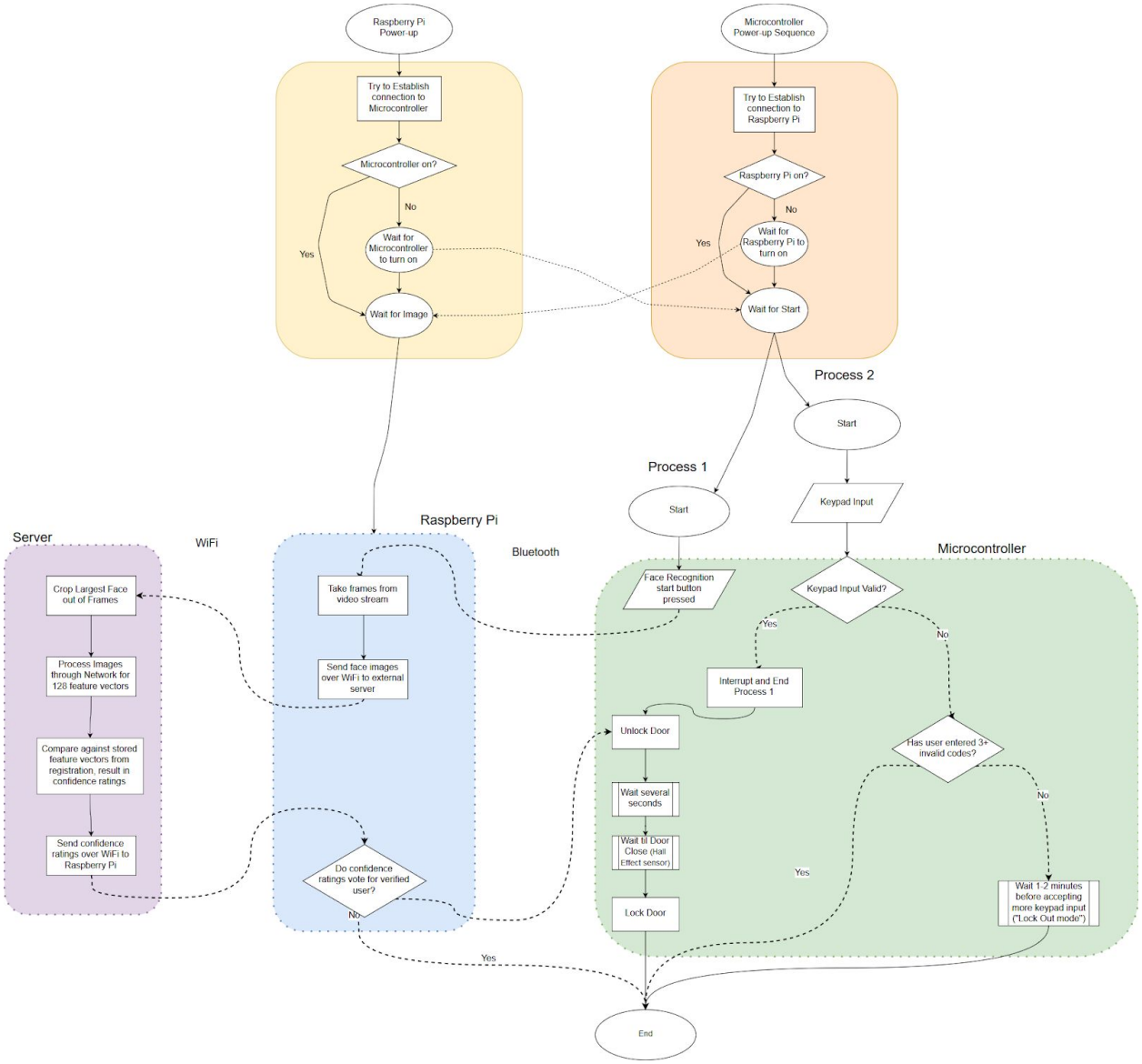
[6] Peters, T. and Govostes, R. (2019). *PyBluez*. [online] GitHub. Available at: https://github.com/karulis/pybluez [Accessed 23 Feb. 2019].

[7] Jones, D. (2019). *Picamera 1.13 Documentation*. [online] Picamera.readthedocs.io. Available at: https://picamera.readthedocs.io/en/release-1.13/index.html [Accessed 17 Feb. 2019].

[8] Thompson, M. and Green, P. (2019). *Raspbian*. [online] Raspbian.org. Available at: https://www.raspbian.org/ [Accessed 17 Feb. 2019].

Appendix 1: Software Component Diagram




Raspberry Pi Power-up
Try to Establish connection to Microcontroller
Microcontroller on?
No
Yes
Wait for Microcontroller to turn on
Wait for Image
Microcontroller Power-up Sequence
Try to Establish connection to Raspberry Pi
Raspberry Pi on?
No
Yes
Wait for Raspberry Pi to turn on
Wait for Start
Process 2
Start
Keypad Input
Process 1
Start
Face Recognition start button pressed
Keypad Input Valid?
Yes
No
Interrupt and End Process 1
Unlock Door
Has user entered 3+ invalid codes?
No
Wait several seconds
Wait til Door Close (Hall Effect sensor)
Yes
Lock Door
Wait 1-2 minutes before accepting more keypad input ("Lock Out mode")
End
Server
WiFi
Raspberry Pi
Bluetooth
Microcontroller
Crop Largest Face out of Frames
Process Images through Network for 128 feature vectors
Compare against stored feature vectors from registration, result in confidence ratings
Send confidence ratings over WiFi to Raspberry Pi
Take frames from video stream
Send face images over WiFi to external server
Do confidence ratings vote for verified user?
No
Yes