



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 10, October 2023

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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# IR-UWB Radar with People Counting Using Hybrid Feature Extraction Method

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**ABSTRACT:** In this paper, Internet of Things has been used to built a visitor counter which can be monitored online. This paper gives brief description about an assistive system designed for Industries in order to help them bring more accuracy over counting system before packaging and reduce the huge loss and saves money. This method is cost efficient and can be easily implemented. This methodology can be implemented in any Industry which uses Scale Counting method. Ultrasonic sensors are used for the detection of existence of the persons and it will count the people in the Mall entering. When Ultrasonic sensors detects an object, it actuates the Servomotor connected with Ultrasonic Sensor. The visitor counter circuit is designed using IR sensors. Automatic crowd density estimation is a technological solution that could help in guaranteeing social distancing by reducing the probability that two persons in a public area come in close proximity to each other while moving around. This paper proposes a novel low complexity RF sensing system for automatic people counting based on low cost UWB transceivers. The proposed system is based on an ordinary classifier that exploits features extracted from the channel impulse response of UWB communication signals. Specifically, features are extracted from the sorted list of singular values obtained from the singular value decomposition applied to the matrix of the channel impulse response vector differences. Experimental results achieved in two different environments show that the proposed system is a promising candidate for future automatic crowd density monitoring systems.

**KEYWORDS:** People counting, IR-UWB radar, hybrid feature extraction, curvelet transform

## I. INTRODUCTION

Social distancing is an effective approach to limit disease diffusion [1]. During the ongoing COVID-19 pandemic, several social distancing measures have been implemented by governments: travel restrictions, border control, closing public places and keeping a 1.5–2 m distance from each other outside. In such a context, there is a growing need for technologies that are able to facilitate social distancing in different scenarios and types of environment. Several recent papers have addressed this topic [2,3,4]. One of such technological solutions is the real-time automatic estimation of the number of people inside a room, which could be used to alert when this number cannot guarantee social distancing. Such systems could be effectively deployed in museums, exhibition areas, commercial centers but also public spaces such as universities. Several approaches for automatic crowd-counting have been proposed in the literature. Two main classes of people counting technologies can be identified [5]: device-based or device-free [6]. The first class estimates the number of people inside an environment by analyzing Radio Frequency (RF) signals transmitted by sensors carried by the monitored people, such as Radio-frequency identification (RFID) tags or smartphones [7]. Among device-based solutions, much interest has been recently devoted to counting systems that correlate the number of people to the number of connections from user devices (e.g., smartphones) to WiFi access points [8] or through passive sensing of WiFi probe request signals [9], periodically transmitted by monitored people devices (without the need for direct connection to access points). Such approaches have some major drawbacks; the first is the need for the monitored people to carry mobile devices or specific sensors (in this latter case the monitored person has to be cooperative).

Moreover, for the WiFi based approaches, there can be the dependency on the direct connection to the access point, the need for a switched-on WiFi interface on monitored device and the fact that the performance can be biased by the number of devices carried by each monitored person. Furthermore, new MAC address randomization techniques does not easily allow identification of Probe Request packets sent by different devices/users.

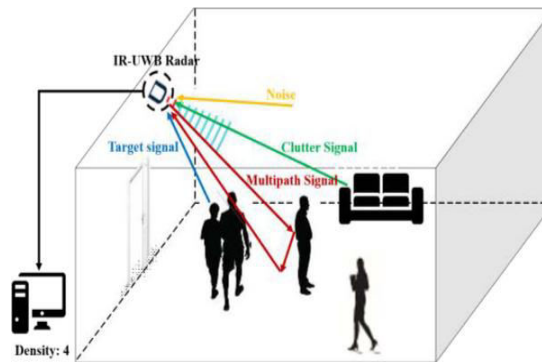


Fig 1: People counting using IR-UWB

People counting solution will help you detect visiting trends, count people per mall zones and floors, identify in real-time how many visitors are in particular areas of the building. It can track occupation history in 5 minute time spans or per second if raw data export is used. Count People is an important practice for understanding the number of consumers coming into your shop as well as the areas they visit most. Traffic visits the shop through various marketing activity and motives, tracking them and evaluating conversions have become the most important metric in 21st century brick-and-mortar retail management tasks. People observation and counting is of great interests in many commercial scenarios. The number of people entering and leaving shops provide useful information to shop merchants and marketers. Since retailers spending time and money on marketing and advertising, they really need metrics to help understand the return on investment as the people counting data can be used as a KPI. For non-commercial scenarios, people counting techniques are also useful in terms of security.

## II. LITERATURE REVIEW

There is more than one method to count the visitors. It ultimately depends on the intensity of people. The following papers were studied and analyzed to understand the current scope of people detection: Bruno F. Carvalho and others [1] have suggested a method that utilizes sensors for detecting people. The ultrasonic sensor plays a dominant role in identifying objects and accurately calculates the distance between the sensor and the objects. "The ultrasonic sensor constantly measures the distance of objects ahead, sending a signal through Trigger pin e receiving through Echo". Two ultrasonic sensors are placed side by side and an algorithm is devised to count the number of visitors entering the premises. They have also implemented another method which uses motion sensors to detect any motion of an object or a person and compared the two methods. Both the methods are successfully tested in an environment. But this method cannot detect more than one person at a time. If two persons pass through the system side by side, the system will detect only one person.

Jeong Woo Choi and others [2] have proposed a method that uses IR-UWB radar sensors for counting people. "IRUWB radar uses an impulse signal that occupies wide bandwidth. It is a technology that transmits an impulse signal and recognizes various situations by processing multiple signals that are received after being reflected from multiple human and objects". The algorithm devised for this method is implemented using ARM Cortex-M4 and Raspberry Pi 2 modules. Two IR-UWB sensors with antennas are fixed to count the number of people. Though the system can detect multiple people at a time, it is not cost efficient. The sensors are high expensive in the market. Another approach using IR sensors was proposed by Jothibas M, Aakash B and others [3].

IR sensors play a vital role in identifying objects. In this method, two IR sensors are placed adjacent to each other which detect the visitors. “The logic behind the working of the counting process is simple, when the person crosses the sensor near the door and then to the sensor away, it recognizes as an increment in count”. Apart from being a bi-directional counter, this method can be used to control home appliances and helps in consuming less electricity. This method cannot detect more than one person at a time. If two persons pass through the system side by side, the system will detect only one person. Jingwen Li [4] have designed an approach that uses BagOf-Features (BOF) model to count the number of pedestrians. “The system can also select pedestrians and non-pedestrians samples automatically and update the classifier in real-time to make it more suitable for certain specific scene. The dataset used is CASIA pedestrian counting dataset and trained using SVM classifier. The system requires real time monitoring of the pedestrians via camera modules which are very expensive.

Kartik Madhira and Aditya Shukla [5] have proposed a method that uses image processing techniques to count human specific areas such as ATMs, retail shops, malls etc. “The people counter solution was made using computer vision library OpenCV for Python computer language”. The method achieved around 80-93% accuracy. The cameras were positioned in many angles to test the accuracy of the method. The system requires real time monitoring of the persons via camera modules which are very expensive. Shubham Mathur and others [6] have come up with a method that uses image processing with sensor feedback for counting people entering or leaving a lab. Histogram of oriented gradients (HOG) technique was used for this method. The images are captured using Raspberry Pi fitted with a RaspiCam. A pair of PIR sensors is installed to instruct the system to capture the images. The data can be sent via Bluetooth to local servers for security purposes. An efficiency of 83% is achieved using this method. The equipment used in this system is very expensive. The sensors add extra cost to the system apart from camera module and Raspberry Pi.

Another method proposed by Dr.P.Satyanarayana and others [7] involves the use of OPEN CV3 using python 3.5.2. “The implementation goes on like the process of background subtraction on the incoming frames followed by the blob analysis using which the person can be detected and by using virtual lines, the count of the people entering and leaving a particular area can be evaluated”. The system requires real time monitoring of the persons via camera modules which are very expensive.

David Beymer [8] proposed a method that involves 3D stereo vision. “The stereo system performs real-time 3D reconstruction by employing table lookup to map from image coordinates and disparities to 3D. Based on the 3D coordinates, the scene is (1) segmented by filtering out pixels outside the volume of interest, and (2) reprojected to a topdown, orthographic view. Finally, people are detected and tracked in the orthographic reprojection using a Gaussian mixture model and Kalman filtering”. The system requires real time monitoring of the persons via camera modules which are very expensive.

### III. METHODS

Fast ever-changing signals and superposed multipaths bring great challenges for dense people counting by amplitudes of each signal. Counting from a single received signal separately is not stable and reliable, therefore the curvelet transform provides statistical features of a radar matrix. Several temporal continuously received signals are considered as a 2- D radar matrix to avoid contingency caused by the single signal. Furthermore, considering the moving continuity and trajectory consistency, trajectories of people are presented as textures with spatial locality information in the matrix. Superposed multipaths show stronger textures and can be obviously observed with the curvelet transform. In addition, the curvelet transform provides a multi-scale and multi-orientation decomposition for the 2-D radar matrix to adequately represent texture and edge information with curve-like features [12], providing information on signal strength and moving direction of people.

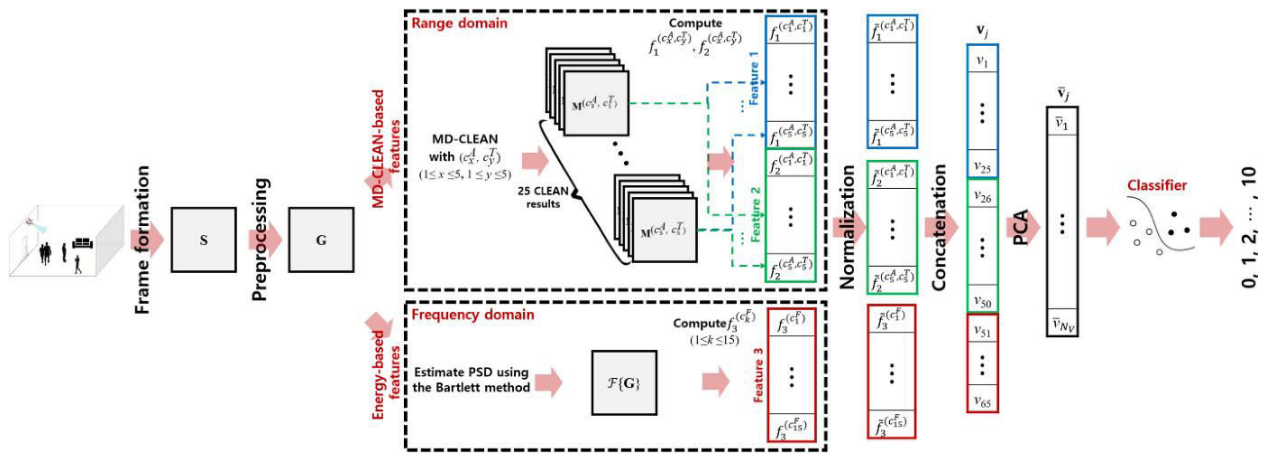


Fig 2: IR-UEB Rader Semantic Scholar

To get detailed features for complementing curvelet transform based statistical features and further analyze the superposed and obstructed signal in dense people counting, several features are extracted from each signal. Clutter signals are removed firstly using a running average based method [5] to analyze the valid signals reflected from people, and feature The maximum amplitude in each distance bin is selected as a feature to represent a candidate point for the presence of people. However, the number of local maximum amplitudes can not represent the number of people when they stand closely. As shown in Fig. 5, the first red circle is obviously detected for the presence of 1 person, but there are 2 persons standing closely. In this case, it is impossible to distinguish the number of people from the amplitude due to the multipaths from different people. But the energy of different people are superposed and distinct significantly in a distance bin, therefore the energy is calculated as the complementary feature by squaring sampled signals and integrating them over each bin.

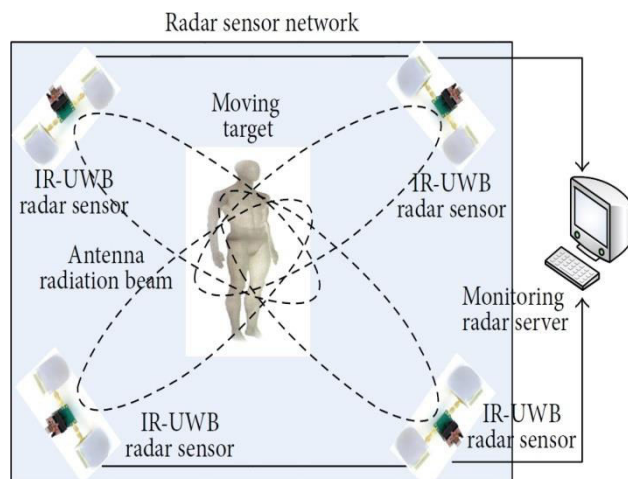


Fig 3: Signal passing IR-UWB Rader

he proposed crowd density estimation system is based on the idea that when people move inside the room, they cause changes in the propagation channel according to some patterns that can be considered statistically independent. In previous works, working on the same principle [14,19], where the LTE or WiFi radio signals are used for counting, the temporal variation of the channel response is *observed* in the frequency domain by collecting and analyzing the so-called CSI. In this work, we are using UWB signals that are characterized by much higher bandwidth: in our experimental set-up, the bandwidth is 500 MHz, while in [14] the bandwidth of the LTE signal is 15 MHz. Therefore, we have chosen to work in the time domain, using the CIR rather than the CSI. We expect that by analysing the

variation in time of the CIR, it is possible to identify a number of independent patterns of temporal variations that is correlated to the number of people in the room. The number of large singular values of the matrix containing the collected CIRs over a given time window, is expected to be proportional to the number of independent patterns and hence the number of people in the room. Therefore, we perform the SVD on the matrix having the CIR vector differences on the rows and we have chosen features that characterize the singular values trend.

#### IV. EXPERIMENTAL RESULTS

passive device-free RF-based crowd counting methods, using either WiFi, LTE or UWB signal. Even if a fair comparison between different methods is not possible as performance is influenced by several aspects of the experimental setup (signal bandwidth, carrier frequency, distance between transmitter and receiver, number of transmitters and receivers, maximum number of people, room size, constraints on the position of TX and RX etc.), it is possible to state that the achieved results are very encouraging, considering that the used transceivers have a bandwidth of 500 MHz, which is lower than the bandwidth, namely 2 GHz, of radar-devices commonly considered for UWB-based crowd counting systems. The proposed approach allows to fully take advantage of the wide bandwidth of UWB in a multipath-rich environment. It is worth outlining that the same approach and processing could be used with other opportunistic radio signals, even characterized by lower bandwidth. In particular, we also evaluated the performance when lower bandwidth signals are available. For a bandwidth of 250 MHz, in room A we have got an average accuracy of 93%93% and for a bandwidth of 125 MHz we have got an accuracy of 88%88%, which are still good results when compared with other low cost device-free passive counting systems.

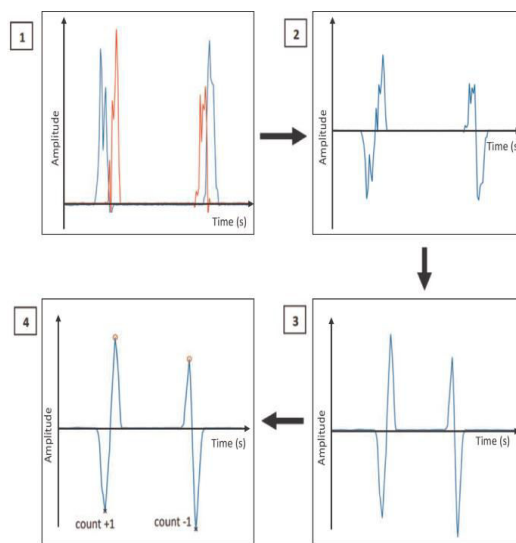


Fig 4: Real Time People Counting using IR-UEB

The hybrid CTF-DBF feature samples extracted from the dataset constructed in this letter with size  $1 \times 300$  are used as input for classification. To verify the effectiveness of the hybrid feature extraction method, four selected classifiers are compared, including decision tree, AdaBoost, random forest and neural network. The decision tree is a rooted tree structure to divide the cases into two subtrees in each node. In this letter, the random forest classifier constructs 200 decision trees to increase the classification ability. The AdaBoost consists 50 base estimators, with the SAMME.R classification algorithm and a linear loss function. The neural network has three hidden layer with 100, 200 and 100 neurons respectively as well as a ReLU activation function, and is optimized by Adam algorithm.

## V. CONCLUSION AND FUTURE SCOPE

a novel UWB-based people counting system, which uses the CIR extracted from low cost commercial UWB transceivers, more commonly used for localization purposes. The proposed system has been tested in two different environments and the achieved results (100%100% accuracy up to 5 people and 89%89% up to 8 people) are very promising and encourage further investigations of its performance for a much higher number of people and also considering a larger variety of application environments. We could not perform such experiments due to COVID-19 limitations on the number of people allowed in one room. Moreover, the proposed approach, which works on the differences between two consecutive CIR, is expected to be rather independent from the background environment, thus making the proposed counting system independent from the room where the training is performed. Therefore, the training phase could be performed once in a *standard* room and then the system could be implemented in different rooms. This will be the subject of further investigations.

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