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A SURFACE AND AIR OBJECT IDENTIFICATION SET

ABSTRACT

This article presents an optic-thermal set which is designed to continuously control monitored space using two vision cameras and a thermo-vision camera installed on a rotary head. On receiving data this set recognizes and identifies floating and low-flying objects on the basis of their classification features and thermal characteristics. The data on location of detected targets is displayed on an electronic chart of the monitored area pursuant to the requirements specified for automated command systems. In addition, the set is capable of tracking movement of selected objects in real time.

Key words:
optic-thermal set, optic sensors, thermal sensors, object recognition.

INTRODUCTION

In order to provide for security of the maritime border of Poland, and as a consequence of the EU border, a system capable of effective monitoring situation in the Polish Economic Exclusive Zone is needed. The experience of the countries in the Baltic Sea region indicate that in order to effectively protect a maritime border border guard services must be equipped with modern observation systems capable of fast identification of floating and flying objects based on data obtained from optic and thermal sensors.

A radar station is a core element in supplying data for a real observation and recognition system. However, some objects are invisible to radar. For this reason,

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the existing radar systems should be additionally equipped with optic-thermal sets. They would perform supporting functions, especially in cases when there is a high probability for invisible to radar objects to appear in the observed area [5, 9].

The optic-thermal set is designed to collect, process and display data from optic and thermal sensors on console monitors in the form of visual images and display detected objects on an electronic chart of the observed area. The set, using data obtained from optic-thermal sensors installed in technical observation posts carries out recognition and identification of floating and flying objects [10]. This is a very important function as regards protection against military and terrorist threats to the Polish coastal area, approaches to harbors and harbor basins.

This set is capable of recording, in real time, data on detected objects received from optic-thermal sensors. This data is saved in the system data base. Storing selected data allows for later reconstruction of the situation for an analysis or for training personnel to operate automated command systems. Depending on the needs the data can be transmitted outside the set.

THE GENERAL DESCRIPTION OF THE SET

The optic-thermal set can co-operate with other Automated Command Systems (ACS)and other systems which employ radar for input of data. All the output data, in the system, on detected objects in an observed area meet the signal transmission standards specified by NMEA 0183 and RS-232. All data is transmitted from the set to the system data base. After the data is displayed on an electronic chart of the observed zone, on a computer monitor, it will provide an operator with a clear situational picture and a possibility of transmitting this data to co-operating ACSs or other observation systems. At the output of the system there will start to appear data in the form of standard messages, analogues to those transmitted by real radar (in accordance with NMEA 0183). The presented set provides for generating digital output data which adheres to IMO standards specified in NMEA 0183, as in the case of modern radar sets used aboard floating vessels. The general structure of the optic-thermal set is presented in figure 1.

The main sensor module in the optic-thermal set includes a thermal camera (CAM THERM) and two color cameras CCD (CAM1 and CAM2) used for day-and--night observation at medium and long ranges. These cameras are characterized by variable focal length both optic and digital, providing for aggregate magnification value of 260 times. These sensors are placed on a common turntable providing for

circular sector-wise observation of the observed space, depending on the performance mode (fig. 2). The control over the turntable is executed using signals worked out by algorithms implemented in the computer. Communication between the computer, the sensors and the turntable is executed by means of Ethernet. This set, owing to two vision cameras, allows for determining ranges of objects appearing in the observed space and parameters of their movement. The other monitor displays data on objects appearing in the observed area obtained by the thermal camera. The data obtained from the cameras are used to identify and classify the detected objects. To identify them thermal and visual features of objects are used. The set has a capability to record visual and thermal pictures of detected objects, which allows for distinguishing between particular classes of objects and their thermal features. This is useful for building data bases and in consequence for fast identification and classification of detected objects, based on their thermal characteristics and visual image features distinguished for a given class.

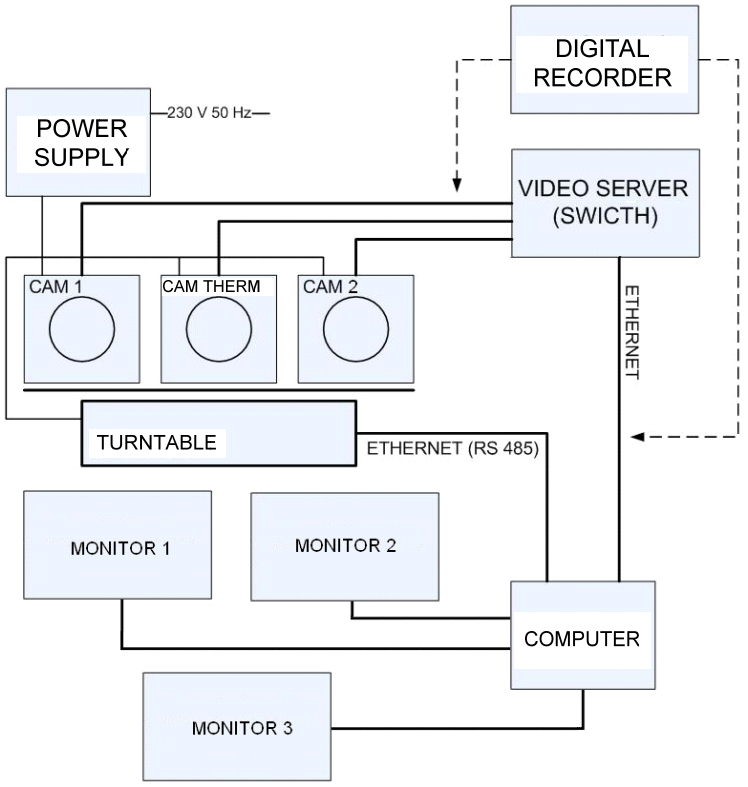

Fig. 1. The general structure of the optic-thermal set

Fig. 2. The turntable together with the sensors

In order for the set to perform the assumed functions it was necessary to select an appropriate hardware and software platform. The system software is enriched with procedures taking into account data circulation within the proposed structure of the set. The toolkit used is uniform as regards contact of an operator with the system — standard OSF/Motif for X-Window applications. Communication between the individual elements of the set fulfills standard TCP/IP. The system contains a strong graphic work station which provides for realization of the implemented algorithms, identification and classification of detected objects, stereoscopic display, and control of sensors and data display devices as well as generating an electronic chart of the observed water region.

This set, using data from sensors on objects in the observed space, displays their location and movement parameters on an electronic chart of the observed water region. The data is displayed on a monitor (MONITOR 3) which is part of the set. A chart of the observed region is displayed on the monitor following standard S-57. This set provides for generating a visual and thermal display of observed space together with algorithms of automated recognition and tracking of selected surface floating objects and low-flying objects in the monitored maritime area based on

data from the optical and thermal sensors. The obtained data, combined with data from the radar system, allow for tracking and controlling movement of own and other objects operating in the regions of concern for the Polish border services. The display of data obtained from the sensors is presented in figure 3.

Fig. 3. An ex ample of data displayed in the set

THE FUNCTIONAL STRUCTURE OF THE SET

The basic functions performed by the optic-thermal set include:

- search of an observed water region providing for stereoscopic and thermal display of this space;
- data transmission from a visual observation post to a set designed to make a stereoscopic and thermal display;
- making a stereoscopic and thermal display using two visual cameras;
- recognition, classification and identification of selected objects, based on their classification features, using a visual and thermal display in real time;
- tracking selected objects using stereoscopic and thermal imaging;
- graphic display of detected objects on an electronic chart of observed water region;
- acquisition and storage of thermal and visual characteristics of floating and low--flying objects in the data base;
- generating data, in the form of standard messages, on detected objects (following NMEA 0183) from the system base to a digital port, in order to supply data to other ACSs;

- providing for repeatability of situations for training purposes and for analysis of a navigation-tactical situation.

In order for the optic-thermal set to perform the presented above functions a functional structure was developed. It consists of modules realizing the particular functions and co-operating with each other. The functional diagram of the set is presented in figure 4.

The communication interface allows the set to transmit data and communicate with other reconnaissance systems. It is also used to start the set, initiate the software and control performance of the set. An operator can, among others, collect from as well as feed into the set thermal and visual characteristics of objects obtained from other systems, and he/she can also recreate a situation in order to analyze it or to train the crew.

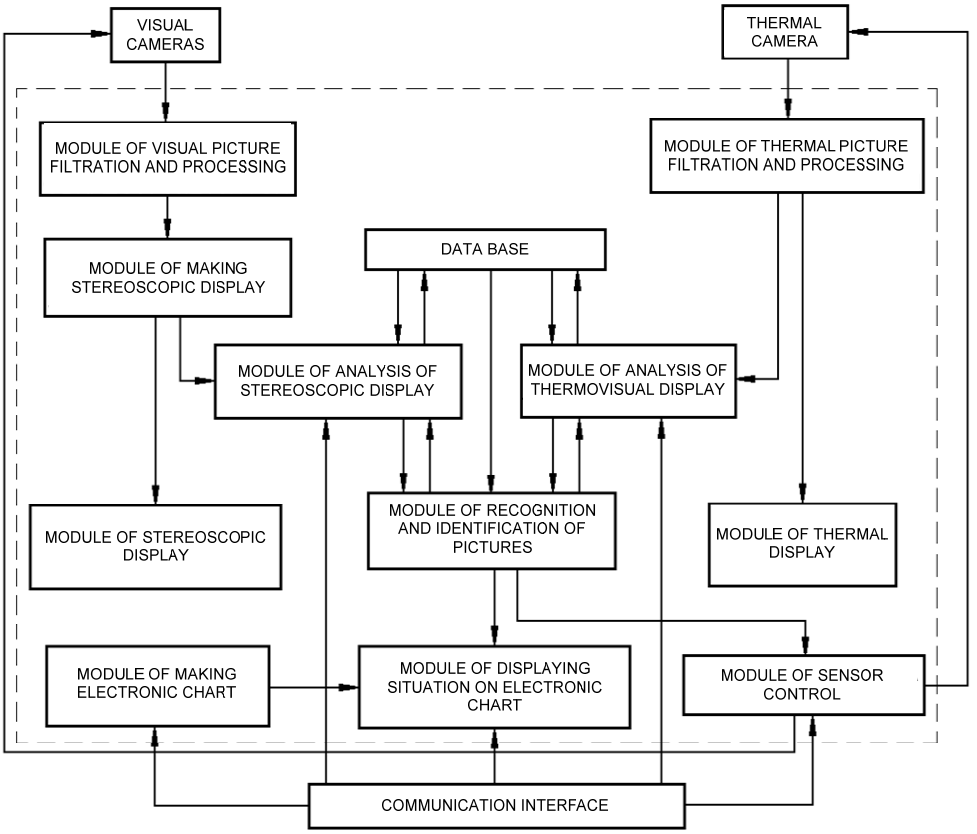

Fig. 4. The functional diagram of the optic-thermal set

The main sensors in the set, used to collect data on objects in the monitored water region are a thermo-visual camera and two visual cameras, which will transform a visual signal into digital form [6]. These images, depending on external conditions, including weather conditions, will be characterized by different quality. In this connection there exists a necessity to improve their quality through filtering processing them. In order to improve the image quality a wide range of image transformation methods are used. They provide for eliminating the effect of interference on the image quality [8]. Modules of visual and thermal image filtration and processing are used to process them. Filters eliminating elements insignificant with regard to recognition of selected elements on a display are imposed on the images [2, 4]. Source image pixels are used in filtration and as a result a new transformed image is obtained. This image is displayed in the form of a set of new pixels, which are made using data from several source image pixels. As a result of such transformation noises are eliminated, and edges and corners are highlighted, i.e. a lot of data, useful in further processing, is extracted from the original image.

The function of the module designed to make a stereoscopic display is to obtain image depth maps necessary to measure distances to selected display elements. The problem, solved with this module, is to obtain depth map, so called 2.5 dimension picture, as through mapping 3D images into 2D pictures, at the stage of obtaining them, depth is lost [7, 11].

A visual and a thermal image of an observed water region, following preliminary processing, is displayed on monitors and at the same time transmitted to the module of thermal and visual display, where it is subjected to quantitative analysis, i.e. recognition and or searching for given elements in the picture [1, 6]. The necessity to automatically recognize and analyze an image is at the moment common and is linked to the fast developing field of IT whose focus of interest are all image processing methods, especially detection of specific elements and their recognition [12]. An important role in analyzing images is played by preliminary processing whose task is to prepare data for final processing and which provides for proper conduct of image analysis. These tasks are carried out by the modules of thermo-visual and stereoscopic display which co-operate with the module of recognition and identification of pictures.

In this last module the image is transformed into a digital description, allowing for making inferences concerned with the quantitative or qualitative occurrence of elements in the image. The following functions are performed in this module:

- recognition, detection, identification, localization, a description of the scene;
- generation of concise and informative representation of an image;

- selection and construction of features;
- interpretation of a decision and estimation by a classifier;
- continuous work on pictures, taking into account the time factor.

Two approaches are possible in the process of image recognition, i.e.:

1. Direct approach, an ex ample of which is the use of neuron networks, some algebraic approaches, e.g. SVD (singular value decomposition) and some applications of SVM (Support Vector Machines). The basic advantage of this approach is performance simplicity. One of disadvantages is limited applicability, i.e. rather small images and uncomplicated objects.
2. Indirect approaches make use of representation of indirect images, e.g. feature vectors, lists of objects and their features, area adjacency graphs. An advantage of this approach is the modular structure of algorithms and a possibility to use UM tools. Disadvantages mostly include higher amount of work and problems in selecting an image representation.

In the developed module the indirect approach is applied. Therefore the algorithms built make use of recognition based on features, i.e. an inference is based on features calculated from the image or they make use of recognition based on a standard, i.e. an inference is based on 'confrontation' with a model, e.g. by comparing or measuring similarities of thermal features. In the process of recognition of objects on a stereoscopic display the recognition encompasses recognition focused on an object and recognition focused on an image. In the former case knowledge of a model of an object under recognition process is required, and this recognition involves deciding if it could 'generate' a given image. In the latter case an image is analyzed through decomposing it into pieces and the obtained decomposition is used to make an inference concerned with the object under recognition. Recognition of stereoscopic images allows for their precise orientation in the space of objects and their identification owing to an additional parameter, i.e. depth.

This module co-operates with the data base, where object standards and their characteristics, as well as with the module of displaying the situation on an electronic chart.

Objects detected and recognized by the set will be presented in the module designed to display a situation on an electronic chart following the requirements specified for ACSs. This module will be fed with data by the module designed to make an electronic chart and the module of picture identification and recognition.

The module of sensor control is fed with data by the module of image identification and recognition, and using this data it generates signals which control

executive elements of the sensors, providing for the appropriate work mode, i.e. search performed in accordance with specific algorithms or tracking selected elements in a thermal or stereoscopic image of the observed water region. This module communicates with an operator through the input interface.

SUMMARY

After algorithms and programs were completed the optic-thermal set developed at the Naval Academy was tested under laboratory conditions, under simulated operational conditions — reflecting real life conditions and during life fire exercises at a field exercise range. The adopted methods for recognition of objects in a monitored water region were put through verification procedures.

This set provides for building a visual stereoscopic and thermal image of observed space together with algorithms of automatic recognition and tracking of selected elements in these images and it allows for recognition and identification of floating and low-flying objects in the space observed by optical and thermal sensors.

The set can be used to carry out further studies concerned with algorithms of visual and thermo-visual image filtration, and with making stereoscopic displays of an observed water region, as well as classification, recognition and identification of selected elements in visual and thermo-visual images in real time. In addition, the set can be used to carry out investigations on thermal characteristics of floating and flying objects under laboratory conditions representing real-life conditions with great accuracy as well as under operational conditions reflecting real-life conditions.

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ZESTAW DO IDENTYFIKACJI OBIEKTÓW NAWODNYCH I POWIETRZNYCH

STRESZCZENIE

W artykule przedstawiono zestaw optyczno-termalny, który przeznaczony jest do ciągłego nadzoru nad obserwowaną przestrzenią za pomocą dwóch kamer wizyjnych i kamery termowizyjnej zainstalowanych na obrotowej głowicy. Zestaw ten wykorzystując pozyskaną informację, dokonuje rozpoznania i identyfikacji obiektów pływających i obiektów nisko lecących na podstawie ich cech klasyfikacyjnych i charakterystyk termicznych. Informacje o położeniu wykrytych obiektów są przedstawione na elektronicznej mapie cyfrowej obserwowanego akwenu zgodnie z wymaganiami stawianymi dla zautomatyzowanych systemów dowodzenia. Ponadto zestaw ten ma możliwość śledzenia ruchu wybranych obiektów w czasie rzeczywistym.

Słowa kluczowe:
zestaw optyczno-termalny, sensory optyczne, sensory termalne, rozpoznawanie obiektów.