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MILITARY PROVING GROUND ELECTRO-OPTICAL SURVEILLANCE SYSTEM DESIGN

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Abstract: *Military proving ground is a common facility for testing of broad spectrum of military equipment, where safety of people, area security, presentation of results during the shooting tests, and general surveillance are very important. In order to obtain safety, security, efficient presentation of results during the shooting tests, and general surveillance, a surveillance system for such proving ground should be provided. Important properties of the proving ground are analysed and system requirements are defined. Based on these requirements the surveillance system is designed and implemented. The created surveillance system comprises the number of imaging sensors, including thermal and visible imaging sensors, communication network, control center and software for monitoring and control. The use of this surveillance system can have an important effect on how proving ground will be used with more efficient use and higher safety and security. Furthermore, with established surveillance system additional advancements are possible including the implementation of artificial intelligence algorithms for easier and more reliable use.*

Keywords: *Surveillance, imaging sensors, thermal imager, software, military proving ground.*

1. INTRODUCTION

The multi-sensor surveillance system is an adaptable modular system for managing distributed imaging sensors using human observed command and control station. Current advances in imaging sensors technology and manufacturing volume provides wider application in the security related multi sensor systems [1-4].

Video surveillance technology has been used in many civil and military applications for decades. There are many known military applications including patrolling national borders, measuring the flow of refugees in troubled areas, monitoring peace treaties, and providing secure perimeters around bases and embassies [5,6], and offten combined with other sensors [7].

It is important to understand system requirements and limitations to optimize surveillance system architecture according to aimed application and budget, and design system control and command software [8].

There is a widely available literature in a filed of civil video surveillance, including intelligent video surveillance [9], critical asset protection, perimeter monitoring, and threat detection [10], real time surveillance of people and their activities [11]. There are also applications in combined military civil environments [12]. However, there are specific requirements for surveillance of a military proving ground, which are not widely available in literature.

A military proving ground is an outdoor area, with specially built objects, used for firing, exercises (training range) or testing of weapons and military equipment (test range). For such area there is a need not just for general surveillance but also to obtain safety, security and more efficient presentation of results during the shooting tests.

In this paper some key design decisions are discussed. The main objective of this paper is to analyze the technological and application limits of the advanced video based surveillance systems generated by specific system mission and application environment as military proving ground is.

As a starting point we presented a basic properties of the selected proving ground facility that causes some limitation in the system arhitecture and generates basic requirements for system control and command software design. After that we described surveillance system architecture and application software requirements. As a final point we described software application structure and functions. All system components are manufacured and software application is tested in laboratory. The most of the hardware is deployed in the field, but some structural changes in the proving ground are not still finalized so system is not completely integrated and tested in the field. According to the results of the laboratory testing results and our previous experiences with complex electrooptical systems instalations in the field we do not expect problems.

2. THE MILITARY PROVING GROUND BASIC PROPERTIES

In order to design a surveillance system for such complex area it was necessary to perform a detail site survey. After the survey it was possible to analyze the properties of the proving ground and to define system requirements.

A satellite image of military proving ground with labeled areas and objects is shown in Figure 1.

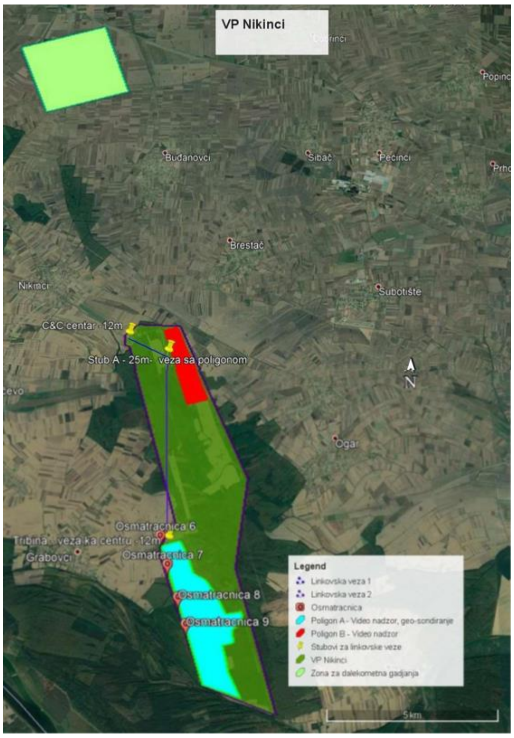

Figure 1. A satellite image of military proving ground with labels of internal areas and objects.

The military proving ground is a complex area consisting of a group of administrative buildings, and the rest is a combination of forests and meadows, where all the shooting and equipment testing is carried out, and additional objects like watchtowers. The forest is planted, about 10-15 meters high, quite dense. Meadows are used for agriculture, where wheat, corn and other agricultural crops are cultivated.

There is a need for military proving ground survaillance with combination of visible and thermal sensors, with three main purposes:

– during the shooting tests to spot a person in the area of the proving ground,
– to show the shooting to clients/visitors of the proving ground, during the shooting tests,
– security surveillance around a clock in order to detect unauthorized intrusions into the area of the proving ground.

If the person is spoted in the restricted area during the shooting, the shooting will be immediatelly stoped. It is not necessary that this person recognition is done automatically, but it would be sufficient for the operator in the monitoring room to see the person in the restricted area.

Safety of people is the most important, and even though there are already defined procedures and measures related to safety, it is always good to have additional insight during the firing tests provided with the surveillance system, especially having in mind that not only military proving ground employees and other people who are involved in tests, but also other people who work in the fields are expected within the area.

Military proving ground security is the next important topic, and similarly like with safety aspect, there are already defined procedures and measures related to security, however it is always good to have additional insight provided with the surveillance system, not only during the firing tests but also in any other time.

During the shooting tests there is a need to present results and real time insight is very valuable and helps to improve efficiency. With the designed solution, it will possible to achieve a significant improvement in operability and control at the proving ground itself, in a quick and effective way, which was the basic requirement.

Based on the collected information, the locations of special interest for the implementation of video surveillance project are defined and for all these locations the coverage zones for cameras are defined. Furthermore, other system requirements are defined.

3. SYSTEM ARCHITECURE AND DESIGN

The main system components are sensors, communication network, control center and software for monitoring and control, as shown in Figure 2.

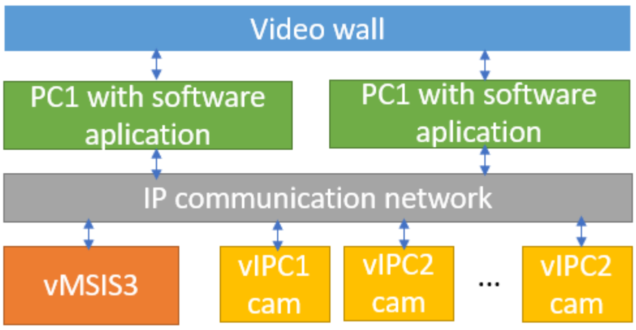

Figure 2. Main system components

The selected sensors for this application are one multisensory imaging system with thermal infrared imager and visible imager integrated on a moving positioner, and a number of fixed CCTV IP cameras. All sensors are connected to the control center through the IP network.

3.1 Imaging sensors

The multisensory imaging system with thermal infrared imager and visible imager integrated on a moving positioner, with integrated automated tracking, is custom designed for this application in order to provide optimal solution for this particular application. The thermal imager is uncooled 640x480, 17 um pitch, LWIR detector coupled with 28-225mm focal length continuous zoom lens, providing a field of view in range from 22,26° in the wide field of view, to 2,77° in the narrow field of view. The visible imager is a color CCD sensor coupled with 23-506mm focal length continuous zoom lens, providing a field of view in range from 11,92° in the wide field of view, to 0,53° in the narrow field of view. The implemented system is shown in Figure 3.

Figure 3. vMSIS3-USD2-C225 electro-optical system with thermal and visible imagers integrated on a pan tilt positioner.

Figure 4 shows coverage zones of vMSIS3-USD2-C225 electro-optical system with 2,77° narrow field of view shown with blue, and 180° area highlighted.

Figure 4. Coverage area with vMSIS3-USD2-C225 in patrol mode of operation

The fixed CCTV IP cameras are vCAM vIPC-3M1 camera modules. The vCAM vIPC-3M1 model is a compact camera designed for indoor and outdoor use. The basic function of this camera is to capture images of the scene, convert them into video content or a series of images, and then send them via the selected telecommunications network and/or save them in the local memory (SD card).

The vCAM vIPC-3M1 camera module is shown in Figure 5.

Figure 5. vCAM vIPC-3M1 camera module

The camera modules are integrated within a standard outdoor enclosure with IP66 protection, as shown in Figure 6.

Figure 6. An IP camera in an outdoor enclosure during the installation

As in this case observation of areas at longer distances is required, the VIPC-3M1 camera is configured to be used with a viewing angle of 30°, for which a human recognition range of up to 400m is expected.

Figure 7 provides coverage zones of fixed vCAM vIPC-3M1 cameras from planned locations.

Figure 7. Area coverage with vCAM vIPC-3M1 cameras configured with 30° field of view

3.2 Network parameters configuration

The communication network is reliable IP network based on fiber optical physical layer and standard passive and active equipment configured for particular need. In Figure 8 is shown block schematic of communication network.

In order to use the network bandwidth in optimal way, all equipment, including the cameras is configured to operate in broadcast mode of operation.

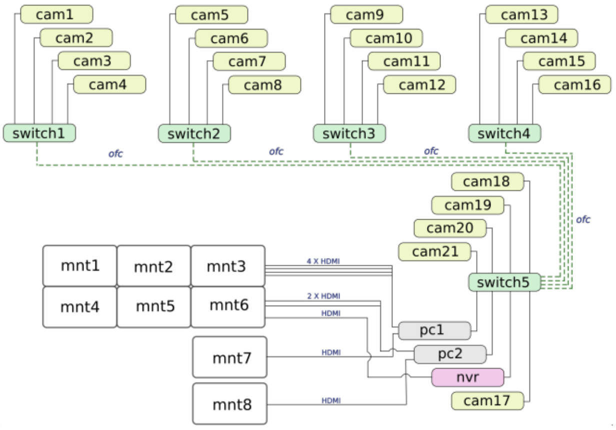

Figure 8. IP communication network

All IP camaras are configured in line with defined IP address plan as shown in Figure 9.

uredjaj	Proizvodjac	Model	oznaka	s/n	IP addr	Subnet	Gateway
svic	Eltex	MES3508P	switch1	PM28004258	**10.10.10.10**	255.255.255.0	10.10.10.01
kamera - osmatracnica 6	Vlatacom	vCam VIPC-3M1	cam01	DS1R-4031017	10.10.10.11	255.255.255.0	10.10.10.01
kamera - osmatracnica 6	Vlatacom	vCam VIPC-3M1	cam02	DS1R-4031020	10.10.10.12	255.255.255.0	10.10.10.01
kamera - osmatracnica 6	Vlatacom	vCam VIPC-3M1	cam03	DS1R-4031021	10.10.10.13	255.255.255.0	10.10.10.01
kamera - osmatracnica 6	Vlatacom	vCam VIPC-3M1	cam04	DS1R-4031022	10.10.10.14	255.255.255.0	10.10.10.01
svic	Eltex	MES3508P	switch2	PM28004125	**10.10.10.20**	255.255.255.0	10.10.10.01
kamera - osmatracnica 7	Vlatacom	vCam VIPC-3M1	cam05	DS1R-4031023	10.10.10.21	255.255.255.0	10.10.10.01
kamera - osmatracnica 7	Vlatacom	vCam VIPC-3M1	cam06	DS1R-4031024	10.10.10.22	255.255.255.0	10.10.10.01
kamera - osmatracnica 7	Vlatacom	vCam VIPC-3M1	cam07	DS1R-4031027	10.10.10.23	255.255.255.0	10.10.10.01
kamera - osmatracnica 7	Vlatacom	vCam VIPC-3M1	cam08	DS1R-4031029	10.10.10.24	255.255.255.0	10.10.10.01
svic	Eltex	MES3508P	switch3	PM28003211	**10.10.10.30**	255.255.255.0	10.10.10.01
kamera - osmatracnica 8	Vlatacom	vCam VIPC-3M1	cam09	DS1R-4031087	10.10.10.31	255.255.255.0	10.10.10.01
kamera - osmatracnica 8	Vlatacom	vCam VIPC-3M1	cam10	DS1R-4031046	10.10.10.32	255.255.255.0	10.10.10.01
kamera - osmatracnica 8	Vlatacom	vCam VIPC-3M1	cam11	DS1R-4031065	10.10.10.33	255.255.255.0	10.10.10.01
kamera - osmatracnica 8	Vlatacom	vCam VIPC-3M1	cam12	DS1R-4031012	10.10.10.34	255.255.255.0	10.10.10.01
svic	Eltex	MES3508P	switch4	PM28007063	**10.10.10.40**	255.255.255.0	10.10.10.01
kamera - osmatracnica 9	Vlatacom	vCam VIPC-3M1	cam13	DS1R-4031013	10.10.10.41	255.255.255.0	10.10.10.01
kamera - osmatracnica 9	Vlatacom	vCam VIPC-3M1	cam14	DS1R-4031014	10.10.10.42	255.255.255.0	10.10.10.01
kamera - osmatracnica 9	Vlatacom	vCam VIPC-3M1	cam15	DS1R-4031015	10.10.10.43	255.255.255.0	10.10.10.01
kamera - osmatracnica 9	Vlatacom	vCam VIPC-3M1	cam16	DS1R-4031019	10.10.10.44	255.255.255.0	10.10.10.01
svic	Eltex	MES2324BAC	switch5	ES32012754	**10.10.10.50**	255.255.255.0	10.10.10.01
kamera	Vlatacom	vCam VIPC-3M1	cam17	DS1R-4031045	10.10.10.51	255.255.255.0	10.10.10.01
kamera	Vlatacom	vCam VIPC-3M1	cam18	DS1R-4031031	10.10.10.52	255.255.255.0	10.10.10.01
kamera	Vlatacom	vCam VIPC-3M1	cam19	DS1R-4031030	10.10.10.53	255.255.255.0	10.10.10.01
kamera	Vlatacom	vCam VIPC-3M1	cam20	DS1R-4031011	10.10.10.54	255.255.255.0	10.10.10.01
kamera - termalna - na krovu	Vlatacom	vMSIS3-USD-C225-T2	cam21	DS4XR09C1001	10.10.10.55	255.255.255.0	10.10.10.01
racunar - operaterski - u kontrolnom	—	Intel i5 12600/16GB	pc1	—	10.10.10.56	255.255.255.0	10.10.10.01
racunar - operaterski - u kontrolnom	—	Intel i5 11400/8GB	pc2	—	10.10.10.57	255.255.255.0	10.10.10.01
snimac - u kontrolnom centru	Dahua	dhi-NVR4232-4KS2/L	nvr	7E07F7FPAZ7DB27	10.10.10.58	255.255.255.0	10.10.10.01
LapTop_1	—	servisni računar	—	—	10.10.10.100	255.255.255.0	10.10.10.01

Figure 9. IP address plan

3.3 Control center

The control center comprises number of video monitors and PC computers with installed software applications for particular application. PC computers are connected and configured to the same network as shown in Figure 8. In order to provide users with more convenient and user-friendly environment a video wall is implemented containing 6 monitors in two rows and three columns as shown in Figure 10. Two monitors will be used for two video streams from multisensor imaging system vMSIS3-USD2-C225, and four monitors will be used for presentation of video streams from fixed vCAM vIPC-3M1 cameras.

Figure 10. Assembling of monitors for 2x3 video wall

For this application a software application with graphical user interface is designed to be able to effectively use a number of IP cameras, which will be described in more details in the following section.

4. SOFTWARE ARCHITECTURE AND DESIGN

As part of this military proving ground video surveillance, it was necessary to develop a software application with a graphical user interface, for the simultaneous display of a number of video streams on one or more monitors. Based on system requirements the software application requirements are defined. The software application is designed to work with video streams using the RTSP protocol and with h.264 compression. The number of simultaneously accepted and displayed streams should be limited only by hardware resources (network, processor, memory, number and size of monitors), and not by the software application implementation. The software application should be designed so that it does not impose an exact limit on the number of video streams. Special attention should be on design of graphic user interface, and it is assumed that a single operator should serve the software application at runtime.

The software application should run on a standard desktop PC running Windows 10 or later. The existence of at least one network adapter with speed of 100Mbps or more is expected. For the display of video streams, it is assumed that a maximum of four monitors per computer will be used. Under one instance of the operating system, it will be possible to run only one instance of the software application at a time.

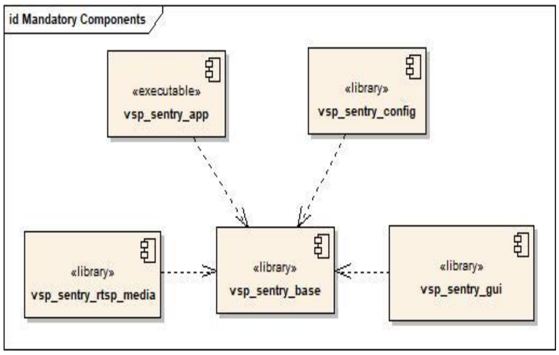

Figure 11. Mandatory components of the software application.

Based on system requirements the software requirements are defined in Vlatacom Institute document "VSP Sentry Functional Specification", and the technical specification was created in Vlatacom Institute document "VSP Sentry Technical Specification – version 1.0.0.".

The main functionality of the software application is presentation of video streams. The screens for displaying video streams are arranged on the layout space in a matrix form with cells of equal size. The number of types and columns of that matrix depends on the number of open screens for displaying video streams. The number of species is always equal to, or one less than, the number of columns. Some examples of the dimensions of this matrix depending on the number of video streams are given in the **Table I.**

Table I. Examples of the dimensions of this matrix depending on the number of video streams.

Number of video streams	Dimension of the matrix display
1	1x1
2	1x2
3, 4	2x2
5, 6	2x3
7, 8, 9	3x3

Opening a new screen to display the stream redistributes depending on the number of open screens and the current dimension of the matrix view. If necessary, a new column or type is added to the matrix display, and the newly opened screen is displayed in the first free cell. The content of the empty cells of the screen layout for displaying video streams should be designed according to the marketing aspect of the application.

The implemented software application consists of several executable components – the software application itself and several shared libraries. The software application is developed within a WPF application project. Other projects are standard Windows dynamic linked libraries. The project is structured this way in order to obtain modularity to the software application, and to be able to easily add a set of features to the software application, or to remove it. Therefore, related features are grouped closely in a single library that may or may not be incorporated into the final configuration of the software application. Some libraries are mandatory to be included in whatever configuration. Minimal set of components is shown in Figure 11.

5. RESULS AND DISCUSSION

The multisensory imaging system with thermal infrared imager and visible imager integrated on a moving positioner has been implemented and tested in laboratory conditions. In Figure 12 image taken with thermal imager with laboratory collimator is shown, and in Figure 13 image taken with thermal imager at narrow field of view (2,77°) with scene of building at 4km distance.

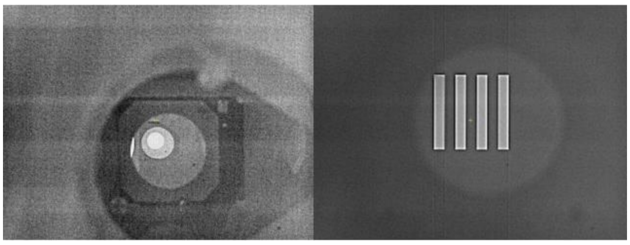

Figure 12. Wide and narrow field of view in laboratory

Figure 13. Narrow field of view (2,77°) – scene with building at 4km distance

The camera modules integrated within a standard outdoor enclosure with IP66 protection are installed on watchtowers. Examples of the camera installations are shown in **Figure 14**. and **Figure 15**.

Figure 14. Cameras installed on the watchtower

Figure 15. View from watchtower with installed cameras

Software application is implemented and tested in laboratory conditions (with outdoor view of cameras) and proved that it is ready for test on the field.

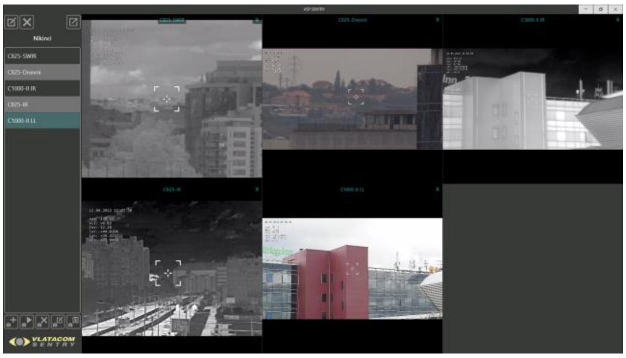

Figure 16. Screenshot of software application GUI during the development and tests

6. CONCLUSION

The surveillance system has been designed and implemented, and partially deployed in the field. In order to put it in full production additional infrastructure work at the military proving ground needs to be done. With the system implemented on the military proving ground, the users will be able to perform testing of military equipment with improved safety and security, and more efficiently. They will be able to monitor and present the results during the shooting tests in a way that was not possible before implementation of this system.

Further development can be focused on the introduction of the additional software application functions:

1. Situational overview of surveillance system cameras.
2. Interactive situational overview of cameras that allows opening and arranging streams for display.
3. Support for recording video streams directly from the software application, or using external accessories and software (NVR).
4. Introduction of alarms based on video analysis - motion detection
5. Classification of detected objects - human, vehicle, animal...
6. Expanding the ability to arrange streams on stream control panels.

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References

[1] PERIĆ,D., LIVADA,B.: *Technical, technological and application limitations of the electro-optical surveillance systems*, 8th International Conference on Defensive Technologies, OTEH 2018, Belgrade, Serbia, 11-12 October 2018

[2] GREIFFENHAGEN,M., COMANICIU,D., NIEMANN,H., RAMESH,V.: *Design, analysis and engineering of video monitoring systems: an approach and case study*, The Proceedings of the IEEE, vol. 89, no. 10, pp. 1498- 1517, October 2001

[3] TSAKANIKAS,V., DAGIUKLAS,T.: *Video surveillance systems-current status and future trends*, Computers & Electrical Engineering, Volume 70, 2018, Pages 736-753, ISSN 0045-7906,

[4] REGAZZONI,C.S., FABRI,G., VERNAZZA,G. (Editors): *Advanced video-based surveillance systems*, Springer Science+Business Media, New York, 1999

[5] COLLINS,R., et al.: *A system for video surveillance and monitoring*, VSAM Final Report, Technical Report, CMURI-TR-00-12, May 2000

[6] FORESTI,G.L., MÄHÖNEN,P., REGAZZONI,C.S. (Editors), *Multimedia video–based surveillance systems: Requirements. Issues and Solutions*, Springer Science+Business Media New York, 2000

[7] FARINA,A., ORTENZI,L., RISTIC,B., and SKVORTSOV,A.: *Integrated Sensor Systems and Data Fusion for Homeland Protection*, Chapter 22 in Academic Press Library in Signal Processing. 2014; 2: 1245–1320, doi: 10.1016/B978-0-12-396500-4.00022-3.

[8] PERIĆ,D., VUJIĆ,S., LIVADA,B.: *Multi-sensor system operator's console: Towards structural and functional optimization*, 7th International Conference on Defensive Technologies, OTEH 2016, Belgrade, Serbia, 6-7 October 2016

[9] DUFOUR,J.Y.(Editor): *Intelligent Video Surveillance Systems*. ISTE Ltd. London and John Wiley & Sons Inc., New York, 2013

[10] LIPTON,A.J., HEARTWELL,C.H., HAERING,N., and MADDEN,D., *Critical Asset Protection, Perimeter Monitoring, and Threat Detection Using Automated Video Surveillance*, white paper, ObjectVideo

[11] HARITAOGLU,I., HARWOOD,D. and DAVIS,L.S., *W4: Real time surveillance of people and their activities*, IEEE Trans. Pattern Anal. Machine Intell., vol. 22, no. 8, pp. 809–830, Aug. 2000.

[12] SKINNER,C.J., COCHRANE,S., FIELD,M., JOHNSTON,R.: *Defence Against Terrorism: The Evolution of Military Surveillance Systems into Effective Counter Terrorism Systems Suitable for Use in Combined Military Civil Environments. Dream or Reality?*, DTIC ADA460826, NATO Conference paper MP-SCI-158-25, October 2004