Integrating Geospatial and CCTV Technologies for Security and Safety Monitoring in Lokoja Metropolis, Nigeria

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Abstract— **Rapid advancement in technology and the desire for security and safety in cities have resulted in a significant number of monitoring tools in contemporary time. One of the most practical tools for metropolitan monitoring is the Closed Circuit Television (CCTV) imaging, which is widely used to generate and update real-time features through surveillance. The current study aims at the integration of geospatial and closed circuit television (CCTV) for monitoring security and safety situations in Lokoja metropolis. Spatial analysis was used to determine suitable locations of CCTV cameras. With the advantages of GIS in geographical space, the system is useful in accomplishing spatiotemporal management of the numerous cameras and its data. The spatial distribution and monitoring range of the CCTV cameras are presented on the GIS map. Also, the layout densities of the cameras as well as other important information are provided in geospatial database. Furthermore, merging the road network and the locations of cameras enhances the system's capacity to obtain accurate topological connection between cameras, as well as other features of interest.**

Keywords— **CTV, crime, GIS, geospatial, urban**

I. INTRODUCTION

There is a rising need for the future cities to be safe, more sustainable, efficient, comfortable, interrelated and 'smart' [1]. A variety of smart technologies are been used in modern time to modify urban infrastructure into "smart" infrastructure. This includes city-wide acquisition of digital data, geospatial systems for finding location, security cameras for video surveillance, and others. There is a significant degree of agreement that the pervasive installation of 24 hours electronic surveillance systems in urban settlements is an outstanding initiative. This is because real-time video monitoring is an essential tool in surveillance systems for various security, law enforcement, and military applications. Generally, real-time data and information affords the capacity to observe actions as they occur, and comprehend how demand are shifting, as well as responding with faster and lower cost solutions. More often than not, video surveillance is basically meant for critical infrastructure protection [2] or in big open public places and events, but they are equally applicable in other areas of interest. The increased prevalence of surveillance cameras in public places in recent time has led scholars to consider Closed Circuit Television (CCTV) systems as a "banal good" that has become part of everyday life [3], [4]. Nowadays, automated surveillance systems forms central core in effective infrastructures that enhance crime detection, prevention and the apprehension of criminals [5], [6]. CCTV systems have also become part of this infrastructure and are now very important and effective systems to implement in today's environments [7], [8] as they are used not only on motorways anymore, but also on cash machines, housing estates, shopping malls, apartments, and car parks [9]-[12]. It is considered as a technical solution to security problems, because it offers effective support in preventing, detecting, and/or prosecuting crimes ranging from major terrorism to minor vandalism [13]. For instance, from the IRA terrorist campaign in the 1990s and the Brixton nail bomber in 1999, to the terrorist incidents in London in July 2005, CCTV released to the public led to early identification of suspects and played an important role in the subsequent prosecutions.

Installation of CCTV is normally done with consideration to important issues like crime, accident, congestion, road conditions, and so forth [14]. These issues take place in geographical locations, and thus can be seen as geospatial problems. Consequently, a geospatial solution to insecurity and danger can be achieved with reasonable efficiency through the integrated system of geospatial and CCTV technologies. Generally, the performance of CCTV systems can be enhanced by optimizing the configuration of cameras in the entire network [15], [16]. In this regard, GIS is highly efficient in determining the optimal positions of cameras based on the analysis of CCTV images. For example, the 'Isovist Analyst' or viewshed analysis in GIS environment is used to identify a minimal number of CCTV for complete coverage of a target area. Also, remote sensing, especially high resolution satellite data are potent tool in planning of CCTV programme. Moreover, GPS is highly effective in fixing appropriate positions of CCTV cameras.

The current paper proposes an integrated system of video surveillance and geospatial method, which fuses the spatial information and camera position to obtain the topological relations of cameras, and between cameras and features of interest. The integrated system is not restricted to displaying only the spatial distribution, or the monitoring range and the layout density of the cameras on the GIS map, but it also establishes the spatiotemporal relationship between the videos of various cameras.

II. MATERIALS AND METHODS

A. Study Area

Lokoja is the administrative capital of Kogi state and is located in the north – central geopolitical zone of Nigeria between latitudes 7º 45´N and 7º 51´N of the Equator and longitudes 6º 41´E and 6º 45´E of the Greenwich Meridian (Figure 1). It occupies a total land area of about 3,180 square kilometres at an altitude of 45 – 125 meters above sea level towards the north-west and at the foot of the Panti ridge. The highest elevation in Lokoja is at the peak of Panti ridge, which is about 400m above mean sea level.

Lokoja enjoys both wet and dry seasons with the total annual rainfall between 804.5mm-1767.1mm, and a range of about 962.6mm while mean rainfall is about 1216.86mm [17]. The mean annual temperature of the study area is about 28.03C and a relative humidity of 30% in the dry season and 70% in the wet season, while the average daily wind speed is 89.9 km/hr.

Lokoja is one of the ancient towns in Nigeria that assumed Metropolitan status before Nigerian independence in 1960. Also, before the establishment of Lokoja as a State capital in 1991, the population was below 40,000. By 1991 it increased to it had a total population of 82, 483 [18], while in 2006, the population stood at 196,643 [19].
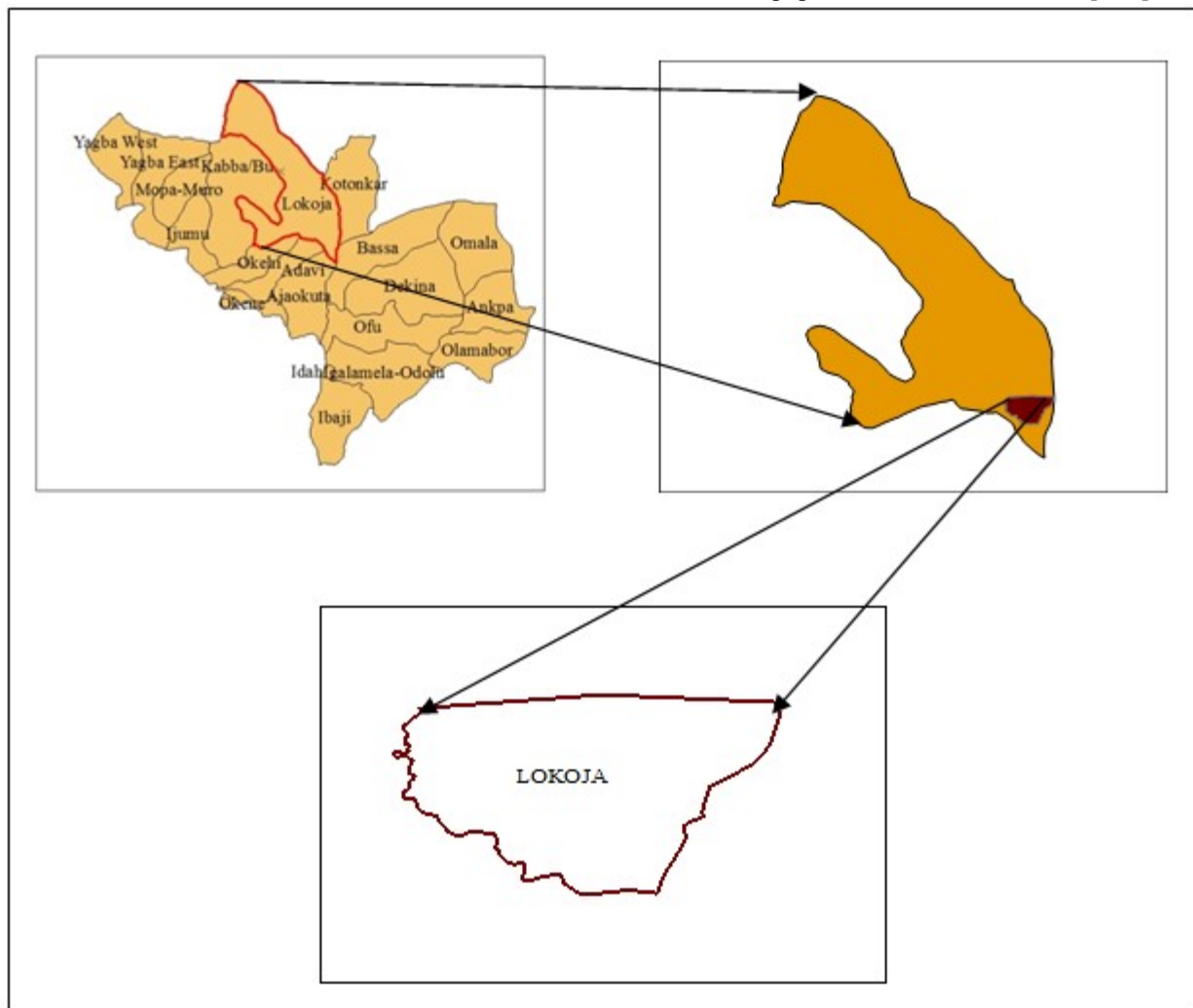

Fig. 1: Location of the Study Area-(top left is the map of Kogi State showing all the L.G.As; top right is the map of Lokoja L.G.A showing Lokoja metropolis in brown color; below shows the boundary of Lokoja metropolis)

B.   Data

The major data used in the current study, include Google earth, horizontal coordinates and elevation data of selected points within the study area.

C.   Location survey and street guide mapping

Location survey was used to acquire sufficient detail for addressing the security and safety requirements of the area of study, and for preparing a site plan with the optimal positioning points for CCTV cameras. Location survey and the site plan are essential in identifying the best positioning for CCTV cameras, the direction of natural light, potential and actual environmental problems, etc. Furthermore, the positioning of CCTV cameras for municipal monitoring is best at road junctions and along streets. Thus, the street guide map of the study area was produced using satellite image of the study area along with field-based (GPS) co-ordinate data.

D.   CCTV System Design

1)   Surveillance Coverage Evaluation

Surveillance performance signifies the degree of efficiency that a target area is being monitored by a CCTV system. In the current study, we propose two indicators as quantitative measures of surveillance performance. These are surveillance resolution and surveillance coverage index. Surveillance resolution indicates how closely a specific object can be monitored with a CCTV system, depending on the location and orientation of the object as well as the cameras of the CCTV system. Surveillance coverage index focuses on a specific region rather than an object, indicating how completely a region of interest can be monitored with more than a specified surveillance resolution.

2)   Spatial Distribution of CCTV Cameras

The spatial spread of CCTV cameras is a major work in CCTV monitoring system design. Upon this, both power supply and communication cable network designs are based. Thus, we selected the best camera locations that can provide the best monitoring and coverage of the entire proposed area in terms of the CCTV view. The height and direction of cameras were determined based on 'viewshed' analysis in GIS.

3)   Power, Communication and topology of CCTV system

Available power source, the communication cable network from every camera to control centre were done in the same way as camera positions are done. Finally, the relationship between cameras and selected salient features was established using GIS analysis.

4)   System architecture

The proposed integrated system uses three-layer architecture, which contains data layer, processing layer and presentation layer.

III. RESULTS AND DISCUSSION

A.   Street guide map of Lokoja metropolis

A section of the street guide map and extract of street statistics of the study area are indicated in Fig 2 and table1 respectively. A total number of 169 streets were mapped and the minimum and maximum street lengths are 0.04km and 10.35km respectively. Also, the sum of the entire length is 114.02km, while the mean and standard deviation are 0.67km and 1.14km respectively.

Regarding temporal aspect, the moving time of object from one camera to another camera based on the road network can be calculated, which is called transition time. Using the transition time, the temporal relationship of video data captured by different cameras can be established. The users can extract the associated video clips which are from various cameras, and achieve continuous object tracking among multiple cameras.
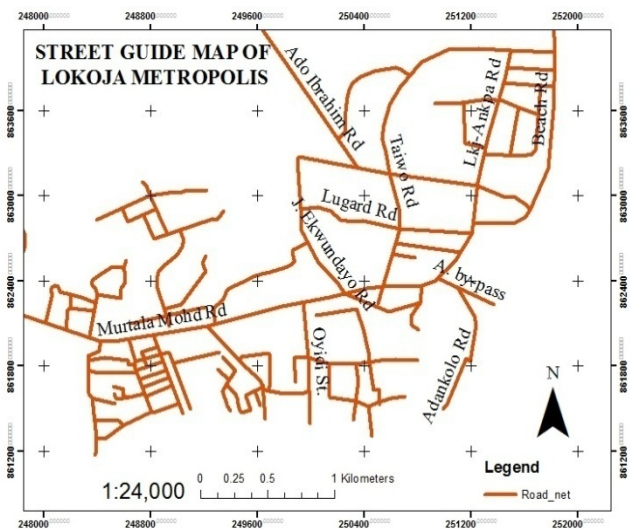

Fig. 2: Street guide map of Lokoja metropolis. (Source: Authors, 2019)

Table1: Extract of streets in the study area. (Source: Authors, 2019)

Name	Length (km)
Abuja-Lokoja	2.78
Daura Rd	10.35
Link Rd	1.68
H. Katsina Way	3.89
Kabba Rd	3.73
Murtala Mohd Rd	3.98
Lokoja-Ajaokuta Rd	0.83
Lokoja -Ankpa Rd	7.46
Taiwo Rd	1.98
Lugard Rd	1.31

B.   Spatial distribution of CCTV cameras in Lokoja metropolis

  The spatial aspect of CCTV camera placement is presented in this section. The proposed total number of cameras in the study area is 13. Each camera is displayed accurately as a point on the GIS map (fig 3). The Euclidian distances between cameras and direction of each camera are also shown (table 2). Based on the spatial reachability, the system is able to search the nearby cameras of the selected camera automatically and provide the actual distances between the selected camera and its nearby cameras. Physical establishment of each camera will require the use of GPS for accurate panning.
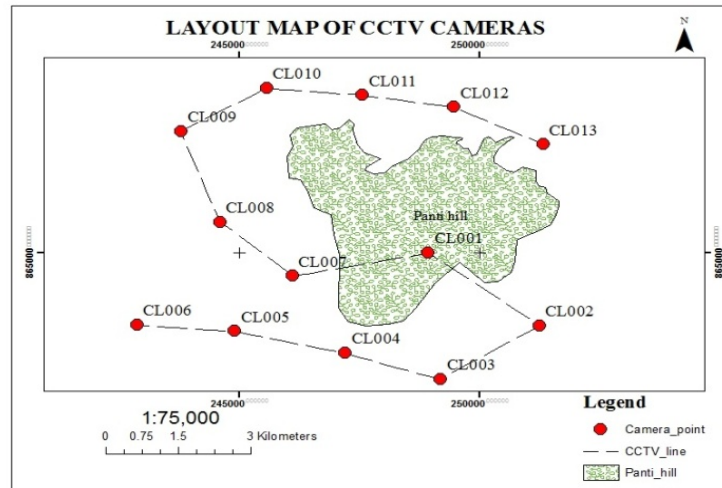

Fig. 3: Layout of proposed distribution of CCTV cameras in Lokoja metropolis. (Source: Authors, 2019)

Table 2: statistics of the proposed CCTV net work for Lokoja metropolis. (Source: Authors, 2019)

From node	Description	Northing (m)	Easting (m)	Bearing º '	Distance (m)	To node
001	Panti Rd	864986.75	248933.89	127º 15'	2,865.12	002
002	NPF Comd.	863288.58	251244.71	238º 32'	2,402.73	003
003	Ganaja Junctn	862035.44	249196.82	288º 11'	2,075.00	004
004	MM Way 1	862647.96	247214.28	283º 31'	2,364.89	005
005	Mammy Mkt	863159.84	244905.45	275º 03'	2,037.06	006
006	Otokiti 1	863303.19	242873.44	XXX	XXX	XXX
001	Panti Rd	864449.62	248933.89	259º 14'	2,877.77	007
007	Stadium	864449.62	246106.69	310º 51'	1,962.92	008
008	HK Way 1	865707.14	244599.47	340º 28'	2,267.69	009
009	Daura Rd 1	867830.60	243803.64	040º 39'	2,033.61	010
010	Felele 2	568836.12	245571.26	095º 43'	2,005.89	011
011	Felele 1	868671.47	247570.38	099º 14'	1,918.46	012
012	Court Rd	868397.19	249469.13	116º 13'	2,050.52	013
013	Int. Mkt	867523.89	251324.39	XXX	XXX	XXX

C.   Power, communication and Topology of CCTV system

Final camera locations are normally determined after checking available power source. However, apart from nodes 002, 003, 005, 007, and 013, the suitable locations as determined in this study does not have easy access to electric supply. Hence alternative (solar) power is suggested. Equally, according to the final camera positions, the installing plan of the communication cable network from every camera to control centre or controller cabinet were done in the same way as camera positions are done. Also, the cable's lengths were acquired through GIS network analysis function. Finally, the relationship between the cameras; and between cameras and selected salient features is presented in fig 4. All in all, there are 13 proposed nodes (camera locations) and 12 arcs (links). Places of interest such as high court and CBN as depicted in the figure 4 also fall either right or left of the arcs.

D.   System architecture

The current study proposes an integrated system which utilizes three-layer architecture, containing data layer, processing layer and presentation layer (Fig.5). For data layer, geographic data is the foundation of GIS functions. Camera attribute data contains the co-ordinate data of cameras, as well as the monitoring distances and bearings. Both geographic data and camera attribute data support the process of camera positioning, distribution density statistics and spatial relation analysis. Video data is captured by cameras and is the base of video analysis.

For processing layer, GIS and video surveillance are two core modules. Camera positioning is the basic mapping process, and distribution density statistics is to count the number of the cameras installed in a certain area. Spatial relation analysis mainly includes searching the reachable cameras and calculating transition time. Video analysis includes object detection, object tracking and object re-identification, which is mainly used for video object processing in single camera. Location of video is to find the video clips which are captured by other cameras but associated with the current video.

For presentation layer, as an interface between the system and users, it consists of map, markers display, video display and interactive interface. It is used to accept the request and return the response results.
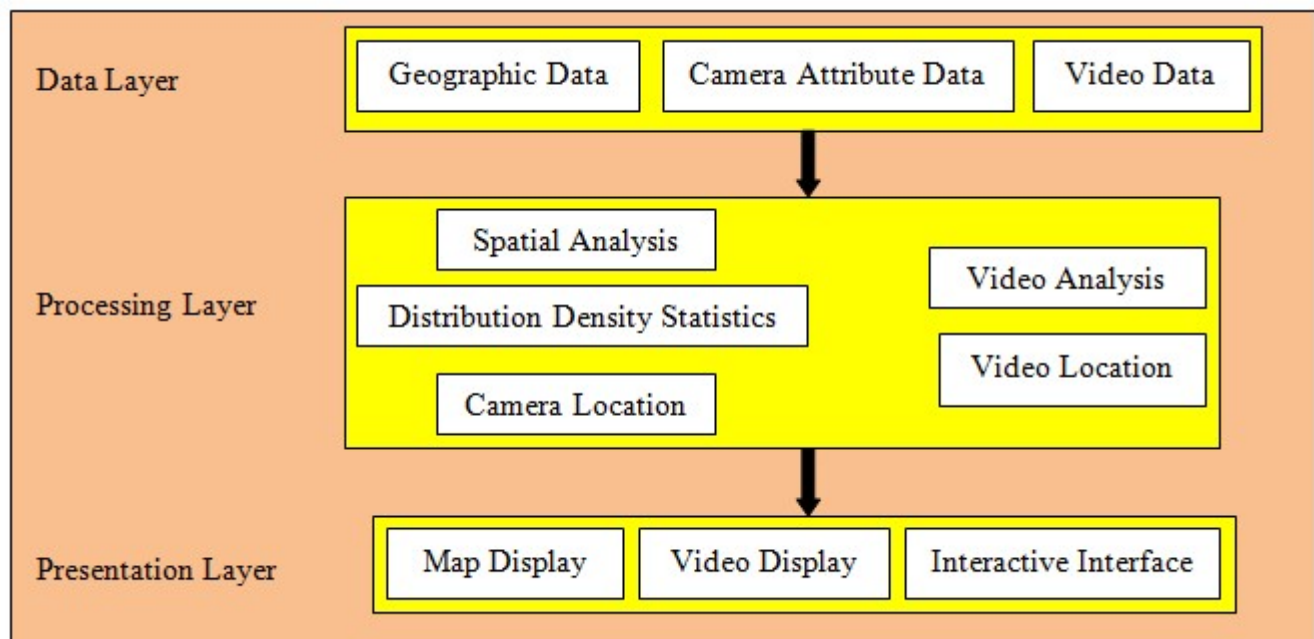

Figure 5: Software architecture of the system.

IV CONCLUSION

For the effective management of massive cameras and video data in video surveillance, it is crucial to obtain the spatial-temporal relationship of cameras fast and accurately. We design a framework of integrated system combining CCTV and geospatial technologies, which has the ability to acquire the accurate spatial-temporal topological relations of cameras. Therefore, the isolated cameras and the fragmented video can be effectively managed based on the spatial-temporal topological relations of cameras.

REFERENCES

[1]. Tiwari, A., Jain, K. (2015). Semantically Enriched Vision of Smart City. *ArcIndia News* 9:30-31. available from esriindiacom

[2]. Buttyá L.; Gessner, D.; Hessler, A.; Langendoerfer, P. (2010). Application of wireless sensor networks in critical infrastructure protection: Challenges and design options (Security and privacy in emerging wireless networks). *IEEE Wirel. Commun.*, 17, 44–49.

[3]. Hier, S.P., Greenberg, J., Walby, K., Lett, D. (2007). Media, communication and the establishment of public camera surveillance programmes in Canada. *Media, Culture & Society*, 29, 727–751.

[4]. Goold, B., Loader, I., Thumala, A. (2013). The banality of security: The curious case of surveillance cameras. *Brit. J. Criminol.*, 53, 977–996.

[5]. Norris, C. and M. McCahill, 2006. CCTV beyond penal modernism? *Brit. J. Criminol.*, 46: 97-118.

[6]. Teague, C., Green, L., Leith, D. Watching me watching you: The use of CCTV to support safer work places for public transport transit offices. In Proceedings of Australian and New Zealand Communication Association Conference, Canberra, Australia, 9 July, 2010.

[7]. Farrington, D.P., Gill, M. Waples, S. Argomaniz, J. (2007). The effects of closed-circuit television on crime, meta-analysis of an English National quasiexperimental multi-site evaluation. *J. Exp. Criminol.*, 3, 21–38.

[8]. Williams, D., (2008). Effective CCTV and the challenge of constructing legitimate suspicion using remote visual images. *J. Invest. Psychol. Offender Profiling*, 4(2), 97–107.

[9]. Welsh, B.C., Farrington, D.P. (2009). Public area CCTV and crime prevention: An updated systematic review and meta-analysis. *Justice Q.,* 26, 716–745.

[10]. Iqbal, M.U. (2010). Samsung lim, privacy Implications of automated GPS tracking and profiling, *IEEE Technol soc mag* , 29(2), 39-46.

[11]. Caplan, J.M., Kennedy, L.W., Petrossian, G. (2011). Police-monitored CCTV cameras in Newark, NJ: A quasi-experimental test of crime deterrence. *J. Exp. Criminol.* 2011, 7, 255–274.

[12]. McLean, S.J., Worden, R.E., Kim, M.S. (2013). Here's Looking at You: An evaluation of public CCTV cameras and their effects on crime and disorder. *Crim. Justice Rev.*, 38, 303–334.

[13]. Khalifa, O.O., Chebil, J., Abdullah, A., Hameed, S. (2011). Ethical issues in monitoring and based tracking systems. *IIUM Engineering J.,* 12(5),

[14]. Pribadi, A., Kurniawan, F., Hariadi, M., Mardi, S., Nugroho, S. (2017). Urban distribution CCTV for smart city using decision tree methods. 2017 International Seminar on Intelligent Technology and Its Application,

[15]. Yabuta, K., Kitazawa, H. Optimum Camera Placement Considering Camera Specification for Security Monitoring. In Proceedings of the IEEE International Symposium on Circuits and Systems, Seattle, WA, USA, 18–21 May 2008; 2114–221

[16]. Liu, J., Sridharan, S., Member, S., Fookes, C. (2014). Optimal camera planning under versatile user constraints in multi-camera image processing systems. *IEEE Trans. Image Process.* 23, 171–184.

[17]. Audu, E. B. (2012c). A descriptive analysis of rainfall for agricultural planning in Lokoja Local Government Area of Kogi State, Nigeria. International Journal of Science and Technology, 2(12), 850 – 855.

[18]. National Population Commission (1991). Final Results of Population Census of Nigeria.

[19]. National Population Commission (2006). Final Results of Population Census of Nigeria.