BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 65 (69), Numărul 4, 2019
Secția
CONSTRUCȚII. ARHITECTURĂ

SYSTEM OF COUNTING USERS OF A PUBLIC BUILDING

BY

MIHAI-CIPRIAN MITREA[*] and ANDREI BURLACU

Technical University “Gh. Asachi” of Iasi,
Faculty of Civil Engineering and Building Services

Received: September 26, 2019
Accepted for publication: November 25, 2019

Abstract. *Fire safety*, defined by Law No. 10 of 1995 as a quality requirement of buildings, was not a priority for beneficiaries and investors in the field of construction; this area has come to the attention of the general public after the Collective Club tragedy in Bucharest. In the wake of this event, the necessity of a minimum security level of fire safety idea has spread addressing the public feeding spaces and educational units. The fire safety security level of a building is maintained at an optimum level as long as the building elements and fire prevention and extinguishing facilities of a building meet the requirements set up at the design stage. Even if these requirements are met, there is still an aspect that may lead to a decrease in the level of fire safety, because at present there is no monitoring of the number of users in a public building, which leads to exceeding the designed value.

In order to improve the fire safety level of the constructions, the creation of a system for counting users in a public building is proposed.

Keywords: fire safety; user counting facility; crowding; fire detection; fire extinguishing.

[*]Corresponding author: *e-mail:* mitreamihai@gmail.com

1. Introduction

In the last decade we witnessed a rise in the citizens' interest for fire safety, a notion that came to the fore after the tragedy at the Collective Club in Bucharest. After this event, the idea that a minimum level of fire safety was a necessity was propagated, being mainly addressed to the public feeding spaces and the educational units. While these two categories of objectives highlight the concern of the general public for the safety of life, in the industrial environment we find, in the same period of time, a concern for the protection of goods.

In order to achieve a high level of fire safety of a building, it is necessary to have this aspect in mind during the design stage and subsequently, it is necessary to adopt organizational measures that will ensure safe exploitation of the construction. During the design stage, constructive measures are focused on, such as fire compartments with fire-resistant walls and fire doors, as well as providing the construction with fire detection equipment and fire extinguishing facilities. Fire extinguishing systems differ according to the extinguishing agent used: gas, aerosols, foam, powder or steam, and the most common being systems using water.

The constructions, installations, and features must be designed and executed so that, in the event of fire, throughout their life, they will ensure:

a) estimation of the load elements stability for a certain period of time;

b) limitation of the appearance and propagation of fire and smoke inside the building;

c) limitation of the spread of fire to neighbourhood;

d) the possibility of the users to evacuate safely or to be saved by other means;

e) security of the fire fighters.

If the aspects regarding the stability of the load-bearing elements are resolved from the construction phase, those regarding the limitation of the appearance and propagation of fire and smoke are solved by providing the construction with fire-warning and extinguishing systems as well as with smoke exhaust installations, while the evacuation of the users involves a detailed analysis because, unlike the first two issues mentioned above, it has a variable component. The evacuation of users implies the sizing of the escape routes according to the maximum number of users envisaged.

The design of the escape routes is based, at this time, on the Fire Safety Regulations for buildings, indicative P118-1999. The norm has specific provisions only for the spaces with the commercial destination, for estimating the number of people who have access in the spaces for the public which, as a

rule, represent at least 2/3 of the store area (shopping centre) and the following densities are taken into account. :

a) For shops, we should have one person per:
– 1 m^2, the ground floor;
– 2 m^2, on the basement and floors 1 and 2 (compared to the area);
– 5 m^2, on the other levels of the basement and floors;

b) For shopping centres (with an area of at least 500 m^2), one person per 5 m^2, regardless of level, is considered.

In addition to this provision regarding the density of persons, the same regulation also defines the notion of crowded room as a room or group of rooms that communicate directly with each other through gaps (protected or unprotected), in which the surface for a person is smaller than 4 m^2 and in which at least 150 people can gather at the same time (theatres, places of assembly, exhibition rooms, museums, clubs, cinemas, shops, casinos, discos, etc.). When located on the ground floor, rooms with more than 200 people are considered crowded. For the design of evacuation routes, the necessary number of evacuation flows is calculated according to the maximum number of persons allowed; the norm regulates the capacity of a flow, in the case of the spaces with commercial destination, with a value of 70. The free width required for the passage of the evacuation flows, in relation to their number, is at least:

– 0.80 m for one flow;
– 1.10 m for two flows;
– 1.60 m for three flows;
– 2.10 m for four flows;
– 2.50 m for five flows;

Exceeding the designed capacity of the maximum number of permitted users generates a great vulnerability, the most relevant example in this respect being the event at the Collective Club in the municipality of Bucharest: at the date of the tragedy, there were 350 users in the club, while the town hall had issued for an operating licence for 80 users in a cumulative area of 425 m^2, *i.e.*, spaces for the public and spaces with other functions. In order to address this problem, with GD No. 915/2015 the state regulated on the obligation of owners of public constructions to comply with the designed capacity and in case the number of users by exceeds 10%, the activity of the economic operator in the respective space shall be stopped. This provision does not guarantee compliance with the maximum number of users allowed because, on the one hand, there is still a tendency on the part of the owners of these locations to receive as many users and on the other hand, the want of staff with control rights in this area makes it impossible to guarantee an adequate level of fire safety to the people in this type of buildings.

2. Facility of Counting People in a Public Building

In the context of those presented above, it is necessary to identify a solution to allow the monitoring of the number of people in a public space at a given time. At this moment there is a concern in the marketing area to monitor the behaviour of customers in order to optimize sales.

In order to keep the number of users within designed parameters, it is necessary to create a system for counting people in order to meet the fire safety requirement, an installation with a regime similar to the fire warning and extinguishing systems, from the point of view of design, implementation, and maintenance.

2.1. Smart Control Access System

The concern for the Internet of Things has generated solutions for connecting different types of sensors, including systems for counting people, without these systems being the main element of research. An example of this is the Smart Control Access System (Alkhodre, 2018), and the associated article focusing on errors that may occur in the IoT. We can be see this system is composed of different sensors (flame, heat, motion, temperature, etc.), access control devices, router and server. In this case, counting the number of people is facilitated by the access system control: the door is normally closed.

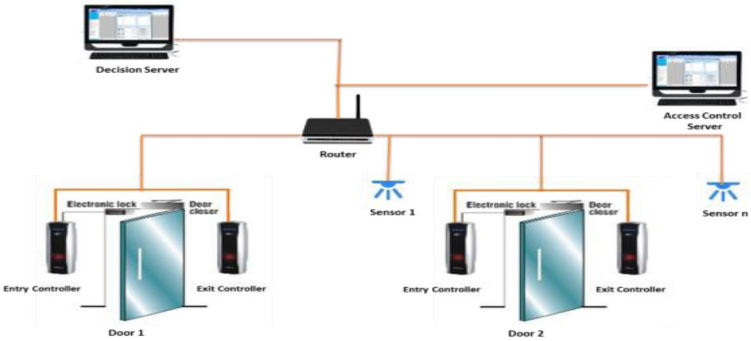

Fig. 1 – Smart Control Access System.

2.2. Counting Through Surveillance Cameras

In *Counting people by RGB or depth overhead cameras* (Del Pizzo *et al.*, 2016), a method based on video monitoring for counting the number of people crossing a virtual line is presented. The method analyses the video

stream captured by a camera mounted on a higher position relative to the counting line, which allows the counting of the number of persons crossing the virtual line and captures each person's direction of passage. This proposed approach has been specifically designed to achieve high accuracy so that it may be adopted in actual cases. A comprehensive evaluation of this method has been made taking into account the main factors able to impact on the counting performance and, in particular, on the capturing technology (traditional RGB camera and depth sensor), installation scenario (interior and exterior), density of people flow (isolated persons and groups of people), capturing frame rate and image resolution. The combination of outputs obtained from RGB sensors and depth was also analysed as a way to improve the counting performance. The experimental results confirm the effectiveness of the proposed method, and the tests carried out on three different CPU architectures demonstrate the possibility to implement the method on both high quality servers for parallel processing of a large number of video streams and on low power processors such as those built-in smart commercial cameras.

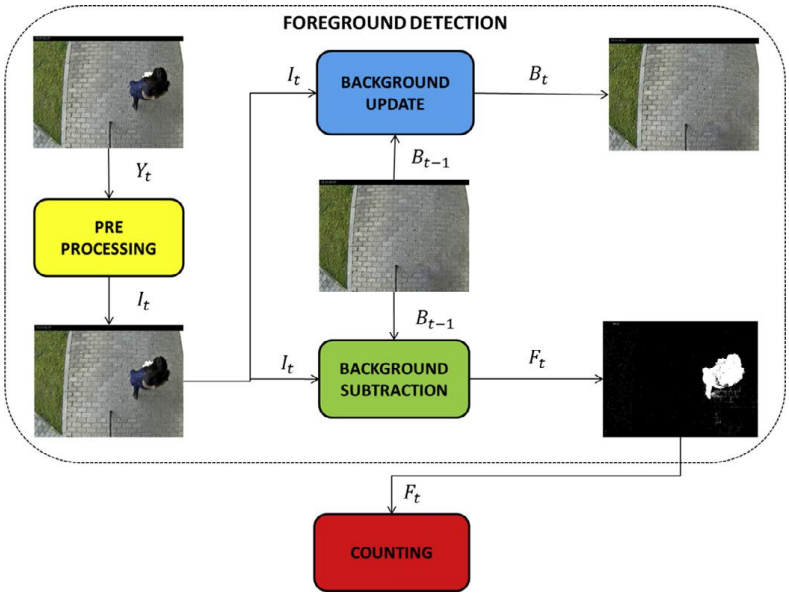

Fig. 2 – The architecture of the proposed system.

2.3. Counting by Thermal Detection

In order to count people, the possibility of placing an 8 × 8 IR sensor on the doors was investigated (Mohammadmoradi H. *et al*., 2017). The solution

offers real-time data, is inexpensive and protects privacy. The main idea is to mount an IR sensor on one side or on the top of the door and count the incoming and outgoing events. The solution extracts and tracks people from the IR images captured using the temperature difference relative to the background. The solution is easy and relies on a Raspberry Pi Zero (only costs $ 5), which makes it an affordable solution. The IR matrix sensor costs less than $ 22 and consumes ~4.5 mA when active. The IR sensor may be mounted on the top or on any side of the door as long as people enter its field of vision. The solution has almost no privacy issues, as the resolution is low and the temperature of the human body is so similar that it is almost impossible to make an identification of the occupants using this sensor. The results show 93% accuracy in estimating the number of occupants in rooms.

Another solution (Orrite-Uruñuela *et al*., 2018) for the use of IR sensors is to include them in a surveillance video camera and, based on an algorithm, people can be detected based on identifying their heads in the image of depth. As the depth images are taken from the top, the heads correspond to the minimum points in the depth maps. In order to identify them, the background elimination procedure is used for motion detection and for the minimal detection of the plane region, applying mathematical analyses. The algorithm also addresses the main problem of the depth sensor, *i.e*., regions that have no value.

The operational principle of thermal detection is identification the heat emission generated by the presence of people and then, by computer analysis, the counting of persons is performed. This system has difficulty when people are motionless, overlapping, and carrying warm things (such as laptops). Applications have been developed based on this principle (Gade *et al*., 2013), which obtain a 4.44% rate of error.

2.4. Counting via Wi-Fi

Fig. 3 is a representation of how the devices track smart phones. The phone is always looking for known Wi-Fi networks so that it can automatically connect to a known network without manually selecting it. The way the phone finds a WiFi network is by sending what is called a "sample request". This sample request is a unique MAC address of the type "40: 68: AD: 80: D3: A0". All WiFi routers are able to track the phone, using the MAC address, without the phone being connected to the internet, the only thing required is for the WiFi turned on. Several routers receive the signal and triangulate, comparing the relative signal power, thus approximating the location.

Fig. 3 – Phone detection via WiFi.

In *Tracking from One Side – Multi-Person Passive Tracking with WiFi Magnitude Measurements* (Karanam *et al*., 2019), the findings of passive tracking of several people walking in an area are presented, using only the size of WiFi signals from a WiFi transmitter and a small number of receivers. Then, a new solution is proposed: it uses only the size of the WiFi signals and their expression relative to the arrival angles of signal paths to the receivers, as well as the movement parameters. This is followed by the application of a two-dimensional SIgnal MUltiple classification algorithm (MUSIC), in order to estimate the mentioned parameters, and then a particle filter with a common probabilistic data association filter is used to track more people walking in the area. This solution has been validated in both indoor and outdoor areas, through 40 tracking experiments from 1 to 3 people, using a single transmission antenna and three laptops as receivers (in total, four Intel WiFi 5300 off-the-raft network interface cards). The results show an extremely accurate tracking (average error of 38 cm in outdoor areas/closed car parks and 55 cm in indoor areas) using WiFi resources.

2.5. Counting by Active IR Sensors

This type of counting implies the existence of an infrared transmitter and an infrared receiver. Sensors are usually located on one side of the door; standard sensors count how many times the infrared light is interrupted. In order to determine the total number of people who entered and exited at the end of the monitoring period, it is necessary to divide the total number of interruptions by two. This solution has a rather high rate of error because the infrared light can be interrupted by two persons passing through the sensors simultaneously.

2.6. Counting by Ultrasonic Detection

The literature has not developed this subject extensively since the results do not have a very good rate of accuracy due to the influence of the type of clothes worn. In principle, the system is composed of a transmitter and a receiver, thus creating an image of the persons passing through the monitored area.

2.7. Counting by Motion Sensors

A motion sensor is a device that detects moving objects, especially people. Such a device is often integrated as a component of a system that automatically executes a task or warns a user about movement in an area. Motion sensors have found widespread use in domestic and commercial applications, with multiple known uses: activating automatic door opening in businesses and public buildings, activating street or interior lights, triggering security cameras to record possible intrusions and use in anti-theft systems. This type of sensors can be useful in the implementation of systems for counting people.

3. Conclusions

So far, the concerns for developing access metering solutions and especially for monitoring customer behaviour inside commercial spaces are found only in the marketing area. Depending on the results of such detailed analyses, new sales techniques are subsequently adopted.

In order to maintain the level of fire safety at the designed level, in the field of user counting, it is necessary to achieve the following two objectives:

- **Creating a user counting facility:**
  - Proposal of a technical prescription defining this facility. The basic layout of this facility would be the following:
  - Proposing a regulation establishing the compulsory use of this installation in public buildings with a certain number of users;
  - In case of exceeding the maximum number allowed by design, the installation will have to trigger the following actions: warning occupants, prevent of additional access, inform the ISU;
  - Physical achievement of such an installation.
- Developing a user counting solution:
  - Create a user counting sensor based on IR technique or video analysis of images from a surveillance camera or another solution described above**.**

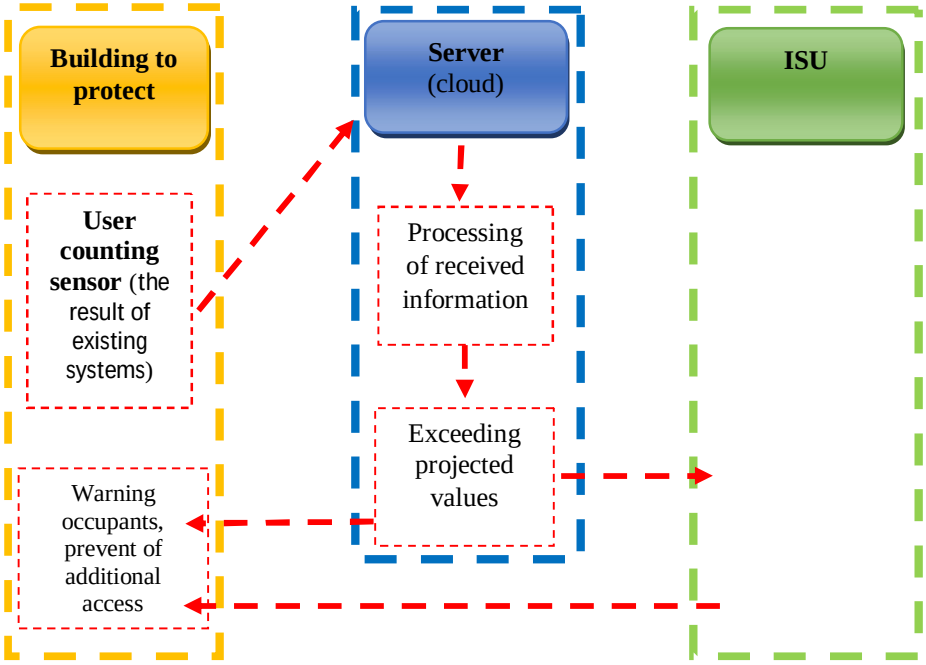

Fig. 4 – Principle scheme of a user counting facility.

REFERENCES

Alkhodre A., *Statistical-Based Trustful Access Control Framework for Smart Campuses*, International Journal of Advanced Computer Science and Applications, **9**, *9* (2018).

Del Pizzo L., Foggia P., Greco A., Percannella G., Vento M., *Counting people by RGB or depth overhead cameras*, at www.sciencedirect.com (2016).

Gade R., Jørgensen A., Moeslund T., *Long-term Occupancy Analysis using Graph-Based Optimisation in Thermal imagery*, IEEE Conference on Computer Vision and Pattern Recognition, at https://ieeexplore-ieee-org.am.e-nformation.ro (2013).

Karanam C., Korany B., Mostofi Y., *Tracking from One Side – Multi-Person Passive Tracking with WiFi Magnitude Measurements*, The 18th International Conference on Information Processing in Sensor Networks (co-located with CPS-IoT Week 2019) (IPSN '19), https://doi.org/10.1145/3302506.3310399 (2019).

Mohammadmoradi H., Munir S., Gnawali O., Shelton C., *Measuring People-Flow Through Doorways Using Easy-to-Install IR Array Sensors*, 13th International Conference on Distributed Computing in Sensor Systems, at https://ieeexplore-ieee-org.am.e-nformation.ro (2017).

Orrite-Uruñuela C., Vicente-Dueñas D., (2018), *Counting People by Infrared Depth Sensors*, 15th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) at https://ieeexplore-ieee-org.am.e-nformation.ro (2018).

* * * *Fire Safety Regulations for buildings, indicative P118-1999*, approved with OMLAPT no. 27/N / 07.04.1999, with subsequent amendments.

INSTLAȚIE DE CONTORIZARE A UTILIZATORILOR UNEI CLĂDIRI PUBLICE

(Rezumat)

Securitatea la incendiu, definită de Legea 10 din 1995 ca fiind o cerință de calitate a construcțiilor, nu a constituit o prioritate pentru beneficiari investitori, acest domeniu venind în atenția publicului larg după tragedia de la Clubul Colectiv din Bucureşti. Ulterior acestui eveniment s-a propagat ideea că asigurarea unui nivel minim de securitate la incendiu este o necesitate, fiind vizate în principal spațiile de alimentație publică şi unitățile de învățământ. Nivelul de securitate la incendiu al unei construcții se menține la un nivel optim atâta timp cât elementele constructive şi instalațiile de prevenire şi stingere a incendiilor aferente unei clădiri respectă condițiile stabilite în etapa de proiectare. Chiar dacă sunt respectate aceste condiții, există totuşi un aspect ce poate conduce la o scădere a nivelului de securitate la incendiu, deoarece în prezent nu se face o monitorizare a numărului de utilizatori dintr-o clădire publică, ceea ce generează depăşiri ale valorii proiectate.

Pentru a îmbunătăți nivelul de securitate la incendiu al construcțiilor, se propune realizarea unei instalații de contorizare a utilizatorilor dintr-o clădire publică.