Video Analytics of Aerial Objects

Andrei Tevyashev
Department of Applied Mathematics
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
andrew.teviashev@nure.ua

Igor Shostko
Department of Infocommunication Engineering
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
iss010166@gmail.com

Oleg Zemlyaniy
Department for Nonlinear Dynamics of Electronic Systems
O. Ya. Usikov Institute for Radiophysics and Electronics
National Academy of Sciences of Ukraine
Kharkiv, Ukraine
zolvas@ukr.net

***Abstract*—This work is devoted to the problem of creating and using video analytics of aerial objects with the aim to solve the variety of problems of airspace monitoring in the visible and infrared frequency ranges for security systems of general and special purpose.**

***Keywords*—aerial object, video analytics, monitoring, security systems.**

I. Introduction

Video analytics (VCA, Video Content Analysis) is a technology that combines a variety of accurate analytical and approximate numerical methods for the automated analysis of the sequences of images that coming from video cameras in real-time mode, as well as from archive records. Video analytics is implemented as software tools (SW) for video content processing. A wide range of mathematical models and methods is a core of the SW for video analytics, which allows video monitoring and performing intellectual analysis of data without the direct human intervention.

Currently, there are numerous examples of successfully solved problems using video analytics technology application in video surveillance systems [1-17]:

- recognition of people and moving vehicles for the purpose of counting their number;
- ID numbers recognition (vehicles, banknotes, documents, etc.);
- detection of events (shifting, movement, crossing of admissible lines and borders, staying in zones, throwing of objects over a fence, etc.);
- detection of dangerous situations (crowds, abandoned objects, fires and smoke, etc.);
- recognition of dangerous objects and identification of human faces and their search in databases.

The global video analytics market is showing its rapid growth due to the fact that the prices for high-resolution video cameras are constantly declining. Individuals, small and medium-sized businesses are now quite able to purchase an autonomous video surveillance system with at least basic video analytics functions. Modern IP cameras have high resolution and remote access capabilities, both over the Internet and through a distributed corporate network, which is a necessary condition for the operation of video analytics systems. Widespread use of IP-cameras allows adequately mirroring the real world onto a parallel world, which is purely digital one with its own settings of strict conditions (laws) of staying and behavior for different subjects of this world. Video analytics, without the intervention of individual persons, allows most effectively monitoring the implementation of these conditions by different parties and, in the first stage, to issue emergency messages in case of violation. In the next steps, the video analytics provides support for decision-making on the measures and facilities that should be applied to the subjects who violated the conditions of stay and behavior, up to their implementation. Airspace monitoring systems use video cameras with rotation, tilt and zoom functions. These are PTZ cameras, named for their ability to rotate left and right in panoramic (horizontal) plane, tilt up and down in vertical plane, zoom and convert images. Rotating cameras perform these actions thanks to a unique combination of pan, tilt and zoom control functions. The overall zoom capability of the PTZ camera consists of digital and optical zoom values. Digital zoom uses electronics to enlarge and reduce the image, while optical zoom uses the lens movement.

The total zoom value of the video camera can be calculated by multiplying the digital and optical zoom values.

II. Basic functions of video analytics of aerial objects

Video analytics of aerial objects (AO) automates a variety of airspace monitoring functions. The basic functions of video analytics software are as follows:

1) obtaining video data, forming and delivery images from video cameras in the visible (VIS) and infrared (IR) frequency bands;

2) image filtering and enhancement provides noise reduction (denoising), elimination of blurring (deblurring), smoothing, increase of contrast and strengthening of edges, improvement of color reproduction, illumination of dark fragments, etc.;

3) AO detection. Detection of the AO is performed using a video motion detector. Video analytics allows selecting and analyzing of all moving AO in the field of view of VIS/IR cameras;

4) identification of the high-contrast points that form the boundary of both specific AO and the boundaries between different objects;

5) formation (selection) of AO tracking point. For stable tracking at selected points, it is usually necessary to fulfill the condition of significant inhomogeneity of the image around the point. Corners meet this condition. The use of corner points is necessary for most tracking methods;

6) AO classification allows dividing the AO being under observation into classes: aircrafts, helicopters, cruise missiles, drones, quadcopters, etc .;

7) AO identification allows performing identification the type of AO within the selected class;

8) AO tracking. The task of AO tracking is following. For each point of observation time it is necessary to ensure the most accurate alignment of the optical axis of the video surveillance camera mounted on the Optical-Electronic Station (OES) with the selected tracking point on the AO image (angular, center of gravity, Chebyshev, most vulnerable, etc.). Trackers that implement tracking algorithms are used to solve this problem;

9) evaluation of the parameters of the AO trajectory. The OES, which are equipped with EO/IR systems and laser rangefinders, for each time t allows measuring three parameters that characterize the state of the AO relative to the location of the OES: azimuth, angle and inclination between the OES and the AO. In the chosen coordinate system, this information is sufficient to estimate the parameters of the AO trajectory;

10) predicting the trajectory of the AO. Kalman filter and its numerous modifications are used in modern video analytics to predict the AO trajectory;

11) detection of events related to the behavior (trajectory) of the AO.

All functions are performed repeatedly, providing continuous refinement of hypotheses about the number, location, the AO type and its intentions in the airspace controlled area. AO recognition means a wide range of tasks: from binary classification of the AO type meaning target/noise distinguishing to the identification or verification of the AO by its features.

The task of airspace monitoring in the visible and infrared bands has been and remains extremely relevant for general and special purpose security systems. The use of video analytics software in airspace monitoring systems makes it possible to solve the problems in the process of video surveillance that are usually only possible for humans, in automatic mode of operation, without human intervention,. This technology is used both to ensure the security of the objects under protection and to stop the AO from being in the controlled airspace. The processing of video streams and images is carried out using high-speed computers, as well as FPGA [18, 19], which significantly increases the speed and efficiency of algorithms used in video analytics.

III. Fields of application of AO Video Analytics

Video analytics of the AO is used with the aim of obtaining an objective assessment of the effectiveness of airspace monitoring, as it is able to produce continuous and automated collection and analysis video data on non-human-dependent basis and generate reports at the request of the user at any time.

Depending on the sizes of the objects under protection, OES can be combined into a single information and monitoring system (IMS). Airspace IMS of general purpose in the visible and infrared frequency bands is used to control the airspace of airfields, to prevent drone flights in crowded places and mass events, monitor compliance with air traffic rules at sporting events and air shows, to protect airspace from drones over private property in order to counteract video recording, etc.

The field of IMS of special application is much wider and includes:

A. Covert, continuous, round-the-clock monitoring of airspace in the visible and infrared frequency bands by the OES sensor network.

The OES sensor network allows performing covert, continuous, round-the-clock monitoring of airspace in the visible and infrared frequency bands. In this case, the control of the AO position in the controlled space is carried out using two or more OES of the sensor network using triangulation, when each OES measure the azimuth and the angle on the AO without the usage of laser rangefinders to measure the slant distance between the AO and each OES. The absence of laser irradiation of the AO does not allow him to identify the fact of its detection. This provides a real opportunity for covert airspace monitoring.

B. External trajectory measurements during AO field tests.

The main purpose of field trials is to measure the external trajectory parameters of the AO (coordinates, velocity vector, angular positions in space, etc.). Using this values one can estimate their quality and identify the causes of abnormal situations. For the most objective assessment of the AO operation at the test during the shot (launch) it is necessary to ensure receiving of initial information and, accordingly, tracking of AO from its start (departure of artillery ammunition from the barrel, and for missiles or jet munitions, respectively, leaving the launcher) to the point of target hitting.

The initial speeds of various missile and artillery projectiles being under test at a modern facilities, can vary from 50 to 2000 m/s, and have the distances of their flight from several hundred meters to tens of kilometers. The OES of small size are used for tracking of the AO, which are located along the route of the AO. Each OES in its area of responsibility is programmed to track the AO on the predicted section of the trajectory. The programming process is automated and performed simultaneously for all OES. Each OES in the process of tracking transmits through the communication channel the current coordinates of the AO for the OES, which is next in line staying in standby mode. Based on these data, the coordinates of the expected capture point and the flight path of the AO are adjusted relative to the predicted values. The number of OES in the IMS is determined depending on the length of the route on which the AO is tested.

C. Management of the AO defeat systems

The rapid pace of creation and use of high-precision weapons (HPW) for massive air attack with the widespread use of anti-radar missiles and electronic countermeasures has revealed an urgent need to create facilities for target detecting and tracking which are alternative to active radars. One of the ways to repel air attacks with maximum secrecy until the opening of fire is the use of small OES of detection, tracking and high-precision targeting to the AO. OES provide the necessary secrecy and the highest accuracy of guidance. The use of narrow-beam thermal imagers operating in the infrared range in the OES allows to ensure round-the-clock and, to a large extent, all-weather and noise immunity of their exploiting. The problem of high-precision targeting of the AO is one of the system-forming problems for almost all tools.

REFERENCES

[1] Шапиро Л., Стокман Д. Компьютерное зрение. М.: Издательство «БИНОМ. Лаборатория знаний», 765 с.

[2] Szeliski Richard. Computer Vision: Algorithms and Applications. Springer, 2010. 933 c.

[3] Shostko I., Tevyashev A., Kulia, Y., Koliadin A. Optical-electronic system of automatic detection and high-precise tracking of aerial objects in real-time // The Third International Workshop on Computer Modeling and Intelligent Systems, CMIS, 2020. P. 784–803.

[4] http://ceur-ws.org/Vol-2608/paper59.pdf

[5] Experimental Researches on Determination of Angles of Side Illumination by Laser Radiation of Optical Devices and Optoelectronic Devices, Kulia Yu., Shostko I., Avchinnikov E., Tevyashev A., Neofitnyi M., Problems of Infocommunications. Science and Technology" (PICS&T-2019): International Scientific-Practical Conference–Kyiv, 2019. P. 319 - 323. Scopus. – El. access: 47496-CFP19PIA-USB/papers/picst19_319.pdf

[6] Tevyashev Andrey, Shostko Igor, Neofitniy Mihail, Koliadin Anton. Laser Opto-Electronic Airspace Monitoring System in The Visible and Infrared Ranges // 2019 IEEE 5th International Conference Actual Problems of Unmanned Aerial Vehicles Developments, APUAVD 2019 – Proceedings, 2019. C. 170–173, DOI: 10,1109 / APUAVD47061.2019.8943887.

[7] Mathematical model and method of optimal placement of optical-electronic systems for trajectory measurements of air objects at test / A. D. Tevjashev, I. S. Shostko, M. V. Neofinyi, S. V. Kolomiyets, I. Yu. Kyrychenko, Yu. D. Pryimachov // Odessa Astronomical Publications. Vol. 32 (2019). C. 171–175. https://doi.org/10.18524/1810-4215.2019.32.182231

[8] Shostko I., Tevyashev A., Neofitnyi M., Kulia Y. Information-measuring system of polygon based on wireless sensor infocommunication network // Chapter in the book Lecture Notes on Data Engineering and Communications Technologies, 48. Publisher: Springer Nature, 2021. C. 649–674.

[9] Shostko I., Tevyashev A., Neofitnyi M., Ageyev D., Gulak S. Information and Measurement System Based on Wireless Sensory Infocommunication Network for Polygon Testing of Guided and Unguided Rockets and Missiles // 2018 International Scientific-Practical Conference on Problems of Infocommunications Science and Technology, PIC S and T 2018 – Proceedings, 2019. C. 705–710.

[10] AAP-6. Словник термінів та визначень НАТО [Електронний ресурс]: NATO/NSA Brussels – BE, 2005. Режим доступу до док.: http://www.nsa.nato.int.

[11] STANAG 1241. Угода НАТО з питань стандартизації. Опис структури ідентифікації НАТО для тактичного використання [Електронний ресурс]: NATO/NSA Brussels – BE, 2005. Режим доступу до док.: http://www.nsa.nato.int.

[12] Artemenko A. M. Problems of standardization of classification of air objects for providing of intergovernmental exchange information about an air situation // Системи обробки інформації, випуск 4 (78), 2009. С. 6–9.

[13] Шостко И.С. Анализ энергопотребления модулей для беспроводных сенсорных сетей стандарта IEEE 802.15.4 / И.С. Шостко, Ю.Э. Соседка // Радиотехника: Всеукр. межвед. научн. - техн. сб.– 2014. – №176. – С.253–257.

[14] Шостко И.С. Анализ потребляемой мощности и продолжительности работы в автономном режиме элементов беспроводных сенсорных сетей / И.С. Шостко, Ю.Э. Соседка // Сборник научных работ ХУВС «Системы обработки информации». – Вып. 5 (121). – 2014. – С. 100-104.

[15] Shostko Igor, Sosedka Julia. Proposals for the Integration of Various Wireless Sensor Networks. / XIIth International Conference "MODERN PROBLEMS OF RADIO ENGINEERING, TELECOMMUNICATIONS, AND COMPUTER SCIENCE", TCSET'2014, February 25 – March 1, Lviv-Slavske, Ukraine. – 2014. – P. 444–445.

[16] Shostko Igor, Kulia Ye. Applications of Multipath Routing for Energy Balancing in Sensor Networks // Scientific and Technical Journal «RADIOELECTRONICS & INFORMATICS». – 2015. − P1 №1. – 2015. – P. 12-16.

[17] Shostko Igor, Kulia Ye. Разработка модели маршрутизации беспроводной сенсорной сети с учётом устранения дисбаланса энергопотребления // Технологический аудит и резервы производства — № 3/2(23), 2015.– С. 94-98.

[18] K. Lukin, O. V. Zemlyaniy, D.Tatyanko, S.Lukin, V.Pascazio. Noise radar design based on FPGA technology: On-board digital waveform generation and real-time correlation processing // Proc. of the 18th International Radar Symposium (IRS2017), Prague, Czech Republic, June 28-30, 2017, pp. 1-7. DOI: 10.23919/IRS.2017.8008223

[19] K.A. Lukin, O.V. Zemlyaniy, D.N. Tatyanko, S. Lukin and V. Pascazio, "FPGA-based time-integrating multichannel correlator for Noise Radar applications," 2016 9th International Kharkiv Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves (MSMW), Kharkiv, 2016, pp. 1-5, DOI: 10.1109/MSMW.2016. 7538135.