# Applied problems of information systems operation

UDC 004.942 **doi:** https://doi.org/10.20998/2522-9052.2022.4.11

Lamiya Nabadova

Institute of Control Systems of ANAS, Baku, Azerbaijan

## DETECTION OF FLIGHT OBJECTS PASSING THROUGH THE CONTROLLED AREA BY SURVEILLANCE CAMERAS

**Abstract.** The article discusses the issue of monitoring air borders with the help of video cameras with the necessary technical capabilities and the detection of dangerous flying objects in order to prevent illegal and potentially dangerous flying objects trying to cross the border by air. The surveillance device is required to operate in the controlled area at the given altitude in a way that not to overlook suspicious flying objects passing through the zone. In order for surveillance devices to carry out the search process, the control zone is first distributed among the devices, and then the search modes of the devices are determined. In order to assess the abilities of any flight object to pass through this control zone during the search along the control lane, the overlooked periods of different points of the control lane during the monitoring process are evaluated and then compared with the flight time of this object.

**Keywords:** flying objects; monitoring zone; border surveillance; monitoring; surveillance cameras.

### Introduction

One of the most important security issues any country.is ensuring air protection of borders and preventing illegal transportation by air.

Therefore, first of all, there is the issue of monitoring separate parts of the borders and detecting suspicious aircrafts.

This work, which is traditionally carried out by border guards, can executed with the help of specially designed devices at a time when technical means and information technology are widely developed.

Paper [1] discusses detection of location of a flying object by two different cameras located at a certain distance from each other. It is clear that the number of such surveillance cameras along the border should be limited.

Therefore, the question arises as to how to place each such device along the border (determine the distance between them) and how to carry out surveillance process in the area allocated for each of them.

This issue can be named the issue of determining the optimal search mode of the surveillance camera. It is clear that during the surveillance process, the surveillance camera can be directed into space in different ways. Determining the optimal search mode means that the surveillance device in the controlled area is oriented in such a way that suspicious flying objects passing through the control zone are detected without being overlooked.

The problem of the optimal searching mode for surveillance cameras requires consideration of two main aspects.

The first aspect is the distribution of the border area among the surveillance cameras. As mentioned above, in [1], it is intended to determine the position of a suspicious flight object in the space with the involvement of another (parallel) camera. An example of the separation of the border zone to the control zones of different cameras is given in Fig/ 1.

Therefore, the border strip must be monitored by at least two cameras. For this purpose, the border area is distributed among the monitoring cameras, each of cameras observes in a control zone allocated for it. If any surveillance camera detects a suspicious object, it transmits information to another camera to follow it, and the spatial coordinates of the suspicious object are detected by two cameras.

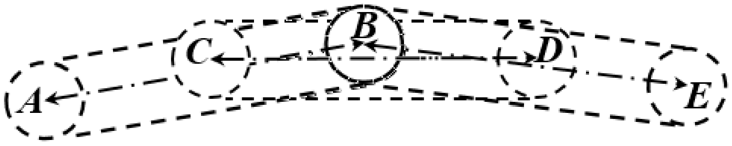


**Fig. 1.** Distribution of monitoring zone among video cameras.
*AB* – I camera, *CD* – II camera, *BD* – III camera

Another aspect is that the cameras have a limited range of viewing distance, as well as a limited range of viewing angles.

Thus, in order to "see" a specific object clearly, the camera needs to switch to identification mode, it demands to direct camera at flying object, depending on the flight altitude of it. In general control mode, the video camera is tuned to a certain limited range of vision.

During the monitoring process, each camera is directed into the sky and moves back and forth in the corresponding part of the observation strip. It is clear that during the movement of the cameras in this way, various parts of the control trajectory remain out of control. In principle, the passage of a dangerous flight object over the control lane may occur if the place is out of control for a sufficient period of time.

Thus, the essence of determining the optimal search mode of the surveillance camera is that, depending on the technical capabilities of the cameras and the dangerous flight object, it is always possible to detect this object.

Thus, from a mathematical point of view, the problem can be considered the problem of determining the optimal mode of motion on a certain trajectory. This type of issue has been addressed, in [2-8] articles.

In the article [2], published in journal of "Mathematical Problem in Engineering" in 2018, the issue of complete coverage of given are with obstacles by multiple robots is investigated. In this paper, the notion of complete coverage of are with obstacles was taken into consideration that, the robots would pass all the obstacles and cover the remaining zone with the trajectory of minimum length by consuming minimal amount of energy and time.

The proposed solution to the problem consists of two stages. Firstly, DARP algorithm (Divide Are based on Robots Initial Positions) [3] has been applied and territory has been divided into several equal subareas among robots. This process carried out according to numbers, capabilities and initial positions of robots. Then, each robot carried out coverage process in the territory allocated for itself. In this way, multi robot coverage problem turned into several single robot coverage problems.

After dividing interesting territory among robots, to calculate best trajectory to fully and efficiently, ACO (Ant Colony Algorithm) was proposed [4]. This algorithm assisted to calculate best trajectory of minimum length to embrace every point of given are by spending less time and decreasing number of turns which ended up with consuming minimum energy.

In article [5] - called "Efficient complete coverage of a known arbitrary environment with applications to aerial operations" the issue of coverage of previously known territory with arbitrary obstacles by single unmanned air vehicle was studied. The proposed algorithm firstly decomposed controlled are into non-overlapping cells using Boustrophedon technique [6], then Reeb graph was constructed which described free coverage are. The next step was calculation of Euler circuit which passes through vertexes of Reeb graph (Euler circuit passes through every vertex only once). Lastly, per-cell motion transformed into complete trajectory.

So, the coverage trajectory became sequence of waypoints. According to less maneuverability of waypoint-based control, this algorithm did not guarantee efficiency in terms of minimum time, energy or minimal covering trajectory.

The main purpose of this algorithm was to cover every single point of controlled are, not to obtain covering trajectory of minimum length.

Paper [7] addresses completely covering previously known area with trajectory of minimum length by multiple robots. İt should be noted that there are obstacles in a controlled area and the places of these obstacles are static.

Additionally, according to the statement of the problem, there is no information Exchange among robots, all robots starts from same initial point and they must end up at same target point.

Paper investigated two algorithms to solve the given coverage problem based on grid-based and cellular decomposition methods. In grid-based decomposition approach, controlled territory is described as a grid-map and each value of cell shows whether or not there is an obstacle.

In cellular decomposition, only free space of controlled zone splits into non-overlapping cells and union oh them represents original free zone. First algorithm is called Coverage with Route Clustering and it is extension of single robot coverage algorithm [5] into multi robot case.

In this case, controlled are is decomposed into non-overlapping cells, minimum coverage trajectory is calculated and the length of this efficient trajectory is distributed among each robot.

Second approach is called Coverage with Area Clustering and in this way, firstly area is distributed among robots, then each subarea decomposed into non-overlapping cells. The covering path is calculated for each robot in zone allocated for it. İn the article, the comparisons of both algorithms have been shown according to different criteria.

However, in terms of the intersection of control zones and the assessment of the period of remaining out of control, the models proposed in these articles do not allow to solve the problem.

The following is a mathematical formalization and solution of the problem.

## Mathematical formalization and solution of the problem

An aircraft can determine its location by image processing on the basis of different principles [3-5]. Different approaches are used depending on the nature of the problem being solved, the characteristics of the cameras taking pictures, as well as the number of pictures taken, the accuracy of object identification, and other criteria.

Let's include the rectangular coordinate system $OXYZ$ with respect to the ground. We will assume that the $OXY$ plane is parallel to the earth's surface, with the $OZ$ axis perpendicular to the $OXY$ plane and directed vertically upwards. α is the angle of view of the camera, and H denotes the average height at which the camera is tuned.

The viewing area of a camera with optics set to a distance H can be considered a circle. Let's denote the radius of this circle by R and the angle of rotation of the camera in the control zone by $\varphi$.

It can be considered that the angle $\varphi$ varies in the interval $[-\varphi_0, \varphi_0]$. Here $\varphi_0$ is determined taking into account the technical capabilities of the routing device. For each distinctive camera, a schematic description of the control area is depicted in Fig. 2.

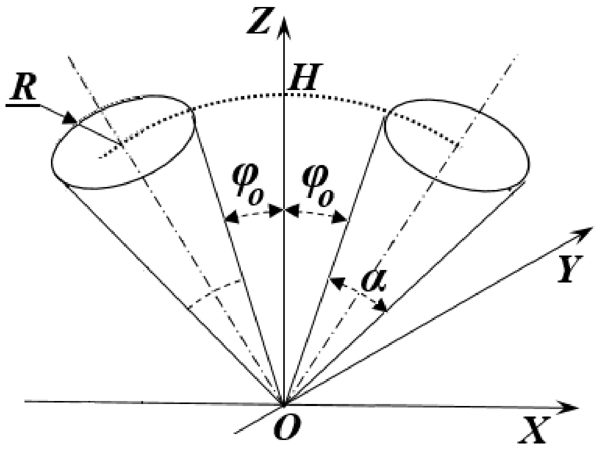


**Fig. 2.** Monitoring of control zone in $[-\varphi_0, \varphi_0]$. interval

As it seems from the Fig. 2,

$$R = H \cdot tg\frac{\alpha}{2}.$$

It is considered that surveillance cameras act synchronously according to the law of harmonic motion. In other words, depending on time $t$, the rotation angle of each camera can be calculated with

$$\varphi = \varphi_0 sin\frac{2\pi}{T}t\,,\ \ t > 0, \quad (1)$$

where $T$ is the full period of back and forth ovement along the lane.

In order to assess the ability of a suspicious flying object to pass through the control lane, it is necessary to first assess the extent to which various parts of the camera are overlooked during the movement along the lane, and then compare this time with the flight time of the object. Depending on the rotating angle $\varphi$, the time of neglected part of monitoring strip is denoted by $T_0(\varphi)$, the maximum value of speed of dangerous flying object passing through this monitoring strip is denoted by $v$. It is considered that $v$ is known.

Then, the time required for such an object to pass through the control zone is:

$$T_1 = \frac{2R}{v} = \frac{2H}{v}tg\frac{\alpha}{2}.$$

To assess the overlooked duration of each point in the control zone, let's look at the $CB$ section in Figure 1, construct the time-dependent functions of overlooked duration through the cameras located at points $C$ and $B$. The control function of the $CB$ zone of the camera located in $B$ according to formula (1) is calculated:

$$\varphi = \varphi_0 \sin\frac{2\pi}{T}t. \quad (2)$$

The control function of the camera located at point $C$ and working synchronously with point $B$ at that zone is calculated:

$$\varphi = \varphi_0\left(1 + \sin\frac{2\pi}{T}t\right). \quad (3)$$

Then the time difference calculated from formulas (2) and (3) for each $\varphi \in [0, \varphi_0]$ determines the overlooked duration of this point:

$$d_{21} = \frac{T}{2} - \frac{T}{\pi}\arcsin\frac{\varphi}{\varphi_0} = \frac{T}{\pi}\left(\frac{\pi}{2} - \arcsin\frac{\varphi}{\varphi_0}\right),$$

$$d_{32} = \frac{T}{2\pi}\left(\arcsin\frac{\varphi}{\varphi_0} - \arcsin\left(\frac{\varphi}{\varphi_0} - 1\right)\right),$$

$$d_{43} = \frac{T}{\pi}\left(\frac{\pi}{2} + \arcsin\left(\frac{\varphi}{\varphi_0} - 1\right)\right),$$

$$d_{14} = \frac{T}{2\pi}\left(\arcsin\left(\frac{\varphi}{\varphi_0} - 1\right) - \arcsin\frac{\varphi}{\varphi_0}\right).$$

It easily seems that,

$$\max_{\varphi}\{T_0(\varphi)\} = \frac{T}{2}.$$

Since the assessment mechanism of other parts of the control strip is similar, the $\frac{T}{2}$ value obtained for the period of overlooked duration can be applied to all its parts.

From the condition

$$T_1 < \frac{T}{2}$$

it is possible to determine the relationship between the required technical parameters of the required surveillance cameras and their operating modes, to prevent the object from passing through the control zone depending on its speed $v$:

$$4 \cdot H \cdot tg\frac{\alpha}{2} < v \cdot T.$$

## Conclusions

In the article the problem of detecting of suspicious flying objects in the border area monitored by surveillance cameras controlled by angular velocity is examined.

Taking into account the viewing angle of the camera, the width of the surveillance area, the time taken by the camera to move from one point to another along the monitored lane, we calculated that at ühich speed the flying objects will be detected by these cameras.

REFERENCES


1. Nabadova, L.N. (2021), "The system of calculating the coordinates of the flying object by applying two surveillance cameras", *The Proceedings of the International Scientific-Practical Conference Dedicated to the Anniversary of the Victory Achieved in the 44 Day Patriotic War*, October, 21-22 2021, Baku, pp. 147–150.
2. Chunqing, G., Yingxin, X., L. Zhanwu, Xu, A., Li, Y. and Chang, Yi. (2018), "Optimal multi robot coverage path planning: Ideal-shaped spanning tree", *Mathematical Problems in Engineering*, China, pp. 1–10.
3. Kapoutsis, A. Ch., Chatzichristofis, S.A. and Kosmatopoulos, E.B. (2017), "DARP: Divide Areas Algorithm for Optimal Multi-Robot Coverage Path Planning", *Journal of Intelligent & Robotic System*, Vol. 86, pp. 663–680, doi: https://doi.org/10.1007/s10846-016-0461-x.
4. Alexandrov D. and Kochetov Y. (1999), "Behavior of Ant Colony Algorithm for the Set Covering Problem", *Operations Research Proceedings*, pp. 255–260, doi: https://doi.org/10.1007/978-3-642-58300-1_38.
5. Xu A., Viriyasuthee, C. and Rekleitis I. (2014), "Efficient Complete Coverage of a known arbitrary environment with applications to aerial operations", Autonomous Robots, 36, pp. 365–381, doi: https://doi.org/10.1007/s10514-013-9364-x.
6. Choset, H. and Pignon, P. (1998), "Coverage Path Planning: The Boustrophedon Decomposition", *Proceedings of 1st International Conference on Field and Service Robotics*: Springer Verlag London Limited, London, December 1997, pp. 216–222.
7. Karapetyan, N., Benson, K., McKinney, C., Taslakian, P. and Rekleitis,I. (2017), "Efficient Multi-Robot Coverage of Known Environment", RJS International Conference on Intelligent Robots and Systems, Vancouver, BC, Canada: IEEE, 24-28 September 2017, pp. 1–7, doi: https://doi.org/10.1109/IROS.2017.8206000.


Received (Надійшла) 19.09.2022
Accepted for publication (Прийнята до друку) 23.11.2022

ВІДОМОСТІ ПРО АВТОРА / ABOUT THE AUTHOR

**Набадова Ламія Назим гизи** – аспірант, головний лаборант Інституту систем управління Національної академії наук Азербайджану, Баку, Азербайджан;

**Lamiya Nabadova** – graduate student, chief laboratory assistant at the Institute of Control Systems of the National Academy of Sciences of Azerbaijan, Baku, Azerbaijan;

e-mail: nabadovalamiya@gmail.com; ORCID ID: http://orcid.org/0000-0003-1353-8515

## Виявлення літаючого об'єкта під час проходження через контрольну зону камер спостереження

Л. Н. Набадова

**Анотація.** Стаття розглядає питання моніторингу повітряних кордонів за допомогою відеокамер з необхідними технічними можливостями та виявлення небезпечних літаючих об'єктів з метою запобігання незаконним і потенційно небезпечним літаючим об'єктам, які намагаються перетнути кордон повітряним шляхом. Пристрій спостереження повинен працювати в контрольованій зоні на заданій висоті таким чином, щоб не пропускати підозрілі літаючі об'єкти, що проходять через зону. Щоб прилади спостереження здійснювали процес пошуку, спочатку розподіляється зона контролю між пристроями, потім визначаються режими пошуку пристроїв. Щоб оцінити здатність будь-якого об'єкта польоту пройти через цю зону управління під час пошуку вздовж контрольної смуги, пропущені періоди різних точок контрольної смуги під час процесу моніторингу оцінюються, а потім порівнюються з часом польоту цього об'єкта.

**Ключові слова:** літаючі об'єкти; зона спостереження; спостереження за кордоном; моніторинг; камери спостереження.