International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Development and Validation of a Camera-Based Illumination Controller for People Detection, Tracking and Recognition using Computational Intelligence

Cesar A. Llorente, Elmer P. Dadios

Abstract*: Illumination is crucial in human activities and in machine vision applications. For indoor surveillance applications, Infrared (IR) Light Emitting Diodes (LEDs) are the common means of providing illumination to the camera to cause no discomfort to human occupants. While IR provides non-obtrusive illumination for the camera, the same energy consumed does not provide the illumination to indoor spaces of the building. This is important if the premises where the camera is installed is not connected to the main power source or electric grid but derives energy from renewable sources. In this work, an illumination controller based on fuzzy logic system is developed and integrated to a vision system and an LED lighting system to provide a constant level of illumination to an object regardless of its distance from the image sensor. The computer vision system performs human object detection and face recognition and outputs fuzzy values representing the inferred distance of detected objects where the fuzzy system generates crisp output of duty cycle settings for the PWM controller for the LED lighting system to provide the required illumination needed by the vision system. Optimum illumination level for the vision system to perform the detection, tracking and face recognition operations must be provided by the system. Using visible Light Emitting Diodes as source of illumination, the system provides illumination both for the proper operation of the camera and human personnel monitoring the premises where the system is installed. This feature is significant in energy-constrained surveillance applications or where there is no power source derived from the electric grid.

Index Terms*: Computational Intelligence, Illumination Controller, IoT, People Tracking, People Recognition.

I. INTRODUCTION

Cameras are used for monitoring and surveillance applications. CCTV (Closed Circuit Television) cameras capture video streams and record the video in a central storage. The videos may be monitored by human operator in real-time or viewed at a later time. IP cameras on the other hand are accessible through the Internet. This provides great flexibility in term of accessibility. Typically, artificial illumination of cameras are done using IR LED light source. IR eliminates light pollution problem and do not pose visual discomfort to people.

The availability of portable low-power devices with high computational power and camera interface allows the development of low-cost camera. Linux operating system can be installed on the system SD card storage devices with a capacity up to 32 GB and programming languages for software development such as C/C++ and python are available during OS installation and configuration. Libraries for Computer Vision, numerical computing and computational intelligence can be easily installed and configured. Wired and wireless communication connectivity is also available on such platforms paving the way to today's Internet of Things (IoT). IoT is an architectural paradigm that interconnects a multitude of sensors and actuators with the goal of equipped with sensors, networking and processing technologies integrating and working together to provide an environment in which smart services are made accessible to the end users. Today, IoT can be found in various applications which include but not limited to Smart Buildings, Smart Cities and Smart Farms.

In this study, the performance of a computer vision system to detect and recognize human face is characterized. The system can infer the distance of the detected face from the image sensor which is used to determine the level of illumination that will be provided. This system is developed in [1] where the light intensity of illumination is automatically adjusted based on the inferred distance of the human object detected in a video stream from the camera. As the face of the person becomes closer to the camera, the level of illumination is decreased and vice-versa. A Raspberry Pi 3 B+ with a camera module is used to run the Haar Cascade classifier Local Binary Pattern Histogram (LBPH) algorithm. The camera is a Sony Exmor IMX219 Sensor Capable of 4K30, 1080P60, 720P180, 8MP.

Revised Manuscript Received on 30 July 2019.
***** Correspondence Author
Cesar A. Llorente*, Electronics and Communications Engineering Department, De La Salle University, Manila, Philippines.
Elmer P. Dadios, Manufacturing Engineering and Management Department, De La Salle University, Manila, Philippines.

II. PRELATED WORKS

In 2009, [1] demonstrated the use of camera for a daylight setting and daylight harvesting, control of motorized for shading control and control of lighting for illumination.

The issue of privacy is the major drawback of the work. [2] proposed an integration of an LED spotlight in addition to the IR light source and ultrasonic sensors to determine the distance of the human object. Tracking of the human body is through IR and ultrasonic sensors which are separate to the camera system. [3] generalized the procedure in the placement of the camera and the source of illumination but do not directly apply to tracking of human object in the scene. [4] provided a framework to estimate the illumination level of the scene without prior knowledge. The work requires initialization the algorithms by inputting initial estimates of the scene. [5] introduced the possibility of using the image sensor as luminance sensor. The illumination level determined the amount of lighting needed to maintain the contrast in the overall view of objects in the shop window under external natural illumination. [6] introduced the use of Kinect depth cameras in order to detect and track human person and to estimate the human activity.

III. METHODOLOGY

The development of the fuzzy logic system starts with the analysis of the output of the computer vision subsystem. Outputs from the vision system are the coordinates and width of the bounding box wherein the distance of the body or face can be inferred. Since illumination is decreased by the square of the distance of the object from the light source, and the detection algorithm works within certain levels of illumination, the input fuzzy sets can be obtained from the experimental data obtained during the characterization of the computer vision algorithm. In the same way, the output fuzzy set can be derived from the illumination level delivered by the LED lighting system at different PWM duty cycles.

Zero order Takagi-Sugeno controller type of fuzzy controller is used to implement the two fuzzy controllers this study. The first controller handle the control of LED lighting subsystem when the distance of the camera falls under the tracking of body detector algorithm, and the second controller handles the lighting control when the distance is within the face detection algorithm range of operations. The fuzzy logic system uses the y coordinates of the bounding box as fuzzy input to infer the distance of the detected object from the image sensor. For the face – camera distance, the fuzzy variable μz is used for representation while μy, is used to represent body – camera distance. For both face and body fuzzy controllers, the membership functions are classified as FAR, MID and NEAR. Table I shows the range of values for the fuzzy sets.

Table I: Fuzzy set membership to represent the input variables that represents the range of distances of the object from the image sensor

Membership	FACE detection and tracking controller (pixels)	Body detection and tracking controller (pixels)
FAR	80 - 90	0 - 60
MID	85 - 100	50 - 80
NEAR	95 - 110	70 - 90

Analysis of the illumination levels needed by the people detection algorithm is at 60% duty cycle to 100% duty cycle for body detection to happen. For face detection, the detection and recognition of the face can be successfully carried out at illumination range from 12.7 lux (30% duty cycle) at 8 feet distance to 98 lux (50% duty cycle) at 2 feet distance. The equivalent distance in feet represented by the pixel values given in Table 1 is provided in Table II.

Table II: Equivalent distance of fuzzy set input membership that represents the range of distances of the object from the image sensor

Membership	FACE detection and tracking (distance in feet)	Body detection and tracking (distance in feet)
FAR	6 - 8	16 - 20
MID	4 - 6	12 - 16
NEAR	2 - 4	8 - 12

The Takagi-Sugeno type of controller can be used since the antecedents are fuzzy while the consequent is a crisp value. In fact the consequent may take only three values: 80% for FAR, 60% duty cycle for MID distances and 40% duty cycle for NEAR distances. FAR and MID distances are distances where people are detected, while NEAR distance is where both the body and face are detected and face can be recognized. Table III and IV show the fuzzy inference rules and the corresponding crisp outputs generated for face and body.

Table III: Inference rules for the body tracking fuzzy logic controller. The output is the % duty cycle of the PWM activation of the LED lighting subsystem.

ANTECEDENT	CONSEQUENT
IF μz = FAR	Duty cycle = 80
IF μz = MID	Duty cycle = 60
IF μz = NEAR	Duty cycle = 40

Table IV: Inference rules for the face tracking fuzzy logic controller. The output is the % duty cycle of the PWM activation of the LED lighting subsystem.

ANTECEDENT	CONSEQUENT
IF μz = FAR	Duty cycle = 60
IF μz = MID	Duty cycle = 50
IF μz = NEAR	Duty cycle = 40

In this experiment, the illumination needed for a detection algorithm running in Raspberry Pi, and the range of distances from the camera for such detection to happen are determined. The floor layout for the test setup is shown in Fig. 1. The camera is positioned 8 feet high and inclined downwards so that the beam of light coming from the LED illuminators illuminates at a 21 feet away from the camera. Five paths were designated along the floor area.

Two paths, PATH 1 and PATH 2 with distances from the camera of 21 feet and 19 feet respectively are on the right side of the camera, PATH 3 and PATH 4, both with a distance of 19 feet from the camera are on the left side, and PATH 5 is directly in front of the camera also 19 feet away.

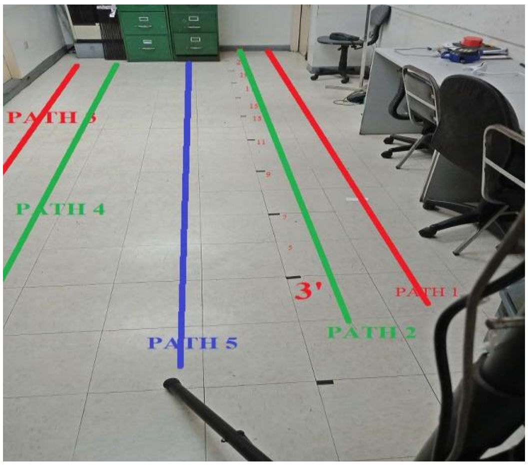

Figure 1: The test bed used for testing the algorithm.

IV. RESULTS AND DISCUSSION

Fig. 2 shows the set of images obtained running the face detection program. The duty cycle of the illumination is fixed to 50% duty cycle to ensure that the illumination is sufficient for detection and recognition. The person is traversing PATH 2 on the test bed used in the study in [10].

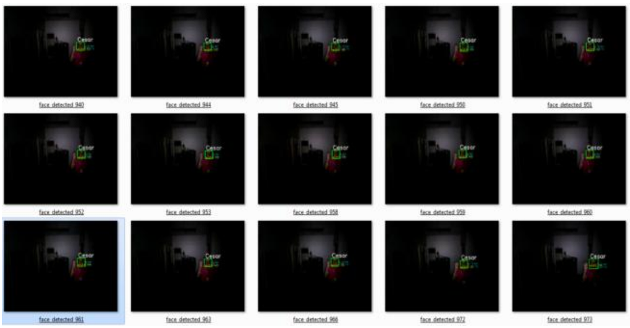

Figure 2: Face recognition in PATH 2

The illumination levels are measured at different distances while the vision algorithm is running and the results are reproduced in Table I. Shaded cells indicate the distance that face detection happened. It can be shown that face detection and recognition can be effectively carried out at a maximum distance of 8 feet at illumination level of 12.7 lux corresponding to 30% duty cycle of PWM activation, and a minimum distance of 2 feet at illumination level of 15 lux corresponding to a duty cycle of 5%. The corresponding lux level of illumination at different duty cycle was provided in [11].

There are no detection that occurred in PATH 1 and PATH 3. This is because these paths are not with in the coverage of the illumination beam, or the face is too oblique that it does not present a frontal view for the face recognition algorithm which requires frontal view of the face to be recognized. Experimental results also indicated that face detection and recognition can be carried out successfully with illumination level of 5% duty cycle up to 8 feet distance provided that the face is almost in-front of the camera and the height almost at face level. Fig. 3 shows capture images when faces are detected and recognized.

Figure 3: Face detection and recognition

For the face recognition function to be carried out by the system, images of the faces to be recognized by the system are collected and stored as a dataset. Once the face dataset is complete, the recognizer is trained for these set of faces. A file that characterizes this dataset is output by the training phase. Fig. 4 shows sample images of the cropped face included in the face dataset. Face detected in images captured by the camera is cropped and resized automatically. Faces are illuminated at different levels.

Figure 4: Sample face taken at different angle in the dataset. The face is cropped to same size, taken from different distances from the camera and illumination levels

Recognition may be positive, false positive or false negative or negative. Fig. 5 shows sample of face at different distances and illumination successfully recognized by the face recognition algorithm. One image in the example is not recognized successfully.

Figure 5: Sample images of detected faces at different distances and illumination successfully recognized by the face recognition algorithm. One image in the example is not recognized successfully.

Data containing the image of the person with the face enclosed in a bounding box if the face of the person is detected. The face is recognized and the face is cropped in the area of the bounding box and stored in secondary storage. Performance of the system is determined by comparing the accuracy of detection and tracking of the human object as it traverses the test bed on designated pathways. Fig. 6 shows the plot of the x-y coordinates of the face detected and recognized with the camera is elevated at 8 feet height while Fig. 7 shows the plot of the x-y coordinates of the face detected and recognized with the camera is elevated at 6 feet high.

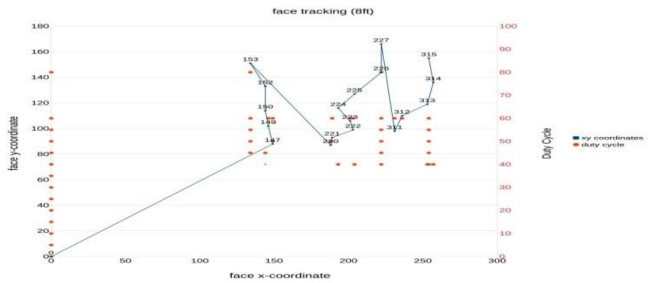

Fig 6: Plot of the trajectory of the x-y coordinates of the bounding box enclosing the face of a person when it is detected in a video frame and the duty cycle of activation level of the LED lighting system. The camera height is 8 feet.

The coordinates are actually the number pixels from the reference (0,0) position to the upper left corner of the bounding box of a face in the captured image. Detected face in image captured by the camera is bounded by a box. The coordinates of upper left corner of the bounding box is recorded and constitute a point in the trajectory as the human person traverses the PATH in the testbed. As shown in the plot of trajectories in Fig. 6, the number indicated in the plot is the frame number in the video where face detection occurred. Indicated also by a dot is the duty cycle of LED Pulse Width Modulation (PWM) activation. The y coordinate serves as the basis for inferring the distance of the human object from the camera or image sensor. The illumination of the LED lighting is automatically set at a level depending upon how far the human object is from the image sensor and the amount of illumination indicated in Table I.

Since as indicated in [9], the LED light source is in the same plane with the image sensor, thus the distance of the image sensor from the human object is the same distance of the light source from the object. The level of activation of the LED lighting is chosen to be 40%, 50%, 60% and 80% duty cycle, which guarantees proper operation of the vision system. The maximum activation of the LED lighting is 80% duty cycle corresponding to 36 lux if the face object is 8 feet away, 60.9 lux if the object is 6 feet away and 138 lux if the distance of the face is 4 feet away from the camera/light source.

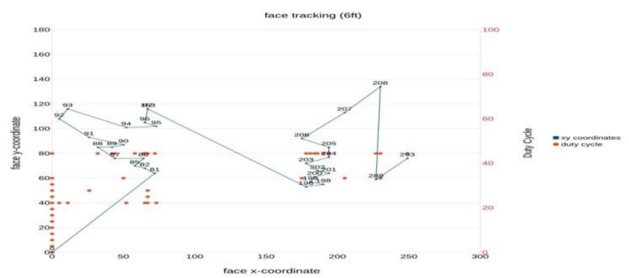

Figure 7: Plot of the trajectory of the x-y coordinates of the bounding box enclosing the face of a person when it is detected in a video frame. The camera height is 6 feet.

It can be inferred from Fig. 6 and Fig. 7 that the LED lighting is activated at different intensity levels based on the distance of the detected human face object from the captured image. In addition, higher face detection occur when the camera is mounted at a height of 6 feet than it is mounted at the height of 8 feet.

For face recognition, the accuracy of the system when tested at camera mounting heights is 6 feet is shown in Table V. At this camera mounting height, the accuracy is 60% recognition accuracy, 29% negative detection and 11 % false recognition.

Table V: System Accuracy for face detection and recognition. camera installed at height of 6 feet.

	Number of frames identified		
Frame numbers	positive	negative	False positive
10 – 59	21	12	17
60 – 109	34	10	6
110 – 159	38	12	0
160 – 209	33	12	5
210 – 259	6	38	6
260 – 319	54	6	0
Total	186	90	34
Accuracy	60%	29%	11%

For camera height of 8 feet, the accuracy is 64% recognition accuracy, 33% negative detection and 3 % false recognition. This is listed in Table VI. Camera mounted at height of 8 feet gives higher accuracy.

Table VI: System Accuracy for face detection and recognition. camera installed at height of 8 feet.

	Number of frames identified		
Frame numbers	positive	negative	False positive
10 – 59	33	17	0
60 – 109	14	7	1
110 – 159	25	11	4
160 – 209	26	12	0
210 – 259	19	2	1
260 – 294	16	19	0
Total	133	68	6
Accuracy	64%	33%	3%

V. CONCLUSIONS AND RECOMMENDATIONS

In this study, the development and characterization of a computer vision system for the detection, tracking and recognition of human face in video is presented. The development platform used for its implementation is a Raspberry Pi B+ board which is considered as a resource constrained platform but was able to carry out the vision processing task in real-time. The system is able to process 16 frames per second and able to capture and record the trajectory of the upper-left corner of the bounding box enclosing the detected face. Using this trajectory, the vision system is able to track the movement of the human person in the video frames as the person moves in the testbed. The y coordinates, provides a means of inferring the distance of the human body from the camera or image sensor. Detection of the human face in a video image by the algorithm can be reliably carried out at distances between 2 feet to 8 feet. The trajectories of the bounding box provide data for inferring relative distance of the human face from the image sensor. Distances between 2 feet and 8 feet from the camera can be reliably inferred.

The height of the camera also affects the m the image sensor. A camera installed at 8 feet height can better infer the distance of the object.

REFERENCES

1. C.A. Llorente, & E.P. Dadios, "*Development and Characterization of a Dimmable LED Luminaire for Body Detection, Tracking and Recognition under Natural and Artificial Low-light Illumination*,. International Journal of Advanced Trends in Computer Science and Engineering 8(2), 246 - 250
2. Viola, P and Jones, M. (2001). Rapid Object Detection using a Boosted Cascade of Simple Features. Avalable online: https://www.cs.cmu.edu/~efros/courses/LBMV07/Papers/viola-cvpr-01.pdf.
3. N. Jiang, Y. Lu, S. Tang, & S. Goto." *Rapid face detection using a multi-mode cascade and Separate Haar Feature*", International Symposium on Intelligent Signal Processing and Communication Systems, 1-4. 2010.
4. M.C. Fernandez, K.J. Gob, A.R. Leonidas, R.J. Ravara, A.A. Bandala, & E.P. Dadios, "*Simultaneous face detection and recognition using Viola-Jones Algorithm and Artificial Neural Networks for identity verification*", IEEE Region 10 Symposium, 672-676, 2014.
5. K. Yadhul, B.M. Thusnavis, P.S. Lakshmi, & A. Saju, "*Face detection and recognition with video database*", International Conference on Electronics and Communication Systems (ICECS), 1-5, 2014.
6. K. Maneesha, N.S. Shree, D.R. Pranav, S. Sindhu, & C. Gururaj. "*Real time face detection robot*", 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 58-64, 2017.
7. L. Cuimei, Q. Zhiliang, J. Nan, & W. Jianhua, "*Human face detection algorithm via Haar cascade classifier combined with three additional classifiers*." 13th IEEE International Conference on Electronic Measurement & Instruments (ICEMI), 483-487, 2017.
8. X. Zhao, & C. Wei, " *A real-time face recognition system based on the improved LBPH algorithm*." IEEE 2nd International Conference on Signal and Image Processing (ICSIP) (pp. 72 - 76). Singapore, Singapore: IEEE, 2017.
9. D.T. Hapsari, C.G. Berliana, P. Winda, & M.A. Soeleman, "*Face Detection Using Haar Cascade in Difference Illumination*". International Seminar on Application for Technology of Information and Communication, 555-559, 2018.
10. C.A. Llorente, & E.P. Dadios, "*Development and Characterization of a Computer Vision System for Human Body Detection and Tracking under Low-light Condition*". International Journal of Advanced Trends in Computer Science and Engineering 8(2), 251 – 254, 2019.
11. C.A. Llorente, A. Abad, & E.P. Dadios, "*Characterizing Illumination Levels of an Image Sensor as Input to a Camera Based Illumination Controller*". IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM 2018), 1-5.

AUTHORS PROFILE

Cesar A. Llorente holds a Certificate in Machine Shop Technology from Negros Occidental College of Arts and Trade, a diploma in Electronics Engineering Technology from Technological University of the Philippines, a degree of Bachelor of Science in Electrical Engineering from Adamson University, a Master of Engineering from Pamantasan ng Lungsod ng Maynila and a PhD-ECE degree from De La Salle University. Dr. Llorente specializes in microcontrollers and FPGA-based embedded systems and in soft computing where he applies computational intelligence for the control of lighting systems and in optimizing land use and minimizing environmental impacts for hybrid electric power generation and in sizing hybrid renewable energy systems. He was a member of the team who build SIKAT and SINAG, the first two solar cars of the Philippines by DLSU.

Elmer P. Dadios earned his Bachelor of Science in Electrical Engineering from the Mindanao State University in Marawi City, Philippines; and his Master of Science in Computer Science from De La Salle University (DLSU) Manila. He got his PhD from the Manufacturing Engineering, Loughborough University, United Kingdom. He is a consultant on software and hardware development in the area of robotics and intelligent systems application. His research interests include: artificial intelligence, evolutionary systems, fuzzy logic, neural networks, Robotics, Mechatronics and Manufacturing Processes. He joined DLSU in May 1992 and currently holds the rank of Full Professor 10 and a University Fellow. He edited and published four books on fuzzy logic systems with InTech (Croatia); He published over 290 technical papers in highly refutable journals and IEEE Xplore. Currently, he serves as editor of the Journal of Advanced Computational Intelligence and Intelligent Informatics (JACIII) published by the Fuji Technology Press, Ltd. (Tokyo, Japan); He is also the editor in chief of the Journal of Computational Intelligence and Engineering Application (JCIEA) published by DLSU Press, Manila, Philippines. He is a member IEEE R10 EXCOM and the chair of the IEEE Asia and Pacific Awards and Recognition Committee. Elmer has earned over 30 recognitions and distinctions from various international and national scientific award-giving bodies and professional organizations. Among the awards he garnered include: The 2019 top 100 scientists listed in Asian Scientist Magazine; The 2019 Leaders in Innovation Fellowship "Fellow" given by the United Kingdom Royal Academy of Engineering; The 2018 D. M. CONSUNJI AWARD for Engineering Research. Achievement Award from the National Research Council of the Philippines (NRCP), and an Outstanding Scientific Paper Award for his "Analysis of Colonic Histopathological Images Using Pixel Intensities and Hough Transform" from the National Academy of Science and Technology (NAST), Philippines. He was also a recipient of the Department of Science and Technology (DOST) 50 Men and Women of Science and Technology; The Department of Science and Technology (DOST) Scholar Achievers. He was the keynote speaker in the 2018 International Winter Symposium on Big-Data, Cybersecurity and IoT in Hokkaido University, Sapporo Japan; a keynote speaker in the the 6th International Conference on Robot Intelligence Technology and Applications (RITA2018) held in Putrajaya, Malaysia.