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A Smart Image Processing System for Hall Management including Social Distancing – "SoDisCop"

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Abstract*—This paper proposes a comprehensive system meeting the multiple objectives of energy saving, crowd control and social distancing in public places such as auditorium, shopping malls, theatres. The system proposed in this paper detects both total and sector wise head count of the people in the hall. The total head count is used for crowd control and the system triggers the relevant authority when it exceeds the capacity of the hall.This paper also proposes the smart management of electrical and electronic devices such as lights and fans based on the sector wise head count. The proposed method monitors the social distancing termed "SoDisCop" and is intentionally kept devoid of complexity targeting low cost implementation.Thenovel feature of this work also meets a critical need during the current covid-19 pandemic.

Keywords—*Video surveillance, OpenCV, Image processing, Face detection, social distancing, Covid-19,*

I. Introduction

The smart hall system proposed in this study addresses a key challenge in Indian society i.e. crowd control in public places such as halls, auditoriums. Video Surveillance based systems are used extensively in recent days, where the crowd is monitored continuously for the purpose of their safety and security. In this proposed method head count is computed using video stream based on which, the electrical and electronic appliances are controlled thereby catering to another key environmental need energy savings. Sector based headcount is used as control criteria for electric appliances in specific sectors. The head count is also used for crowd control. If the people occupancy in the hall exceeds the maximum limit, notification is sent through GSM to respective in-charge person about the same. This paper includes social distancing monitoring in the hall by detecting the distances between the faces with GSM notifications for violations.

II. Literature Review

Various researches have been performed in this field as a part of smart hall management and crowd control. The earlier works exhibit strong dependency on the sensors and advanced camera technology and hence unlike the below proposed low cost but effective methodology will fall under higher end of the cost spectrum [2],[3],[10].The common method of head count is to use sensors at the entrances and detect the inflow and out of the people from the hall or vehicle [12]. The commonly used sensors are laser beam, infra-red sensor, thermal sensorand video camera. The most accurate headcount can be obtained through mechanical turnstiles but will result in constrained movement of people and hence not a suitable option [2]. Apart from complexity of consolidating the data through multiple entrances which is the norm in medium to large sized halls, the sensors-based system also requires network connectivity for data concentration and consolidation at the central system controller [7],[8]. Continuous video data through the network is a probable cause for loading the network. Occupancy or headcount-based energy management pays rich dividends through energy saved in HVAC systems [11]. Motion detection sensors play a key role in detecting the occupancy of the hall and controlling the switching of energy elements. Often these systems result in erroneous operation when the occupants are still without any movement and are mostly suited for binary operations. Headcount based energy management system overcomes these deficiencies offering linear control of the utilities.Social distancing has beensubject of many on-going studies involving people tracking and controllingthe spread of Covid-19 [9]

III. Smart Hall Management Using Imageprocessing

The system proposed utilizes OpenCv library and implemented in python. In this study, the proposed system implementation is hosted on a raspberry Pi 3 controller.Fig. 1. and Fig. 2. depicts the context and signal flow of the system respectively.

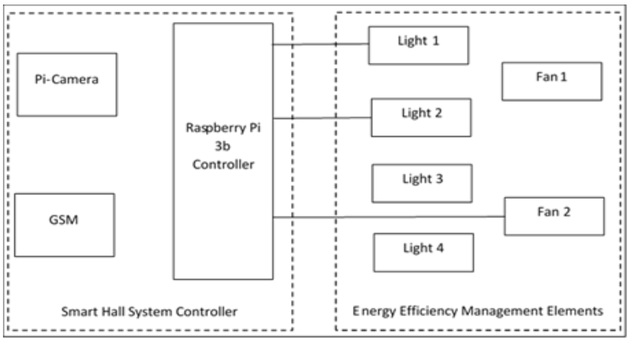

Fig. 1. Context diagram

The controller with camera forms the core of the system for computing the head count in software through image processing routines.Face detection routines of OpenCVare used for head count in each frame of the video stream from the camera.The software also triggers the energy management actions through the output ports of the controller. A variable control is also implemented through PWM control. Crowd control and Social distancing alerts are generated in GSM add on. The controller uses serial interface to communicate with GSM addon.

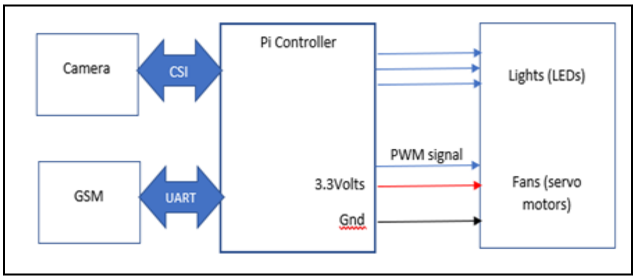

Fig. 2.Signal flow Diagram

IV. Image Processing Based Hall Management

The proposed methods for major features are described below.

A. Head count and crowd control

Face detection is accomplished in software through frontalface cascade routine[1] of OpenCV . This routine is based on pretrained Haar cascade models for faces. The Raspberry-Face-Recognitionmaster/haarcascade_frontalfacemmodels are downloaded in to the controller memory and specified as classifier for cascade detection. The main advantage of the cascade used in detection is rapid detection of faces and the quick discard of portions in image unlikely to contain faces. The current implementation uses frontal faces detection methodology and is captured in the fig 3.The detection runs without any degradation inperformance in the form of either delay or missing reading of frame) with frame rate of 15 frames per sec at the highest resolution of Pi camera (1920x1080).The headcount determined for the hall is then checked against the hall capacity for triggering the alarm for crowd control through GSM interface to relevant authority.

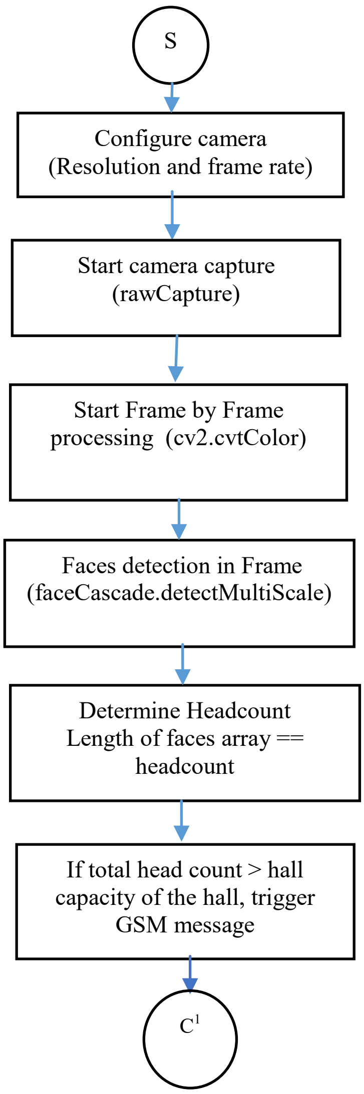

Fig. 3. Flow diagram of Head count and Crowd Control

B. Sector wise head count and Energy savings Scheme

The sector wise head count is computed by evaluating the x and y co-ordinates of each of the faces detected and determining the sector where the face lies. For this determination the left top corner of the detected face indicated by the x, y coordinates is used as the criteria and hence duplicate counting for the faces overlapping with multiple sectors is eliminated. Based on the sector wise head count being greater than zero, the light for the specific sectors represented by LED is turned ON .

Basedon any of top and bottom sectors in specific half being greater than zero , fan for the specific sectors represented by servomotor is turned ON . This scheme is used as a sample for implementation . However the proposed method is to accommodate any energy mamagment scheme suitable for hall. Extending the coverage of energy efficiency in terms of the number of sectors or adding utility items is easily handled in software. With a wifi capable hardware such as Rasberry Pi , the switching on and off commands can be extended to wifi-compatible switches. The scheme for sector wise head count and energy saving is shown in fig 4

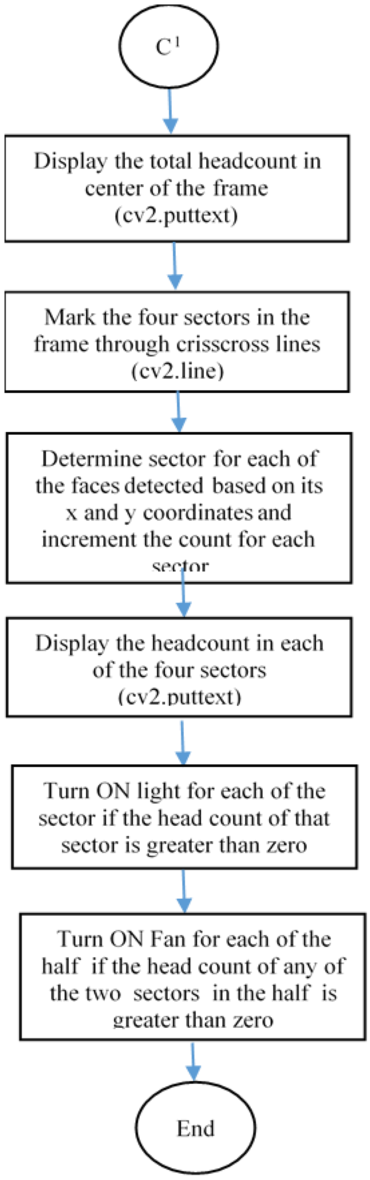

Fig.4. Flow diagram of Sectorwise count and energy svaing

C. Social Distancing monitoring (SodisCop feature).

The current Covid-19 pandemic has mandated social distancing of 1metre as a critical safety guideline throughout the world by World Health Organization [6]. In this paper a novel way of determining the social distancing is proposed.The algorithm has been captured as a flow diagram in fig. 5.

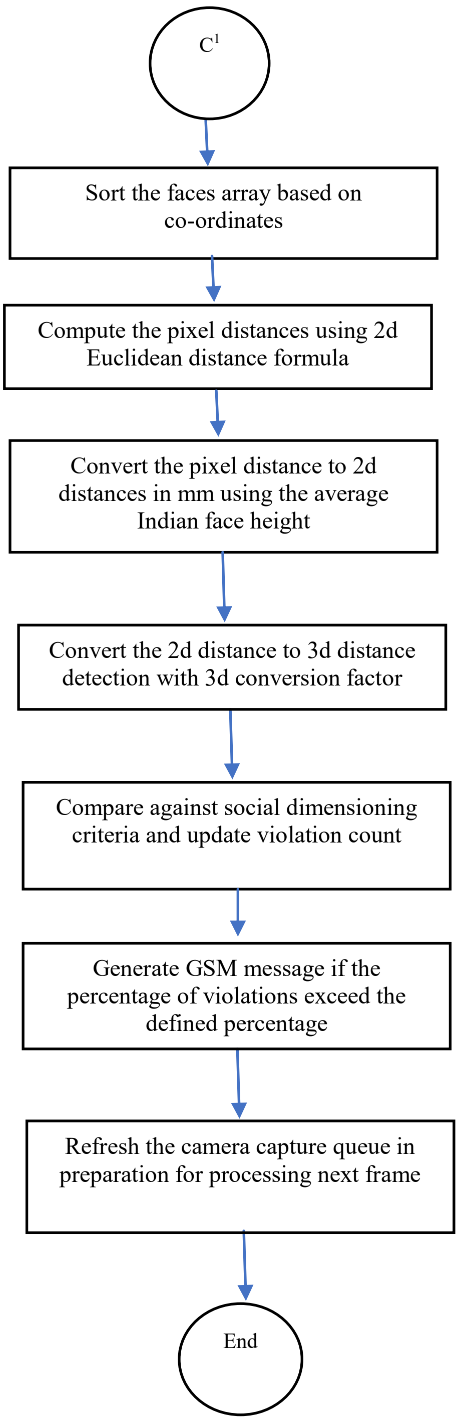

Fig 5 – Flow diagram of Social distancing Monitoring

The frame with the faces detected as part of the headcount forms the basis of determining the distances between each person in the hall. The x, y co-ordinates in pixels of the left top corner (left zygion) of each face captured by face cascade routine represents the location of the faces and are used in computing the distances between the faces and other faces using Euclidean distance formula[1].These distances in pixels is converted to physical distances in mm using a scaling factor based on the average facial height of Indians [4]. To improve the accuracy of distance computation, the average of heights is computed for the two faces for which distance measurement is being computed.

This distance which lies in 2d plane is compensated for the depth introduced by the 3d space for which camera frame is captured. In this proposed method, the variation of the heights of the faces caused by the depthsis used as a means of compensating the 2d distance and compute the 3d distance. The algorithm is designed to accommodate the fact that 3d distance is always greater than the 2d distance by maintaining the compensation factor greater than or equal to unity

The distances computed is compared with World Health Organization (WHO) guideline of 1metre [6] to trigger the count of social distancing of violations. The overall social distancing compliance status in the hall is measured as percentage of violations to the total number of distances measured. When the percentage of violations exceeds 10%, a message is generated through GSM to the relevant authority. The 10% percent violations limit will also avoid any intermittent erroneous detection and annunciation of social distancing violations. Any single violation as long as headcount is less than 10 will trigger the social distancing violation message. The limit also serves to avoid any spurious/borderline violation triggering in case of larger head count complying with social distancing most of the times.

The algorithm without computational complexity does not result in any significant delay in responding to social distance violation. Current social distance measurement between left zygions of faces can be easily switched to left eye to eliminate any impact of masks.

V. RESULTS AND DISCUSSIONS

The proposed method described in this paper was validatedusing the hardware as listed in Table 1

TABLE 1 – Hardware[a]

#	Description
1	**Raspberry Pi 3 board with** Quad Core 1.2GHz Broadcom BCM2837 64bit CPU,1GB RAM
2	**Pi camera rev 1.3,** 5 Megapixels resolution
3	**Raspberry PI GSM Add-on based on SIM800 V1.0**

[a]This list excludes LEDs and servos for energy management simulation

A. Experimental Results

The results are summarized infor each of the below functions proposed in the method

1. Head count and Crowd control
2. Energy Management
3. Social distancing

[1]The Euclidean distance between two points in either 2-dimensional or 3-dimensional space measures the length of a segment connecting the two points. The Pythagorean Theorem is used to calculate the distance between two points,

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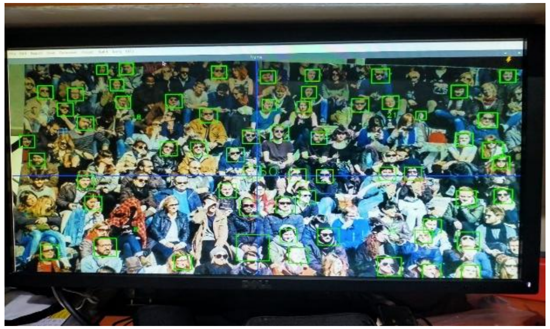
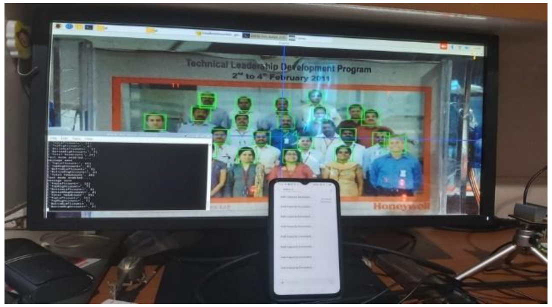
<table>
<tr><th>Sl. #</th><th>Description</th><th>Results</th></tr>
<tr><td rowspan="3">1</td><td>HEAD COUNT AND CROWD CONTROL
Test case 1
The frame is divided into four sectors and the headcount detected of each sector is shown in Fig 6. Head count algorithm based on face detection proposed was able to capture the headcount with 100% accuracy forall the four sectors of the frame.</td><td>
Fig 6 – Sector wise head count detction of a standing audience</td></tr>
<tr><td>Test Case 2
As a corner case, the headcount was tested with a crowd image of more than 60 people. The algorithm detected 60 faces accurately asshown in Fig 7.The detection accuracy is dependent on the resolution of the camera.</td><td>
Fig 7 – Head count detection for a crowd of more than 60 people</td></tr>
<tr><td>Test case 3
This test is for crowd management. Once the headcount in the hall exceeds its capacity, a message is sent to the respective in charge person that “Hall Capacity is exceeded” so that immediate action can be taken to regulate the crowd. Fig 8 captures the result of this case including GSM message sent to the cell phone.</td><td>
Fig 8 – Crowd Management</td></tr>
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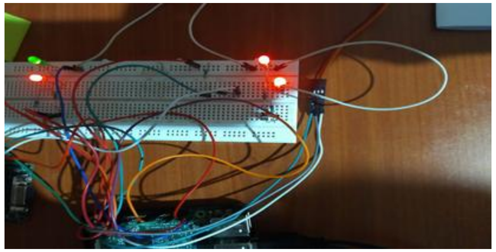
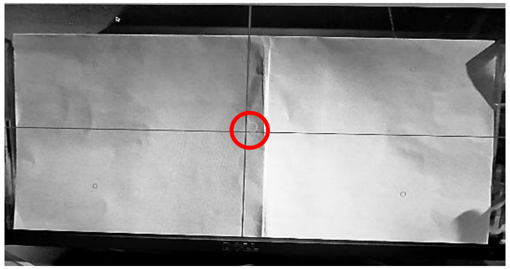
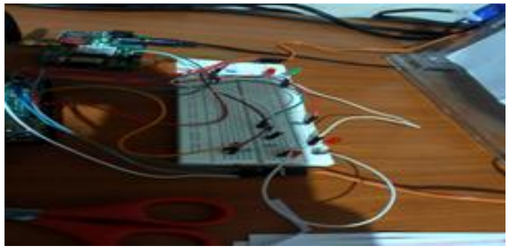
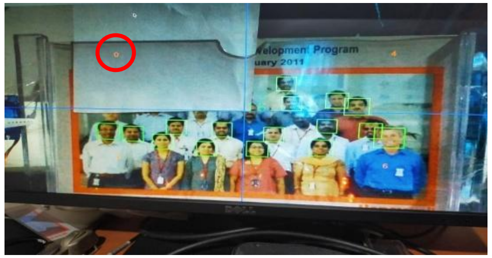
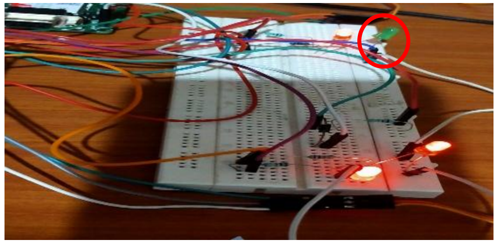
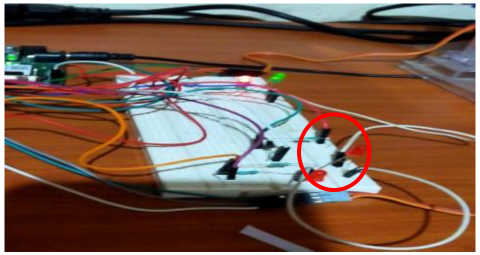
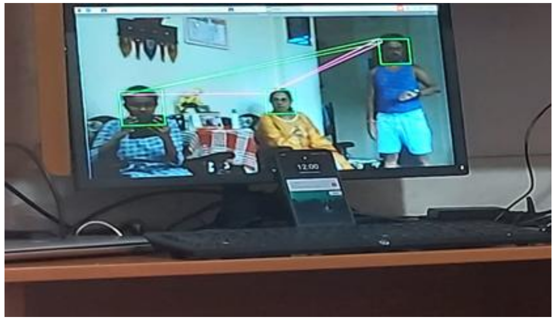
<table>
<tr><th>Sl. #</th><th>Description</th><th>Results</th></tr>
<tr><td rowspan="4">2</td><td>ENERGY MANAGEMENT

Test Case 1:
This case is for all the four sectors of the frame having headcount greater than zero as shown in fig 9</td><td>
Fig 9 – Energy Management with all four sectors occupied</td></tr>
<tr><td>The lights corresponding to each of the four sectors represented by four LEDs are switched ON as shown in Fig 10</td><td>
Fig 10 – Lights (LEDs) for all four sectors ON</td></tr>
<tr><td>Test Case 2
Zero head count in hall is simulated by focusing the camera on to a blank screen (blanked out with a white paper). The head count is detected as zero for all the four sectors as indicated in Fig 11.</td><td>
Fig 11 – Zero Head count in all four sectors</td></tr>
<tr><td>All the four sectors’ lights are now commanded off by the controller as shown in Fig 12</td><td>
Fig 12 – All lights areswitched OFF</td></tr>
</table>

Sl. #	Description	Results
2	**ENERGY MANAGEMENT (contd.)** **Test Case 3**: Left top sector headcount made zero (blankedout). As shown in Fig 13, the headcount for that sector is correctly computed by the algorithm as zero. The lights corresponding to Left top sectoris switchedOFF in line with energy management objective as shown in Fig 14 **Test Case 4** This test case is for Fans control portion of the energy management. The fans are simulatedby two servo motors one for each half of the auditorium. The right half of the auditorium is blanked out as shown in Fig 15. Servo motors and LEDs corresponding to the right half of the auditorium are controlled OFF as part of energy management. The right servo motor at zero degrees is shown in fig 15 and the LEDS in fig 16	 Fig 13 – Head count detected zero for the blanked sector  Fig 14 – Light for zero headcount sector is OFF  Fig 15 – Light for zero headcount sector is OFF  Fig 16 – Light for zero headcount sector is OFF

Sl. #	Description	Results
3	**Social distancing** The test involved three-member audience in a living room. the green lines indicate that social distancing criteria > 1metre being met while the pink lines indicate the social distancing is violated (< 1metre). With only one of the three distance measurements meeting the social distancing criteria, a GSM message is generated indicating social distancing violations and sent to the cell phone for relevant authority as shown in screen capture in Fig 18.	 Fig 17 – social distancing monitoring  Fig 18 – social distancing violation message

B. Validation of the distance measurement algorithm through computation

A sample study of 24 occupants in a frame (Fig 19) indicates healthy congruence between the distances computed from the algorithm proposed in this paper and computed values from the physical positioning of audience. The error exceedances marked in red were analyzed and found to be due to variations in facial dimensions (one of them is due to a foreigner being part of the group). Social distancing violations accuracy is 100% and includes one safer detection as a violation of a border line computed value. The results of this validation are captured in table 2 below.

TABLE 2– Social distancing algorithm Validation

x	y	h	2d distance as per Euclidian formula (mm)	3d adjusted as per proposed method (mm)	Depth(mm)	computed value (based on physical position) in mm	Percentage Error
871	710	71	0				
1072	705	72	337.4470144	342.1997893	0	337.4470144	1.4084507
1310	687	75	722.6335772	763.345328	0	722.6335772	5.6338028
693	676	71	306.2841138	306.2841138	0	306.2841138	0
570	633	74	514.2501092	535.978987	150	535.6801049	0.0557949
468	621	78	664.7686749	730.3092485	150	681.4817614	7.1649001
1129	620	74	452.2711297	471.3811775	200	494.5191349	-4.6788801
1546	615	90	1016.127807	1288.049333	200	1035.623349	24.374304
931	601	70	211.7832625	214.8087377	200	291.2939242	-26.257048
748	592	73	284.0823433	292.0846628	200	347.423053	-15.928244
1486	590	70	1066.549714	1081.786139	200	1085.139758	-0.3090495
1332	572	67	836.8904548	886.854064	200	860.4566423	3.0678387
1232	537	70	681.3827711	691.1168107	250	725.7978236	-4.7783297
480	518	77	706.3739855	766.0675618	300	767.4400351	-0.1788379
847	500	64	375.763519	416.8626539	300	480.8307626	-13.303664
1039	500	72	451.3530931	457.7101789	300	541.9590526	-15.545247
667	463	74	530.2367497	552.6411194	400	664.1919984	-16.794975
1430	461	77	992.3502881	1076.210876	400	1069.934154	0.5866456
1197	452	67	723.0266149	766.1923829	400	826.297456	-7.2740237
1362	434	70	958.7331312	972.4293188	400	1038.830697	-6.3919345
854	405	64	543.0638277	602.4614339	450	705.2788959	-14.57827
1026	405	61	622.0467416	724.0216173	450	767.7513587	-5.6958208
701	384	60	673.5808655	797.0706908	450	810.0686282	-1.6045477
1172	347	72	791.4314463	802.5783681	500	936.1430095	-14.267547

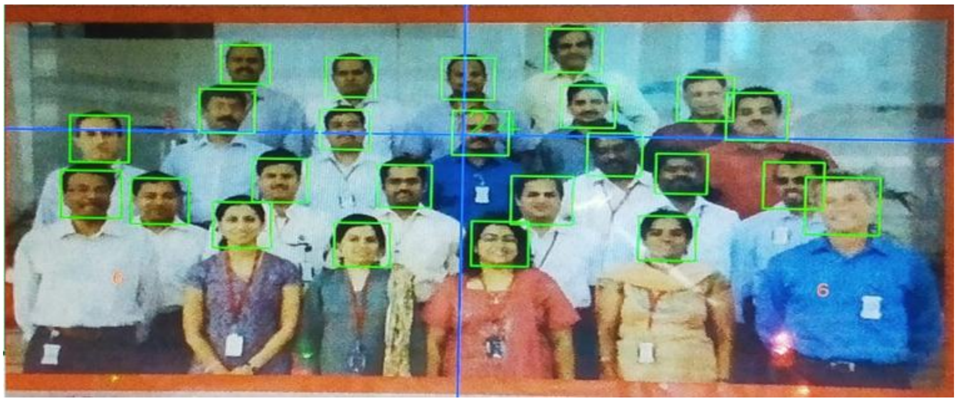


Fig 19 – sample frame used for validation

VI. CONCLUSION AND FUTURE WORK

The proposed method /system addresses the critical challenges having useful application in current environment energy savings, crowd control and last but not least social distancing, a very important aspect of Covid-19 pandemic. The proposed algorithms are easy to implement, devoid of complexity and has the advantage of scalability to address halls with larger physical dimensions. The software is designed with portability in mind and is based on open source.The cost of the method proposed is low and with the right positioning of a camera with moderate features to focus on audience alone in full frame, the method is found to deliver accurate results meeting the objectives of this study. The software's portability provides another opportunity of integrating in to video surveillance applications with existing CCTV in auditoriums/public places. The presented work in this paper is based on frontal face detection and hence there is scope for future work to cover lateral face detection as well as human contour detection. The current work uses average facial height-based distance estimation in an image and is independent of the focal length camera. The accuracy of the distance measurement can be enhanced by inclusion of the focal length of the cameraas future work.

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