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OPERATION ZONE OF SINGLESENSOR PASSIVE OPTONAVIGATIONAL SYSTEM

ABSTRACT

Heat field emitted by moving object may be used to localize the object by means of applied thermo-vision cameras making a passive optonavigation system of appropriate configuration. Attempts of determining a zone of such a system operation have been made in this article — operation of the referred system is based on application of one thermo-vision camera making a one-sensor azimuth-stadiometric system. Factors having impact on extend of the zone operation and their influence on the zone's size itself and on the system's operation are presented here.

Keywords:
optonavigation, operational zone, accuracy zone.

INTRODUCTION

Supervision and Monitoring System of Marine Traffic Safety (SMRM) is a basic subsystem of National System of Marine Safety (KSBM) enabling effective execution of tasks related to assurance of the marine traffic safety and reaction of traffic services subordinated to Directors of Maritime Offices in dangerous situations. The system consists of currently operating traffic control services and new central points for the traffic safety supervision and monitoring (a main centre and auxiliary centres of the KSBM). Operation of the system has been based on coast stations of Automatic Identification System (AIS) and radar stations being developed with additional sensor systems.

Thermo-vision is one of methods of gaining data about objects' positions — it may be applied to build autonomic passive optonavigation system or as an element of the (S)MRM system.

CONCEPT OF PASSIVE OPTONAVIGATIONAL SYSTEM

Positioning system, which operation (determination of object's position with a passive method applied) is based on application of at least two thermo-vision cameras, has been named the optonavigation system. Appropriate configuration of the cameras — the system elements — enables creation of an operative zone covering a certain water region, and the zone's extend depends on the cameras' ranges and the system's geometry. Mapping in mid infrared band of thermal radiation emitted by bodies of temperature higher than absolute zero shall be used to localize moving water surface and air objects present in the system's operative zone.

The following variants of the system, depending on the sensors' number, may be distinguished:

- one-sensor combined (azimuth-stadiometric) system;
- two-sensor azimuth system;
- multi-sensor system.

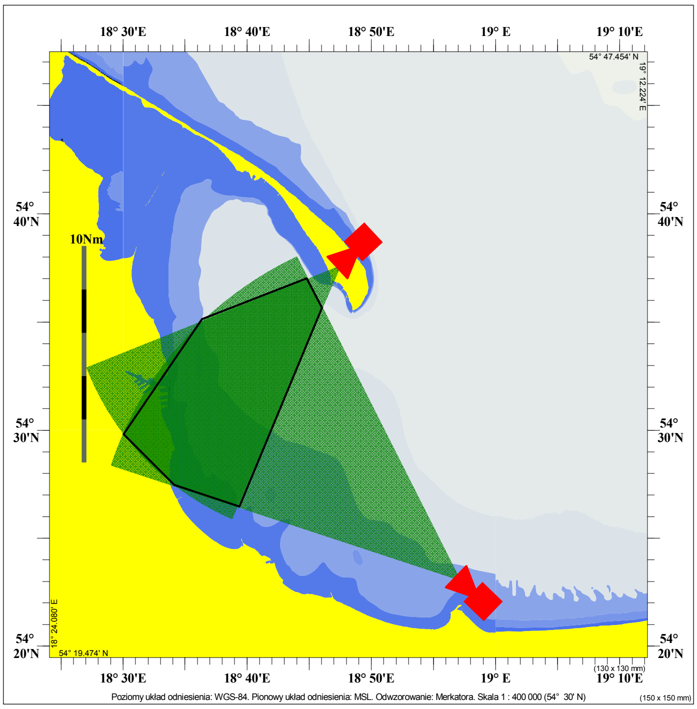

Fig. 1. Observation sectors of thermo-vision cameras and working zone

The assumption is that a one-sensor system shall be elaborated in the first stage and also the operative and accuracy zones shall be determined. Then, a two-sensor system shall be developed — operating based on two thermo-vision cameras, adapted for future additional development into a multi-sensor system to increase accuracy of the positions' determination and to extend surface of the zone operation.

Observation sectors of thermo-vision cameras and working zone have been shown in figure 1.

OPERATION ZONE OF RADIONAVIGATION SYSTEM

Problems of determining the accuracy zones and operative zones of radionavigation systems are commonly known and applied. Extend of the radionavigation operative system is a function of:

- the system's kind;
- ranges of coast stations' ranges;
- geometric layout of the coast stations (length of the bases' lines and angles between them);
- assumed minimal values of intersection angles of positioning lines.

One usually aims at achievement of one of the following targets when designing the layout of particular navigation system's coast stations in a given region:

- achievement of the zone's maximal range in a given direction;
- achievement of the zone's maximal surface;
- achievement of maximal distance in the given water region;
- achievement of the largest possible area characterized with the highest possible accuracy.

Determination of the operative zone and aiming at achievement of the above-said targets is applicable for the optonavigation system. Extend of the zone shall be limited by the thermo-vision camera's observation sector due to the fact that they are isotropic instruments, similar to antennas of the radio-navigation systems.

OPERATION ZONE OF OPTONAVIGATION SYSTEM

Main factors determining extend of optonavigation system's operative zone are as the following:

- the thermo-vision camera's observation sector;
- the camera's range;
- altitude of the installed camera;
- inclination angle of optical axis.

Spatial presentation of the working zone has been shown in figure 2.

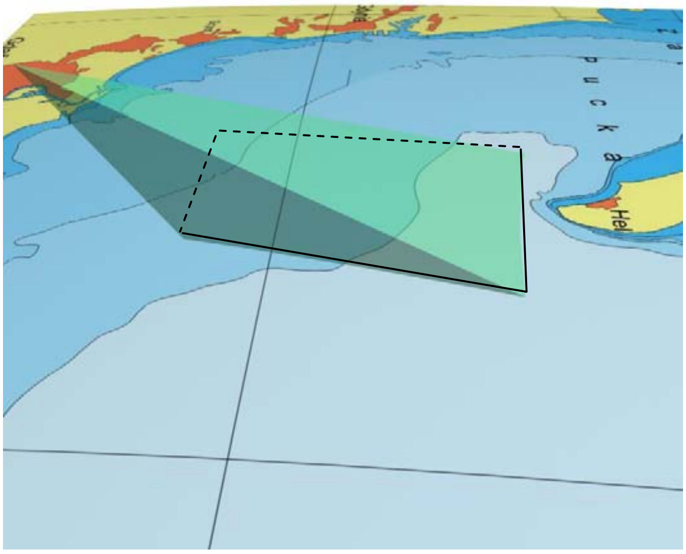

Fig. 2. 3D presentation of the working zone

OBSERVATION SECTOR OF THE THERMO-VISION CAMERA

Typical observation sectors of the thermo-vision cameras are included within limits of (40–45) × (30–35)°. Surface of the observation sector shall depend on:

- inclination angle of the camera's optical axis;
- ratio of the water region picture's surface to entire picture;
- distance between the operative zone and the camera.

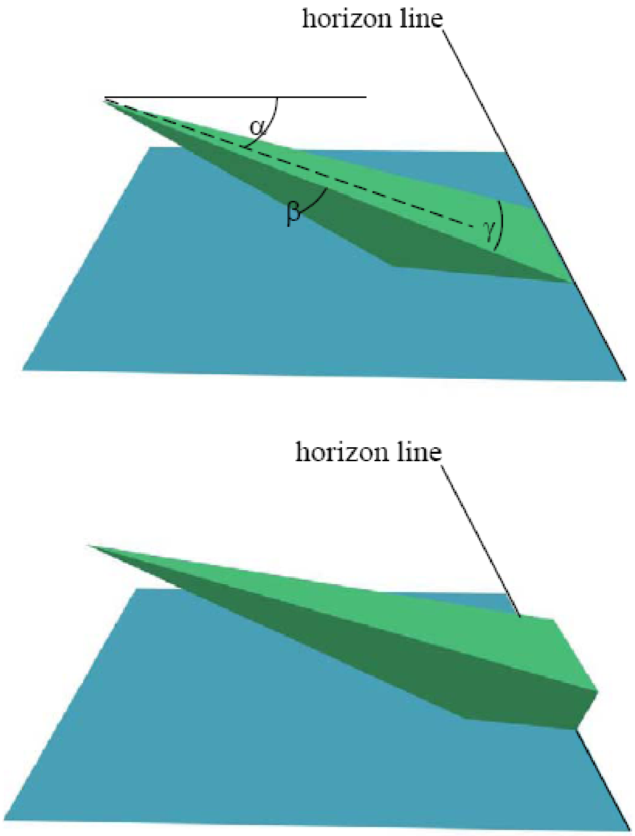

Fig. 3a. Influence of inclination angle of the thermo-vision camera’s optical angle on the observation sector

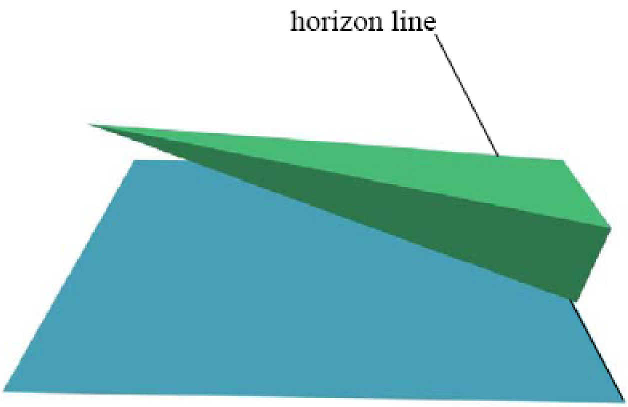

Fig. 3b. Influence of inclination angle of the thermo-vision camera’s optical angle on the observation sector

For typical observation sectors, increased distance between the camera and the operative zone shall result in enlargement of their surfaces and thus — in better discrimination of detected objects, due to enlargement of the water region's surface corresponding to one unit of resolution. However, one should take worse detective capabilities into account for longer distances because of limited range and sensitivity of the camera. Influence of inclination angle of the thermo-vision camera's optical angle on the observation sector have been shown in figure 3 (3a and 3b).

INCLINATION ANGLE OF THE THERMOVISION CAMERA'S OPTICAL AXIS

Due to a change of the camera's inclination angle, achievement of the following variants is possible:

— horizon line's position is in the lower edge of the picture or beyond — an air situation is mapped, without possibility of detecting water surface objects;
— horizon line's position is in the lower edge of the picture or beyond — an air situation is mapped, without possibility of detecting water surface objects;
— horizon line's position is within the observation sector — the observation sector is divided into water surface and air parts;
— horizon line's position is in the upper edge of the picture or beyond — the entire observation sector is dedicated for the sea water region, with a possibility of detecting air objects located within a pyramid which base is made by the water region and the thermo-vision camera makes its top.

The thermovision camera's observation sectors are presented in figure 4.

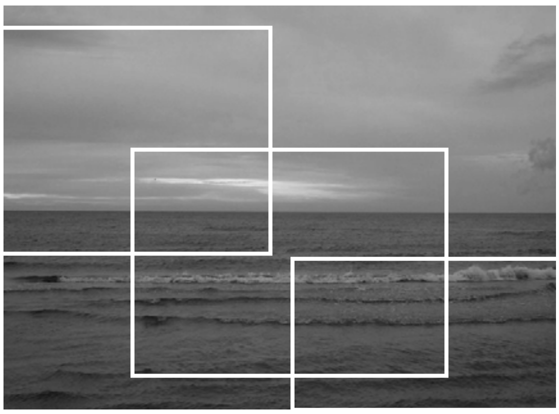

Fig. 4. Observation sector of the thermo-vision camera depending on inclination angle of the thermo-vision camera's optical axis

ALTITUDE OF THE INSTALLED CAMERA

Altitude of the installed camera shall have impact on:

- minimal distance for detection of the object;
- distinguish ability in respect to distance.

Assuming that particular operation variant is selected in respect to the horizon line's position (resulting from the inclination angle of the camera's optical axis), the following effects shall be achieved if the camera is installed higher:

- increased inclination angle of the camera;
- increased distance from the operative zone;
- decreased imaged deformations.

Higher altitude of the installed camera, at selection — for example — of marine variant for which the horizon's edge is located in the picture's upper limit, apart from increased inclination angle of the camera, shall result in size compensation of the elementary surface units in the lower and upper parts of the picture and in smaller imaged deformations. For a camera installed at lower altitude, just above surface of the sea water, size of the surface unit shall be much smaller than in the upper part.

Influence of altitude of the installed camera on the operation zone have been shown in figure 5.

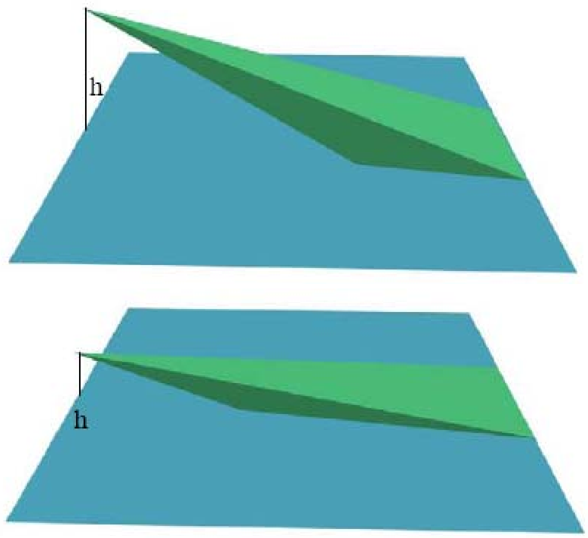

Fig. 5. Influence of altitude of the installed camera on the operation zone

Due to technical reasons, it is not possible to obtain very high altitudes for the camera installation.

RESOLUTION UNIT'S AND OPERATION ZONE'S AREA

The resolution unit should be considered a trapezoid which dimensions shall depend on:

— altitude of the installed camera;
— inclination angle of the camera's optical axis;
— resolution;
— observation sector.

Influence of altitude of the installed camera on the operation zone has been shown in figure 6.

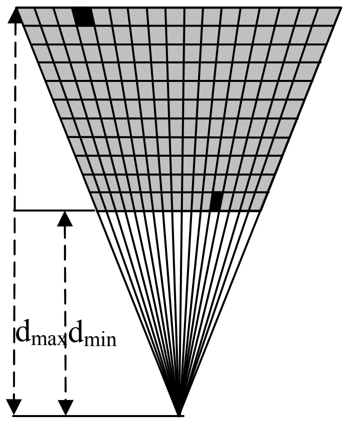

Fig. 6. Influence of altitude of the installed camera on the operation zone

Distance to the closer edge of the operative zone may be determined with the formula:

$$d_{\min} = h \sin\left(\alpha + \frac{\beta}{2}\right), \tag{1}$$

where:
h — altitude of the camera;
α — inclination angle of the camera's optical axis;
β — observation sector in vertical plane.

Similarly, distance to the further edge of the operative zone may be determined with the formula:

$$d_{\min} = h \sin\left(\alpha - \frac{\beta}{2}\right). \tag{2}$$

Bases of the trapezoid: the closer one - on the edge of *i*th row vector, and the more distant one — on the edge of (*i*+1)th row vector, may be determined with the formula:

$$d_i = h \sin\left(\alpha - \frac{\beta}{2} + i\frac{\beta}{n}\right), \tag{3}$$

where:
n — vertical resolution of the image.

CONCLUSIONS

Preface for consideration of passive optonavigation system has been presented in the article. Dependences given to determinate parameters of the one-sensor system's operative zone make a first phase of works over the system. Next phases should be as the following:

- research over display of objects of various sizes with a use of real images;
- experimental determination of detection limits of various size objects for typical thermo-vision camera;
- experimental determination of distance discrimination and resolution within angle coordinates;
- determination of accuracy zones based on real images;
- determination of operative zone and accuracy zones of two-sensor system;
- definition of possibilities to construct the system in real conditions;
- definition of justification for development of the system to a multi-sensor variant.

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STREFA DZIAŁANIA JEDNOSENSOROWEGO PASYWNEGO SYSTEMU OPTONAWIGACYJNEGO

STRESZCZENIE

Pole cieplne emitowane przez poruszający się obiekt może być wykorzystywane do jego lokalizowania za pomocą kamer termowizyjnych tworzących system optonawigacyjny o odpowiedniej konfiguracji. W artykule podjęto próby określenia strefy działania takiego systemu — działanie systemu jest oparte na zastosowaniu jednej kamery termowizyjnej tworzącej jednosensorowy system azymuto-stadiometryczny. Przedstawiono czynniki wywierające wpływ na zakres strefy działania oraz wielkość samej strefy i funkcjonowanie systemu.

Słowa kluczowe:
optonawigacja, strefa działania, strefa dokładności.

Recenzent dr hab. inż. Lucjan Gucma