On the Design of a Cost-Effective and Lightweight People Counting Sensor

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Abstract. People counting finds applications in many scenarios where the density of people present in an area is crucial. Although, there are a lot of research on people counting using image processing and pattern recognition, we focus on less complex, lightweight, cost effective, and low energy people counters. In this paper, we have detailed methods and algorithms for people counting using proximity sensors. We have also shown the experimental results for various designs of people counters and compared them with the actual results.

1 Introduction

People-sensing is gaining a lot of attention as ubiquitous computing and sensor networks are increasingly focusing on human inhabited environments and their behavior, especially, in applications, where activities of people are monitored and analysed. People sensing plays an important role in applications such as crowd monitoring, security management, and transportation systems.

In applications where traffic flow is important, crowd analysis needs to be done to estimate the density of the crowd. Reference [1] details unsupervised method to detect individuals in a crowded environment, thus counting the number of people accurately, even when they are moving in crowds. In military and security applications, people sensing, or people counting plays a crucial role, and [2] details vision based, real time people counting system at a security door. In transportation systems, where the frequency of public transport plays an important role in getting people around, deciding the frequency at which the trains need to ply, [3] provides methods of counting people entering and leaving a train and hence enabling decision on right train frequencies.

People counting algorithms, and methods vary largely with different mechanisms and sensors with different capabilities, ranging from cameras, CCTVs to motion sensors, proximity sensors, and ultrasonic sensors. A lot of research on people counting, has been done by using visual cameras for image processing and pattern recognition to accurately count the number of people. For instance, [4] shows a method for counting people entering or leaving a bus using video processing and [5] describes robust solution for people counting using image processing.

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However, these techniques demand a high processing time, energy, and also are more expensive to install in scenarios, where power is limited. Therefore, to address cost-effectiveness, low-energy, and lightweight system to count the number of people in a given region while maintaining privacy, we have developed an efficient people counter with low error rates.

2 Overview

People sensing focuses on detecting the presence of a person, which can be used in applications such as automatically switching on/off a light; counting the number of people, so that we can estimate approximately how many people are present in a room; location of the person, so that we can know the exact location of the person; tracking a person, which gives temporal and spatial information of a person; and identity of the person, which specifies who the person is [6]. Such information can be fetched either by instrumented approach, where people carry instrument/device for sensing purposes, or uninstrumented approach, where people do not need to carry any device.

Instrumented approaches deal with devices communicating to other devices to notify their presence both temporally and spatially, which includes a GPS sensors, tracking application, etc., which are carried by people wherever they go. Uninstrumented approaches deal with sensors such as motion, proximity, pressure mats, cameras, microphones, etc., which are not meant to be carried by people. In an uninstrumented approach, single sensor gives accurate information only under certain circumstances and fails to provide information in others. In a few other scenarios, sensor fusion can provide useful information for people sensing by evening out the negative effects caused, when used individually. For instance, a fusion of microphone and camera can be used in applications such as conference rooms where the person speaking is focused by the camera [7].

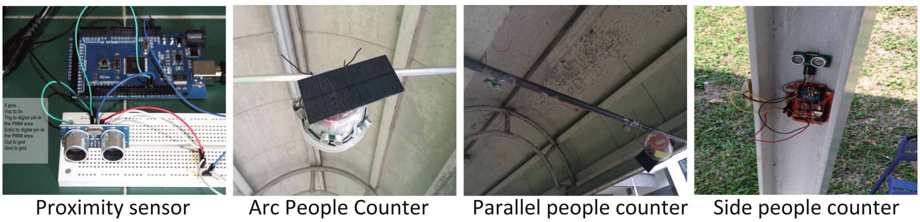

Fig. 1. Different people counters

Although, a lot of research focusses on sensing and tracking people through image processing, we are focusing on algorithms to use cost-effective sensors for the implementation of people counting mechanisms. We mainly focus on using proximity sensors (ultrasonic sensors) in our research for people counting.

3 Three Designs of People Counter Using Proximity Sensors

Proximity sensor is used in our design for people counting. By varying the orientation and number of sensors used, we have developed three different people counters. In this section, we detail our people couters. Figure 1 shows different people counter set up.

3.1 Parallel People Counter

A parallel people counter, was built by placing 2 proximity sensors in parallel, at a distance of 80 cm. The sensors have a beamwidth angle of 55 degrees and range of 4 m. The number of sensors depend on the range of field that is to be covered for people counting. However, with this design, counting a person can be difficult in a place where the range of 2 sensors intersect and sometimes can result in double counting.

3.2 Arc People Counter

An arc people counter, was built by placing 3 proximity sensors in an arc shape, so that they can be deployed in a single place covering almost 3.5 m width for people counting. As compared to parallel people counter, for arc people counter, we do not need to worry about how many sensors to be installed and the distance between the sensors, but only need one arc people counter to cover the range.

3.3 Side People Counter

Side people counter was built by placing just 1 proximity sensor for people counting, with range of the sensor being 4 m, but, the optimal distance for accurate people counting is seen within the range of 2.9 m. As there may be some objects blocking in front of the sensor (especially, in corridors where usually there is an other pillar opposite to the pillar we have installed the sensor), our algorithm calculates the bouncing distance at the setup phase, by repeatedly looking for a bounce back obstacle. For instance, in a corridor, where there is an other pillar at 1.5 m, the bouncing distance will be assigned to 1.5 m. However, when there are no obstacles, default distance will be set to 2.9 m.

In all the three designs, it is challenging to accurately count the number of people when two or more people are passing by very closely.

4 Algorithms

We have developed two algorithms, one for parallel and arc people counter, and another one for side people counter. The following section details the algorithms. Each of the algorithms compute and ignore stationary objects around.

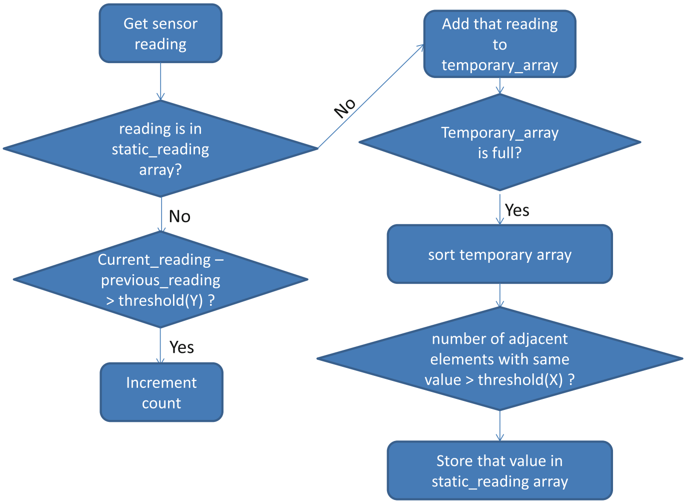

Fig. 2. Flow chart for arc and parallel people counter algorithm

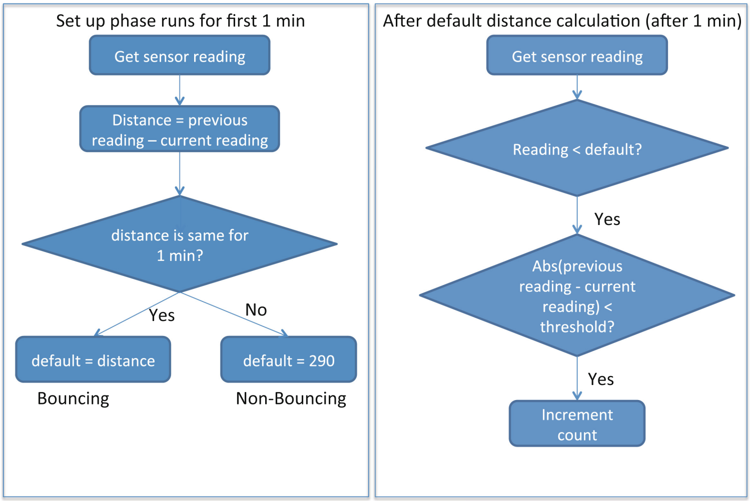

Fig. 3. Flow chart for bouncing and non-bouncing side people counter algorithm

Figure 2 shows a flow chart for arc and parallel people counter algorithm. In this algorithm, we fetch sensor readings periodically. When we receive a reading, we check if that reading matches any reading that is stored on static reading array, if it matches, we ignore that reading, else, we check the difference between the current reading and previous reading, and if that is more than a threshold, say Y, which was set to 80 for parallel and 100 for arc and can vary slightly according to the place, where the people counter is placed (so that if a person is carrying a bag, it should not be counted as another person), then we increment the count. Also, when the reading does not match any entry on static reading array, we store that in a temporary array. When the size of this array reaches a pre-set threshold (120), we sort the array and calculate number of adjacent elements with same reading, if that is greater than a threshold, say X(X can range from 20–40 and we set it to 30 for our experiments), we add that to the static reading array, thus building the static reading array dynamically. By varying the values for X and Y, we can use this algorithm in parallel people counters and arc people counters. All through our experiments, we have considered size of static reading array as 40 and this value was chosen by trial and error method and by setting it at 40, we got considerably accurate counts.

Figure 3 shows flow chart for bouncing and non-bouncing side people counter algorithm. In this method, there is a set up phase that runs for the first 1 min after installation to register the obstacles blocking the people counter, i.e., for a scenario where there is a narrow corridor, bouncing back distance is calculated and registered and people counting algorithm assigns this distance as a default distance. After the set up phase, when there is a new reading and that reading is less than the default distance, we check if the absolute difference between the previous and the current reading is less than a threshold (to avoid double counting in cases when people are carrying bags), then increment the counter. For non-bouncing, we set default distance to 290 cm as that is the optimal distance where proximity sensor give accurate values for people counting.

5 Experiments and Results

We conducted experiments for people counting, by placing all four people counters side-by-side, namely arc, parallel, side (with a bouncing object at 1.6 m), side (without any bouncing objects opposite), along with manually counting number of people passing by, to compare the accuracy of each method for 3 h. In our setup, we have used Arduino microcontroller for processing, and we have used solar panel to charge the batteries for people counters that can be installed outdoors. We have used 2000 mAh battery and 2 W solar panel for charging the battery, which makes the people counters self-sustainable. The cost estimation for building people counters can range from 122 USD for side people counter, to 200 USD for arc and parallel counters.

In Fig. 4 we present our observations for each of the four people counters. Over a period of one hour, there were total 132 people pass by, and side people counter with bouncing counted 120 (9.09 % error), side people counter with non-bouncing counted 125 (5.30 % error), arc people counter counted 113 (14.39 % error), and parallel people counter counted 104 (21.21 % error). By far, we observe that side people counter with bouncing, and non-bouncing are more accurate than the arc, and parallel people counters.

Our future work would focus on building algorithms to manage different traffic conditions and accurately counting people in passages and corridors in home/offices with different waking speeds, counting people in crowds, and determining the counting error in complex scenarios.

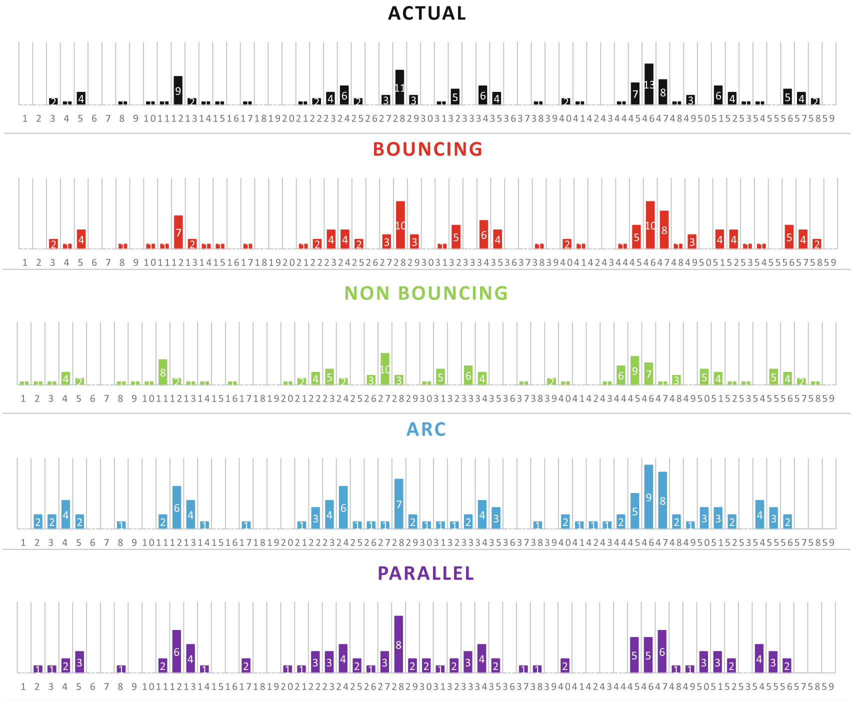

Fig. 4. People counting results with different methods

6 Conclusion

In this paper, we describe a cost-effective, lightweight, simple and low-energy people counting systems. We have worked on people counting algorithms using proximity sensors by varying their orientation and number of sensors used to cover a desired area. We show that side people counter design performs better than arc, and parallel people counter designs, with an error of 5.30 % for a period of one hour with 132 people passing by.

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