Original Research Article

Using 3D Tools to Design CCTV Monitoring System for Ghanaian University: A case of C.K. Tedam University of Technology and Applied Sciences (CKT-UTAS)

ABSTRACT

CCTV monitoring system is an essential security tool for visual surveillance accelerating the investigation in potential criminal activities when the need arises. Although expensive, universities mostly with public-access campuses in general, all need this system mainly to maintain safety and security in real-time, allowing legitimate students and staff to access campus resources and concurrently preventing any unauthorized persons access within the campus as well as responding to incidents with necessary action. C. K. Tedam University of Technology and Applied Sciences (CKT-UTAS) is a university in the Upper East Region of Ghana that does not have such a monitoring system. Since it is a newly established public university, its allocated funds are limited and could not be used to establish such an expensive system. To supplement their ongoing efforts in building security monitoring system, this study constitutes the blueprint procedures for building economical but reliable and efficient CCTV camera system for monitoring the property on campus and also the in and out of students and university staff members. The CCTV system was tested in monitoring vantage security post of the University. After observing and analyzing the trends in data from both the physical and our proposed automated monitoring approach, it can be concluded that the CCTV camera setup outperforms the physical and manual form or monitoring vantage security posts on University campus. Since the of monitoring security post using the proposed CCTV setup is advantageous in requiring lesser human effort and skills, it can be recommended for universities with low income-flow and low budget. This probably can make the university campus more secure and reliable

Keywords: CCTV monitoring system, Ghanaian Universities, C.K. Tedam University of Technology and Applied Sciences, Video surveillance system, Security

1. INTRODUCTION

Video surveillance using CCTV camera setup is a major tool for monitoring areas of interests. Among the promising methods of intelligently securing and monitoring public areas, CCTV camera setups are common. These CCTV setups do not only capturing the video shots. Such a setup plays an important role in intelligently analyzing special incidents such as crime [1, 2] Road accidents [3, 4]. This can be attributed to the fact that there are abundance of auxiliary technologies that are compatible and can be used concurrently with such setups. Computer vision technologies can be incorporated into the camera system of such setups [5]. Through such technologies, the CCTV camera setups can be used to actively interact with the outside real world. Target objects from the real world can be perceived [6], recognized [7], detected [8, 9], counted [10, 11], classified [12, 13] and even further be tracked across frames [8, 14, 15] Intelligent CCTV camera setup can include advanced computer vision functions like behavior recognition [16, 17], monitoring the hand hygiene compliance by health workers [18], disaster monitoring [19, 20]. In these ways, video recordings from CCTV camera setups are analyzed using computer vision and image processing techniques to track, monitor and analyze data in the case of an incident and prevent the future possibility of them occurring again.

At this point, it can be agreed that video surveillance systems are primarily designed with the aim of visually inspecting target objects. When designing such systems, several factors needed to be taking into consideration in order to ensure efficiency in the system [5, 21, 22]. One of such factors is the coverage zones of the visible areas. Coverage zones are adjusted also with a primary aim at minimizing blind zones [22]. Adjusting camera to a desired coverage zone is dependent on regulating certain properties of the setup which mainly include camera location and camera height [5]. Also known as camera view area, it is a region of the outside world the camera lens covers. All objects (or parts of objects) inside this region area will be visible on the output monitor screen, whilst object outside the region will not be visible [23]. It is much more appropriate and faster to project the view area when designing CCTV systems view area is mostly modeled in the form of a 2D triangle or a rectangle from the side view or as a quadrilateral from the top view [21]. Kim et. al. [24] considered the CCTV camera view and its angle in measuring crowd. Another factor that needed to be taken into consideration in designing CCTV surveillance systems is the camera positions. Camera positions depicts the pointing direction of the camera that is (from left to the right or from right to the left, and from top to down or fro down to top [21]. In any case a camera position is a contributing parameter to determine the camera coverage area

Another factor is software usd to plan out the design layout of the surveillance system [25]. Computer software and other mobile applications are used by professionals in CCTV design as supporting tools that assist with ensuring precision and speed in layout designs for video surveillance system [5, 21, 22, 25] in their research works, explained some of these special software tools used for the development of video surveillance systems. Moreover, since different CCTV designs have different properties and purpose of setup, their Pixels Per Meter (PPM) (or PPF - Pixels Per Foot (PPF)) settings are also considered when designing these CCTV systems. PPM/PPF are measurement tools used to define the potential image details in the video quality captured by the camera [26]. According to European Standard EN 62676 [27, 28], color coding is associated to the following PPM requirements for various video surveillance tasks: Identification – 250 PPM (color coded pink); Recognition – 125 PPM (color coded red); Observation – 62 PPM (color coded yellow); Detection – 25 PPM (color coded green); Monitoring – 12 PPM (color coded blue).

Video surveillance using CCTV camera setup has been used to monitor public places of which University campuses are of no exception. Ma et. al. [29] researched into the design of campus video surveillance system. Sarikonda and Bhutada [30] worked on a customized campus surveillance system. Although not much research has been conducted, universities in African countries are not exempted from the research trend in investigating the used of CCTV camera setup to monitor University campuses. To the best of knowledge, only two research has been conducted to study the use of CCTV camera system as a tool to monitor security in Ghanaian university. Ansong and Ofori-Dwumfuo [31] investigated in the use of CCTV in crime combating in a Ghanaian university. Similarly, Kwaa-Aidoo and Agbeko [32] also analyzed information system security of a Ghanaian university.

This study contribute to this trend of research and propose a blueprint strategy for designing an economical but reliable and efficient CCTV system for monitoring security on the Navrongo campus of C.K Tedam University of Technology and Applied Sciences (CKT-UTAS), a newly established public university in the Upper East Region of Ghana. This setup aims not to only supplement the current setup of the Ghanaian University that requires physical presence of security personnel at post all time, but to also enhance and automate visual coverage some sensitive areas which the current security setup is not capable of monitoring. The study evaluates the effectiveness of the proposed CCTV system design in automating the monitoring of the University's entrance security post compared to the manual form existing security setup

2. METHODOLOGY

This section describes all the research procedures and methodologies as well as the procedures undertaken to setup and design the CCTV monitoring system. The research area, methods and techniques used for gathering data for this research work including the data collection tools are also discussed.

2.1 Research Study Area

C.K. Tedam University of Technology and Applied Science (CKT-UTAS) is one of the newly established autonomous universities in Ghana. The C.K. Tedam University of Technology and Applied Sciences (CKT-UTAS) was established by an Act of Parliament (ACT 1000) which came into effect in August, 2019. Prior to gaining autonomous status, CKT-UTAS was one of four campuses of the University for Development Studies (UDS). C.K. Tedam University of Technology and Applied Sciences (CKT-UTAS), the premier public university of the Upper East Region of Ghana established at Navrongo in the Kassena-Nankana District. The mandate of the University as spelt out in the parent Act is to disseminate knowledge related to theory and practical development in integrated technology and applied sciences. It currently has five (5) schools/faculties including the School of Computing and Information Sciences (SCIS). The school is made up four main academic departments and a center .The researchers of this study are members of Department of Cyber Security and Computer Engineering Technology (DCSCET)

2.2 Research Design

The adopted research design followed comparative. It involved the comparison of observational sessions between CCTV design setup and human observers.

2.3 Participants

The study population are the students, lecturers and administrators, thus teaching and non-teaching staff of the university and the visitors to the university who mainly used the university during the period of observation and data collection.

2.4 Data Collection Procedures through Observation

All observation sessions were conducted in the presence of all researchers. However, the observation team mainly consisted of two (2) researchers, who are the first (Observer 1) and last (Observer 2) authors of this paper. The corresponding author/researcher (the first author and Observer 1) is the project supervisor of the co-author researcher (the last author and Observer 2) who is diploma student at the Department of Cyber Security and Computer Engineering Technology (DCSCET), School of Computing and Information Sciences (SCIS), C.K. Tedam University of Technology and Applied Sciences (CKT-UTAS). These two researchers were primarily, the observers at the university entrance gate. They both agreed on standard procedures before observation began. The standard included independent observation sessions. Observation took three weeks excluding Wednesdays and Sundays. The observations were performed in August 2022. Each observation session lasted from morning around 8:00am to afternoon at 4:00pm, with a one hour break at 10:00am and another at 1:00pm, and events were recorded in a provided notebook. Observer 2, the diploma student miss two days (observation sessions) within the last third week of the data collection. Each observer was to take part of a total of 15 observation sessions, 1 for each day and 5 sessions for a week. Whereas observer 2 attended the observation sessions for all 15 days, Observer 1 was able to just attend 13 out of the total of 15 observation session because he missed two days.

We realized no effects of him being absent (with permission) for the two data during the data collection so we went ahead to analyses the data collected. To control the effects of his absenteeism in data collection on the results, the five (5) sessions of the last third week for the Observer 1 who attended all the observation settings was separated into two parts, the first part consisted of three (3) sessions and the other second part consisted of two (2) sessions. Another records were obtained from an observation session with a setup that mimics the proposed CCTV camera setup. All records were taking for all the fifteen (15) days for this CCTV observation setup, 5 for each week. We also separated into two parts, the 5 observation session for this CCTV setup. The first part consisted of three (3) sessions and the other second part also consisted of two (2) sessions. Decomposing the 5 sessions for a week into two parts, for the Observer 1 and that of the CCTV setup, the first part of records with three (3) observation sessions could be analyses at par with the three (3) sessions of the Observer 2. During each observation session, the number of moments when a person or a vehicle (including Tri-cycles because this is a major means of the transportation at the study area) entered or exited the University main gates were manually recorded in a designated notebook. Simultaneously, a phone was mounted on a tripod pole to simulate the CCTV camera system to be mounted in front of the University entrance gate. The notion here is to count people and vehicle entry and exit with CCTV. This problem was treated as people and vehicle counting and flow control management using CCTV. Observation data derived from physical and CCTV setup observation method were collected and recorded on standard notebook for further data analysis.

2.5 Data Analysis Procedures

Standard statistical data analysis procedures were adopted. We mainly analyzed the data by computing the correlation between the recorded from three (3) observers (Observer 1 and 2 as well as the CCTV Setup). An acceptable correlation coefficient between the records of three observers was expected to be 0.75 or higher, which we achieved. Correlation coefficient value between 0.50–0.70 were considered to signify good correlation and results of 0.75–1.00 to signify excellent correlation. We also measure and visualized the mean differences between the three (3) observers suing the Bland-Altman plots. Statistical analysis was calculated using Microsoft Excel version 2016 and MedCalc application version 20 64 bit.

2.6 Ethical Considerations

The ethical operation of the surveillance camera system is associated with obligations imposed by law. To the best of our knowledge, there were no existent laws that governs the use of any form of surveillance cameras in the public areas of the university under study, C. K. Tedam University of Technology and Applied Sciences (CKT-UTAS). For facts, laws regulating public area camera surveillances are not common worldwide. Very few cities have them and ours is of no exception. Thus, the city in which the University is situated, that is, Navrongo in the Upper East Region of Ghana, as at the time of writing this research had no clear laws regulating the ethical use of surveillance system at public places. Although there exist no special university law camera systems, this area is not completely without legislation. For this reason, an informal ethical approval was sought from the security unit of the university to conduct this study.

As the proposed camera system intends to record personal data (mostly identifiable characteristics of persons such as their facial structure and vehicle information such as number plate), we primarily considered contents within The Data Protection Act, 2012 (Act

843) (Data Protection Commission, Ghana, 2012) of Ghana, on the protection of personal data, to ethically guide design, development, implementation and experiment of the proposed camera system. The Data Protection Act, 2012 (Act 843) sets out the rules and principles governing the collection, use, disclosure and care for your personal data or information by a data controller or processor (Data Protection Commission, Ghana, 2012).

2.7 Procedure for designing a Campus Security Camera System

For the purpose of actually monitoring target objects on selected sites in real time, a CCTV camera system may have a number of camera unit devices that are placed in various locations. During the installation of a particular CCTV unit camera, the designer begins by picking the precise camera positions, visually inspecting the camera's coverage areas, and constantly adjusting it to a satisfactory image resolution until the targets are vividly visible in the captured image. The study adopt the following practices in designing security camera system

2.7.1 Campus Site Visitation

The first important practice is walking the campus space in person completing a thorough site walk or survey. Through this site survey, we visit the university campus under study and gather all requirements which are essential for a customized system design. We took plenty of pictures that could help to design and select the different types of security cameras that to be used in the surveillance system. To make the most of the site visitation, the entire campus layout was roughly sketched on a piece of paper. This sketch was to later assist the design of a digital map of the campus site.

Satellite imagery from Google Maps was pulled for the campus. We pull up the location with Latitude coordinate as 10.866101910244307 and Longitude coordinate as –1.077925664697788, in the degrees, minutes, and seconds (DMS) format direction 10°51'58.4" North 1°04'41.6" West. This location in the said direction is labelled as C. K. Tedam University of Technology and Applied Sciences (CKT-UTAS) on Google Map, as shown in Fig. 1. The university, CKT-UTAS is located at Navrongo in the Kasena Nankana East of the Upper East Region of Ghana[1]

Once digital map is obtained, we import it into our chosen video surveillance digital system design platform, the IPVM Design Calculator (updated for Version 3.1)[2], which becomes a plan on which the CCTV cameras can be set up to keep track of the position coordinates and attributes of each camera device on the surveyed site.

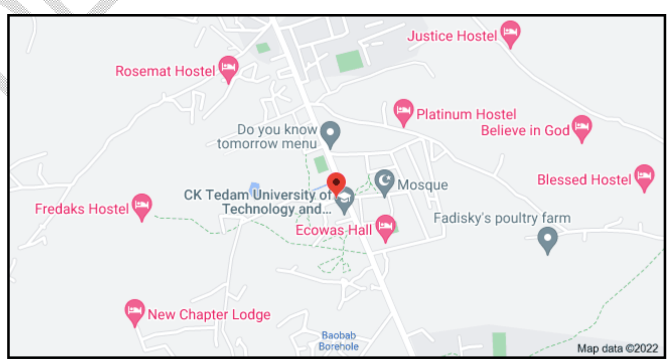
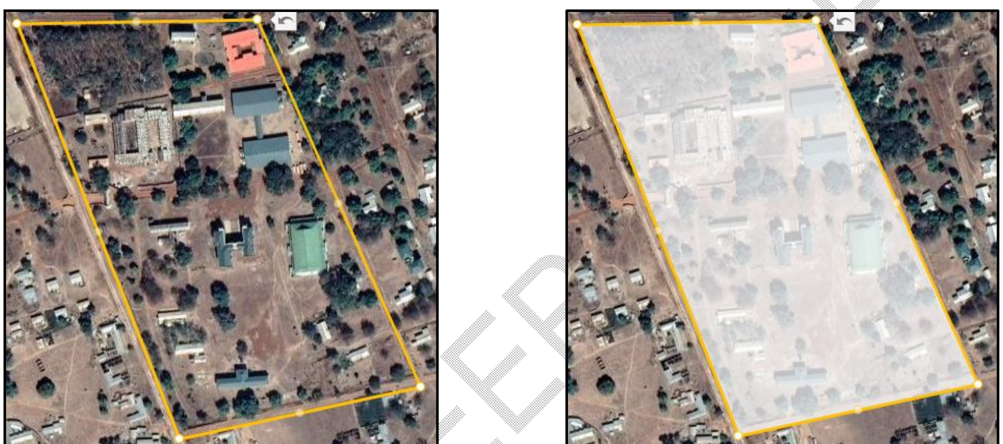


Fig. 1. Location C. K. Tedam University of Technology and Applied Sciences on Google Maps

[1]Link to the location on Google Map is https://goo.gl/maps/ZGk3qXmHRU932VoN7
[2]https://calculator.ipvm.com/

2.7.2 Digitalizing Campus Site

We change the location by entering into at the lower right side control panel of the design calculator, the desired address with the latitude and longitude coordinate 10.866101910244307 and –1.077925664697788 (in decimal degrees (DD) format 10.866101910244307, –1.077925664697788). We searched and navigated to the CKT-UTAS University. The Satellite canvas was then chosen for our design. We use the Satellite canvas of the entered location coordinates as our floor plan. With the floor plan specified, scaling to equate the distances of objects, especially building objects, of the real world to the floor plan could be easily done. From the initial site visitation, distances were taken between some site buildings. We then manually used the measurement tool in IPVM to compute and enter the distance for the distance on the Satellite floorplan. With the distance known, a markup boundary was drawn as a quadrilateral for the entire site plan of the side of the campus that is assigned for the study. This is shown in Fig. 2.



(a) boundary without fill (b) boundary with fill (translucent white)

Fig. 2. Bounded markup quadrilateral for the assigned campus site

2.7.3 Camera and Design Configuration

After visiting and digitalizing the campus site, the next obvious practice is to select the specific camera models suitable for our task. Instead of using generic camera model, specific camera models were searched for, their various configurations were tested and just two camera models were marked as favourite from the 10,000+ models. The selection was mainly based on the Brand Manufacturer, Resolution and Field of View. This chosen models are recommended to be used repeatedly on any project that has to do with the design and implementation of CCTV camera system for the CKT-UTAS University. Subsequent subparagraphs explains in details, the practices undertaken to arrive at the two chosen favourite cameras.

2.7.4 Choice of Cameras

Since there are varieties of CCTV camera models to choose from for securing the campus site, we considered two (2) types of cameras that properly suits our situation, premises and appropriate or vital for the right application. These two types of cameras are the Bullet and the PTZ Dome Camera type of CCTV cameras

2.7.4.1 Bullet Camera

Our ideal case is for outdoor use, for that reason, the adopted bullet cameras are long and cylindrical in shape and are ideal for outdoor use. The other reason of choosing this camera type is to be able to achieve a long distance viewing. Other accessories that could be used to supplement the long usage of this camera is an installed waterproof protective casings and with inbuilt heatsinks and some cooling fans. With such a setup, not only will the protective cases shield the CCTV cameras from natural elements like dust, dirt and rain water, it will also use its inbuilt cooling system to cool down the temperature of the CCTV camera, most especially during Hamattan (summer) period where the weather in Navrongo is extremely hot between 28 to 45 degrees

2.7.4.1 PTZ Dome Camera

PTZ CCTV cameras embodies the Pan, Tilt and Zoom features of the lens in a single camera. This feature allows the lens of the camera to be panned left to right (rotated sideways along the *x*–plane), titled up and down (rotated up and down along the *y*–plane), zoomed far and near to enable surveillance capture wide area clearly. We also chose a PTZ camera of dome shape type for our outdoor campus CCTV security and surveillance installation. This shape design of the PTZ camera disguises where the camera lens is actually pointing to so that onlookers cannot tell the current focus of the camera. This is a great piece of security design.

As would be discussed in the Section 2.7.5.1, we used the JVSG CCTV Lens Calculator to decide on the specific camera of each type to be used. After playing around different types of bullet and PTZ dome cameras in the online calculator, it could be recommended that the Hikvison PTZ-T4225I-D dome camera and the DS-2CD1021-I bullet CCTV camera were specifically chosen

(a) Hikvison PTZ-T4225I-D Dome Camera[3] (b) DS-2CD1021-I Bullet camera[4]

Fig. 3. Properties of the chosen specific cameras and their model specifications

2.7.4.2 Labelling the Positions for Adding Cameras to digital site

New cameras were added in accordance to the specification discussed in this study. Before adding cameras though, their position markers were placed on the digital campus site map. The desired location at which cameras will be placed on the physical site are marked with filled circle/dots as shown in the Figure 3. In terms of camera positioning, the digital campus site was divided into three sections with each division having a unique color code.

[3] https://www.jvsg.com/cameras/Hikvision/PTZ-T4225I-D/
[4] https://www.jvsg.com/cameras/Hikvision/DS-2CD1021-I/

Fig. 4. Camera Positions marked on the digital campus site plan.

After marking camera positions, we can then add cameras to the scene or Satellite canvas. Camera coverage is manipulated by dragging the subject at the edge of the coverage cone to expand the coverage area

2.7.5 Adopted Software Tools for the CCTV System Design

The section concentrate on describing some basic functionalities and components of the software tools used that are relevant in designing and mapping the CCTV systems. In general, whilst some of the tools used are available online, other are PC desktop (offline) tools

2.7.5.1 JVSG CCTV Lens Calculator

This is an online application[5]. Through the online calculator of camera focal length, the quality of captured image can be maintained. With the use of this application, we were able to deduce the specific models for the selected two camera types discussed earlier. The two cameras chosen are the Hikvison's PTZ-T4225I-D dome camera and the Hikvison's DS-2CD1021-I bullet CCTV camera. This choice was mainly influenced by their ease purchase and accessibility in the Ghanaian market. This tool could also be used to compute some parameters such as the Field of View (FOV), camera (ground) and target heights as well as camera resolutions. Appropriately setting the camera height and down tilt towards he ground, closes the blind spot gap. For this reason, it was observed to be best if these parameters were manually set for the purpose of our design. A screenshot of the interface for the JVSG CCTV Lens Calculator is shown in Fig. .5.

[5] https://www.jvsg.com/calculators/cctv-lens-calculator/ https://www.jvsg.com/focal-length-lens-calculator/

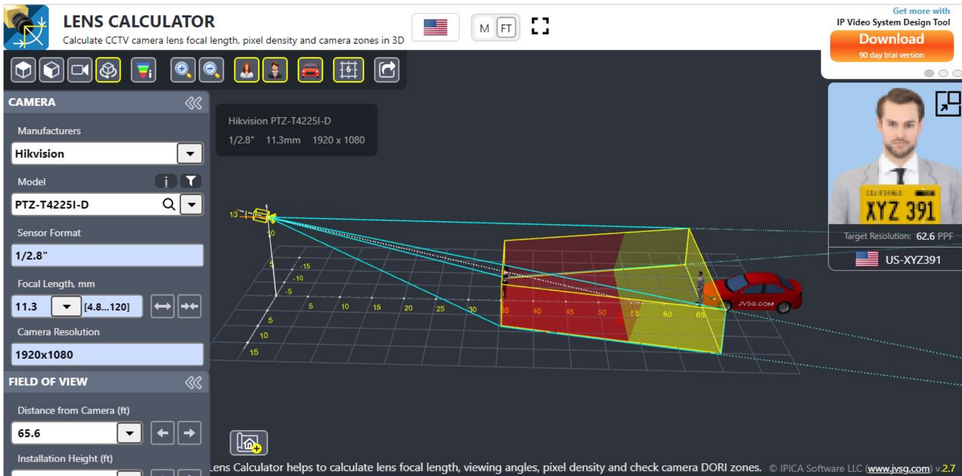


Fig. 5. Application interface for JVSG CCTV Lens Calculator

Setting for the parameters listed above, the height from the ground (i.e. 4 meters of 13.1 feet), and the distance covered (i.e. 20 meters of 65.6 feet) and target height (i.e. 2 meters of 6.6 feet) for all cameras, was set to be equal. For the target height, we used the average height of a human being. To facilitate the best usage of the proposed CCTV system, an essential requirement is to obtain the FOV information the camera, so that useful visual information could be clearly and promptly assessed in case a security threat (such as theft) occurs. For this thoughts in mind, only the Field of View (FOV) width and the horizontal angle of the camera were set differently according to the camera type to suite our design. For the bullet type of CCTV camera we set the FOV width and the horizontal angle to be 8 meters and 22.8 degrees respectively whilst that of the PTZ dome CCTV camera type was set to be 30 feet for the FOV width and 25.6 degrees for the horizontal angle. Fig. 6. below shows these settings

(a) Settings for Bullet-type camera (b) Settings for Dome-type camera

Fig. 6. Camera field of view (FOV) settings

2.7.5.2 IPVM CCTV Design Calculator Tool

The CCTV design tool, the IPVM Design Calculator (updated for Version 3.1) is an online design tool that was used. Through this tool camera could be added to the CCTV design. This is a designer with the support for Google Maps. The camera was placed at designated areas on the map of CKT-UTAS. This designer tool can show the camera's view with the support from the Google map, and approximate the image quality still utilizing the data from the Google Maps application. An important aspect of this feature is that the designer enables preview of camera view where street view exist on the Google Map for the location at which the camera was placed. In other words, if Street View are available on Google Maps for the location on which the camera is placed in IPVM, a preview of the camera scene will be showed on the right side of the IPVM application's interface. Fig. 7. shows a real shot depicting the image of the location at the right side of the application interface.

Fig. 7. IPVM Calculator previewing the security camera view of CKT-UTAS entrance

By some adjustments, we set the viewing angle and distance between the camera and the target to be monitored. Through this feature, the area that is monitored by the camera can be changed. The direction of the camera as well as the distance of the camera view from the target was adjusted to the desired length with the person subject object at the edge of the coverage cone. The camera's Field of View (FOV) width was adjusted to the desired size with the corner of the coverage cone. This is depicted in Fig. 8.

Fig. 8. IPVM Calculator showing camera positions on map of CKT-UTAS

2.7.5.3 Trimble SketchUp

We use Trimble Inc.'s SketchUp Pro 2022 version 22.0.316 64bit to model the 3D space of CKT-UTAS. In creating the 3D polygon models and objesct, we used the three classic drawing tools, thus the pencil, ellipse and rectangle, and subsequently other models like the asphalt streets, the street lights and the cameras on poles were downloaded from SketchUp 3D Warehouse6. The 3D Warehouse, as the name implies is a 'warehouse' of large collection and library, where a lot of 3D models, products and catalogues pre-designed and uploaded by existing users of the application, can be found. Fig. 9. shows screenshot of the interface for SketchUp Pro 2022

[6] https://3dwarehouse.sketchup.com/

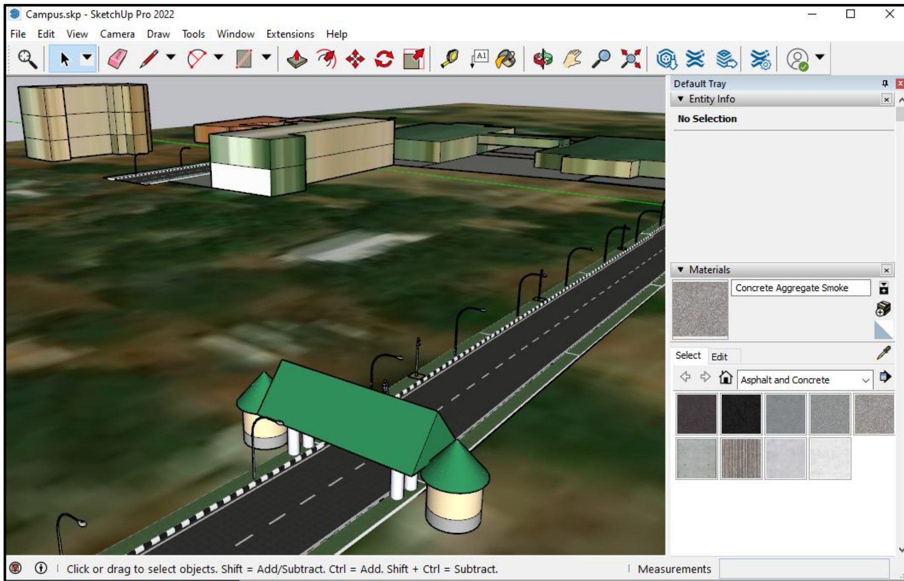


Fig. 9. Interface of Trimble SketchUp Pro 2022 with 3D polygon models of CKT-UTAS

2.7.5.4 JVSG – CCTV design software

This professional software, JVSG – CCTV Designer[7] is an IP video system design tool (the original title of the software), which supports the design of CCTV systems with less risk of making errors in configurations. To use this software, first 3D model of the CKT-UTAS campus is created using SketchUp software as shown in Figure 3. above. This 3D model of the campus is served as the plan of the university into which actual functioning camera with clearly defined configurations and parameters could be placed. Since the JVSG – CCTV Designer supports importing model of the Collada format (with *.dae* file extension), there is the need to convert our CKT-UTAS campus model built in SketchUp into a file with *.dae* file extension. Models built in SketchUp software are in the file format with *.skp* file extension. Therefore, SketchUp models with *.skp* file extension are converted into Collada format within the Sketchup application suing the menu option *menu→File→Export→3D Model→*.dae*. Then, the exported *.skp* file to *.dae* file is imported into the IP video system design tool and loaded as the working environment in which subsequently, camera equipment are added.

[7] https://www.jvsg.com/

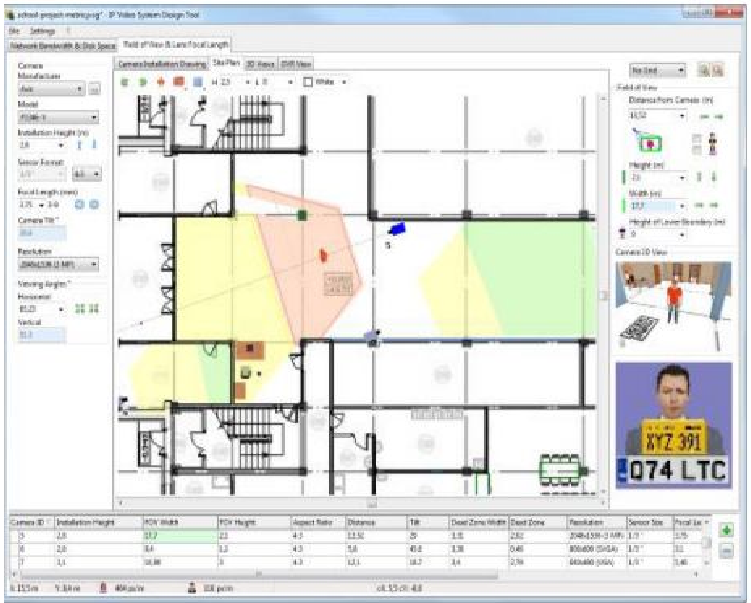


Fig. 10. Interface of the JVSG – IP CCTV System Design Tool

This was followed by adding the camera at the designated location points that were labelled IPVM software as shown in Figure 3 above. The tool was also used to actually preview the Field of View (FOV), camera viewing angle and focal lengths parameters that were also set using the JVSG CCTV Lens Calculator. The important preview feature of this IP Video System Design Tool is that the area of camera vision are divided into zones with color coding labels which depicts where views are reachable and where views are blocked by obstacles such as wall of buildings. These zones are labelled in accordance to the PPF/PPM zone standards.

Pixels Per Foot (PPF) / Pixels Per Meter (PPM) is a fundamental and valuable metric for specifying video surveillance image quality. By standards, the PPF/PPM zones visually displays four (4) color coding as labels for different regions dependent on the purpose of camera view in that region. These zones are set as follows; 100ppf+ / 328ppm+ for facial recognition; 50ppf - 99ppf/ 164ppm to 327ppm to for identification; 10ppf to 49ppf / 33ppm to 163ppm for people and vehicle detection; 9ppf / 32ppm and lower for general coverage/visibility. This standard was slightly modified to suite our campus environment. The modification here was mainly influenced by the settings from the JVSG CCTV Lens Calculator. Per each mounted camera, six (6) different color coding from the PPF/PPM zone standards are used to label the different regions within the camera's field of view to help with identification of mainly vehicle pleat numbers and human body stature and faces. The currently set zone labels are as shown in Fig. 11.

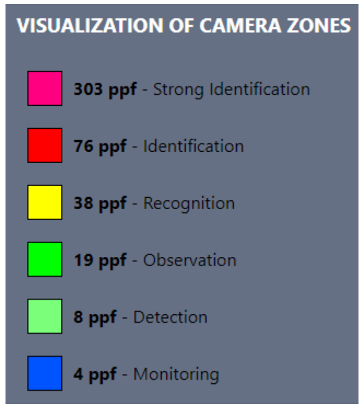


Fig. 11. Adopted Pixels Per Foot (PPF) / Pixels Per Meter (PPM) Zone color coding labels

3. RESULTS AND DISCUSSION

This chapter presents the results of the study data. First, the data collected were collated into tables and discussed to identify the trends and patterns in them. Lastly, data components are compared to each other to determine if the propose CCTV setup design is sufficient for monitoring the entry and exit flow activities to and from the campus.

3.2 Testing the performance of the proposed CCTV monitoring system

The primary objective of this study was to test the capabilities of the proposed CCTV system in enhancing monitoring of entrance or exit of students, staff (teaching and non-teaching) and visitors in C. K. Tedam University of Technology and Applied Sciences (CKT-UTAS). The system monitors in real-time, the visual information during entry and exit events at the security post. Currently, the entry and exit security post is being assigned larger number of security personnel to guard the post. This is strenuous and error prone. There are numerous instances when theft has occurred and unidentified persons/vehicles has been granted access to the campus without any knowledge about such incidence.

3.2.1 Data breakdown from Observation

For this reason, observations were performed and the data is collated in Table 1 and Table 2. During the observation, data was collected to mimic the scenario when a security personnel is manually assigned the entry and exit post and the scenario when the CCTV camera is set up at the same entry and exit post.

Total number of observation sessions is 43. The total number of combined recorded events where persons entered and exited the university through its main entrance is 19,777 out of which Observer 1 recorded 7,009 instances, Observer 2 recorded 5,789 and observation from the CCTV setup recorded 6,979.

Table 1. Person (Human) Data breakdown collected from observation.

Observation Details	Number of sessions (in days)	8-10am		11am-1pm		2-4pm		Total
		Entry	Exit	Entry	Exit	Entry	Exit	
Observer 1	***15***	***2236***	***914***	***1409***	***1224***	***693***	***533***	***7009***
Week 1	5	787	246	472	412	231	194	2342
Week 2	5	639	312	520	459	176	213	2319
Week 3	3	420	231	172	216	195	88	1322
	2	390	125	245	137	91	38	1026

Observer 2	***13***	***1818***	***770***	***1143***	***1087***	***493***	***478***	***5789***
Week 1	5	787	232	450	412	231	190	2302
Week 2	5	617	312	520	459	169	200	2277
Week 3	3	414	226	173	216	93	88	1210
CCTV Setup	***15***	***2245***	***890***	***1402***	***1224***	***690***	***528***	***6979***
Week 1	5	803	250	471	412	231	194	2361
Week 2	5	640	301	520	459	170	205	2295
Week 3	3	420	220	173	215	195	88	1311
	2	382	119	238	138	94	41	1012
Total	**43**	**6299**	**2574**	**3954**	**3535**	**1876**	**1539**	**19777**

We can deduced that, if Observer 2 had attended all his 15 observation sessions instead of the 13 recorded, he would have roughly recorded a value closer to 7,000 session closer to the value recorded by the Observer 1 and the CCTV Setup. In each 43 observation session for vehicles (Cars and Tri-cycles) recorded in the designated notebook, total number of combined recorded events where vehicle drove into (entry) and out (exited) the university through its main entrance is 6,451 for all the 43 observation sessions by all participants (Observer 1 and 2 as well as the CCTV Setup). Comparatively, the records for the observation of vehicle versus that of the persons is low. In effect, for all the 15 days, Observer 1 recorded 2,244 total number of vehicles entering and exiting the CKT-UTAS through the campus' entrance but recorded 7,009 persons doing same activity.

Table 2. Vehicles (Cars and Tri-cycles) data breakdown collected from observation

Observation Details	**Number of sessions (in days)**	**8-10am**		**11am-1pm**		**2-4pm**		**Total**
		Entry	**Exit**	**Entry**	**Exit**	**Entry**	**Exit**	
Observer 1	***15***	***558***	***438***	***416***	***360***	***256***	***216***	***2244***
Week 1	5	182	141	152	126	90	83	774
Week 2	5	210	171	120	132	86	85	804
Week 3	3	98	74	81	64	49	31	397
	2	68	52	63	38	31	17	269
Observer 2	***13***	***478***	***373***	***353***	***316***	***226***	***199***	***1945***
Week 1	5	176	141	152	120	90	83	762
Week 2	5	203	162	120	132	86	85	788
Week 3	3	99	70	81	64	50	31	395
CCTV Setup	***15***	***567***	***438***	***423***	***359***	***258***	***217***	***2262***
Week 1	5	190	141	155	127	90	83	786
Week 2	5	207	170	123	132	86	85	803
Week 3	3	98	75	81	65	51	31	401
	2	72	52	64	35	31	18	272
Total	**43**	**1603**	**1249**	**1192**	**1035**	**740**	**632**	**6451**

Also, Observer 2 recorded 1,945 total number of vehicles entering and exiting the CKT-UTAS through the campus' entrance but recorded 5,789 persons doing same activity. With the CCTV setup, 2,262 total number of vehicles included the Tri-cycles were recorded entering or exiting the entrance of CKT-UTAS but recorded 6,979 persons doing similar activity. This shows that more persons enter and exit the campus than vehicles do.

3.2.2 Correlation and Mean Differences of Data from Observation

Overall, 43 observation sessions yielded complete data. Those included 19,777 recorded entry and exit events for person targets and 6,451 for vehicle targets. Out of the 43 sessions, 39 observation sessions was used to establish the Correlation coefficient reliability. This is because, the Observer 2 could not attend all but 13 (13 out of 15) of the days used to perform the observation. For this reason, records for the first 13 days were taken for all the three (3) observer participants (Observer 1 and 2 as well as the CCTV Setup). The Correlation reliability coefficient of 39 observation sessions is presented in Table 3.

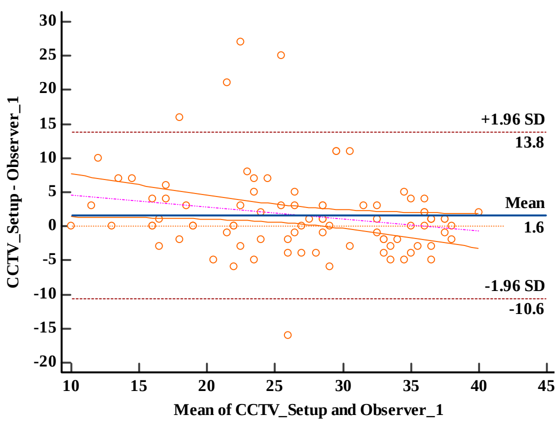
Table 3. Correlation reliability coefficient of 39 observation sessions

Target of Observation	Mean Difference		Correlation	
	Observer 1 & CCTV Setup	Observer 2 & CCTV Setup	Observer 1 & CCTV Setup	Observer 2 & CCTV Setup
Person	1.6 ± 0.23	0.4 ± 0.77	0.86	0.84
Vehicles and Tri-cycle	0.3 ± 0.85	0.5 ± 0.64	0.91	0.95

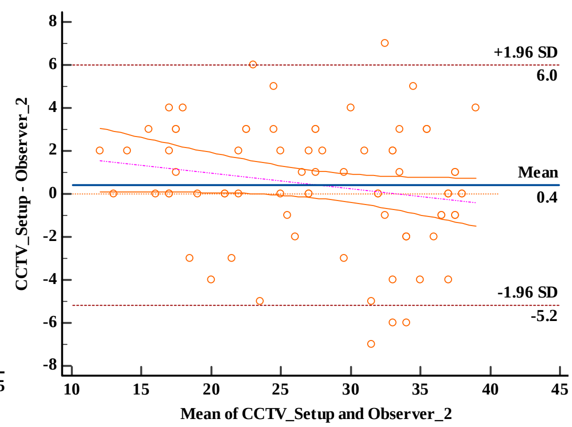
The mean compliance difference between the three forms of observation sessions were computed. In the observation session using the Observer 1 physical method to monitor persons, its mean difference with the CCTV setup method is 1.6±0.23 with a high positive correlation of 0.86. The mean difference and correlation between the use of Observer 1 and CCTV setup to monitor vehicles (Cars and Tri-cycles) entering and exiting the University's campus are 0.3±0.85 and 0.91 respectively. The mean difference and correlation between the use of Observer 2 and CCTV setup to monitor persons entering and exiting the University's campus are 0.4±0.77 and 0.84 respectively. In relation to monitoring the entry and exit of vehicles (Cars and Tri-cycles) in and out of CKT-UTAS's campus, the mean difference and correlation between the use of Observer 2 and CCTV setup are 0.5±0.64 and 0.95 respectively. This indicates that the effects of physical and manual method of guarding and monitoring security post is similar to when using the CCTV setup to monitor same target objects. Also, high correlation coefficients and low mean difference values confirmed the previous belief in the security of the proposed CCTV setup. In other words, the reliability and correlation assessment of the manual from of monitoring security posts showed higher compliance with the monitoring of security posts using the proposed CCTV setup.

Since the monitoring of security post using the proposed CCTV setup is advantageous in requiring lesser human effort and skills, and exert little strain on the campus' security personnel, coupled with the fact that its performance is comparably and in some situations higher than that of the manual method of monitoring security post, it can be recommended to adopt our proposed system for efficient security and monitoring.

Mean differences between the three observations sessions are visualized using the Bland Altman plots shown in Fig. 12 (a–f).



(a)



(b)

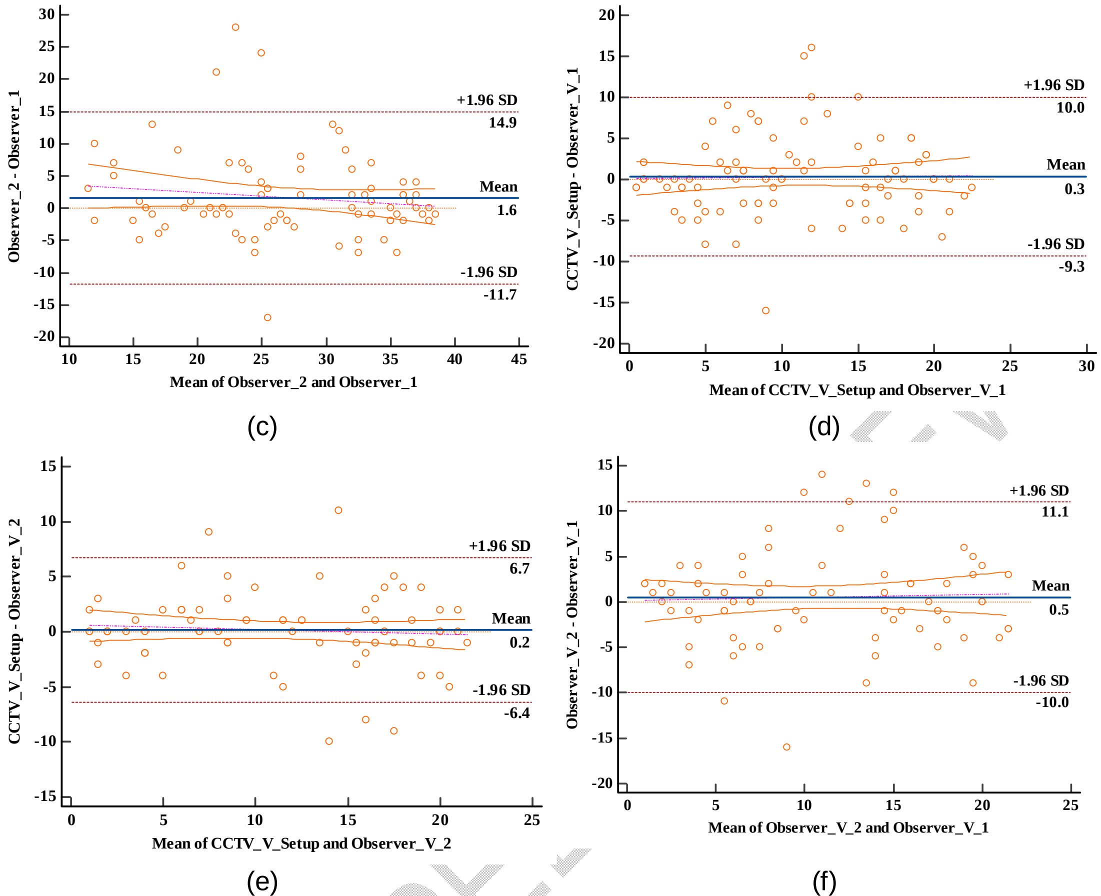


Fig. 12. Bland Altman plot of mean differences between (a) CCTV Setup and Observer 1 (persons/humans), (b) CCTV Setup and Observer 2 (persons/humans), (c) Observer 1 and Observer 2 (persons/humans), (d) CCTV Setup and Observer 1 (vehicles & tri-cycles), (e) CCTV Setup and Observer 2 (vehicles & tri-cycles), (f) Observer 1 and Observer 2 (vehicles & tri-cycles)

4. CONCLUSION AND RECOMMENDATIONS

This sections presents the conclusion and give the necessary recommendations regarding the design and implementation of the CCTV camera system for monitoring Ghanaian University.

4.2 Conclusion

The main objective of this study was to design and test a CCTV system in monitoring vantage points of C. K. Tedam University of Technology and Applied Sciences (CKT-UTAS). The system monitors in real-time, the visual information of targets at security posts situated across the campus. Currently, these security post is being assigned larger number of security personnel to physically guard the post. This is requires much efforts, time and error prone. CCTV setup is advantageous in automating the monitoring process with no or less human effort and skills. In this study, we compare the performances a proposed CCTV monitoring system with physical/manual monitoring approach. After observing and analyzing the trends in data from both the physical and our proposed automated monitoring approach, it can be concluded that the CCTV camera setup outperforms the physical and manual form or monitoring vantage security posts on University campus. The CCTV system was found to be a reliable tool for monitoring security posts such as the entry and exit post of the University Campus

4.3 Recommendations

Since the monitoring of security post using the proposed CCTV setup is advantageous in requiring lesser human effort and skills, and exert little strain on the campus' security personnel, coupled with the fact that its performance is comparably and in some situations higher than that of the manual method of monitoring security post, it can be recommended to adopt the proposed CCTV camera setup system for efficient security and monitoring

Ethical Approval

An informal ethical approval was sought from the security unit of the university to conduct this study

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Welsh, B. C., Piza, E. L., Thomas, A. L., & Farrington, D. P. (2020). Private security and closed-circuit television (CCTV) surveillance: A systematic review of function and performance. *Journal of Contemporary Criminal Justice*, *36*(1), 56-69.
2. Circo, G., & McGarrell, E. (2021). Estimating the impact of an integrated CCTV program on crime. *Journal of experimental criminology*, *17*(1), 129-150.
3. Veni, S., Anand, R., & Santosh, B. (2021). Road accident detection and severity determination from CCTV surveillance. In *Advances in Distributed Computing and Machine Learning* (pp. 247-256). Springer, Singapore.
4. Han, J. H., Ok, S. H., Song, K., & Jang, D. Y. (2017). CCTV monitoring system development for safety management and privacy in manufacturing site. *Journal of the Korean Society of Manufacturing Technology Engineers*, *26*(3), 272-277.
5. Polyakov, V., Mezhenin, A., Vereskun, V., Korobeynikov, A., & Shapovalov, V. (2021). Synthetic Datasets for Testing Video Security Systems. In *International Conference on Intelligent Information Technologies for Industry* (pp. 672-680). Springer, Cham.
6. Yoon, Y. I., & Chun, J. A. (2014). Tracking System for mobile user Based on CCTV. In *The International Conference on Information Networking 2014 (ICOIN2014)* (pp. 374-378). IEEE.
7. Kanyal, H. S., Goel, M., Tomar, A. S., Yadav, H. K., & Singh, K. (2020). Object Recognition and Security Improvement by Enhancing the Features of CCTV. In *2020 9th International Conference System Modeling and Advancement in Research Trends (SMART)* (pp. 245-248). IEEE.

8. Acharya, D., Khoshelham, K., & Winter, S. (2017). Real-time detection and tracking of pedestrians in CCTV images using a deep convolutional neural network. In *Proceedings of the 4th Annual Conference of Research@ Locate, Sydney, Australia* (pp. 3-6).
9. Grega, M., Matiolański, A., Guzik, P., & Leszczuk, M. (2016). Automated detection of firearms and knives in a CCTV image. *Sensors*, *16*(1), 47.
10. Ar, M. L. A., Nugraha, Y., Ernesto, A., Kanggrawan, J. I., & Suherman, A. L. (2020). A computer vision-based object detection and counting for COVID-19 protocol compliance: a case study of Jakarta. In *2020 International Conference on ICT for Smart Society (ICISS)* (pp. 1-5). IEEE.
11. Pardamean, B., Abid, F., Cenggoro, T. W., Elwirehardja, G. N., & Muljo, H. H. (2022). Counting people inside a region-of-interest in CCTV footage with deep learning. *PeerJ Computer Science*, *8*, e1067.
12. Jang, H., Hwang, T. H., Yang, H. J., & Jeong, D. S. (2014). Highway incident detection and classification algorithms using multi-channel CCTV. *Journal of the Institute of Electronics and Information Engineers*, *51*(2), 23-29.
13. Buch, Norbert, Mark Cracknell, James Orwell, and Sergio A. Velastin (2009). "Vehicle localisation and classification in urban CCTV streams." *Proc. 16th ITS WC* (2009): 1-8.
14. Haritaoglu, I., Harwood, D., & Davis, L. S. (1998a). W^4: Who? When? Where? What? a real time system for detecting and tracking people. In *Proceedings Third IEEE International Conference on Automatic Face and Gesture Recognition* (pp. 222-227). IEEE.
15. Haritaoglu, I., Harwood, D., & Davis, L. S. (1998b). W^4S: A real-time system for detecting and tracking people in 2½D . In *European Conference on computer vision* (pp. 877-892). Springer, Berlin, Heidelberg.
16. Shim, Y. B., & Park, H. J. (2015). A study on a violence recognition system with cctv. *Journal of Digital Contents Society*, *16*(1), 25-32.
17. Popoola, O. P., & Wang, K. (2012). Video-based abnormal human behavior recognition—A review. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *42*(6), 865-878.
18. Brotfain, E., Livshiz-Riven, I., Gushansky, A., Erblat, A., Koyfman, L., Ziv, T., & Borer, A. (2017). Monitoring the hand hygiene compliance of health care workers in a general intensive care unit: Use of continuous closed circle television versus overt observation. *American journal of infection control*, *45*(8), 849-854.
19. Hong, J. H., Lu, Y. H., & Chen, C. H. (2019). The use of CCTV in the emergency response: A 3D GIS perspective. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 19-25.
20. Ma, G., & Wu, Z. (2020). BIM-based building fire emergency management: Combining building users' behavior decisions. *Automation in Construction*, *109*, 102975.
21. Utochkin, S. (2003). The principles of CCTV design in VideoCAD. *CCTV Software. Available online: http://www. cctvcad. com (accessed on 13th August 2022)*.

22. Mezhenin, A., Izvozchikova, V., & Ivanova, V. (2018). Use of point clouds for video surveillance system cover zone imitation. In *MICSECS*.
23. Lee, L. K., Zachariah, M., & Everett, P. (1995, July). CCTV camera site selection: a field experience. In *Pacific Rim TransTech Conference. 1995 Vehicle Navigation and Information Systems Conference Proceedings. 6th International VNIS. A Ride into the Future* (pp. 21-27). IEEE.
24. Kim, Y., Park, S., & Kim, H. (2017). Crowdedness measuring system considering view angle of CCTV camera. In *2017 International Conference on Information and Communication Technology Convergence (ICTC)* (pp. 1149-1152). IEEE.
25. Adamek, M., Bařinová, M., & Havíř, T. (2016). Software for CCTV systems design. In *MATEC Web of Conferences 20th International Conference on Circuits, Systems, Communications and Computers (CSCC 2016)*. EDP Sciences.
26. Lahtinen, T., Sintonen, L., Turtiainen, H., & Costin, A. (2021). Towards CCTV-aware Routing and Navigation for Privacy, Anonymity, and Safety-Feasibility Study in Jyväskylä. In *2021 28th Conference of Open Innovations Association (FRUCT)* (pp. 252-263). IEEE.
27. British Standard Institution - BSI (2015a). Multi-part Document BS EN 62676 - Video surveillance systems for use in security applications, pp. 1–82, 2015. https://doi.org/10.3403/BSEN62676. Accessed from https://landingpage.bsigroup .com/LandingPage/Series?UPI=BS%20EN%2062676 on 4th July 2022.
28. British Standard Institution - BSI (2015b). British Standards Document BS EN 62676-Part 4 Video surveillance systems for use in security applications. Application guidelines, pp. 1–82, 2015. https://doi.org/10.3403/30311580. Accessed from https://landingpage.bsigroup.com/LandingPage/Undated?UPI=00 0000000030319373 on 4th July 2022.
29. Ma, J., Xv, N., Zhao, Y., Li, S., & Li, J. (2017). Research and Design of Campus Video Surveillance System. In *2016 International Forum on Mechanical, Control and Automation (IFMCA 2016)* (pp. 146-149). Atlantis Press.
30. Sarikonda Poojitha, D., & Bhutada, S. (2020). Customized campus surveillance system. International Research Journal of Engineering and Technology (IRJET). Volume: 07 Issue: 01. Page 737-739
31. Ansong, K. K., & Ofori-Dwumfuo, G. O. (2015). The use of CCTV in crime combating in a Ghanaian university. *Research Journal of Applied Sciences, Engineering and Technology*, *11*(11), 1196-1209.
32. Kwaa-Aidoo, E. K., & Agbeko, M. (2018). An analysis of information system security of a Ghanaian university. *International Journal of Information Security Science*, *7*(2), 90-99.