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Energy Conservation in Commercial Places Based On Real Time Occupancy Detection

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***Abstract*— This paper proposes a method to boost the energy efficiency of air conditioners based on occupancy detection. A robust bidirectional people counter is proposed for estimating the real time crowd density in indoor spaces. A video surveillance camera mounted near the entrance films the crowd entering and exiting the place. The proposed algorithm extracts each person from the crowd, tracks each extracted person and then counts the person on making physical contact with a baseline. The tons of refrigeration required for cooling a place is directly proportional to the crowd density. According to the guidelines given by the Energy Star program of U.S. Environmental Protection Agency, the real time people count along with the floor space can be used to calculate the exact refrigeration tons required for cooling a place. A new breed of air conditioners called variable capacity air conditioners, having the ability to vary their tonnage over a wide range, are automatically adjusted to run at the computed refrigeration tons, thus adhering to Energy Star recommendation at real time. The novel method proposed in this paper would ensure that an air conditioner does not work more than what is exactly required. In the future, the proposed method can be implemented in air conditioners for saving energy in crowded indoor environments.**

***Index Terms*— Crowd, People counting, Video Segmentation, Air conditioner, Energy saving.**

I. Introduction

In the past few years, there has been a huge demand for energy and the best way to tackle this problem is by preventing wastage of energy. Air-conditioning systems consume a sizable majority of the total energy consumed in this world and optimizing them for energy saving is the need of the hour. The thermal effect of human beings is negligible when there are only a few people in the room. But interestingly, a large group of people produce a highly significant heating effect [9, 10] that can drastically affect the energy required to cool a hall. Most of the commercial places run their air-conditioners at full capacity all the time as the number and the distribution of people cannot be predicted. Also, commercial places have large fluctuations in crowd density and energy has to be saved without causing loss of comfort.

This paper aims at conserving energy by estimating the crowd density level at indoor environments such as auditoriums, showrooms, supermarkets and calculating the exact cooling capacity required as per the guidelines given by Energy Star [8] and Natural Resources Canada [11] for adjusting variable capacity air-conditioning systems that have the ability to vary their cooling capacity over a wide range from 35% to 100% [12]. A bi-directional people counter based on video image processing has been proposed for counting people in indoor environments. The system captures object information using CCTV camera, analyses the captured data using video processing and pattern recognition technology and computes crowd density. The exact tonnage required is calculated as per the guidelines of Energy Star [8]. Finally the system adjusts the tonnage of variable capacity air-conditioner to the exact tonnage required.

II. Related Works

When more than one person is passing through an entrance at the same time, traditional people counting systems, such as turnstiles, tally counters, and infrared beams, fail to give an accurate count. To overcome this problem, computer vision systems based on video image processing were employed. Some of the methods [1]-[6] that can count people passing through a region of interest were studied. The method proposed by [1] improved the performance of background subtraction technique by renewing the background frequently. But the method was not able cope with changes in illumination. The algorithm proposed in [2] extracts the moving objects using frame difference technique and applies morphological filters to reduce isolated noise and fill holes in the object region. But the method was not able to tackle occlusion. To overcome occlusion, [3] repositioned the camera to get a bird's eye view of the moving people. The method proposed in [4] aims at avoiding recounting of the same person by using multiple cameras distributed over region of interest. The method proposed in [5] aims at detecting and tracking pedestrians by mounting a single camera from the ceiling of the entrance and enclosing each person in a bounding box. Sometimes people touch each other while walking and this makes detection difficult. This problem, generally referred to as the 'merge-split problem' can be tackled successfully by [5]. The method proposed in [6] aims at solving people-image overlapping by using area and colour information of pedestrians. The methods discussed above have not yielded a comprehensive solution and are incapable of providing a reliable estimate of the number of people inside a hall.

In this paper, a bi-directional people counter based on segmentation and tracking has been proposed for overcoming the shortcomings of existing methods. The estimated real-time crowd count along with the floor space of the hall are used to calculate the exact tonnage required as per the guidelines of Energy Star [8] and Natural Resources Canada [11]. Then, the tonnage of variable capacity air-conditioner is set to the exact tonnage required, thus conserving energy.

III. THE PROPOSED ALGORITHM

In the proposed method, a CCTV camera is positioned to get a bird's eye view of the crowd moving through the entrance, so that occlusion and people-image overlapping are reduced. Each person is extracted from the moving crowd using segmentation based on people-image features. Each extracted person is enclosed within a bounding box and tracked using intersection-checking technique. The tracked person is counted on making physical contact with a baseline. Finally, this people count along with the floor space is used to calculate the exact air-conditioner tonnage required at real-time, as per the guidelines given by Energy Star [8] and Natural Resources Canada [11]. The computed value is fed to the invertor driving the compressor of the variable capacity air-conditioning unit. Figure 1 describes the proposed algorithm which includes segmentation module, tracking and counting module and tonnage calculation module.

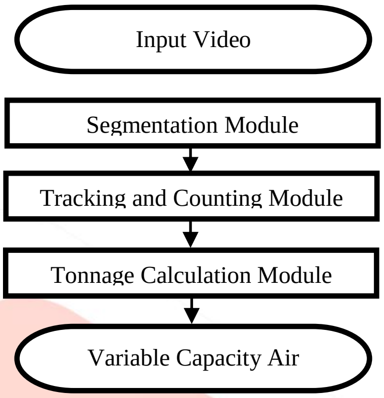

Fig. 1. The Proposed Algorithm

A. SEGMENTATION MODULE

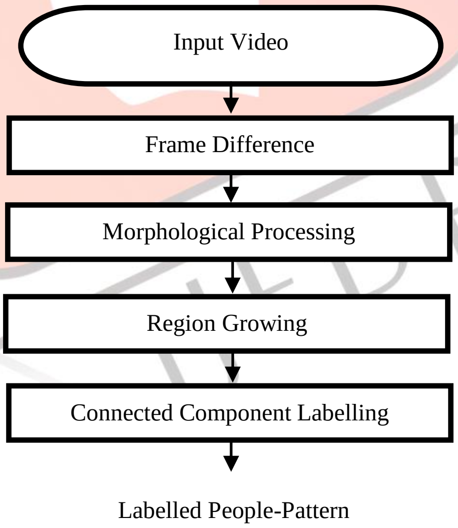

Fig. 2. Segmentation Module

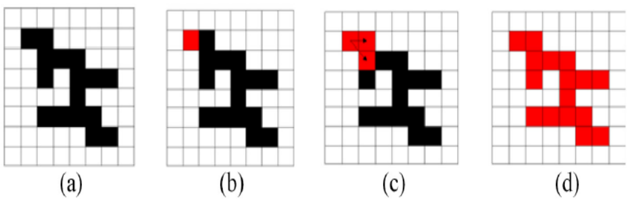

Fig. 3. Eight-connected Region Growing (a)Input image; (b)Seed selection; (c)Pixels added to seed region; (d)Output Image.

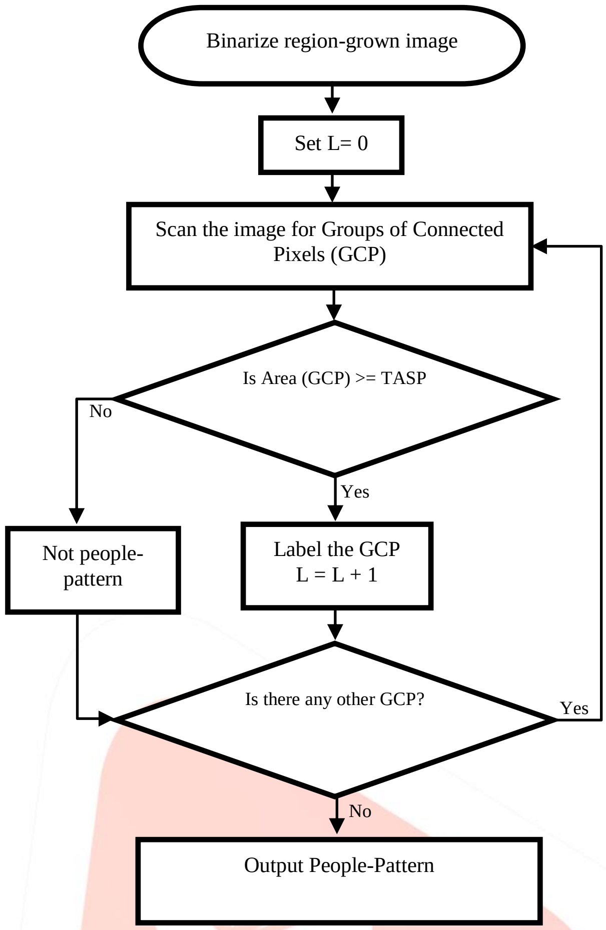

Fig. 4. The proposed Connected-component labelling algorithm.

Background subtraction cannot be employed because of its inability to overcome the effects of varying illumination. The Optical-flow method, in spite of its robustness is not desirable because of being computationally expensive. The method proposed in this paper extracts the moving objects using frame difference technique and applies morphological filters to reduce isolated noise, enhance boundaries and fill holes in the object region. Figure 2 describes the steps involved in the segmentation module.

The morphological processing technique yields the outlines of the moving objects. The region growing algorithm is employed for filling the hollow regions within the outlines of the object regions. The first step in the region growing process is to choose some seed points based on factors such as pixel intensity, colour, pixel spacing, etc. The neighboring pixels are then analyzed and if they match the characteristics of the seed, they are added to the seed region. We use the eight-connection growth, where all adjacent pixels in all eight directions are analyzed and the pixels that have the same characteristics as that of the seed are added to the seed region. Figure 3 taken from [7] illustrates the process of region growing.

Now, the connected-component labelling process illustrated in Figure 4, is employed for extracting and labelling the connected pixels with the same characteristics. The image resulting from region-growing process is transformed into a binary image. The label L is initialized to 0. The binarized image is scanned for Groups of Connected Pixels, which will be referred to as GCP. If the area of any GCP is greater than TASP i.e. the Typical Area of a Single Person, then it is considered as a people-pattern and assigned a label. Else, it is considered not to be a people-pattern. This process is continued till all the GCP are evaluated. In the end, all the people-pattern are extracted.

Now, each people-pattern is considered to be an object and enclosed in a bounded box. If the area of the bounded box BBarea is greater than TASP, then the object is considered to have more than one person. In such cases, the object is fractioned into sub-objects based on dimensions of the bounding box as shown.

The object is fractioned into K sub-objects. In the above calculation, TW is the threshold value for the width of a people-pattern and TH is the threshold value for the height of a people-pattern. BB_{width} and BB_{height} represent the dimensions of the bounding box.

If $BB_{area} > TASP$ then

If $BB_{width} > TW$ then

$K_w = Round(BB_{width}/TW)$

If $BB_{height} > TH$ then

$K_h = Round(BB_{height}/TH)$

$K = K_w * K_h$

B. TRACKING AND COUNTING MODULE

The labelled people-patterns obtained from the previous step have to be tracked, so that they can be counted on making physical contact with a baseline. The tracking is done by enclosing the people-patterns within bounding-boxes and checking the intersection of the bounding boxes across multiple consecutive frames. If the bounding boxes of consecutive frames intersect with one another for identical people-patterns, then the boxes are considered to pertain to the same person.

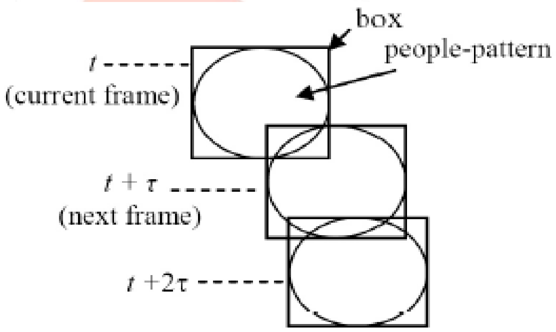

Fig. 5. Tracking of a bounding-boxes and checking for intersection

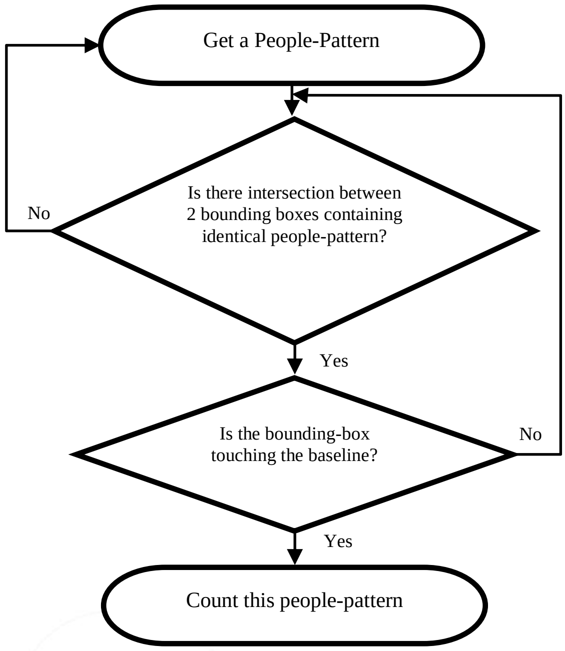

Fig. 6. The proposed Counting Algorithm

If the bounding boxes do not intersect across multiple frames for identical people-patterns, then the boxes are considered to belong to different people. The bounding boxes may get disjointed because of abrupt turning back or running and in these situations the algorithm aborts the tracking of that box. The Figure 5 shows the drifting of bounding boxes across successive frames and their intersection indicates that they pertain to the same person.

The process of checking for intersection between successive bounding boxes will be carried out continuously until the person wanders out of view. The people being tracked are counted on making physical contact with a baseline. The Figure 6 describes the process of counting.

C. Tonnage Calculation Module

The aim of the project is to ensure that the air conditioner does not work more than what is exactly required. Calculating the exact cooling capacity required is done based on the guidelines given by Energy Star [8] and Natural Resources Canada [11]. The computed result is used for adjusting the cooling capacity of the variable capacity air-conditioner. Table 1, taken from Cornell University Ergonomics Web [9], represents the heat released by a human during various activities. As per [8] and [11] each person in a hall emits approximately 600 Btu of energy per hour. From the above modules we obtain the number of people inside the hall. Suppose 100 people are there in the hall, then 60,000 Btu/h of heat is produced.

Table 1. Heat released by human during activities

Table 2. Basic Cooling Capacity based on Floor Space

Activity	Met	Btu/h
Sleeping	1.0	356
Light activity	1.6	571
Walking at 2 km/h	*1.9*	675
Domestic Work	2.9	1043
Walking at 5 km/h	3.4	1228
Running at 12 km/h	8.5	3070

Area To Be Cooled (in square feet)	Capacity Needed (in Btu/h)	Capacity Needed (in Ton)
150	5,000	0.4
400	*9,000*	*0.75*
550	12,000	1.0
1000	18,000	1.5
1500	24,000	2
2000	30,000	2.5
2500	34,000	2.8

Table 2 is taken from Energy Star's recommendations for sizing an Air-Conditioner [8]. For calculating the exact cooling capacity required for a hall of 1,500 sq. ft., Energy Star recommends a basic cooling capacity of 24,000 Btu/h, i.e. 2 Tons of refrigeration with an addition of 600 Btu/h for each person in the hall [8], [11]. When 100 people are there in the 1,500 sq. ft. hall, they release 60,000 Btu/h of heat, which would require an additional 5 Tons of refrigeration. The cooling capacity required for a hall of 1,500 sq. ft. with 100 people is calculated as 7 Tons of refrigeration, as depicted by Figure 7.

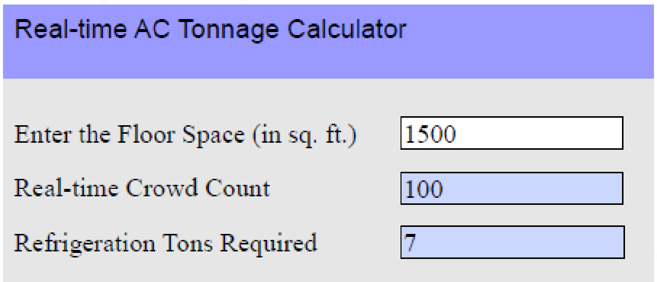

Fig. 7. Calculation of Cooling Capacity required for a hall of 1500 sq. ft. with 100 people

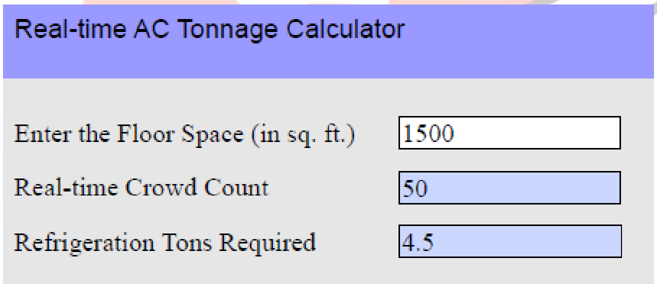

Fig. 8. Calculation of Cooling Capacity required for a hall of 1500 sq. ft. with 50 people

But when 50 people are there in the 1,500 sq. ft. hall, they release only 30,000 Btu/h of heat, and the cooling capacity required is reduced to 4.5 Tons of refrigeration, as depicted in Figure 8. Thus considerable amount of energy can be saved without compromising on comfort by running the variable capacity air-conditioner at 4.5 tons instead of 7 Tons.

Figure 7 and Figure 8 show the user interface, where the floor space of the hall has to be entered manually and the system computes the crowd count via video segmentation and estimates the required cooling capacity using the guidelines given by Energy Star [8]. Thus, in crowded commercial places which have large fluctuations in the number of people, the exact cooling capacity required can be calculated automatically and used for controlling variable capacity air-conditioners, which have the capacity to vary their cooling capacity over a wide range, usually from 35% to 100% [12].

IV. Conclusion

The paper proposes a method for conserving energy by employing a bi-directional people counter for estimating crowd density in indoor environments and then adjusting a variable capacity air conditioner according to real-time crowd density and floor space, following the guidelines of Energy Star. By adjusting the tonnage of variable capacity air-conditioner to the exact tonnage required, energy can be saved without compromising on comfort. The result of the crowd counting is generally affected by factors such as illumination, occlusion etc. and the proposed method will provide a cost-effective people-counting technique that can overcome the influence of changing illumination. This method would ensure that the air-conditioner does not work more than what is exactly required, thus preventing wastage of energy. In the future, the proposed method can be implemented in embedded systems to reduce the energy consumption in commercial places.

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