

AN APPROACH FOR DESIGNING A VIDEO SURVEILLANCE SYSTEM FOR MARITIME BORDER AND COASTAL AREAS

Assistant Professor Neli Stoycheva

Nikola Vaptsarov Naval Academy

DOI : <https://doi.org/10.63662/mns7zf42>

Abstract: Designing a video surveillance system for maritime boundaries and coastal areas requires a complex approach based on specific criteria related to terrain characteristics, climatic conditions, and requirements for the technical parameters of the devices. The main factors in the equipment selection include geographical features such as the length and width of the surveillance area, flora and fauna, terrain accessibility, and degree of illuminance. Also important are climatic and meteorological conditions, such as high humidity and temperature fluctuations, which affect the durability of the equipment.

This paper presents the camera requirements, including resolution, infrared backlight, and additional intelligent features such as image analysis and thermal imaging. Communication technologies for data transmission and the necessity of maintaining continuous connectivity with monitoring centers are considered, as well as the implementation of alternative energy sources in remote areas.

The design is based on a multi-criteria analysis that evaluates the technical parameters of the devices according to the set criteria. A performance coefficient is introduced, as values above the set threshold reinforce the system's reliability and efficiency. Lower values can lead to system failure and disruption of the basic security and monitoring function. This ensures full coverage of the area and effective border security management.

The listed criteria, their consideration, selection of appropriate technology, and identification of integration possibilities with other systems are only the first steps in designing this type of systems.

Keywords: video system design; video surveillance system; maritime boundaries; surveillance area; image analysis; thermal imaging; border security management

1. Introduction

Technical assistance at maritime borders is essential to support security, resource management and environmental monitoring. Key technologies used are: video and radio technical surveillance systems; drones and UAVs; sensors and underwater systems; satellite surveillance and geospatial technologies.

Bulgaria's maritime border in the Black Sea is protected by an integrated video and radio surveillance system, which is part of the overall border control system. The main objective is to prevent illegal immigration, smuggling and other illegal activities.

The purpose of this paper is to present an approach for designing a video surveillance system for maritime border and coastal areas. The approach involves considering criteria for selecting technical parameters of the system modules and evaluating the performance of the criteria through mathematical expression. The main idea to present this approach is in the mass design of video systems, which neglects many factors affecting the system performance and reliability.

2. Capabilities of modern sea surface and coastline monitoring technologies.

CCTV systems are used to monitor the sea surface and coastline, and their task is to provide clear images in different weather conditions and at night. These technologies provide the necessary tools to effectively monitor and respond to a variety of challenges.

Current technologies create many opportunities to secure and monitor large areas, including land borders, maritime boundaries, and coastlines, creating the conditions to download detailed data, process it, and transmit it to duty centers.

CCTV systems are an essential component for security, environmental protection and marine resource management. Their capabilities are used in the fight against illegal migration and smuggling; in cooperation with border services, they provide real-time information, facilitating coordination and response; monitoring shipping to track vessel movements to prevent accidents and illegal activities.

They can also be designed to help the environment to monitor pollution, detect oil spills and other contaminants, allowing rapid responses to limit damage. Another purpose of CCTV systems is biodiversity monitoring.

CCTV systems also have a public function: improving infrastructure and public safety; managing port activities to ensure the safety and efficiency of cargo handling operations and aiding rapid assessment and response to natural disasters.

3. Design of a video surveillance system taking into account the criteria for selecting the technical parameters of the devices.

The design of the CCTV system is highly dependent on the function it has to perform: security, informative or public. This function determines the choice of the technique and the specific technical parameters of the devices of the system

The design and construction of a working video surveillance system for maritime border and coastlines is based on the evaluation of selection criteria for technical parameters of the system modules that meet the given conditions. To achieve this objective, the following criteria have been developed:

Reporting the features of the observed geographical coordinates:

- Area of observation- longitude and latitude; appropriate height from which to download data;
- Flora and fauna - vegetation and animal species characteristic of the observed areas;
- Terrain accessibility: easily or difficult to access; presence of barriers that impede access; assessment of the location and functionality of barriers according to the types of security systems used.
- Illumination of the environment: presence of natural light or auxiliary lighting.
Environmental specifics absorb or reflect light.

Maritime boundaries have a number of characteristics that make them unique yet challenging to secure and monitor. The sea surface has its particularities in day and night observation.

Shorelines can be sand dunes and beaches that change under the influence of wind and water; rocky shorelines combined with woodland where obstacles and low light conditions occur; estuaries where fresh and sea water meet.

These differences in viewing areas also determine the requirements for guarding and monitoring equipment.

Climatic and meteorological conditions that affect:

- Humidity;
- Temperature fluctuations;
- Storms and hurricanes: these areas are at risk from tropical storms, hurricanes and other extreme weather events.

Marine conditions can be harsh on equipment. The use of saltwater corrosion resistant materials and specialized hulls is key. The technical parameters of this type of protection are within: temperature compensation of -40~+70C; vandal protection (IK10); standard for outdoor installation (IP67) and mandatory built-in lightning protection.

Fog, rain and stormy waves reduce the weighting factor in the evaluation of CCTV criteria and require the use of radio technical monitoring.

These terrain features at maritime boundaries and coastal areas make them unique and require specific approaches in the design of CCTV systems to balance the technical parameters in the selection of devices to achieve maximum coverage and visualisation of the monitored area.

Another challenge in designing a maritime border security system is the provision of power sources:

In remote areas there may be problems with energy supplies. Solutions such as solar photovoltaic panels and wind turbines can provide the necessary energy.

Transmission medium (cabling) and selection of communication and network devices for data transmission [1].

The development of technology at the present time allows us to use network equipment that has reached the following technical parameters when designing this type of systems:

Smart managed PoE network switch; n-count Fast Ethernet ports + n-count Uplink combo ports; PoE+ power supply; Ethernet signal transmission from 100 to 250 m; support for remote upgrade, reset, log viewing, configuration; network topology visualization; real-time alarming. Devices for wireless network signal transmission up to 5 km, with transmission speed up to 867Mbps. These are wireless IP video signal transmission kits at 5.8Ghz CPE; Web management features and Cloud support; PoE power supply.

Connecting connectors from end devices to meet the (cite standard) standard, matching, input impedances and output signal levels they use [2].

Continuous connection to the monitoring center.

Uninterrupted internet connectivity is critical for remote monitoring. Alternatively, satellite or other communication methods are used to provide real-time data transmission to control centres.

CCTV and radar systems are linked to a national coordination centre that provides centralised monitoring and management of border security.

Bulgaria cooperates with the border services of neighbouring countries and international organisations such as the European Agency for the Management of Operational Cooperation at the External Borders (Frontex) to ensure effective surveillance and response at international level [3] .

Data recording: locally via micro SDXC card on the camera; centrally on a network recorder or server; and a combination of both methods for greater data security.

Professional software for centralized monitoring and network management.

For DVR/NVR/IP cameras/encoders/decoders; client-server architecture; support over 1000 devices/3000 channels per server; ability to unify multiple servers into a single centralized system (RSM Smart Video Wall module); open platform with support for ONVIF compliant cameras; support modules for Smart IP camera analytics functions: license plate recognition, people counting, Heat Map zones; Smart Video Wall module.

Video surveillance camera selection.

- High resolution cameras. Technical parameters of the cameras to provide quality image with the perimeter features provided.

Resolution of the cameras. Recommended relative to current technology capabilities 8.0 Megapixels (3840x2160@25 fps); 12 Megapixels (4K) (4000×3000@25 fps)

Sensor: 1/1.8";1/1.7" Progressive Scan CMOS sensor;

Illuminance 0.005 Lux@F1.6 (0 Lux IR on); 0.009Lux@F1.2 (0 Lux IR on)

IR illumination technology selection with selected parameters: IR beam length and angle. (also set as IR range). Intelligent IR illumination up to 400m. with automatic adjustment at Controllable IP PTZ camera. ; Intelligent illumination with laser illumination up to 500 m. with automatic adjustment depending on the magnification

Lens [4] : varifocal motorized P-iris lens 2.8~12mm (horizontal angle 96°~46°) with remote adjustment;

For Managed IP PTZ camera lens 6~252 mm; 7.5~315 mm; 42X and 60X optical/16X digital zoom;

Availability of additional filters such as: mechanical IR filter; 3D DNR noise filter (3D-Digital Noise Reduction); DWDR (Digital Wide Dynamic Range); HLC/BLC/EIS; Rapid Focus technology for PTZ cameras; audio input/output; alarm inputs and relay outputs

Compression: H.265+/H.265/ H.264+/H.264

- Artificial intelligence cameras and image analytics: CCTV systems increasingly incorporate AI technologies that automatically analyse images and detect anomalies or suspicious activity.

Dedicated AI smart IP camera includes intelligent perimeter security features: line crossing/area intrusion with the ability to classify objects (people/vehicles), left (missing) object/frame change/object counting, and false alarm filtering. Smart Tracking feature; traffic features: license plate/color/vehicle brand recognition.

Deep Learning Algorithm, intelligent analysis functions: Face Capture/Audio Detection face detection and matching (n number of libraries with up to 30000 faces in total) with alarming, face counting (option up to 30 faces at the same time), body and face feature detection, helmet wearing detection.

- Thermal imaging cameras: allow monitoring of the area in darkness, bad weather conditions and in low visibility, detecting thermal emissions from people and vessels.

Newer technologies use combined (Bi-Spectrum) thermal imaging and daylight IP cameras.

They operate with different modes: combined (bi-spectrum image fusion)/Picture-in-picture/self (Image switching). Thermal imaging camera has uncooled VOx sensor 160x120@25 fps (output resolution 320x240), pixel interval 17 µm; optional lenses 3/6/10 mm (hor. 50°/25°/16°); detection of people up to 91/182/285 m, vehicles up to 280/559/875 m; intelligent

functions/detection: line crossing, zone entry/exit, temperature detection ($\pm 8^{\circ}\text{C}$), fire detection;
built-in light and sound alarm for active prevention;
Integration with sensor systems.

Cameras are often combined with motion sensors, temperature sensors and other devices for complete monitoring [5].

Integration with other surveillance and security systems.

Figure 1 shows an example of thermal camera images with analytical functions in coastal monitoring.



Fig. 1. Thermal camera images with analytical functions in coastal surveillance.

4. Approach for assessing the fulfilment of the criteria.

The design approach is based on a multi-criteria analysis to evaluate the system based on the selection of technical parameters of the devices according to the set criteria. The evaluation is set by the author according to his competence and experience.

The paper proposes that the evaluation of the fulfilment of the criteria defining the requirements for the technical parameters should be called fulfilment factor F_c . It is assumed that the fulfilment factor F_c is less than or equal to one ($F_c \leq 1$).

F_c is represented by formula (1) of the form:

$$F_c = \sum_{n=1}^{10} W_n K_n \leq 1, \quad (1)$$

Where $W_n K_n$ is the fulfilment of the criteria presented above from 1 to 10.

Each of the criteria K_n , where $n = \overline{1,10}$, is assigned a weight W_n , $n = \overline{1,10}$, where the product $W_n K_n$ belongs to the set M :

$$M = \{0.02, 0.04, 0.06, 0.08, 0.1\}$$

Through an experimental approach, the author determined the project approval values based on a criteria fulfillment factor, $F_c > 0.6$

This value is achieved by considering how much each criterion can be underestimated without affecting the security of the CCTV system. For values of $F_c \leq 0.6$ it is assumed that one of the criteria is very underestimated and this has a negative impact on the performance of the system.

System crashes and loss of information may occur. It follows that the basic security function of the CCTV system is not fulfilled.

5. Conclusions and summaries

The presented approach enables the designer to speed up the design process and minimize possible errors. It is a systematic approach to consider the criteria for selecting technical parameters to the system, taking into account the specific conditions of the environment in which it is being built.

The approach has some limitations:

- Not all criteria can be measured qualitatively and quantitatively, which may be a prerequisite for some differences in the values of the set “M” .
- It does not describe the architectures that can be used. They are specific to each environment and system requirements.

The design approach can be used as a tool to assist in considering the criteria, but is not sufficient to provide a complete design proposal.

The criteria listed, their consideration, the selection of appropriate technology and the determination of integration capabilities with other systems are all part of a process that underpins the security of the specified system.

REFERENCES

ANDONOV, A., 2015. *Communication circuits and signals*. Sofia.

DAMJANOVSKI, V., 2014. *CCTV: From Light to Pixels*.

DIMITROVA, E., 2017. *Analysis of the possibilities of integrating video surveillance to remote monitoring and control systems*. Available on: <https://mtc-aj.com/library/1521.pdf> [last viewed: 9 June 2025].

FRONTEX, 2014. *Handbook to the Operational Plan: Joint Maritime Operations*. Available on: <https://www.statewatch.org/news/2017/feb/eu-frontex-handbook-joint-maritime-operations-censored.pdf> [last viewed: 9 July 2020].

ROGALSKI, A. & CHRZANOWSKI, K., 2014. *Infrared devices and techniques (revision)*. In: *Metrology and Measurement*.

Assistant Professor Neli Stoycheva
Nikola Vaptsarov Naval Academy (Bulgaria)
9002 Varna, Bulgaria
E-mail: n.stoycheva@naval-acad.bg

