ECE 445: Senior Design

Project Proposal

Room Occupancy Sensing (ROS)

Team Members:

Yohann Puri

Aakarsh Sethi

Steve Wang

TA: Eric Clark

I. Introduction

Objective

Our objective is to solve the problem of keeping track of the number of people entering and leaving a room, thereby giving us the net occupancy of a room. The goal is to build a mat that can be put on the floor at a doorway so that it could keep track of the number of people walking in and out of a room.

The mat must be designed to distinguish between people entering and leaving the room so as to calculate the net number of people in the room at any given time. The complexity of the problem stems from the issue of checking whether the object going over the mat is a human being or not. The mat will only count humans and not objects like trolleys or trash cans or boxes passing through the mat and entering or leaving the room. The counting would also have to take care of multiple people entering the room at the same time(Limited to 2 due to the dimensions of the mat).

Background

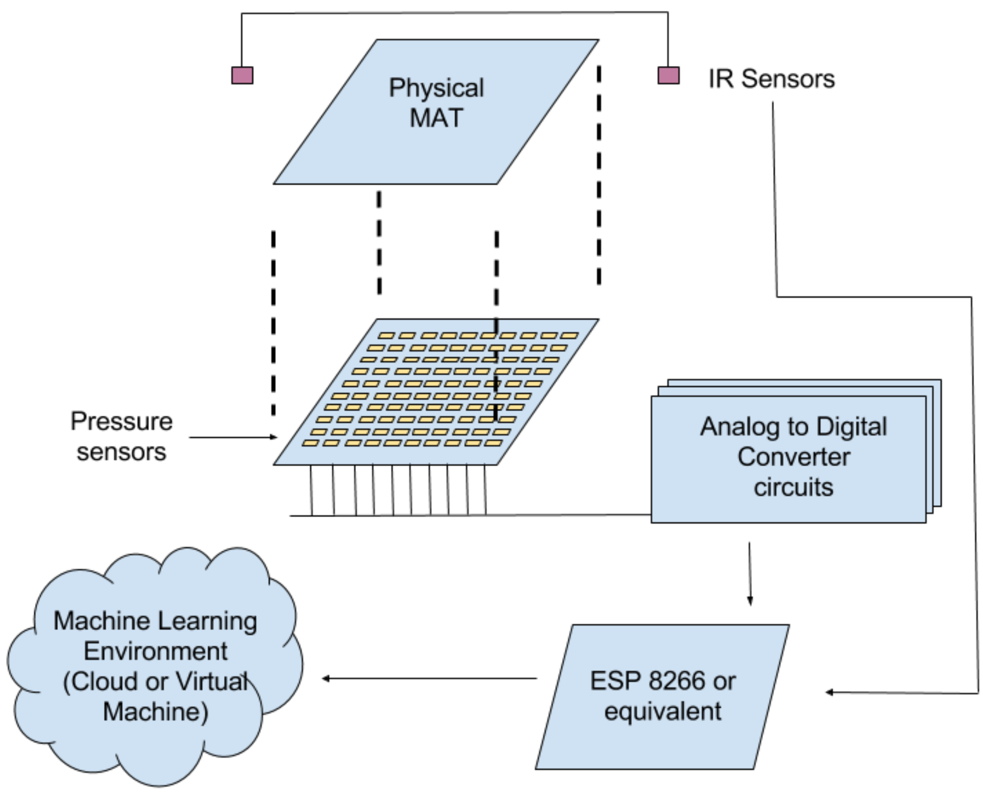
Sensing the occupancy of a room is a prevalent problem in modern Internet of Things scenarios. There are a lot of applications for a device that can deliver a count on the number of people in a room. From trivial applications like getting a count of people in a classroom to bigger applications like monitoring the number of people visiting a business at certain hours of the day of a bank after it has closed or the number of people that entered a restaurant on any given night. A potential device can be coupled with an app and give you information about waiting lines in restaurants or ATMs or any service provider as a matter of fact. Potentially, malls could have these mats at the entrance of every store, thereby giving them information regarding the popularity of each store and the prime locations around the mall. Room occupancy data trends can be used to optimize better resource allocation in terms of labor and staff. Most importantly, this data could be used to control energy consumption for dynamic air conditioning or heating in a room. We thus feel that creating a device like the occupancy sensing mat can have a major impact on a lot of businesses.

High-Level Requirements for a prototype

1. The mat must be able to identify the difference between a foot-fall, and any number of objects that are instead rolled across the mat. It must also be able to do this with up to two objects passing over the mat simultaneously.
2. The mat must be able to tell the direction in which a person or object is moving across its surface.
3. And lastly, it must be able to keep track of the total of number of people who have entered or left the room and have an error rate of less than 20% (missed persons or false positives) over the course of 1 hour.

II. Design

Block Diagram



The five main blocks in our design are as follows:

1) The mat - This contains an array of pressure sensors sewn into a physical mat that people step onto.
2) The ADC circuits - These converts all the analog pressure sensor signals into digital signals for transmission to our machine learning
3) IR Sensors - These are coupled so that we can learn the direction of people crossing the mat.
4) ESP 8266 or equivalent chip - This is a minimalistic chip that has wireless capabilities which will help get our data onto a virtual machine or into the cloud

5) The machine learning - This machine learning uses the snapshots obtained from the sensors along with data from the IR sensors to count how many people are in the room.

Functional Overview

Our sensor mat will be composed of an array of force sensors arranged in a pattern that will determine the position of objects pressed against the surface of the mat. We will be using a type of conductive rubber that changes resistivity when deformed, and either sandwich it between two grids of conductive thread, or cut it into smaller pieces to be individually made into force sensitive sensors. The decision on which direction we are going with will be made after we prototype a 0.5 ft x 0.5 ft conductive thread mesh.

The entire sensing area will be broken up into different regions, each with an identical ADC circuit for collecting all sensor readings in that region. Finally, the sensor data will get shifted onto the host computer.

Additionally, a pair of IR detectors on the front and back of the mat will determine the direction in which an object is moving over the sensing area. These sensors will only be attached by wire, and can be moved and aligned separately from the main sensing array. The data they collect will get passed to the host computer as well.

The host computer will be composed of an ESP8266, which will pre-processes the IR and force sensor data and provide TCP/IP over Wifi for sending our data to a remote machine.

At the remote virtual machine we will process our sensor and IR data. We intend to only store the past 5 instances of sensing data and intend to use historical information to create overlays of sensor data in cases of incomplete snapshot. A training set will be obtained by collecting data from the mat over a period of 4-7 days in a variety of environments(homes of friends) so as to collect a variety of data samples. If training data is obtained in an unsupervised manner, K-Means clustering will be used to separate the data into different classes. Once the right value of K is found in this case using the knee graph, we will use that to classify data. The only assumption here being that most of these activations would be from human contact since the mat is placed in a home. For any data collected in a supervised data, we would label the data ourselves.

Once we have a labeled dataset of sufficient size we will be dividing it into training(45%), validation(25%) and 3 banks of test data(10% each). Using the training and validation data we will train the following classifiers : Bayes, Logistic Regression, (K = 1-50) Nearest neighbor, Gaussian RBF + Support Vector Machine). Once trained, each of these classifiers will be put through our three banks of test data. Test data will be considered dirty once used. The best model will then be chosen for our machine learning algorithm based on prediction error from test data.

Since the result we need is a hard yes or no question, “hinge loss” and “logistic loss” will be used as quantifiers in choosing a model with a little more bias given towards the hinge loss.

Block Requirements

Sensor array -

1) Create prototype using conductive thread and make a decision on its use as compared to discrete conductive sheet sensors
2) Build an array of sensors that deliver a normalized pressure value in analog format
3) Build Analog to Digital Converter circuits that aggregate sensor data and deliver them to the ESP8266

IR -

1) Create a coupled IR sensor that triggers when an object crosses the direction of its forward vector
2) Deliver coupled IR data to the ESP8266

ESP 8266 -

1) Open a wireless connection to a virtual machine/cloud storage.
2) Transmit timestamped and labeled data from IR sensor block and ADC blocks to remote location.
3) Error checking using parity or checksums

Machine learning -

1) Collect and label training data(Manually or K-Means clustering) from use of the mat
2) Run different classifiers on one time use test data after training on collected training data to choose best classifier using hinge loss and logistic loss functions
3) Apply classifier to real time data received from the ESP8266 and output a count for the number of people that is within a 20% error margin

Risk Analysis

The riskiest part of our work lies in the machine learning. The reason for this is because a good model would require a sufficient amount of training data with an extraction of a large number of features. For example, foot falls may be from different shoes, different soles, people with different body weights, different ages and traveling at different speeds. Therefore being able to create a model that can detect the presence of a person would require a sufficiently large data set with sufficiently large feature vectors. This becomes even more complicated when two people are walking on the mat simultaneously

Tolerances -

The tolerances we are assigning due to these difficulties include :

1) A limit of two people on the mat at any given time.
2) A generous time constraint for the model to classify new data, assign whether it was a person and update the room count - Aim - 1 update every 2.5 minutes
3) Error tolerance of plus and minus 20% over the course of 1 hour. Example - If 50 people walked in and out of an area in 1 hour we would like our count to be between 40 and 60.

Ethics and Safety

The sensor array and data collection methods we implement may be misused to collect biometric data from people without their consent by collecting and saving raw sensor data and performing analysis beyond simple object identification. This can include identification of heights, weights, gaits, etc. The ACM Code of Ethics (1.8 Honor Confidentiality) and IEEE Code of Conduct (1) state that personal information collected outside the scope of a project must be kept confidential. To avoid ethical breaches, no data we collect will be associated with any person's identity without their consent, and no data can be collected about any specific person using the hardware and software we provide.

The real reason why people counting is a large issue in workplace scenarios is because people don't want cameras or mics in the workplace. This is why we have chosen an approach that avoids the use of any cameras or audio recordings.