People Counting using Multiple Time of Flight Sensors

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Abstract— **This research is focused on automatically counting how many people pass by the sensors. Multiple Time of Flight (ToF) sensors are used. Compare to normal camera, ToF sensor can measure the distance information from the sensors to the object instead of color information. By using those distance information, some new possibilities of way to detect and count people, other than just use normal color information.**

I. Introduction

Natural disasters are happening everywhere. Japan is famous for its earthquake, typhoon for Philippines, or flood for Indonesia. There are three things we can do about disasters, first is to predict when it will come, second is to evacuate when the disaster came, and third is the restoration after disaster. This paper is focused on the second one. In evacuation, it is important to make sure that everyone are safe. That is why, we need to know the number of people in the building or the evacuation site.

There are some applications to calculate how many people have passed a certain point. Most of them used a camera[5] and using image processing method to counting the number of people who passed a certain point (they called it counting line) and the direction they go. In this case, we want to try to use Time of Flight (ToF) sensors to calculate the number of people. By using the distance information instead of color information may help us to detect people. There are some researchers that also use ToF camera to detect people[1,2,4]. sensors to calculate the number of people. By using the distance information instead of color information may help us to detect people. There are some researchers that also use ToF camera to detect people[1,2,4].

II. Methodology

ToF sensor is a sensor that can measure the distance between the sensor and the object in front of sensor based on the known speed of light.

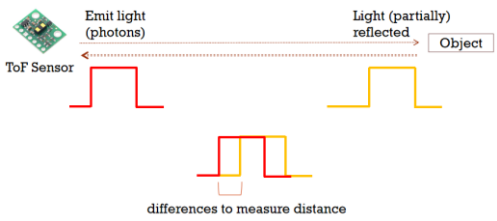

Figure 1. How ToF sensor works

In figure 1 explain how ToF sensor works. First, the sensor will emit a light signal. When the light hit some object, it will be partially reflected. The sensor also has a receiver to receive the reflected light. After that, the sensor will compare the delay between when the light is emitted and the light is received and then the sensor can calculate the distance by this formula.

Distance = delta_time * speed_of_light/2

The speed of light is known and has approximately 300,000,000 meters per second. The maximum distance is determined by the length of the light pulse that is emitted. The length of the light is the maximum delta time. By using the previous formula, we can get the maximum distance that the sensor can detect.

In this research, we use VL53L1X that using 940 nm invisible laser (class 1). In this research the ToF sensors connected Raspberry Pi.

III. Design

We design on how we should transfer the data from TOF sensor to server. The idea of this design is flexibility. Raspberry pi's role is to control and getting data from TOF sensors and send it to the server.

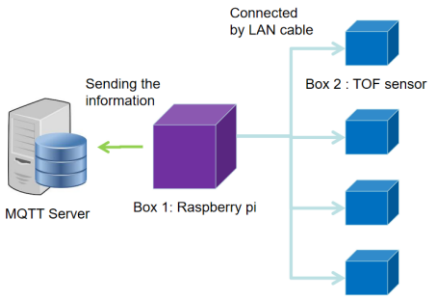

Figure 2. The design of the device

There are 2 boxes in this design, Box 1 is the raspberry pi box, and Box 2 is the ToF sensors box. Box 1 and Box 2 is connected by LAN cable. In this case the raspberry pi will take the information from 4 sensors at once, and send it using wifi connection to the MQTT server. The MQTT server will get data from multiple raspberry pi which is from different places.

Figure 3. Box 1 (left) and Box 2 (right)

A raspberry pi will control multiple sensors and will be placed near door (design 1 or 2) or in the hallway (design 3)

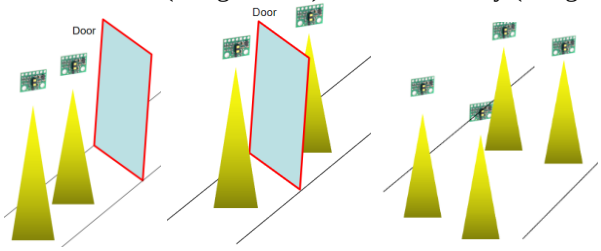

Figure 4. Placement design 1(left), 2(middle), 3 (right)

This device is planned to being used in evacuation drill at Tokyo Institute of Technology. But because of some problems in software and internet connection, we failed to test it in November 2019.

IV. Automatic Labeling

Signal data is provided by ToF sensors. There is no label in the data whether there is a person or not. In this case, we are doing clustering of 1 day data. Because there are a lot of "no people" data so we used subdata where is some people are detected pass by the sensors.

In the preprocessing, we group the data to 5 sequence data for same sensor as 1 data. 5 sequence data is equal around 2 seconds data for the same sensors. In this step, we want to do automatically labeling for the data we have. Because we have a big imbalanced data between "there is people" and "there is noone" data, so we choose to do clustering to give them label first, instead of learning.

Before we are doing the clustering, PCA is being used to simplify and reduce the dimensionality of the data. For the clustering method, we choose is hierarchical clustering, and we found 7 big classes.

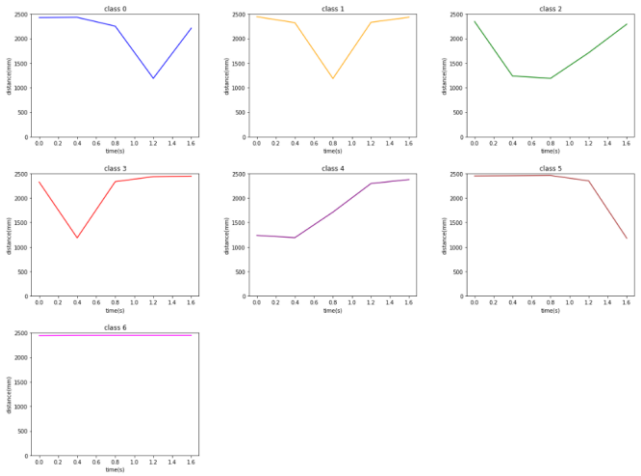

Figure 5. Clustering classes

After we have those classes, we put a reading label, it is +1 for class 0-3, +0.5 for class 4 and 5, and +0 for class 6 based on is there a person or not. Class 4 and 5 get 0.5 because on those classes they only have half of the full signal circle, so we don't double counting it.

On our data, we got 42 +1 label, 15 +0.5 label, and 3923 +0 label. It still very imbalanced data, so we need to be careful to use it. By using those 3 labels we can count the number of people that pass by a sensor.

V. Conclusion

With TOF sensors, we can detect people from another point of view. In this research, we are using 5 sequence data that equal to 2 seconds data. We need to check whether we can reduce the time that we need to know whether there is a person or not. For example, by increasing the frame rate of the sensors, or by reduce the interval of data reading become 1 second.

Right now the distribution of label we have is 42:15:3923. This is very imbalanced data for learning, because machine learning is the best when the data is balanced. We are still trying to take some data and also using some resampling techniques like over sample minority class or under sample majority class.

Another thing that we need to be careful is the height of the ceiling and person, in this case we use hallway that has ~2400 mm in height and the participant height is around 1700 - 1800 mm, so we need to check whether it still working on different height or can detect a child how pass by the sensors. The similar problems happened when we use threshold method to detect people. Because the threshold is fixed, so we need to adjust the threshold depend on the condition of the hallway.

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