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SYSTEM DESIGN OF VIDEO SURVEILLANCE

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Abstract. This paper describes the steps involved in designing of a video surveillance system. It discusses the theory of video surveillance types, components involved, selection of the best equipment, and also a detailed virtual design. An introduction of the concept of video surveillance systems is followed by the detailed discussion of design considerations and the design verification. The system is designed to monitor a bank floor where the monitor displays the desired output from a simulated implementation of the system.

Keywords: system design, video surveillance, CCTV.

INTRODUCTION

There are many different types of Closed Circuit Television (CCTV) systems available, analogue and digital, wired and wireless and their modes of operation vary; however, the basic components are more or less the same: a camera, a lens, a monitor, and (for wired systems) cables that carry the signal from one place to another. Many systems also use video recorders to record the video footage [1].

The camera picks up the signal from the area being monitored via the lens (which determines how far and how much the camera can see, and which is often bought separately) and can be either wired or wireless. In a wired system, the camera sends the signals through a cable to the monitor; in wireless systems, no cable is needed, and the camera broadcasts the signal straight to the monitor [2].

The monitor can be either a simple television set (without tuning capacity) or a PC or laptop. Most wired analogue systems use television monitors, while digital and wireless systems tend to use computers as monitors for which remote viewing is possible, often via the internet.

For recording purposes, the monitor is accompanied by a video recorder, a Video Cassette Recorder (VCR) for analogue systems, or a Digital Video Recorder (DVR), or Network Video Recorder (NVR) for digital systems. A DVR can actually replace the monitor as the receiving device, since many DVRs are stand-alone units that do everything a computer would do: receive, record, and store the information for later viewing [3].

Closed Circuit Television refers to a system of surveillance cameras that sends signals to a specific location, a monitor, or PC. CCTV systems are commonly used to monitor banks, shopping malls, and government facilities, and these days, as CCTV technology becomes more affordable and easier to use, more and more people are installing CCTV cameras in their homes and businesses.

Closed Circuit Television system is an integral component of the security measures that may need to be adopted by an institution. The institution's premises may need to be monitored on a regular basis to ensure safety. The need and extent of safety required helps in deciding the investment required for the CCTV system; for example, deciding whether procuring a single camera and monitor will suffice or a complex video surveillance system with multiple cameras, multiple operators and digital recorders are required [4].

DESIGN AND METHODOLOGY

Before any installation of video surveillance system, an in-depth study of the site must be carried out with the following aims:

1. Identifying need of the system.
2. Identification of the objective of the security concern, whether it is outside or inside, near or far.
3. Identification of area needing surveillance.
4. Where the cameras will be installed.
5. Identification of the prevailing light conditions.
6. How the images will be captured, viewed, recorded and stored for observation and reference.
7. The system design.
8. Purchasing the right products and making installation decisions that help save time, effort and money.

Site study and analysis

Field view

It is important to work with the end user to understand what field of view is required to be seen on the monitor. The field of view is the width and height of the scene as viewed by the lens. It depends upon the focal length and distance of the object.

Any field of view has some critical area which is the target area. For example, when the camera is viewing a gate, the space the car is coming through is the critical viewing area or if one is watching the door, the space occupied by a person walking through the door is a critical viewing area. In the same way, every scene has a critical viewing area. This critical viewing area is usually ignored while selecting a lens for an application. After the installation is complete, it is not uncommon to hear comments that the end user wants to positively identify the person, but is not able to do so with the lens installed. The following steps outline the procedure for performing the site analysis.

Step 1

Identification of the scene area which needs to be covered by the lens and estimation of the width or vertical height of the scene is done.

Step 2

Estimation of the distance from the camera to the scene.

Step 3

To calculate the focal length of the lens, standard formula method, and lens wheel calculator method are used. In standard formula method, the focal length can be calculated using either the scene width or height formulas. In lens wheel calculator method, many lens manufacturers provide this lens calculator. It is quite simple to use and the focal length of the lens can easily be calculated depending upon the object distance and scene dimensions. The limitation is that it does not tell how large the critical viewing area will be on the monitor.

Step 4

In any scene, there are areas or moving objects, which are critical. It is important to understand what is required, for a detection or positive identification.

Step 5

Calculating of the viewing area of the scene and also of the critical viewing area by multiplying the horizontal and vertical dimensions, and dividing the critical viewing area with the total viewing area to get the size of the critical viewing area in the monitor.

Step 6

If the proportion of the critical viewing area is as expected, then the calculated focal length is used; if not, then the focal length is changed till the correct proportion is found or the distance of the camera is changed until the correct proportion is found. If this fails, one may have to choose a lens which is the nearest to the requirement.

Prevailing light conditions

Several measurements need to be undertaken to ensure that the correct camera is chosen for the prevailing lighting conditions on the scene. Finally, a comparison of the actual light at the scene with the minimum scene illumination is made. If the light available is more than the minimum scene illumination indicated, then the current camera can be used. If the actual light at the scene is lower than the adjusted minimum scene illumination of the camera, then the camera setting may require adjustment or an alternative solution is necessary.

Choice of camera and data transmission modes

Choice of camera

There are many different camera and data relaying modes to choose from however an informed choice should be derived from the best value for money, robustness, future proofing, ease of installation and maintenance and fast deplorability.

For these reasons, fixed wired cameras are chosen over wireless ones because although wireless cameras can be moved to other locations requiring observation, they require dedicated frequencies, for data transmission to and from cameras, that are prone to interruptions and which may end up distorting the picture. The picture quality is also seriously compromised which means that if the signal to be retransmitted over the internet for remote viewing for example, any further degradation of the picture quality would result in an unusable image.

Calculations of minimum scene illumination. Various losses dramatically reduce the level of illumination reaching the faceplate. Hence, in general CCTV rules of thumb are often used to approximate a calculation. For example if the faceplate illumination is quoted as 1 lux, the actual average illumination falling onto the horizontal should be 200 × lux or more to receive good pictures (e.g. 0,1 lux at faceplate = 20 lux average horizontal requirement).

If the camera illumination level is quoted then it will need 10 × lux average horizontal for a good picture and 50 × lux, for full video recording quality pictures.

Choice of video system

There is also the choice between using analogue or digital data transmission. DVRs have the advantages of superior search capabilities, remote access and easier integration with other security systems over traditional analogue and VCR systems. This informs the choice of digital video over the analogue type.

Choice of data transmission mode

Here, the choice of using an IP based wiring system is already dictated by the decision to use DVRs instead of VCRs for storage and retrieval of the surveillance data. The use of fibre-optics is not considered because the cost is too expensive to the end user.

Operational and equipment specifications

Equipment

The following equipment are used.

1. Stand-alone DVR(Model NVR1004+).
2. Cameras (There are many choices from CMOS to Charge Couple Device(CCD) and even IR-cameras which take images in the dark. CCD cameras are recommended over CMOS ones, as for IR-cameras, they are only good for close distances).
3. Cables (point-to-point unshielded twisted pair wire, 24–16 American Wire Gauge (AWG) (0, 5–1,5mm), stranded or solid, category 2 or better).
4. Router(s).
5. Power supply cables.
6. Electrical sockets.
7. Mounting brackets (for mounting the cameras).

The video signal may co-exist in the same wire bundle as other video, telephone, data, control signals, or low-voltage power. Shielded twisted pair wire is not recommended; however multi-pair wire (6 pair or more) with an overall shield is recommended. Un-twisted wire should also not be used. For safety, video signals should never be placed in same conduit as high voltage wiring.

After the equipment has been acquired, some other specifications that may to be identified are: operation of system, system to be installed or connected, and future expansion.

Installation of the system

After identifying the sites where the cameras are to be installed, cables are laid down from the cameras to the DVR. After the DVR is configured, it can be set to record only when there is movement in the area. This will reduce the hard disk requirements tremendously.

The system can be set up as shown in Fig. 1. The DVR is connected to the router (192.168.0.1) using LAN cables.

The following should be noted about the connection:

1. The IP addresses are arbitrarily assigned.

2. The PC computer (192.168.0.3) is there to set up the DVR via a user interface that is accessible via the LAN connection.

3. The ADSL modem provides internet access to the system.

4. Only 2 cameras are indicated to be connected here however this is determined by the number of ports available at the DVR.

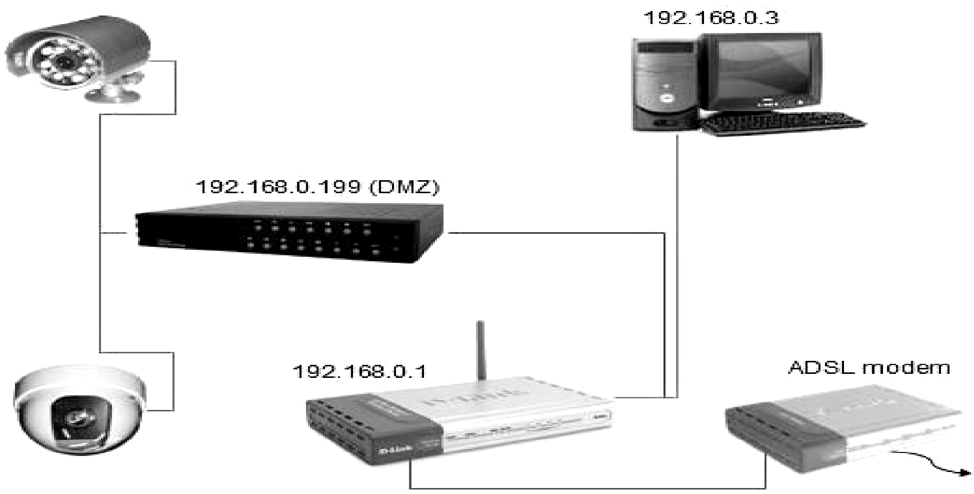

Fig. 1. DVR camera setup

Design using videoCAD

Due to various constraints pertaining physical design of the system, a more computer based approach is favored since such modeling would not only make the eventual installation more manageable but also practical results could be simulated with an aim of perfecting the proposed system way before implementation. Additionally no one company approached is willing to share their architectural plans with this designer citing, various reasons including fear of industrial espionage and the risk that such non contractual disclosure could lead to security breaches within their premises. For these reasons, this designer is inclined to model a system using CCTV system simulation software known as videoCAD which is freely available on the internet (as a Demo version) and which is adequate to accomplish the objectives of this particular paper.

The following steps are carried out in order to implement the system as a computer simulated video surveillance system:

1. Identification of the area under surveillance.
2. 3D mapping of the area.
3. Introduction of different camera types into the area under surveillance.
4. Placement of “objects” that may be construed as intrusions or otherwise, at strategic locations with a view of testing the relevance of camera placement areas.
5. Viewing of the surveyed area on a simulated monitor.
6. Calculations of illumination to ascertain that night-time surveillance is possible using the same cameras with luminaries’ where necessary.

7. Conclusion as to the success or failures of the system and what it would take to make it a reality.

Identification of the area under surveillance

For the purposes of this particular paper, a bank floor area is chosen as a good example to demonstrate the proposed system. The bank floor plan includes two floors, an upper ground floor and a lower ground floor both of which would be equipped with cameras to survey activities in the key area in an around them.

Two exterior areas are also identified; the ATM area and the car park area which also need dedicated cameras capable of night-time surveillance.

The following areas are identified as key areas requiring constant camera monitoring: lower ground floor level: front door and desk, ATM lobby and entrance, banking hall, teller booths, back office, back office-banking hall adjoining doorway and room and counting room. Upper ground floor level: open work plan area, parking area.

All cameras with the exception of the ATM entrance and front entrance cameras are Pan-Tilt-Zoom (PTZ) cameras. The use of fixed cameras is to avoid tampering with the person identification setting on those cameras surveying key areas.

All cameras installed are dome type overhead at a height of 3m (approximately) from normal floor level.

3D mapping of the area

Construction of the area in need of surveillance is done using AUTOCAD and videoCAD computer software both running on a Windows Vista operating system.

Introduction of cameras to the areas under surveillance

Cameras are placed at strategic positions in the identified areas. Care is taken not to unnecessarily place too many cameras surveying one scene leading to redundancy and unnecessary expense. For example one camera with a pan feature is installed to survey the back office and washrooms area, however the ATM area being a critical security area has dedicated cameras monitoring the entrance (to ATM booths) and another to view the ATMs.

Calculations of illumination to ascertain that night-time surveillance is possible using the same camera setup

At this stage, the following assumptions have to be made:

1. Specification of camera sensitivity would be supplied by the manufacturer.

2. A luminaire would be used also whose specifications would also be known.

RESULTS

Calculation of minimum scene illumination

Data from Field survey

The following data are considered:

1. Area to be viewed: Building wall.
2. Distance from subject to camera: 10 m.

3. Average horizontal illumination: 100 lux average (50% minimum).
4. Plane of subject to be viewed: vertical.
5. Reflectivity of subject: wall, average 30% (minimum).
6. Intensity of lighting off wall: 312,5 candelas.
7. Reflectivity of ground in front of the wall: average 37% (minimum).
8. Assume f-stop value lens and iris: F1.4.

Camera data

The following data are considered:

- Minimum faceplate illumination of the chosen camera: 0,1 lux for good pictures.
- Minimum scene illumination of chosen camera: 0,6 lux.
- F1.4.
- 50% reflection.

Available illumination at the camera lens

- Light falling in front of the wall: 100 lux average.
- Minimum light falling in front of the wall: 50% of average = 50 lux.
- Minimum light reflected from ground onto the wall: 37% of minimum at ground = 18,5 lux.
- Minimum light from the wall toward the camera: 30% of that arriving on wall from ground = 18,5 · 0,3= 5,55 lux. Intensity at this point is 312,5 candelas(given).
- Loss of light due to distance to camera (assuming light reflected directly towards camera):

$$E = I / d^2 ,$$

where E= lux level at the camera; I = intensity in candelas at the wall; d = distance from wall to camera;

$$E = 312 / 10^2 = 3{,}124\, lux .$$

Theoretical illumination

At the faceplate of camera with an F1.4, c is given by

$$C = 1/4 f^2 ,$$

where $C =$ illumination level at faceplate with 100% transmittance and $f = f$ -stop value used on iris;

$$C = 1/(4 \cdot 1,\ 4^2) = 0{,}127$$ (Or 12,7% of that arriving at the camera).

Thus, faceplate illumination available = 3,125 lux · 0,127 = 0,39 lux.

Camera minimum faceplate illumination = 0,1 lux. Rule of thumb: required faceplate illumination × 200 = average horizontal illumination required at scene = 0,1 · 200 = 20 lux. Actual horizontal average (100 lux) and minimum (50 lux) are both well above 20 lux required by the rule of thumb calculation.

Camera scene illumination level

Rule of thumb: 10 × camera illumination level required for good picture = $0{,}6 \cdot 10 = 6$ lux, (Both 100 lux average and 50 lux minimum are well over this).

Camera distances and faceplate illuminations

Table shows faceplate illumination at different distances where faceplate illumination $= E \times C$.

Faceplate illumination at different distances

Distance from scene to camera	10	8	6	4	2	2
Faceplate Illumination (lux)	0,39	0,619	1,102	2,48	9,92	39,68

From Table, the selected camera is suitable for use within the distances shown since the calculated faceplate illumination exceeds the minimum value indicated on the camera (0,1 lux). At very large distances (see Fig. 2) however the illumination approaches 0,1 and the camera becomes unusable. Hence the selected camera is capable of effectively being used in the CCTV system.

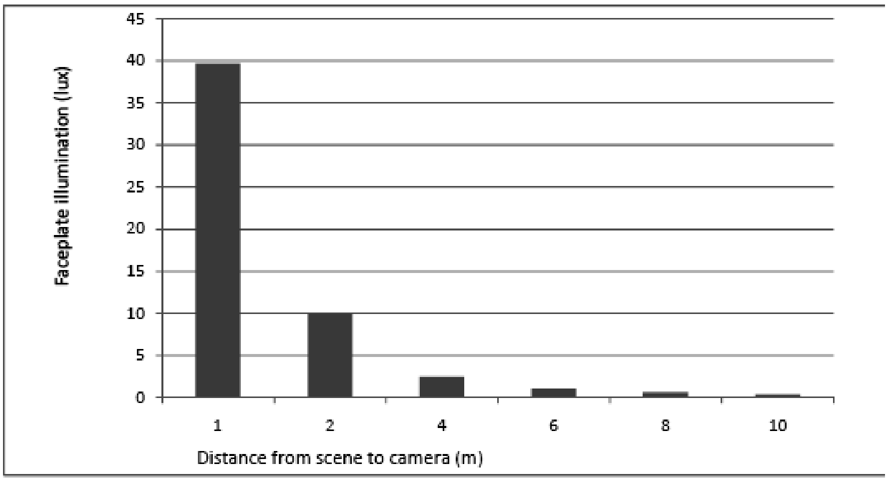

Fig. 2. Faceplate illuminations at different distances

Lighting level calculations are required to be provided by the system designer to show how a chosen camera would be suitable, many manufacturers make it difficult for the true camera needs or performance to be established by publishing either partial information, introducing unseen assumptions, which enhance apparent performance, or deliberately inflating the claims.

Viewing the surveyed area on a monitor

A total of 15 cameras in total are used to survey both the lower and upper ground floors as shown in Fig. 3.

It is possible to select a particular camera and pan to a desired angle, indicating that the user could effectively alter the view angle to a point of particular interest.

The ATM camera is installed such that it could only be used for person detection. This is done as a security measure to prevent misuse of the system to read confidential data from the ATM while a customer is using the ATM machine.

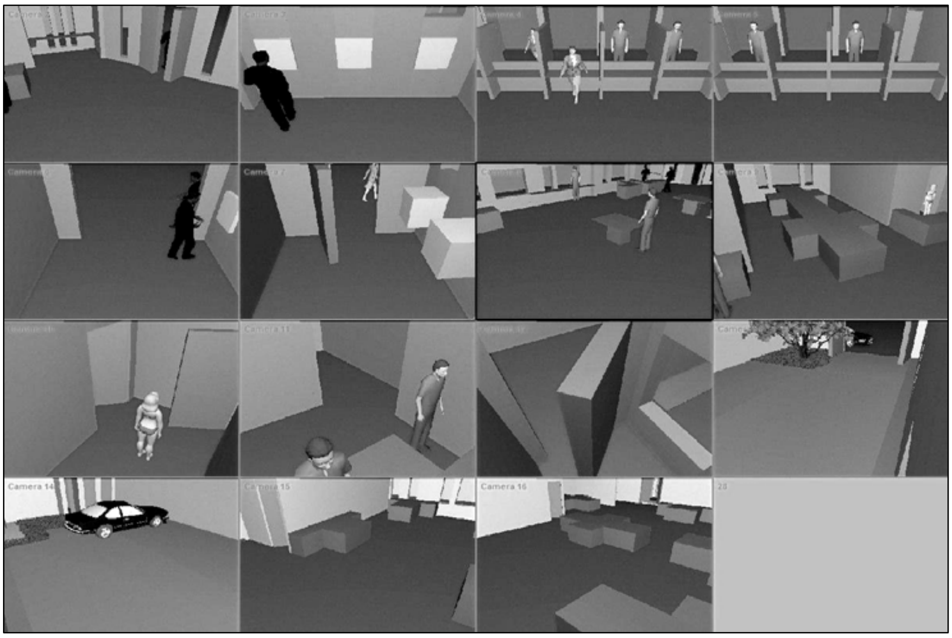

Fig. 3. View of the area under monitor

Night-time surveillance

Night-time surveillance results are obtained which proves that the system can be used (together with the appropriate luminaires) to survey a specific area at night as can be seen in Fig. 4.

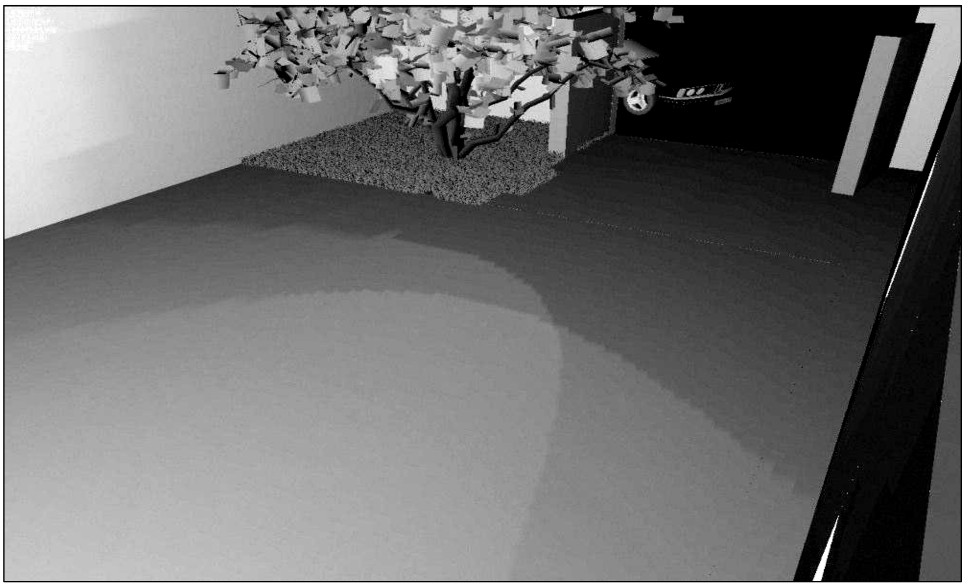

Fig. 4. Parking area under night time surveillance with illuminators

Satisfactory scene surveillance is obtained after incorporating illuminators into the system. It is possible that the luminaire(s) could double as security lamps and in so doing deter potential security threats.

A disadvantage here would be that the system would largely remain insecure if the illuminators are to be switched off during night-time surveillance hours. A possible counter to this would be to incorporate an alarm system which would be triggered by a switch off of the lighting.

CONCLUSION

The system design parameters were used to model a video surveillance system using videoCAD software, which was able to produce a useful security monitoring tool. The importance of such a model was also demonstrated by the fact that tedious camera mounting and removal exercises to ascertain optimum camera placement positions would be eliminated. This would be beneficial to fast deployment of such a system by cutting down on design time and cost of implementation. Further the design also looked at night-time surveillance and demonstrated that this could be accomplished using the software.

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