

**computer vision detection**

**edge iot device for counting people in a region of interest**

AAI 521 – TEAM 6

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## **1. Executive Summary**

#### **1.1.1 Project Goal**

A proposed Edge IoT device that will be used to count the number of people in a Region Of Interest (ROI) based of a few sensors in the device. This document introduces our new IoT Edge Device, Model 2. We have manufactured in the past our Model 1 which had multiple sensors (described below) and a larger footprint. Our goal with Model 2 is to reduce the size by reducing the number of sensors, which one is a high definition camera that will enable to use a ML algorithm, such as, YOLO, and by that reduce the cost to manufacturing.

The goal is to have this Model 2 device estimate in real-time the people count in a room or any region (ROI) based on the sensors in the system. (See design for more details). The device will use existing sensors available on the market and will use AI services to calculate the large amounts of data to estimate the detection and count. The ML and DL will calculate patterns showing correlations between the various main data subjects:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Camera | Temperature | Sound | CO2 Level |

**This project section will focus only on the Camera sensor and the frame captures it produces. (Testing is done on a dataset of existing MP4 files)**

#### **1.1.2 What is the source of the dataset?**

The source of the data is based on the following source:

Existing public domain MP4 files:

1. City\_Hall\_IOT1
2. NY-City-Crowd
3. Crowd5

#### **2. The Strategy**

**What is your IoT application/system? Who will use it?**

This IoT technology can be used in various scenarios where there is the need for tracking people occupancy if for general information, regulatory, or associations, for instance with correlation to time of day. Some examples including:

* In a smart home to track the number of occupants in the home at specific times of the day.
* In an industrial setting to monitor employees in office spaces or a manufacturing plant.
* Public service centers, such as Supermarkets, Restaurants.
* In a Smart City to monitor the number of people in common and shared indoor spaces.

This current dataset is focused on 0-3 so we will focus on the smart home scenario and will track the number of occupants in the home.

**What industry does your IoT application/system fit into? (smart home, healthcare, smart city, personal devices, industrial IoT)**

The industry that this application fits into is in the Smart Home category. The Smart Home is a growing field and this type of occupancy monitoring functionality can be used as an augmentation to an existing security system or general home monitoring system. The users are general consumers/home owners who want to monitor home occupancy. This information can be used to further make informed decisions on items such as energy efficiency based on occupancy, as an example.

## **Phase One**

#### *2.1 The Idea*

The idea is to develop an IoT device that will estimate the number of occupants in a location that the device will cover.

This information can help with larger public locations that require information about occupants numbers and locations, this enables this places to better the space design, and information about why some areas have more occupants than others, and make decisions based on this.

This can also be used for security services to identify tenant presence and even possible threats.

The plan is to have a commercial structure device and a home device that is less hardware robust.

#### *2.2 Markets*

The commercial structure device is intended to be sold through specialized professionals that deal with buildouts of large public spaces. The device will be available through the reseller networks, and e-commerce sites.

The home device will be available on Amazon and similar retail sites.

#### *2.3 Prototype*

We will build a prototype that will be tested and be the proof-of-concept. This will be presented to the stakeholders and after approvals will be the device to present to production.

#### *2.4 Designing the Device*

The full design needs to be approved, and all building components need to be approved and secured for receiving.

#### *2.5 Certifications*

Any required certifications will need to be completed prior to launch date.

#### *2.6 Marketing*

Marketing channels need to be identified. Any sales brokers need to be contacted and establish relationships.

#### *2.7 Legal*

Any legal agreements or such need to be established, approved, and executed.

#### *2.8 Production*

The device needs to be released to the production markets, following the Marketing and Legal process plans.

#### *2.9 Maintenance and Support*

A Customer Service group needs to be in place to support the device and evaluate the device for its performance and note all as for the need to look at how to improve the device for future new releases. (Versions)

## **3. The Design**

#### 3.1 System Architecture

##### *3.1.1: Sensors and Electronics*

* The device needs to be small enough to fit into any location in a space.
* It needs to be easy to install and handle.

It needs to have enough real estate internally to include :

**A Passive Infrared (PIR) sensor that is an infrared distance sensor with a range of 20-150 cm. Motion Sensor: Made by: Sharp: Model: GP2Y0A21YK0F**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 4.5 V to 5.5 V | Detection range: 20 cm to 150 cm |
| Output type: Analog | Response time: < 30 ms |
| Operating temperature range: 0°C to 40°C |  |

**A Microphone: Made by: Knowels, Model: INMP441**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 1.8 V to 3.6 V | Sensitivity: -38 dBV/Pa (typical) |
| Frequency response: 50 Hz to 20 kHz | Signal-to-Noise Ratio (SNR): 57 dB (typical) |
| Total harmonic distortion (THD): < 1% | Acoustic overload point (AOP): > 110 dB SPL |
| Operating temperature range: -40°C to 85°C |  |

**A non-dispersive infrared (NDIR) CO2 sensor: Made by: Winsen Electronics Model: MH-Z19**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 5 V DC | Operating current: < 150 mA |
| CO2 measurement range: 400 to 5000 ppm | Accuracy: ±(50 ppm + 3% of the reading) |
| Response time: < 90 seconds | Communication interface: UART |
| Operating temperature range: -10°C to 50°C |  |

**A Light-to-digital converters (LDC) sensor: Made by: Avago Technologies Model: APDS-9301**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 2.7 V to 3.6 V DC | Operating current: < 2 mA |
| Light measurement range: 0.25 lux to 64 klux | Output format: I2C |
| Operating temperature range: -40°C to 85°C |  |

**A Temperature-to-digital converters sensor: Made By: Texas Instruments Model: LM75**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 2.7 V to 5.5 V DC | Operating current: 1.2 mA typical |
| Temperature measurement range: -55°C to 125°C | Accuracy: ±2°C |
| Output format: I2C | Operating temperature range: -55°C to 125°C |

**A real-time clock (RTC) for Time Stamp: Made By: STMicroelectronics Model: M41T62**

* + - Specifications:

|  |  |
| --- | --- |
| Operating voltage: 2.0 V to 5.5 V DC | Operating current: 320 nA typical in battery-backed mode |
| Operating temperature range: -40°C to 85°C | Accuracy: ±2 min/year |
| Output format: I2C or SPI | Battery backup: Supports backup of time and date information with a coin-cell battery. |

**A System-on-a-chip (SoC) mother board that contain a microcontroller, wireless connectivity, and other components on a single chip. Made by: Espressif Systems Model: ESP8266**

* + - Specifications:

|  |  |
| --- | --- |
| Microcontroller: Tensilica L106 32-bit processor | Operating voltage: 2.5 V to 3.6 V DC |
| Operating current: 80 mA typical | Operating temperature range: -40°C to 85°C |
| Wi-Fi connectivity: 802.11b/g/n, supports AP, Station, and AP+Station modes | Memory: 128 KB to 512 KB flash memory, 80 KB SRAM |
| Digital I/O pins: 10 | Analog input pins: 1 |
| Dimensions: 40.5 mm x 25.0 mm |  |

**An Intel Atom CPU: Made by: Intel Model: ATOM Z6xx**

* + - Specification:

|  |  |
| --- | --- |
| Cores: Intel Atom processors can have anywhere from 1 to 4 cores | Clock Speed: Intel Atom processors have clock speeds ranging from 1.0 GHz to 2.0 GHz |
| Cache: Intel Atom processors have L1 and L2 cache, ranging from 128 KB to 1 MB | Instruction Set: Intel Atom processors support the x86 instruction set |
| TDP: The thermal design power (TDP) of Intel Atom processors is typically between 2W and 10W | Graphics: Intel Atom processors have integrated graphics, typically Intel HD Graphics |
| Memory: Intel Atom processors support DDR3 or DDR4 memory, up to 4 GB | Connectivity: Intel Atom processors have integrated connectivity options, such as Ethernet, Wi-Fi, and Bluetooth |

**DDR3 memory 4 GB capacity: Made by: Kingston Model: PC3-6400**

* + - Specification:

|  |  |
| --- | --- |
| Storage: The Intel® 3D NAND SATA SSD | Form factor: 2.5 inch or mSATA |
| Interface: SATA III (6 Gbps) | Capacity: Up to 4 TB |
| Performance: Sequential read/write speeds of up to 550/520 MB/s | Endurance: Varies based on capacity and model, with typical write endurance of up to 320 TBW |
| Power consumption: Active power consumption of up to 3.5 W, and low power consumption during idle and DevSleep modes | Reliability: Built-in error correction and end-to-end data protection, with support for SMART and TRIM commands |

**Camera: Made by: DFRobot: FIT0701**

* + - Specification:

|  |  |
| --- | --- |
| Resolution: 720x640 | Form factor: 30mm x 25mm x 21.4 mm |
| Interface: USB | Capacity: Up to 4 TB |
| Performance: 0.3 MegaPixels USB Camera for Raspberry Pi and NVIDIA Jetson Nano | Video Format: MJPG, YUV |
| Power consumption: 5V | Reliability: Temp: -20C to +70C |

##### *3.1.2: The Enclosure*

This will be a small device from commercial graded plastic. It will have a mounting device to screw into a surface. A mounting kit will also be available for angle mounts.

##### *Image 2: Plastic Enclosure v1*

A close-up of a machine

Description automatically generated with low confidence

The Enclosure Specifications:

* Made from Polyethylene (PE) moisture-resistant and light weight.
* Dimensions: W 3.5” x H 2” x D 2”
* Weight: 5 Oz.
* Color: 3 color offer: White, Gray, Black

##### *3.1.3 The Blueprint of the Occupant-IoT By LEVEL3*



##### *3.1.4 WiFi Communication*

The IoT device will communicate via the Intel ATOM built in hardware supporting a wide range of communications including: IEEE 802.11, Standard Wi-Fi 2.4 and 5 Ghz and new 6 Ghz , 3G, and WinMAX, enabling an Always Connected usage model.

Messaging is handled through the MQTT messaging protocol supported by the ATOM Intel WiFi services. The Python programming language can be used to generate MQTT messages.

#### *3.1.5 Edge Computing*

The IoT device has the ATOM CPU and a Linux Operating System. On board is 64 GB of DDR3 RAM. There is a 64GB SD Card that has the Linux OS installed in. The system uses a NoSQL Database table as a local repository. The system will process data readings from the sensors in real-time, and store 48 hours of data locally.

The results locally are transmitted to a URL link for a Dashboard view.

After 48 hours the data is queued via the MQTT protocol to the AWS S3 service.

#### *3.1.6 AWS S3 Services, MQTT and Dashboard*

The IoT device after 48 hours of local data will utilize the MQTT to queue and send data to S3, here are the steps:

1. Configure the IoT device to use the MQTT protocol to connect to AWS IoT Core.
2. Use an MQTT client to publish the data to an MQTT topic in AWS IoT Core. The topic should be configured to route data to a specified S3 bucket.
3. Create an AWS IoT Core rule that triggers an action to send the data to S3 when it is published to the MQTT topic.
4. Configure the S3 bucket to receive the data from the device.
5. Configure permissions and security for the S3 bucket and the IoT device.
6. Start publishing data to the MQTT topic from the IoT device.
7. The data will be routed to the S3 bucket by AWS IoT Core when the rule is triggered.

The data will be stored in the DynamoD-NoSQL database for speed (and there are no relational database requirements) .

QuickSight AWS will be utilized for building a more comprehensive Dashboard.

Diagram, schematic

Description automatically generated

#### **4. Data Processing and Insights**

**Edge Device Processing**

On each edge device gathered the data from the sensor devices in order to predict the room occupancy based on sensor input. The model is retrieved from the central server and predictions are processed locally.

## **5. Coding and Data Process Flow**

*5.2 Data Processing Flow Chart*

## **6. Coding in Python**

Notes: