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THE APPLICATION OF SPATIAL TRIANGULATION FOR INSTANTANEOUS TRACKING OF FLYING OBJECTS IN SPECIFIED AREA

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ABSTRACT:
This paper deals with the question of precise real-time determination of the spatial position of multiple detected point objects by implementation of passive infrared systems for searching, tracking and monitoring. In the scope of presented investigation, the determination of the spatial coordinates of the objects is based on their angular coordinates, previously obtained by the methods of successive detection and spatial triangulation.
KEYWORDS:
IRST, tracking, triangulation, multisensor, passive network.

1. INTRODUCTION

One of the main difficulties in the real-time signal tracing of flying objects is how to obtain highly reliable information. Possible difficulties may be prevented by careful selection of: sensors, the way of their implementation in the system and the determination method of detected object's parameters. The signature structure of the object with formed trace depends on the variation of both the concentration and spatial distribution of exhausted particles, on the engine type and on the flying object's shape, size and height. Our method of triangulation depends on the sensitivity and space resolution of infrared systems for flying objects search and tracking, IRST (Infra Red Search and Tracking system) [1, 2], incorporated in a monitoring network. A multisensor network of IRST systems has many convenient characteristics, like long range of detection, passive operation, low probability of error etc. Their optimal concept [3, 4] enables high spectral range, wide visible area, low distortion and adequate modulation transfer function (MTF). In the network, IRST systems function independently from other sensor systems during the process of determination of the object parameters. This differs from the methods where the systems are coupled with radar systems and where tracking is based on interactive multiple-model of filtering and on multiple-hypothesis tracking IMM-MHT [5]. Optoelectronic (OE) systems are characterized by high spatial and temporal resolutions, and they provide the azimuth and the elevation of detected object. By their connection into the network and by adequate implementation of spatial triangulation [6,-8], it is possible to simplify the determination of the distance parameter. In our method of spatial triangulation, one segment of a command information system (CIS), type C4I2SR, which corresponds to one part of an optoelectronic network of IRST sensor systems, has been analyzed. The reliability of the method has been tested, taking into account the performances of chosen sensors, the performances of the network as well as the response time of the system. For the sake of better and faster data processing, the output data are consisted of both the coordinates of the objects in the Cartesian coordinate system and the reliability parameter provided by this method.

2. METHODOLOGY: TEORETICAL OVERWIEV FOR SIMULATION ANALYSE

2.1. The conception of a sensor network based on IRST sensor systems

The sensor network for spatial triangulation of objects captured in observed space and in real time relies on the CIS, which has following advantages:

- The possibility of inexpensive realization by using commercial devices and systems; this influences the network density (the number of sensors, communication devices and computer equipment per square area, where these devices have been placed according to specific criteria) and its quality; it is not necessary to use the devices and systems of particular purpose, except in the case of particular demands;
- The flexibility of the system;
- The possibility of placing, controlling, managing, maintenance and supervising of the whole system by small number of experts;
- Instantaneous detection and tracking of multiple distant objects.

Due to the passive mode of operation, the system is insensitive on disturbances, which is of outmost importance in tracking of unregistered flying objects in specified area of the sky over protected territory.

The flexibility of the system is due to relatively uncomplicated structure of the network. Sensor cells are dispersed on the ground and connected in the network. Having in mind the current level of development in sensor technology, one can say that the hierarchy of the connections can be changed quickly and conveniently. Sensor cells are consisted of three to six IRST sensor systems. Each IRST system is enclosed in a mobile station and is uniquely coupled with appropriate communication devices and a commercial computer. The computer is provided with software packages necessary for the station to function and to be supported – one of the lowest-level elements of the CIS.

The cell modeling considered various structures, from three sensors placed in the corners of an equilateral triangle, to six sensors placed in the corners of an equilateral hexagon. Three demands appeared:

- To search the area allocated to an individual sensor as quickly as possible;
- To maintain high reliability during the operation;
- To implement as few sensors as possible.

Various sensor networks, with symmetrical and asymmetrical cell architectures, have been considered, and the network characteristics have been analyzed in respect of the CIS response.

In this paper, the operation of a simplified sensor cell has been modeled by one of the ST programs (ST is an internal term and stands for the spatial triangulation) and the results of a numerical simulation with the implementation of the spatial triangulation have been presented. One sensor cell, consisted of three non-collinearly IRST sensor systems placed on the ground and mutually displaced from 2 to 4 km, has been considered. The procedure of synchronization enabled these systems to simultaneously and uniquely detect and track the changes in the observed area up to 40 km distance. The model of observation, formed with three pairs of coupled IRST systems, practically is stereovision.

2.2. Input/output vector arrays of data and the implementation of the spatial triangulation

The sensor cells are networked depending on the CIS conception. Inside one cell, the structure and the connection hierarchy is specific for each particular model. Each cell is allocated a specific area of the sky to observe, thus obtaining the distribution of flying objects. For each cell and its area, following vectors are defined:

One, corresponding to the partitive set $C_p \subset C$ of flying objects, which are in one precisely defined part of the observed area [9]:

$$C_p = [C_{p1}(x_{p1}, y_{p1}, z_{p1}, t_i), C_{p2}(x_{p2}, y_{p2}, z_{p2}, t_i), \cdots, C_{pk}(x_{pk}, y_{pk}, z_{pk}, t_i)] \quad (1)$$

where the set C_p is represented by an array of n vectors, defined by the Cartesian coordinates x_{pj}, y_{pj}, z_{pj} ($j=1,k$) and by the time t_i. The coordinates belong to objects captured in the time t_i over specified (selected) area of the sky. The subscript p corresponds to the sensor which detects dispersed targets in the area, while k is a number of captured objects of a particular partitive set, so:

$$C = \sum_{p=1}^{l} C_p ,$$

The other, corresponding to projected images of the partitive set of flying objects for each sensor inside a considered cell:

$$S_p = [C_{p1}(\alpha_{p1}, \beta_{p1}, t_i) \cdot P_{p1}, C_{p2}(\alpha_{p2}, \beta_{p2}, t_i) \cdot P_{p2}, \cdots, C_{pk}(\alpha_{pk}, \beta_{pk}, t_i) \cdot P_{pk}] \quad (2)$$

S_p denotes the array of the vectors of projected images (here, the subscript p has the same meaning as the subscript p in Eq.1); P_{pj}, $j=1,k$, is the probability of the occurrence of the object (i.e. the occurrence of the object's signal in the image); P equals 1 if the object occurred in the area; P equals 0 otherwise - the object is either obstructed by another one or faded due to some signal decaying in the atmosphere.

The sensors operate synchronously and search the area in the direction of increasing azimuth. The signals from detected flying objects are selected and successively numerated from higher to lower values of the elevation (for a particular azimuth value) towards increasing azimuth. It is obvious that the numeration of the vector array C_p does not correspond to the numeration of the vector arrays S_p; the numeration inside one of the vector arrays S_p is not unique. This is one of the major problems of the spatial triangulation. Another problem is related to the atmospheric conditions. Namely, it is not possible to distinctively track the local contrast variations in the image from one segment to another, due to stochastic variations in the atmosphere. Besides this uncertainty, there is also the uncertainty of detection (detection probability > 50%) of very distant objects, which points to the presence of a false signal (a false-alarm signal).

Due to the false-alarm signal, in each sensor's station an array of false-detected signals would appear:

$$L_p = [L_{p1}(\alpha_{p1}, \beta_{p1}, t_i), L_{p2}(\alpha_{p2}, \beta_{p2}, t_i), \cdots, L_{pq}(\alpha_{pq}, \beta_{pq}, t_i)] \quad (3)$$

where L_p denotes vector arrays of false detected flying objects, p denotes the index of the sensor station, q denotes the ordinal number of the (false detected flying) object in the vector in the moment t_i in observed area; in the same sense are implemented the indices by the values of azimuth (α) and elevation (β) of false detected flying objects.

Generally, vector arrays of projected images are defined for each sensor:

$$S_p = [L_{p1}(\alpha_{p1}, \beta_{p2}, t_i),, L_{pq}(\alpha_{pq}, \beta_{pq}, t_i), C_{p1}(\alpha_{p1}, \beta_{pi}, t_i) \cdot P_{p1},, C_{pk}(\alpha_{pk}, \beta_{pk}, t_i) \cdot P_{pk}] \quad (4)$$

In the process of the spatial triangulation over the area covered by the cell, it is necessary:

- In the set of projected images of the partitive set, to distinct the signature of actually occurring flying objects from the false signals;
- To determine the distance of each of the detected objects;
- To transform the coordinates into the Cartesian coordinate system.

The coordinates of sensor stations in the cell as well as in the whole network, are uniquely determined. Delay times (the image formation time, the time of parameters calculation for targeted objects in a frame, the time for formatting the data of the objects targeted in one frame, etc.) are well-defined and short.

Since it is not possible to uniquely obtain both the number and the distribution of both false and true signals in the image, the input vector arrays (of projected images of the partitive set of objects), described by Eq.4, can be practically expressed as:

$$S_p = [s_{p1}(\alpha_{p1}, \beta_{p1}, t_i), \cdots, s_{pr}(\alpha_{pr}, \beta_{pr}, t_i)] \quad (5)$$

where s_{pj} denotes the element of the set, j=1..r, and r represents the total number of detected signals in a frame. The time t_i is characteristic for vector arrays of the cell during one frame formation on each of the sensors. The time t_i, "the system time", is transferred together with the data about the objects and their trajectories, and is used to track a particular object (to detect its trajectory). During the process of the spatial triangulation, the azimuth and the elevation are also stored in the computer memory as "the address of a potential flying object". The coordinates of false signals will be suppressed during the calculation and the distances from the main sensor station to each of the detected objects will be determined. Moreover, the data of the distance between the main sensor and the object is used to transform the object's coordinates into the Cartesian ones, thus becoming the new address of the object. Besides the objects' coordinates and "the system time", a reliability parameter is adhered to the vector array. The reliability parameter is a new parameter, correspondent to each of the elements. The final expression of the outgoing vector array of captured objects in the area and the time for the cell is:

$$S_p = \left[s_{p1}(x_{p1}, y_{p1}, z_{p1}, T_{p1}, t_i), \cdots, s_{pm}(x_{pm}, y_{pm}, z_{pm}, T_{pm}, t_i)\right] \quad (6)$$

where T is the reliability parameter, and m is the final number of detected objects.

Extremely high spatial resolution of the IRST [10] (visible area being approximately ~10 mrad) justifies the implementation of the spatial triangulation for stereovision observation in the following manner: two IRST systems, positioned in the corners of a triangle (coupling via common side) are implemented three times.

For the beginning of the consideration, let us focus on one pair of IRST systems implemented in the process of the spatial triangulation. During the distance calculation, the input vector arrays have to be modified. As in Eq.5, the value of the azimuth in the input vector arrays is corrected in respect to the azimuth of the stations distance projections, measured from the north direction in the plane of the main station's azimuth α_{PTp}. The index *p* corresponds to the station from which the angle of the azimuth is measured.

For: $\alpha_{PTp} \geq 180^0$:

$$\alpha_{PTp}\begin{cases} 0, \alpha_{PTp} - 180 : \\ \alpha_{PTp} - 180, \alpha_{PTp} : \\ \alpha_{PTp}, 360 : \end{cases} \quad \alpha^*_{pj} = \begin{cases} \alpha_{pj} + (360 - \alpha_{PTp}) \\ \alpha_{PTp} - \alpha_{pj} \\ \alpha_{pj} - \alpha_{PTp} \end{cases}$$

and for $\alpha_{PT} \leq 180^0$:

$$\alpha_{PTp}\begin{cases} 0, \alpha_{PTp} : \\ \alpha_{PTp}, \alpha_{PTp} + 180 : \\ \alpha_{PTp} + 180, 360 : \end{cases} \quad \alpha^*_{pj} = \begin{cases} \alpha_{PTp} - \alpha_{pj} \\ \alpha_{pj} - \alpha_{PTp} \\ \alpha_{PTp} + (360 - \alpha_{pj}) \end{cases}$$

so the arrays of input vectors (* denotes the corrected value) are expressed as:

$$S_p = [s_{p1}(\alpha^*_{p1}, \beta_{p1}, t_i), \cdots, s_{pr}(\alpha^*_{pr}, \beta_{pr}, t_i)] \quad (7)$$

The coupling of the input coordinates, involved in the process of the triangulation, is not uniquely determined. Potential distances between the elements of the input vector are calculated by the implementation of the sine theorem (a matrix of distance pairs is formed) [9, 11]:

$$\begin{cases} R^*_{1i} = \dfrac{p_{pS1S2} \cdot \sin(\alpha^*_{pj})}{\sin(\alpha^*_{pi} + \alpha^*_{pj})} \\ R^*_{2j} = \dfrac{p_{pS1S2} \cdot \sin(\alpha^*_{pi})}{\sin(\alpha^*_{pi} + \alpha^*_{pj})} \end{cases} \quad (8)$$

Here, *R* are distances from the object to one of the two stations, *i* and *j* correspond to the pair of the object's coordinates in the matrix of distance pairs, and p_{pS1S2} represents the projection of the distance between two stations into the plane of the azimuth of the main station.

The verification of the data validity is performed depending on the height parameter:

$$H_1 = H_2 - (z_{S1} - z_{S2})$$

or:

$$R^*_{1i} \cdot tg(\beta_{pi}) = R^*_{2j} \cdot tg(\beta_{pj}) - (z_{S1} - z_{S2}) \quad (9)$$

A new parameter is z, denoting the height of the stations, *S1* and *S2*. Taking into account the reality of the system, the height difference is calculated depending on the acceptable tolerance of the error, h_{gr}, which is determined in the program:

$$R^{*}_{1i} \cdot tg(\beta_{pi}) - [R^{*}_{2j} \cdot tg(\beta_{pj}) - (z_{S1} - z_{S2})] < h_{gr} \tag{10}$$

Fulfilling the condition (10) means that the specific pair of vectors has been found in different input vector arrays - a pair whose parameters determine the potential flying object. Two vectors from the matrix of the distance pairs, each from its vector array, are expelled; the size of the data matrix as well as the number of calculation reduces. A search for the pair of one input vector continues until a corresponding pair is found. If no corresponding vectors have been found in the input array of another vector, the next vector of the reference vector array is examined.

The parameter R_{pi} increases the vector dimension and is determined as:

$$R_{pi} = R^{*}_{pi} \cdot \cos(\beta_{pi}) = \frac{p_{pS1S2} \cdot \sin(\alpha^{*}_{pj})}{\sin(\alpha^{*}_{pi} + \alpha^{*}_{pj})} \cdot \cos(\beta_{pi}) \tag{11}$$

Finally, the first output vector (with potential objects) of the main station is obtained:

$$S^{(1)}_{p} = \left[s^{(1)}_{p1}(\alpha^{*}_{p1}, \beta_{p1}, R_{p1}, t_i), , s^{(1)}_{pm}(\alpha_{pm^*}, \beta_{pm}, R_{pm}, t_i), s^{(1)}_{G1}(\alpha^{*}_{G1}, \beta_{G1}, R_{G1}, t_i), , s^{(1)}_{Gk}(\alpha^{*}_{Gk}, \beta_{Gk}, R_{Gk}, t_i) \right] \tag{12}$$

where the index *G* represents the array of the calculation error, while the index *k* shows the total number of false generated objects. The implementation of the triangulation expels all the false targets generated on each of the sensor systems during one period of area searching. In order to avoid the false-generated targets (specific cases of the spatial distribution and modes of flight of the group of flying objects), implemented program uses two tests. The first one compares the input vector array of the main station, expressed by Eq.7 to the first output array of the main station. The test selects as valid all output vectors in which there is a match of values of both the azimuth and the elevation with a specific vector from the input vector array. It is therefore possible to memorize one or all of the false-generated vectors which describe the presence of the object (a mask in front of or a mask behind of an object). This problem is finally solved by the implementation of the comparative second test, on the level of the sensor cell. After the implementation of the first test, the spherical coordinates of the objects are transformed to the Cartesian and new output vector arrays on the main unit are compared. If the vectors in all of the three last formed output vector arrays are recognized as identical, then the vector is given the verification factor T_p=3 and is separated in the final output vector array. If the vectors in two output vector arrays are recognized as identical, then the vector is given the verification factor T_p=2 and is considered to be semi-correct (i.e. the case when it is not possible to perform enough precise measurements, or when the object is too distant to be detected). If the vector is not recognized as identical in no more than in one output vector array, the vector is given the verification factor T_p=1 and is considered as incorrect (computing error, the object is too distant etc.). Generally, the output vector array, expressed in Eq.6, represents the array with the verification factor T_p=3. Depending on the purpose of the program, the output vector array may be provided the vectors with the verification factor T_p=2. It is because of the expectations that in some of the following moments of tracking their factor of verification will become T_p=3 or T_p=1 (i.e., disappear). The vectors in the array are ordered in the above mentioned way, but the vectors with T_p=3 are presented firstly, and then the vectors with T_p=2. High reliability may also be achieved by careful conception of the sensor network.

3. FINAL RESULTS

3.1. Input parameters of the IRST sensor system

Implemented IRST sensor system may fulfill following demands:

- the detection of an object with the radiation intensity of 10 *W/sr* on the distance of 50 km;
- mean average of atmospheric losses may be approximated with the factor of 0.3;
- NETD < 0.01 *K* [12];
- *MTF* > 0.5 [12].

Selected parameters are estimated as [12, 13]:

- Sensor field of view (FOV) - 360^0 x 20^0, 360^0 x 40^0 and 360^0 x 60^0;
- Searching time of the whole area – 1*s*, 2*s* and 4*s*;
- Aperture diameter – 254*mm*;
- $F^{\#}$ = 1;
- Scanning mode;
- Wavelength range - from 3 to 5 *μm*;
- Specific detectivity of a detector - $2*10^{11} cmHz^{1/2}/W$;
- Instantaneous field of view (IFOV) - 0,2*mrad*, 0,35*mrad* and 0,5*mrad*;
- The length of a detector array – 1024, 2048 and 4096 detectors.

3.2. The results of a numerical simulation performed by ST-1 for the cell model

Captured potential objects are represented with input vectors inside corresponding stations of the sensor cell. The objects are used to select actually occurring flying objects and their complete data vector which defines them - this requires a certain amount of time. In order to test this time, we created a simulation program which defines:

- The length of randomly generated vector arrays, arrays which represent the number of potential objects;
- The Cartesian coordinates of objects and false targets;
- The random distribution of the input vector array of the station which describes both present objects and false targets inside the observed area (in the program, the number of objects seen from particular station is varied by random selection or by precise definition, depending on the mode of research);
- The start of the ST-1; the formation of the output vector with correct data, reliability and the time needed for the calculation.

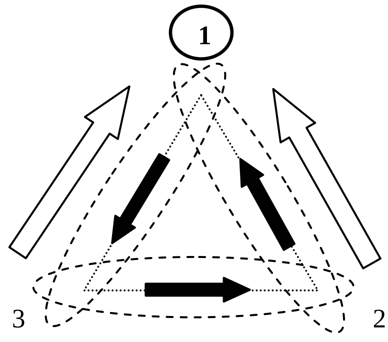

Figure 1. The schematic representation of the sensor cell

The end of the output data verification/sorting procedure is the outcome of the output vector array, which is transferred to end users via CIS. In Fig.1, the schematic of the sensor cell is presented, together with the data flow during the execution of the program and the forming of final output vector arrays of data of actually present objects.

In Fig.1, the sensors (sensor stations) are marked with digits. The pairs of stations, with vector arrays involved in the spatial triangulation one by one, are represented by the ellipses. The directions of the arrows on the triangle sides depict the data flow directions from the subordinate to the main stations in the scope of one pair of the stations for execution of the ST-1. It is obvious that each station in this model (considering the coupling of the stations) has both roles (subordinate as well as main), but within different pairs. The reliability on the object as well as the probability of its successful capture is measured by output data comparison. Output vectors, obtained from an individual station, are transferred to the station 1, the main station of the cell.

The ST-1 takes input vectors from two coupled sensors as input values, as described in Eq.5. After that, it corrects the input vector values in respect to the azimuth of the stations mutual distance projection onto the plane of the azimuth of the main station. In the process of the determination of the distance parameters by the triangulation, the stations are paired and, for each pair, one station is declared to be the main. This station is considered to be the referent for the determination of the distance between the object and the sensor. The output vector of the pair of stations represents the Cartesian coordinates of captured objects and is transferred to the main station of the cell. In the main station of the cell, a final output vector is formed, which includes both the attached reliability parameters and the system time, as described in the Eq.6.

The simulation program contains following units:

1. A numerical procedure for random generation of the Cartesian coordinates of the objects flying inside the area observed by one sensor cell; the number of the objects is provided beforehand and should be less than a hundred;
2. A numerical procedure which distributes the coordinates of the objects to the stations, depending on the probability of the occurrence of false-captured objects;
3. A numerical procedure for random generation of the Cartesian coordinates of false objects inside the area observed by one sensor cell, depending on the probability of false capture of the objects (for each station of the sensor cell); maximum probability of the presence of the false objects per sensor station is 50%;
4. A numerical procedure for the transformation of all attached Cartesian coordinates into spherical ones for each of the stations;
5. A procedure for input vectors forming (without the distance parameter);
6. The start of the ST-1;
7. The time measurement;
8. The output data verification (i.e., validity check of the simulation model).

The results of the simulation are presented in Fig.2and in Table 1.

In Fig.2, the mean time needed for the determination of the final output vector array is presented, based on the values presented in Table 1.

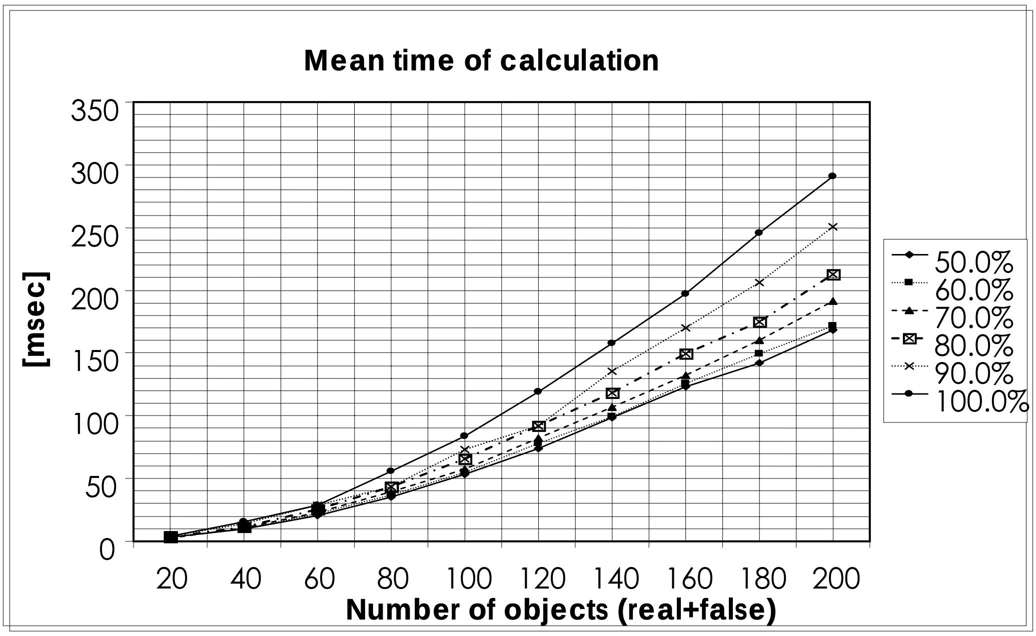

Figure 2. Graphical presentation of the mean time needed for the determination of the final output vector array

Table1. Calculation mean time (in ms) for the determination of final output vector array for variable number of potential objects and the probability of the actual occurrence of the objects (in %)

Calculation mean time [ms]		The probability of the actual occurrence of the objects in %					
		50.0	60.0	70.0	80.0	90.0	100.0
Variable number of potential objects	20	3.485	2.885	2.765	3.46	3.82	4.085
	40	9.995	10.25	11.025	11.91	13.65	15.4
	60	20.915	21.815	22.81	25.37	28.36	28.36
	80	35.105	36.77	39.405	43.47	43.47	55.525
	100	53.57	55.065	57.585	65.355	73.135	84.085
	120	73.605	77.78	82.335	92	92	119.43
	140	98.4	99.69	106.455	118.58	135.62	157.555
	160	123.04	125.955	132.115	149.805	169.77	197.375
	180	142.125	149.235	160.08	175.15	205.89	245.96
	200	168.025	171.605	191.41	212.755	250.78	290.75

In Table 1, the mean time needed for the calculation (in ms), depending on the number of potential objects and on the probability of actually captured objects, is presented. 20 different data types were varied for each choice.

3.3. Analysis and discussion

Under assumed conditions, the maximum number of objects flying in the area observed by a particular sensor cell, without the possibility to collide, is theoretically estimated to be around a hundred. In the program, the number of potential objects is numerically varied up to 200. It is actually possible to assign high values in the program, but this has no physical sense for the capability of this type of the cell, because the collision in the area becomes a certain event when the number of objects exceeds 100. The experience, earlier calculations and the literature point out that, practically, for small objects, a space 7km by 7km should be reserved in the plane of the azimuth, for all heights of the flight (the tube) [10, 12, 13]. For objects pairs, a 10km by 10km room may be used for all heights of the flight [10, 12, 13], for the sake of shortening the calculation time.

Taking into account the physical sense of false objects, it was assumed for this calculation that both the number of captured objects and the number of false-captured objects on all stations are approximately the same (in performed simulation, the two numbers were taken to be identical). Only the ratio between the numbers of false and actual objects has been varied.

The algorithm for the determination of the distance parameters of captured objects by method of spatial triangulation does not take into consideration the objects having the angle in the plane of the azimuth less than 5° in respect to the direction (p_{pS1S2}) of the calculation. To determine the distance and other parameters of these objects, the other direction inside the zone enclosing the targets is used. Thus, the error in the determination of the object distance is decreased. The algorithm assumes that the target height and distance errors are less than 50 m. Framing time of a panoramic image is 1 s, while the minimum time of the system response (the time elapsed from the moment of the first acquisition of the object to the response of the end-user) is less then 7 s. The necessary coordinate transform as well as data sorting (the array ascending by the azimuth) has been included in the program.

Let there be a theoretical possibility that at least one false object exists in one frame after the process of spatial triangulation, but this probability is rather small. The probability that the same event appears in the next moment (the process is repeated for each frame), after the spatial triangulation of the next frame, is even less than the previous one.

There is a possibility that the number of detected objects is less by at least one, due to the obstruction by other objects. In the process of continuous spatial triangulation, performed for each frame, the probability to detect such an object increases (the distribution of the objects changes dynamically).

The spatial triangulation is applicable in the sky observation for various needs:

- The tracking of variations in the atmosphere,
- The observation of the air traffic,
- The observation and the control in the protection of a specific object (building, protected area, etc.)
- The military purposes.

It is of particular interest in the air traffic, where the application of the CIS may help in the protection against incidents, regardless of their nature (including deliberate incidents). During the regular traffic, flying objects occurring in the area are differentiated by: size, construction, mode of flight, priority, the importance of the load (people, goods …), etc.

By developing the example, it is obvious that each regular flight has its permission, approval, precisely defined flight route, the flight zone, allowed discrepancies of defined routes, etc.

In the case of a sudden deviation of the route, a quick reaction is really necessary. Concerning contemporary observation systems, the protection against unwanted events consequences due to such deviations is relatively small, because the reaction time of these systems is greater than the time for the incident to occur in or out of the air area. The concept of the reaction, which isolates the possibility of the incident from the area, assumes that the organization of the traffic is such that allowed flights (routes, zones, etc.) are distant from the objects of special interest, economic objects and urban areas. The objects of special social interest are reachable only by special dedicated flights, specially defined routes, with special means of flight identification and control. The objects of special interest should be provided with the CIS for immediate reaction to the threat from the air.

The other case assumes the appearance of an uninvited object in the area. In this case, the application of the passive sensor system of the CIS (for the observation of the area) provides the selection of such an object based on the known trajectory bases for allowed and approved flights. This work considers this other case by the implementation of the sensor system with devices for image formation based on the appearance of the contrast. The system provides the measurement of spherical (angular) coordinates of captured objects, the determination of their distances form the sensor station, the transformation of measured and calculated coordinates of the objects and their instant tracking.

Unfortunately, from the other side, the availability of the commercial components for the observation system integration, allows the possibility for sophisticated disturbance of the air traffic, both into and out of the area.

4. CONCLUSIONS

The simulation approved the obtaining of highly reliable information of P=0.82 probability, in real time, by the implementation of a sensor network based on the IRST system, because of the great range of remote detection, passive mode of operation, small probability of error, high reliability, etc. The possibility of the optimal conception of the structure of a sensor cell was pointed out and the time needed for the calculation of the coordinate values of the objects by the ST-1 was shown. Achieved times of operation of the simulation program were less than 1 s on PII, and less than 1/10 of second on PIV.

The IRST system enables the panoramic search of the area for the time T=1s. The possibilities when the search periods were T=2s and T=4s were also considered, as well as the simulating the IRST system by the implementation of the FLIR and adequate scanning system with the area search time of T=4s. It is well known that the transfer of the information on the objects in this way, by a communication channel, with the implementation of a crypto-protection, needs T<3s, which shows that it is possible to perform the reaction of the CIS system for the time T<7s, which is a remarkable result, having in mind that it is expected that the estimated time of the reaction to be T<13s.

It can be assumed that each target is uniquely reflected from the domain of the originals into the domain of the images. By considering this problem in respect to passive systems with the formation of images, assumed in this work, the identification of the objects which are not planned or which are not at the allowed route, can be performed in familiar, convenient and simple way, thus providing the prompt reaction of the system.

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