Vol. 02, No. 2 (2020) 127-136, doi: 10.24874/PES02.02.003

Proceedings on Engineering Sciences

www.pesjournal.net

DEPLOYING BACKGROUND SUBTRACTION APPROACH FOR TRACKING AND DETECTING MOVING OBJECTS

Rodney Kadadi
Garima Devpriya
Ismail W. R. Taifa [1]

Keywords:

Video surveillance systems; Background subtraction; Motion detection; Raspberry Pi; Security system; System architecture.

A B S T R A C T

This paper illustrates the deployment of the background subtraction (BGS) approach in detecting and tracking the targeted moving objects (MOs). Through the BGS method, there is a potential of cost-saving because the process of storing data occurs once the motion is detected. The aim was to detect the MOs effectively. The applied technique is applicable at all scenarios and places that need the real-time video surveillance systems (VSS), including airports, forest, frequent entrances for criminals, traffic monitoring, country borders, cash machines, schools, banks, among other challenging outdoor and indoor areas. The concept of installing VSS is substantially much needed. The BGS method was employed with fewer complications so that the approach can be utilised in a pragmatic manner (conditions) where the VSS is highly needed. The VSS must be more convenient, effective and efficient to enhance advanced security systems.

1. INTRODUCTION

The twenty-first century has witnessed technological advancements in several sectors. One of the essential needs is the issue of safety and security of human beings along with their essential properties. Nowadays, security issues are more critical than ever before. This is contrary to the twenty-century situations whereby security concerns were mainly for military premises, essential government offices and other similar sensitive areas within any country. Industry and academician have kept researching to improve the available security and safety systems of human possessions with other precious properties so that to be safe from any danger or harm from other dangerous people. Some of the areas that require advanced technology in securing their premises include schools, malls, common entrances for criminals, banks, cash machines, sports stadium, countries' borders, traffic systems, personal houses, airports, bus terminals, ferry and ship terminals, military camps, public transport systems, and the like.

Of course, the tremendous explosion of several forms of video contents has been powered by reasonably priced video cameras, together with the expansion of internet usage. Nowadays, the research on the deployment of video surveillance systems (VSS) or security cameras are more mature because people pay much attention due to the massive increase in safety and security issues. By 2014, globally, there were over two hundred and forty-

[1] Corresponding author: Ismail W. R. Taifa
Email: taifaismail@yahoo.com

five million security total installed cameras (SDM, 2016). Such a huge volume of cameras suggests that up to date, the number has increased due to great awareness about insecurity scenarios being witnessed globally. Asia is leading by having sixty-five per cent of all installed security cameras. In fact, installations of the VSS increase in numbers, though percentage-wise, there is a decrease year after year (SDM, 2016).

Besides the VSS issues, there is an increase in human-computer interactions and video retrieval. Intelligent VSS is among the crucial parts of the safeguarding system. VSS encompasses a unified system that has a robust ability to prevent any related harm to human beings with their valuable possessions. Up to date, there are several applications of video monitoring systems – VSS.

As a result, such systems should be developed with strong and advanced technologies for it to be intuitive, convenient and to have enough information content. VSS habitually detects objects, people, events or other targeted stationary and moving objects in various forms of environments, both indoor and outdoor. Normally, VSS encompasses fixed security cameras directed at the events of interest, together with computer systems, mainly for processing images before notifying human analysts or operators. In designing and developing robust security system, it is imperative to come up with a system that can act and react precisely and quickly in detecting and identifying the moving objects (MOs) as targeted. The systems encompass artificial intelligence (AI), pattern recognition, automatic control, image processing, etc.

As a result of the vital security and safety issues, it is imperative to make sure that all people are safeguarded, and their precious properties are highly protected as well. Globally, there is a growth of the internet. This has fuelled a great revolution in the information technology (IT) domain. With the new digitalisation of several IT-enabled systems, researchers are innovating and creating motion detection and tracking security systems that are more effective and efficient. Advanced IT, indeed, is helping in safeguarding people's belongings.

In many years ago, cameras were not that much-given attention as the security problems were not up to the critical condition as it is nowadays. This has now fuelled people to see that VSS is highly imperative in people's life due to crime rates in all countries. The VSS is needed at homes, airports, forest, common entrances for criminals, malls, country borders, sports stadiums, shopping malls, universities, homes, schools, banks, among other challenging outdoor and indoor areas.VSS is slowly becoming the necessary system at all places which have valuable assets or where there is a massive gathering of people. Therefore, due to the need for providing an efficient detection of MOs solution; this research focused on designing an approach to detect MOs through background subtraction (BGS).

Other parts of this article are arranged in the following order. Section 2 highlights the theoretical underpinnings on executing BGS and some of the challenges of the BGS technique. In Section 3, we discussed the pertinent methods (techniques) and the applied materials. The frame difference, BGS and image segmentation are discussed intensively as well. Likewise, we discussed ASMH, the used software specifications, Raspberry Pi, OCV, along with the flow of detecting the MOs. The experiments, together with the generated findings, are given in Section 4, while Section 5 states the practical contribution from this noteworthy study. Lastly, the concluding remarks, the study's limitations and the possible future research are in Section 6.

2. THEORETICAL BACKGROUND

The motion detection (MD) process is the most substantial action in VSS. According to Suresh and Lavanya (2014, p.16), the MD "is usually a software-based monitoring system which, when it detects the motion will signal the surveillance camera to begin capturing the event or shows the motion detection using the graphical method or by indicating an alarm." Moreover, tracking and detecting the MOs in a video have potential functions in robotics and VSS, as well as in facilitating the computer-human-interactions (Sharma et al., 2017).

An excellent fundamental of the advanced image processing and several machines learning tasks for the MD analysis encompasses "(i) human and MOs detection and tracking; (ii) human behaviour interpretation; and (iii) advanced behaviour analysis" (Zaman et al., 2017). MD necessitates the presence of VSS. The phrase "surveillance" fundamentally entails monitoring the behaviour of certain objects, both moving and stationary, deeply (Ukunde & Shete, 2018).

The twenty-first century has witnessed many projects regarding the VSS, as this is broadly researched in the computer vision and artificial intelligence. Researchers, for instance., Sharma et al. (2017), mention the broad range of applications that can be obtained through the use of VSS in dynamic and sophisticated scenes. These include monitoring activities, events, suspicious behaviour, as well as ensuring the security of people. One of the primary goals of the VSS is to gather appropriate data (information) concerning the behaviour of an object, together with the respective stance of the focused parts in the specific "sensing environment" (Wen-Tsuen et al., 2008).

Similarly, the study by Kamate and Yilmazer (2015) deployed an adaptive BGS approach to detect the MOs. Likewise, they applied "Continuously Adaptive Mean-Shift tracking" and "Lucas-Kanade optical flow tracking" approaches to detect the MOs in their study. Their findings were replicated to indicate the usefulness of the applied methodologies.

Concerning the VSS, many approaches are applied in detecting and tracking MOs. Several methods have comparable strategies regarding the frames from the "current video stream" in contrast to the previously received frames or simply associating it in contrast to the "background frame" (Zaman et al., 2017). According to Jana and Borkar (2017), to recognise and detect an object on or after the incessant video streams, reasonable methodologies have already been recommended by many academics. This consists of the frame differencing or the BGS technique, especially the most frequently deemed as an initial step in detecting the MOs.

Furthermore, recent years have witnessed the implementation of the "Cloud-based video surveillance (CBVS)", and today, the CBVS generates many opportunities in the surveillance field (Song et al., 2014). The traditional VSS has been applied for an extended period. Such a system involves several video cameras to monitor the entire environment, both effectively and efficiently. In gathering a huge volume of audio information or the required video information, the human operator(s) is needed.

Additionally, it involves great computation to finalise the targeted task. Consistent with Ukunde & Shete (2018), there are costs associated with the traditional VSS. The efficiency, effectiveness and the associated costs for the traditional VSS are because of the installed cameras which must be placed at several visible and non-visible locations (places) to come up with efficient VSS. Nevertheless, to reduce the costs, there is a necessity for installing inexpensive wireless sensors as well as the Internet Protocol (IP) camera.

There are numerous suitable approaches to execute BGS. The presence of several methods is due to several criteria. Still, some researchers concur on a categorisation subject to the difficulties of the investigated "video sequence" in conjunction with the background description (Herrero & Bescós, 2009). The appropriate BGS methods comprise of the following:

a) Kernel density estimation
b) A mixture of Gaussians
c) Frame differencing (Temporal median filter)
d) Running Gaussian average
e) Eigen backgrounds
f) Co-occurrence of variations in image

Although people still apply the BGS approaches, there are challenges regarding them. These include camouflage amongst the foreground object(s) and the background, appearing in low-quality recordings, camera jitter, image noise, illumination changes, either sudden or gradual, among others.

Furthermore, it is well understood that surveillance and security systems traditionally rely on a network of video cameras. The human operator(s) should monitor cameras so that to recognise the tasks in the camera's area of observation. One of the challenges is that recently there is a massive increase in cameras deployments. This has created a workload for all human operators. It is imperative to find the best ways of reducing the workforce requirements in monitoring the deployed cameras. For larger targeted areas, this enforces huge workloads which require a large number of human resources.

3. MATERIALS AND APPROACHES

3.1 Frame difference (FD)

We applied BGS through the FD. This technique employs more than one neighbouring frame grounded in the image of the time series. Mahamuni et al. (2014) state how this approach has fewer difficulties in its deployment. FD is regarded as being very greatly adaptive to many changes in the dynamic scene. Nevertheless, it becomes typically unsuccessful in detecting the complete pertinent pixels of several forms of the MOs. So, some other similar approaches are required to be deployed for better results (Sahasri & Gireesh, 2017).

The fundamental concern of the BGS technique is based on separating the observed image of the projected image, which is static. In such a manner, once the image is observed, it is then emulated as the "background" and at the same time, the "estimated image" comprises of appropriate objects which are recognised as "foreground" (Sahasri & Gireesh, 2017). According to Dhananjaya et al. (2015, p.38), let "image be represented as F_((x, y, t-1)) and background as K_((x, y, t)) at time t." For the process of deploying the FD approach, the background frame is epitomised, as presented in Equations 1 and 2. Further discussion on how the median filter deploys the "median of n" for the earlier frames can be referred from the study executed by Dhananjaya et al. (2015) and Sahasri & Gireesh (2017).

$$F_{(x,\ y,\ t-1)} = K_{(x,\ y,\ t)} \tag{1}$$

Afterwards, the background is accordingly predicted when:

$$Threshold < \left|F_{(x,y,t-1)} = K_{(x,y,t)}\right| \tag{2}$$

3.2 BGS and image segmentation

The BGS approach was applied to detect the MOs. Equation 3 illustrates the BGS method. BGS involves less memory than CCTV cameras. The base of this method is to identify the MOs. The observed image is imitated as the background, whilst the projected image comprises appropriate objects called a foreground" (Dhananjaya et al., 2015). The background-image should represent a scene in the absence of the MOs and should update frequently. BGS helps motion segmentation (division). It executes it in static images (Fan et al., 2012). Development of the computer vision systems requires the vital stage, that is BGS.

$$P[I(t)]-P[B]=P[F(t)] \tag{3}$$

Whereby P[B] is the "background-image; F is the image foreground soon after having completed calculating at the specified period of time, preferably in seconds; P[I(t)] is the pixel value" (Yang, 2005; Madane & Bhura, 2016).

From the video stream, the BGS helps to detect MOs. According to Toyama et al. (1999), there is no need for antecedent knowledge of the studied objects. Several algorithms exist to separate foreground objects (Sobral & Vacavant, 2014). Since the 1990s, researchers have been studying the BGS extensively, specifically in deploying the VSS in detecting MOs (Sobral & Vacavant, 2014). Several algorithms exist regarding the BGS technique. Many of these are established by segmenting the "foreground objects" out of the sequential background. Mostly, they share a similar scheme (see Figure 1).

The MOs are detected by reducing one pixel at a time from the present frame, then deduct from the prior frame. After creating the first "frame", it is then contrasted with the subsequent "frame". Whenever the differences between the first and the subsequent frame exceeded the set threshold value, detection of the MOs is a result. BGS is much sensitive to the environment, such as light intensity. Thus, the BGS method should be used in the environment with a known background. Also, when considering the live video, the basic principle of all these approaches relies on the way to detect, perform and track the MOs. The process of detecting the MOs begins by segmenting. Segmentation is executed in consideration of the image of the specific background. There are numerous security and safety developed systems; however, many of such systems are prone to some weaknesses, one being the requirement of human operators.

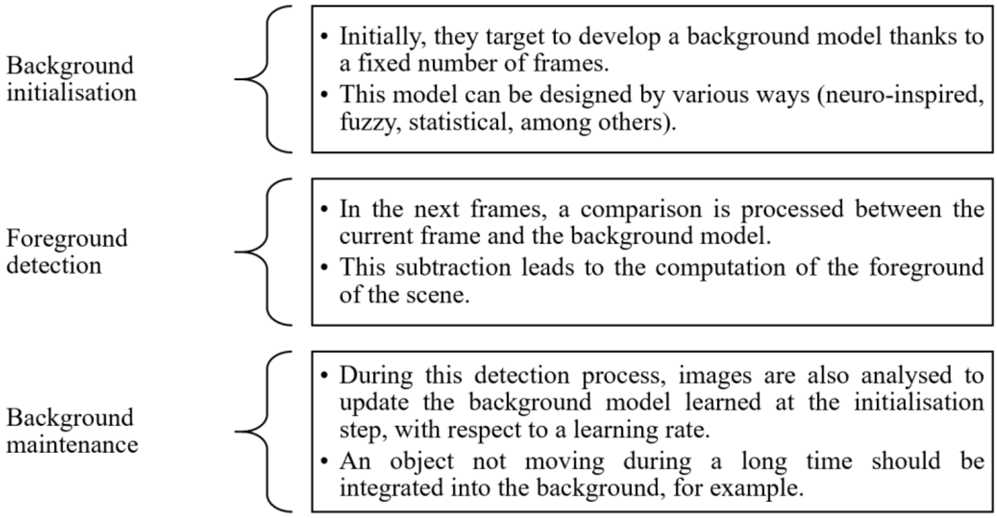

Figure 1. The schemes that shared by several algorithms for the BGS methods (Sobral & Vacavant, 2014, p.4).

3.3 Software and materials (hardware)

a) Logitech 270C camera

Figure 2 is the Logitech C270 camera deployed in detecting the MOs in this study. Such a camera is ascribed as being less costly, specifically when compared it with other cameras that can be employed in similar aims. One of its weaknesses is that this type of camera has Raspberry Pi which has less power supply. To counteract this weakness, it requires the use of an external power hub. The resolution of the Logitech 270C camera is 1280 × 720 pixels. The high definition (HD) 720 p feature is also supported. The camera can capture images up to three megapixels.

Figure 2. The used camera.

b) Adrafruit Stepper Motor HATs (ASMH)

According to Vashistha et al. (2019, p.581), the "Raspberry Pi is [not] equipped with lot many Pulse-width modulations (PWM) pins hence Adafruit motor

HAT is used to control four mounted DC 5 v motors and protect Raspberry Pi from short circuit. It is a fully-dedicated PWM driver chip to be connected to Raspberry Pi through GPIO pins, [and] it is used to control mounted DC 5v bi-directional motors" with specific eight-bit in selecting speed. To execute the aim of this study, we deployed the ASMH (Figure 3).

Figure 3. Stepper Motor Hat (Adafruit Industries, 2019, p.5)

c) Open-source computer vision (OCV)

Intel® developed an OCV. It is a computer vision library (Rekleitis, 2004). Typically, an OCV is for manipulating image data (Murthy et al., 2016). It operates filtering and contour detection. OCV executes the motion assessment. Matlab programming is slow when compared to an OCV system (Ambadas & Bodake, 2017). The OCV has a large resource structure if equated with Matlab. An OCV has large probabilities approaches. An OCV helps to perform image processing based on real-time. The library of OCV is employed for applying Python (with the latest version three), C++ and C programming languages which are much essential in processing VSS algorithms and images. The rudimentary "image processing modules" involves "detection of location" and the MOs (Ambadas & Bodake, 2017).

d) Raspberry Pi (RP) overview

Figure 4 represents an RP board. The processing capability of the RP 2 is six times when compared with earlier versions. RP 2 consists of an advanced "Broadcom BCM2836 processor". Such a processor is a robust "advanced RISC Machine (ARM) Cortex-A7" (Ramya et al., 2017). The RISC means the "Reduced Instruction Set Computer." RP is a developed microprocessor which executes a few categories of "computer instructions" to operate at a higher speed. In fact, for one second, RISC can execute more millions of instructions. The RP board also rises to 1 Gbyte for its memory capacity. RP has more than "35,000 packages, pre-gathered software bundled in a nice format for easy installation on the Raspberry Pi board" (Sheshai, 2016, p.15).

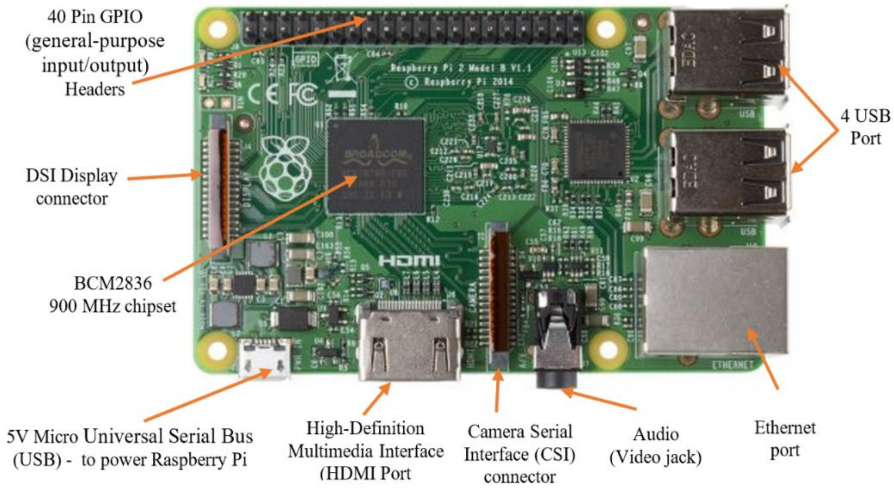

Figure 4. Raspberry Pi board (Ramya et al., 2017)

d) Software specification

The study considered Linux through a computer. Linux possesses the leading installed base when compared to another general-purpose OS (Jana & Borkar, 2017).

3.3 Motion detection flow

This study integrated a Logitech C270 camera, RP (second version), HDMI connector, laptop. The flow diagram (architecture) is represented in Figure 5. In ensuring an effective system, all essential information can be communicated using the "particle filter" to "Raspbian OS" by means of an Ethernet. Afterwards, the provided "visual image or video" is communicated in connection to the specified Raspbian OS window that was founded on Linux OS. The video is captured once the carefully chosen upper and lower values of the colour of the MOs being identified using the "particle filter." An OCV has a significant focal task, like taking visual image or video and colour code matching (Ambadas & Bodake, 2017).

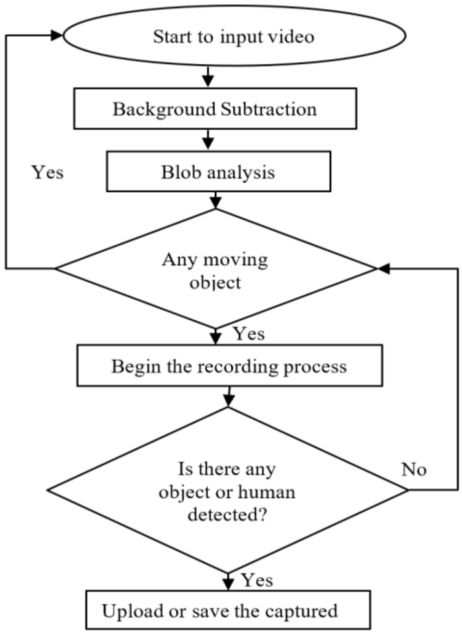

Figure 5. Flowchart of detecting MOs.

The framework of detecting motion is illustrated in Figure 5, while an algorithm flowchart of the BGS is in Figure 6. Logitech C270 camera is the major input component, as it provides the video frame to the corresponding processor unit. Having turned on the developed security system, the BGS starts to analyse the video stream of MOs in the targeted area. To effectively improve the system, it required the blob analysis that differentiates several MOs. Finally, the captured image or video is recorded, and after the definite time, mostly in a few seconds, the video or image is uploaded or saved automatically to the specified server.

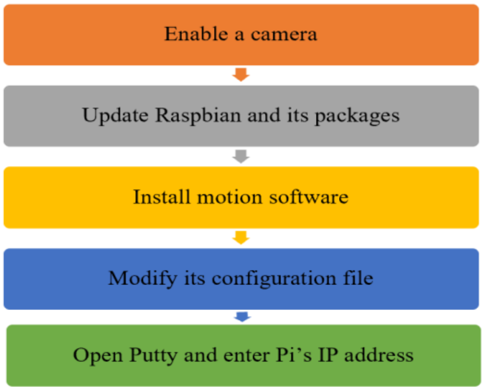

Figure 6. The flow diagram about BGS.

4. EXPERIMENTS AND RESULTS

Figures 7 and 8 describe the assembled MOs tracking system using BGS. An OCV software-assisted to set up the tracking system. The Logitech 270C camera was deployed to capture the frame, which was considered as the first frame. The first frame was compared afterwards with the subsequent frame(s). Whenever the differences between the first and the subsequent frame exceeded the set threshold value, the detection of the MOs was the result. The wired setup of the installed experiment is in Figure 9. Likewise, in Figure 10, there are the findings of the detected image and/or motion. The image has 1280 × 720 pixels. The system can capture images attributable to three megapixels. If there are any MOs at the targeted area, the developed system assesses the video before storing it to the specified memory server. There is also a possibility of exporting the captured video and image to other external files. The external files can be sent to an email of the cloud server. This allows analysing the captured incidence by the human operator or analyst.

Figure 7. The setup for testing the used motor.

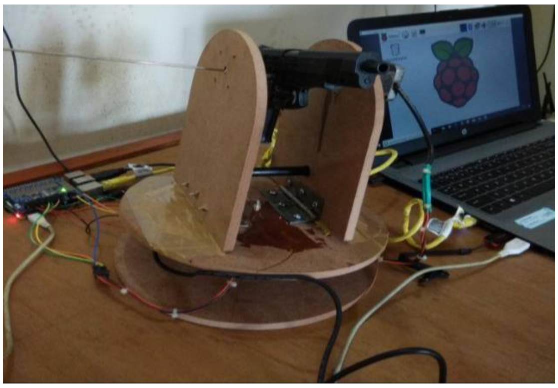

Figure 8. A completed motion tracking system.

Figure 9. Wired setup of the project.

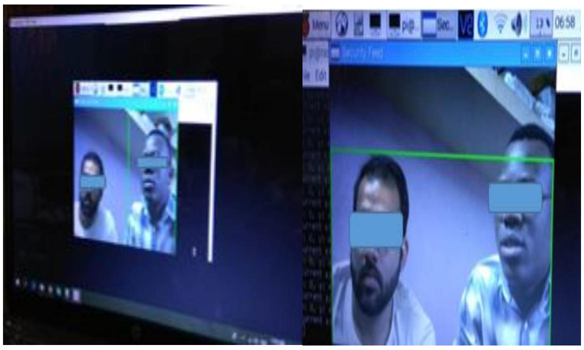

Figure 10. The recognized human faces through the developed security system.

5. PRACTICAL CONTRIBUTION

To develop the procedure to detect and track the MOs is important in today's life due to the great concerns about safety and security, both for human beings and their treasured possessions. The required systems can be installed at all significant places or the vulnerable places. These places include airports, buses stations, universities, forest preservation, sports stadiums, ATM or cash machines, schools, banks, stores, traffic monitoring, universities, malls, country borders, industrial plants, military camps, and any other imperative places where security is much needed. We have proposed the sampling through the combination of the BGS frames that were sampled for a definite time. We have also included experiments that have shown great motion detection for the MOs and tracking of the targeted objects.

6. CONCLUSION, LIMITATIONS AND POSSIBLE FUTURE WORK

6.1 Concluding remarks

Human beings, together with their precious assets, require effective and efficient VSS. In this study, the BGS approach shows the potentiality of saving cost because the process of storing data occurs once the motion has been detected. The research was conducted to enable detecting MOs efficiently. The applied technique is applicable at all scenarios that need real-time VSS, including airports, forest, traffic monitoring, borders, cash machines, schools, banks, among other challenging outdoor and indoor areas.

We have applied the BGS approach with much simplicity so that the approach can be used in a pragmatic manner where the VSS is a must. Essentially, the concept of installing VSS is much needed. The VSS must be more convenient, effective and efficient to enhance advanced security and safety systems. In addition, the used approach ensures safety and security through the detection of the MOs without controlling the system manually.

Despite that this study has deployed the BGS technique with great achievement, nevertheless, there is a need for continuously improving so that to have the most improved VSS. Since 2011, globally, both industry and academician have witnessed the fourth industrial revolution (4IR) which is much associated with "Industry 4.0" (Taifa & Vhora, 2019; Taifa, Hayes, & Stalker, 2019). Thus, from such a fundamental transformation, some of its concepts can also play a great part to improve the VSS with great impact.

6.2 Limitations and potential future research

First, we intend to develop a comparative study that would integrate the applied methods with other similar techniques. The aim will be to get results that are more convenient compared with similar approaches to get the best VSS. It is expected that the performance of the VSS shall be more improved through consideration of the threshold values by allowing object detection even for the tiny MOs. Secondly, the considered BGS is attributed to the low processing speed of images than the needed requirements in today's advanced IT-enabled systems. Of course, OCV is acknowledged to be the best library to process video and images in developing VSS. Thus, it is imperative to develop VSS which can accomplish the MD of the MOs. Then send either "emails" or the "Short Message Service (SMS)" instantly to the sysadmin or the possessor of the particular systems for immediate evaluation on whether there is a harm, or nothing dangerous associated with the detected MOs. Third, some researchers report on the used BGS method that is an old technique and suffers from many drawbacks as it is based on the intensity variation of objects. The research on hand will be extended by using morphological operations to detect MOs easily. So, the results of both methods will be compared and analysed to establish the differences and make commanding conclusions. There are also many motion estimation techniques, including the Lucas Kanade method, Pel-recursive approaches, Netravali-Robbins, Cafforio-Rocca, among others. The authors shall perform another study to have a look at these techniques and apply them. The comparison with other existing security systems will also be carried out with some valid metrics to get a good comparison of the results. This is because an integrated approach (Taifa et al., 2019) of several approaches have been acknowledged to lead to generate astronomical improvements when applied strategically (Taifa & Desai, 2017; Chawasemerwa et al., 2018).

Acknowledgement: This study would not have been completed should we not have received assistance from several people. Thus, we express our greatest gratitude to all people who supported us to undertake this study.

References:

Adafruit Industries (2019). *Adafruit DC and Stepper Motor HAT for Raspberry Pi*. Retrieved from https://cdn-learn.adafruit.com/downloads/pdf/adafruit-dc-and-stepper-motor-hat-for-raspberry-pi.pdf

Ambadas, B. D., & Bodake, S. H. (2017). Raspberry Pi based Single object tracking using Bayesian filter example. In *2017 International Conference for Convergence in Technology* (pp. 366-370). Mumbai, India: IEEE. https://doi.org/10.1109/I2CT.2017.8226153

Chawasemerwa, T., Taifa, I. W., & Hartmann, D. (2018). Development of a doctor scheduling system: a constraint satisfaction and penalty minimisation scheduling model. *International Journal of Research in Industrial Engineering*, *7*(4), 396-422. https://doi.org/10.22105/riej.2018.160257.1068

Dhananjaya, B., Murthy, B. R., & Thimmaiah, P. (2015). Detection of objects in aerial videos for object extraction and tracking for UAV applications. *International Journal of Computer Applications*, *112*(12), 37-42.

Fan, X., Zhang, F., Wang, H., & Lu, X. (2012). The System of Face Detection Based on OpenCV. *2012 24th Chinese Control and Decision Conference (CCDC)*, 648-651. https://doi.org/10.1109/CCDC.2012.6242980

Herrero, S., & Bescós, J. (2009). Background Subtraction Techniques: Systematic Evaluation and Comparative Analysis. In J. Blanc-Talon, W. Philips, D. Popescu, & P. Scheunders (Eds.), *11th International Conference, ACIVS 2009* (pp. 33-42). Bordeaux, France: Springer-Verlag Berlin Heidelberg.

Jana, S., & Borkar, S. (2017). Autonomous Object Detection and Tracking using Raspberry Pi, *7*(7), 14151–14155.

Kamate, S., & Yilmazer, N. (2015). Application of Object Detection and Tracking Techniques for Unmanned Aerial Vehicles. *Procedia Computer Science*, *61*, 436-441. https://doi.org/10.1016/j.procs.2015.09.183

Madane, S., & Bhura, S. (2016). Traffic Surveillance: Theoretical Survey of Video Motion Detection. *International Journal of Science Technology & Engineering*, *2*(08), 207-211.

Mahamuni, P., Patil, R., & Thakar, H. (2014). Moving object detection using background subtraction algorithm using Simulink. *IJRET: International Journal of Research in Engineering and Technology*, 594-598.

Murthy, V. V. S., Aravind, C. H., Jayasri, K., Mounika, K., & Akhil, T. V. V. R. (2016). An automatic motion detection system for a camera surveillance video. *Indian Journal of Science and Technology*, *9*(17). https://doi.org/10.17485/ijst/2016/v9i17/93119

Ramya, K. V. M., Premalatha, B., & Mishra, R. (2017). Electricity power consumption monitoring system. *International Journal of Professional Engineering Studies*, *VIII*(3), 132-137.

Rekleitis, I. M. (2004). *A Particle Filter Tutorial for Mobile Robot Localization*. *Technical report TR-CIM-04-02*. Centre for Intelligent Machines, McGill University, Montreal.

Sahasri, M., & Gireesh, C. (2017). Object Motion Detection and Tracking for Video Surveillance. *International Journal of Engineering Trends and Technology*, 161-164.

SDM. (2016). Rise of surveillance camera installed base slows. Retrieved December 11, 2019, from https://www.sdmmag.com/articles/92407-rise-of-surveillance-camera-installed-base-slows

Sharma, R. D., Agrwal, S. L., Gupta, S. K., & Prajapati, A. (2017). Optimized dynamic background subtraction technique for moving object detection and tracking. In *2017 2nd International Conference on Telecommunication and Networks (TEL-NET)* (pp. 1-3). Noida, India: IEEE. https://doi.org/10.1109/TEL-NET.2017.8343526

Sheshai, S. S. (2016). *Raspberry Pi based security system PRJ Index 156*. The University of Nairobi.

Sobral, A., & Vacavant, A. (2014). A comprehensive review of background subtraction algorithms evaluated with synthetic and real videos. *Computer Vision and Image Understanding*, *122*, 4-21. https://doi.org/10.1016/j.cviu.2013.12.005

Song, B., Tian, Y., & Zhou, B. (2014). Design and evaluation of remote video surveillance system on private cloud. In *2014 International Symposium on Biometrics and Security Technologies (ISBAST)* (pp. 256-262). Kuala Lumpur, Malaysia: IEEE. https://doi.org/10.1109/ISBAST.2014.7013131

Suresh, D. S., & Lavanya, M. P. (2014). Motion Detection and Tracking using Background Subtraction and Consecutive Frames Difference Method. *International Journal of Research Studies in Science, Engineering and Technology*, *1*(5), 16-22.

Taifa, I. W., & Desai, D. A. (2017). User requirements customization and attractive quality creation for design improvement attributes. *International Journal for Quality Research*, *11*(1), 131-148. https://doi.org/10.18421/IJQR11.01-08

Taifa, I. W. R, Hayes, S. G., & Stalker, I. D. (2019). Towards a digital revolution in the UK apparel manufacturing: an Industry 4.0 perspective. In *2nd International Conference on Sustainable Smart Manufacturing (S2M 2019), Manchester, United Kingdom*. Manchester, United Kingdom.

Taifa, I. W. R., Desai, D. A., & Bulsara, N. M. (2019). The development of an ergonomically designed product through an integrated product team approach. *International Journal of Occupational Safety and Ergonomics*, 1-19. https://doi.org/10.1080/10803548.2018.1557398

Taifa, I. W. R., & Vhora, T. N. (2019). Cycle time reduction for productivity improvement in the manufacturing industry. *Journal of Industrial Engineering and Management Studies*, *6*(2), 147-164. https://doi.org/10.22116/JIEMS.2019.93495

Toyama, K., Krumm, J., Brumitt, B., & Meyers, B. (1999). Wallflower: Principles and practice of background maintenance. In *Proceedings of the Seventh IEEE International Conference on Computer Vision* (Vol. 1, pp. 255-261). Kerkyra, Greece, Greece: IEEE. https://doi.org/10.1109/ICCV.1999.791228

Ukunde, N., & Shete, V. V. (2018). Home Surveillance System Using Internet of Things. In H. S. Saini, R. K. Singh, G. Kumar, G. M. Rather, & K. Santhi (Eds.), *Innovations in Electronics and Communication Engineering, Lecture Notes in Networks and Systems 7* (pp. 79-85). Springer Singapore. https://doi.org/10.1007/978-981-10-3812-9_8

Vashistha, S., Shruti, & Khatri, Y. (2019). A.H.R.D - Autonomous Human Recognition Device. In *2019 4th International Conference on Information Systems and Computer Networks (ISCON)* (pp. 578-583). GLA University, Mathura, UP, India: IEEE. https://doi.org/10.1109/ISCON47742.2019.9036266

Wen-Tsuen, C., Po-Yu, C., Wei-Shun, L., & Chi-fu, H. (2008). Design and Implementation of a Real Time Video Surveillance System with Wireless Sensor Networks. In *VTC Spring 2008 - IEEE Vehicular Technology Conference* (pp. 218-222). Singapore, Singapore: IEEE. https://doi.org/10.1109/VETECS.2008.57

Yang, S. K. (2005). *Human motion detection system (video motion detection module)*. Universiti Tunku Abdul Rahman.

Zaman, K. F. H., Ali, M. H., Shafie, A. A., & Rizman, Z. I. (2017). Efficient Human Motion Detection with Adaptive Background for Vision-Based Security System. *International Journal on Advanced Science, Engineering and Information Technology*, *7*(3), 1026. https://doi.org/10.18517/ijaseit.7.3.1329

Rodney Kadadi
Department of Electronics & Communications,
G H Patel College of Engineering & Technology,
Vallabh Vidyanagar,
Anand,
Gujarat,
India
rodneykadadi@gmail.com

Garima Devpriya
Department of Electronics & Communications,
G H Patel College of Engineering & Technology,
Vallabh Vidyanagar,
Anand,
Gujarat,
India
gdevpriya@gmail.com

Ismail W. R. Taifa
Department of Mechanical and Industrial Engineering,
College of Engineering and Technology, University of Dar es Salaam,
Dar es Salaam,
Tanzania
taifaismail@yahoo.com