Геометрияповерхностей и кривых

REMOVAL OF THE FALSE TARGETS IN THE ISSUESOF SPATIAL TRIANGULATION BY PROJECTIVE GEOMETRY METHODS

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This paper deals with an issue of determination of the spatial coordinates within confined area in general terms. Mobile air space control stations were set and related to the system of spatial triangulation. As a result of the air space "scanning", targets appear in adequate representation, representing identified aircrafts and other flying objects (FOs). The main objective is interpretation of collected data processing, in order to determine the reliable coordinates of an aircraft. The problem of false target identification occurs when data are analyzed from only two stations. Descriptive Geometry method, for the construction of the planes containing rays targeted from the station towards the flying objects, in both classic-orthogonal projections and 3D model, as well, offers the solution of a problem. Dynamic 3D model consists of two flying objects, monitored from two stations in predefined time periods. The constructive 3D solutions represent geometrical locus of false targets trajectories, for several settings of flaying objects and monitoring stations. The analyses have shown geometrical positioning of the third station impact to the exact FO's coordinates determination. The geometrical solution could be the key for the development of numerical method, which will lead to applied software solution.

KEY WORDS: spatial triangulation, target coordinates, geometrical model, false targets trajectories.

Introduction

For the improvement of the air space control and within research for the efficient flying object (further FO) detection[1] [1-5], spatial triangular network of mobile stations for the detection and monitoring in infra-red range - IRST (Infra Red Search and Tracking) is set. Each set of (three) stations carry out a task of successive "scanning" of the air space segment, resulting with the field of points – i.e. detected FOs (targets). The objective of data processing, collected from three stations, is determination of the exact coordinates of FOs (targets). This is three-phase procedure:

[1] This is the exact FO's coordinate determination

1. Determination of geometrical locus* of possible FOs, when observed from a single station (* a straight line connecting monitoring station and FO).

2. Monitoring from two stations A & B of specifically defined FO's (trajectories), when possible false target's coordinates are of meeting point of two straight lines – joining FOs and adequate monitoring stations.

3. Introduction of the third station C, which serves for the exact FO's coordinates determination.

1. The Concept of the Geometrical Model

Geometrical Model (Fig. 1) is consisting of two mobile land based stations A & B and two FO-targets[2] a_1& a_2 within air space segment, at undetermined altitude and mutual distance. FOs are represented by trajectory segment, within time interval Δt, from position a_1, i.e. a_2, to the new relative position $\tilde{a}_1$ i.e.$\tilde{a}_2$.

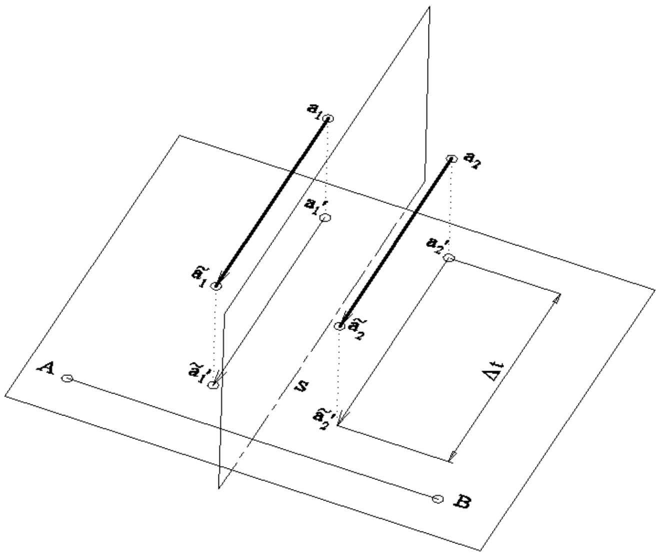

Fig. 1

Regarding practical aspect, it is important to know a distance between FOs – D_{min} and the FO's altitudes too, because of identification and the time interval between two subsequent air space segment monitoring. Concerning geometrical aspect, the above mentioned factors have no influence to the solution. During computer data processing, for the FO coordinates determination, the difference in station elevations is taken into consideration too. Possible elevation difference towards Azimuth plane is computed. In this analysis it is assumed that all stations are at the same elevation.

1.1. Starting Assumptions

The following assumptions are adopted for the geometrical model:

- FOs are moving horizontally and maintain the parallel alignment
- FOs are maintaining the identical speed

[2]It is important to emphasize that remote objects (targets), could be at first approximation considered as points. If object is closer, the adopted point represents the geometrical center of the 'object's silhouette'.

- Air space control stations A, B and C are in the Azimuth plane.

Geometrical analysis of starting assumptions shows appearance of the false targets, during monitoring of two targets from two monitoring stations[3]. It requires geometrical positioning and afterwards, the method for elimination of these false targets.

2. Moving of the Flaying Objects – Models

There is a broad range of possible models of moving of FOs. Therefore four models of FOs movement are partially brought up here:

IFOs are moving horizontally, in parallel alignment, with identical speed v=const[4], at same altitude *h*– at minimal orthogonal distance (Fig. 2)

IIFOs are moving horizontally, in parallel alignment, with identical speed v=const, at different altitudes$h_1$and h_2– at minimal orthogonal distance (Fig. 3)

IIIFOs are moving horizontally, in parallel alignment, with identical speed v=const, at the same altitude *h*, within "formation" (Fig. 4)

IVFOs are moving horizontally, in parallel alignment, with identical speed v-const, at different altitudes$h_1$and h_2, within "formation" (Fig. 5).

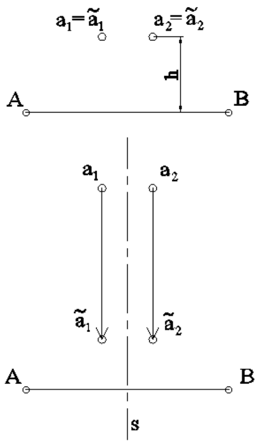

Fig. 2

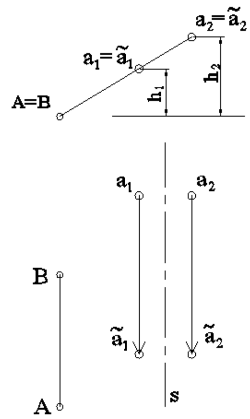

Fig. 3

Each figure (Fig.2 - Fig.5) is represented by two orthogonal projections of models: front view (top drawing), and top view (lower drawing).

3. The Solutions for the Assumed Models

Each of the assumed models, predefined with specific setting of FOs, in the given time interval, and the adequate solutions for geometrical locus of the false targets (further *glt*), will be analyzed in order to figure out the way for prompt false targets elimination, upon detection. Designation of FOs, stations and time intervals are in compliance with Descriptive Geometry.

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[3]When observing, two targets a_1 and a_2, from two monitoring stations, one can notice cross section of lines – the connectors of stations and targets, in two extra points called "false targets".

[4]In the case of various speeds of FOs, Descriptive Geometry would give the same results which detection cannot confirm.

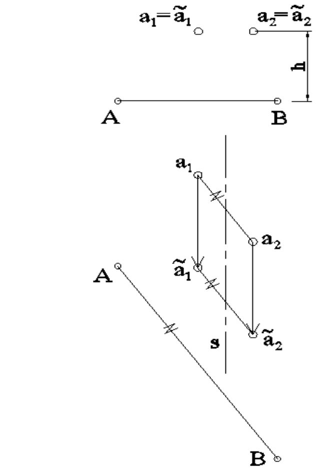

Fig. 4

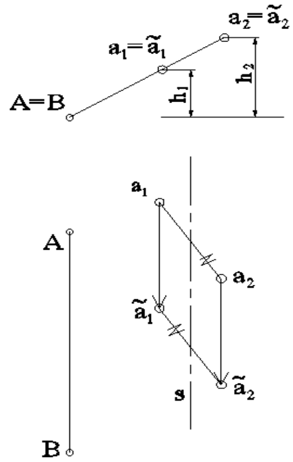

Fig. 5

3.1 Model I

This model is presented in Fig. 6, as the specific T moment, where targets a_1 and a_2 can be found and then, after time interval Δ t, another moment $\tilde{T}$ is considered. In the moment T, in meeting points of the straight line segments: Aa_1, Ba_2 and Aa_2, Ba_2, the false targets L and $\boldsymbol{l}$ appear, respectively. In the subsequent moment $\tilde{T}$, likewise, in the meeting points of straight line segments $A\tilde{a}_1$, $B\tilde{a}_2$ and Aa_2, Ba_1, the false targets $\tilde{L}$ and $\tilde{l}$ appear, respectively.

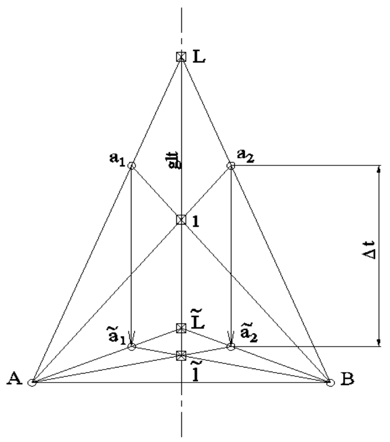

Fig. 6

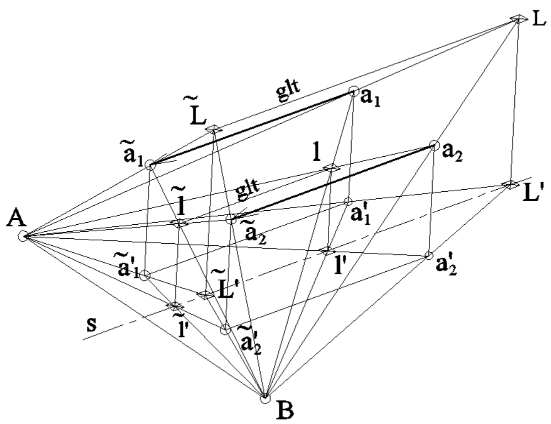

Fig. 6a

One must point out that the false targets appear when four points: two stations A & B and two monitored targets a_1& a_2, are coplanar. In dynamic terms, the geometrical locus of the false recognized FOs (glt) are two horizontal straight lines (Fig. 6a), positioned above each other, in the plane of symmetry *s,* of stations A & B.

3.1.1. Model Ia

In the given moment T, FO's trajectories are perpendicular to the connection line of the stations A & B, in relation to the translated axes *s* (Fig. 7). Connections of the pairs of false targets $L, \tilde{L}$, and $l, \tilde{l}$ are horizontal straight lines, parallel to the FO's trajectories, i.e.

geometrical locuses of the false targets - glt (Fig. 7a). These are intersecting lines of two planes containing one station and adequate FO's trajectory (the planes $Aa_1\tilde{a}_1$ and $Ba_2\tilde{a}_2$, meet along connection $L,\tilde{L}$, likewise, planes $Ba_1\tilde{a}_1$ and $Aa_2\tilde{a}_2$ meet along connection $l,\tilde{l}$).

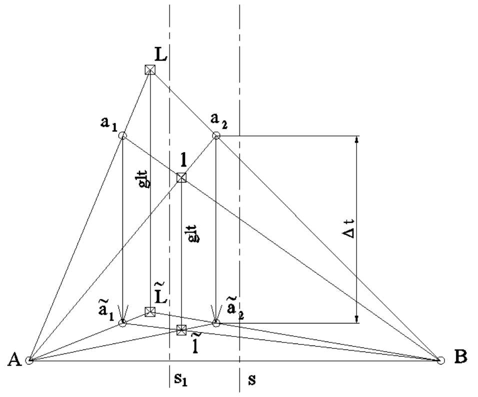

Fig. 7

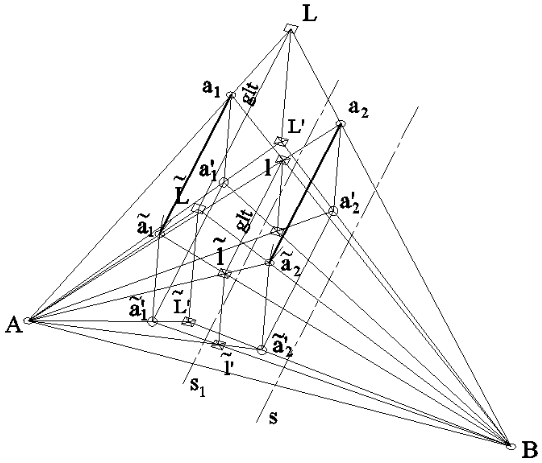

Fig. 7a

Geometrical locus of the false targets (glt) were found in 3D model (Fig. 7a), as two horizontal lines parallel to the FO's trajectories, at different altitudes, moved with respect to the plane of symmetry s (of the stations A & B) and plane of symmetry s_1 (of the two FOs).

Control of model I, when 3rd station C added (in model I), is represented in Fig. 8. Top view presents monitoring rays (lines) and their meeting points -apparent false targets: $\tilde{L}_{AC}{}^*$, $\tilde{L}_{BC}{}^*$and $\tilde{l}_{AC}{}^*$, $\tilde{l}_{AC}{}^*$, likewise $l_{AC}{}^*$, $l_{BC}{}^*$ and $L_{AC}{}^*$, $L_{BC}{}^*$. Nevertheless, the monitoring lines from the pairs of stations A & C, and B& C towards targets$\tilde{a}_1$ &$\tilde{a}_2$, and a_1& a_2, are bypassing in space (as shown in Fig. 8a), because sets of four points A,C, $\tilde{a}_1,\tilde{a}_2$; B,C, $\tilde{a}_1$, $\tilde{a}_2$, and A,C,a_1,a_2 ; B,C,a_1,a_2 are not coplanar.

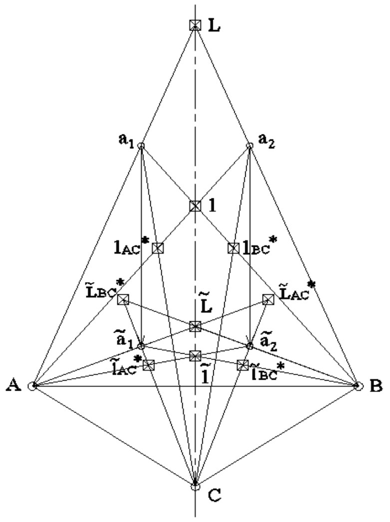

Fig.8

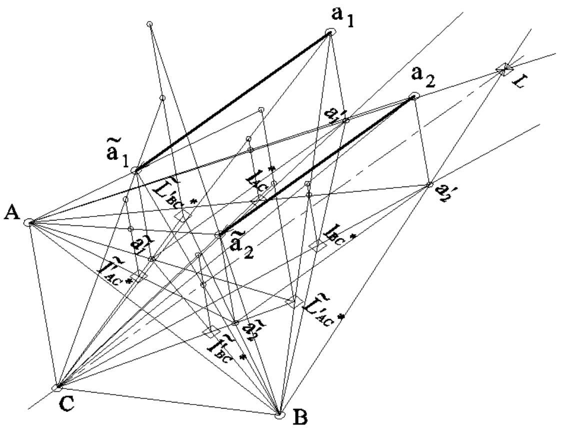

Fig.8a

Conclusion for the Models I &Ia

- False targets appear only when two stations (A and B) and two monitored targets (a_1& a_2) are coplanar, and additionally, if connection line of the monitoring stations A & B is perpendicular to the FO's trajectories.
- By introduction of the third station C, anywhere in the Azimuth plane (if stations A, B and C are in non-collinear position) the exact position of both targets can be determined, i.e. confirmed.
- False targets can be eliminated by setting of two stations A & B in position where their connection is not perpendicular to the FOs trajectories.

3.2. Model II

Two FO's targets are shown in Fig. 9. Both FOs have horizontal flying trajectories on the different altitudes. A connection of stations A and B is set parallel to the FO's trajectories, obtaining the same plane including trajectories.[5]

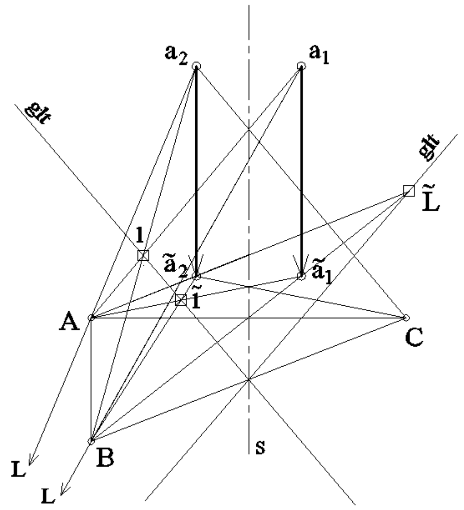

Fig. 9

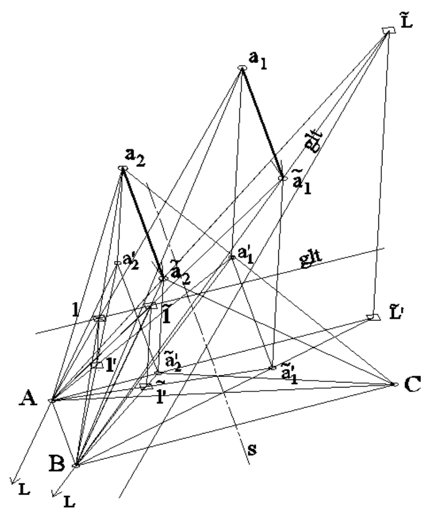

Fig. 9a

The trajectories $a_1,\tilde{a}_1$ and $a_2,\tilde{a}_2$ are horizontal lines of inclined plane, where stations A and B are also included (all six points: stations and FOs are coplanar). The false target l arises as meeting point of straight lines Aa_1& Ba_2 and false target L, as meeting point of straight lines Aa_2 and Ba_1 and likewise, $B\tilde{a}_1$ and $A\tilde{a}_2$meet in $\tilde{L}$, while $B\tilde{a}_2$ and $A\tilde{a}_1$ meet in $\tilde{l}$.Meeting points (false targets) of all the other corresponding pairs of straight lines(rays) of two monitoring beams from stations A & B lay on two connectors $L,\tilde{L}$and $l,\tilde{l},$which are geometric locuses of the false targets. These are two inclined lines *glt* in the observed plane (model in Fig. 9a). They meet in the plane of symmetry *s* of FO's trajectories.

The case (Fig. 10) when FO's trajectories a_1 & a_2 are perpendicular to the connection line of the stations A & B, is also considered. The assumed false targets, with labels l, $\tilde{l}$,

[5]Observing from direction of the FO's trajectories, the plane, containing stations and targets, is seen as a straight line, while trajectories and connector AB appear as points.

L,   in the top view (Fig. 10), do not appear in the model (Fig.10a), because four points (stations A& B and FOs a_1& a_2) are not coplanar. Therefore the connections of A $_1$and B $_2$, A $_2$ and B $_1$, likewise, Aa_2 and Ba_1,Aa_1 and Ba_2, by pass, so it won't be any false targets (Fig. 10a).

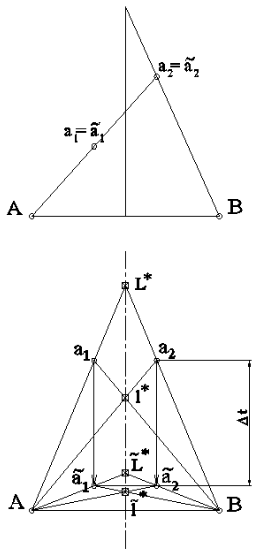

Fig.10

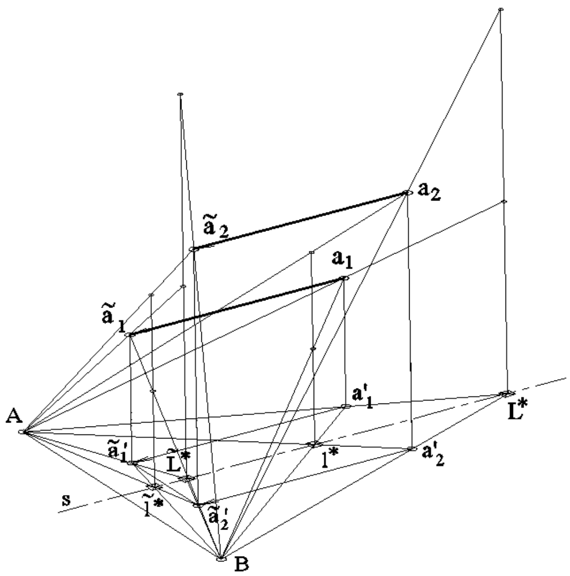

Fig.10a

The 3rd station C was added to the base model (Fig. 11), previously shown in Fig 9. Connection AC is perpendicular to FO's trajectories (like in model in Fig. 5, where no false targets can be found), and connection BC is inclined in relation to the FO's trajectories, creating a disposition for the false target removal. When monitoring targets a_1 and a_2, i.e. $_1$ and $_2$, from the stations B and C, apparent false targets *l**, *, *L**, *appear only in the top view (Fig.11), while the 3D model (Fig. 9a), regarding non-coplanar position of stations and targets, obtains confirmation of thetrue targets.

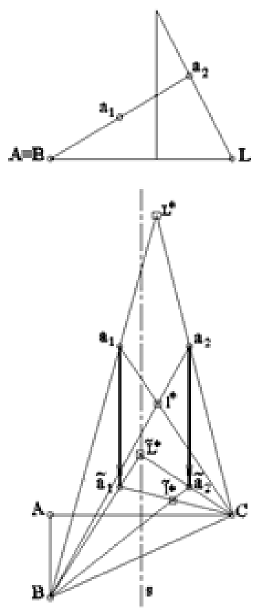

Fig. 11

Conclusion for the Model II

- The false targets appear only if the connection line, of the pair of monitoring stations, in the air control system, is parallel to the FO's trajectories and, additionally, if observed targets and stations are coplanar.
- If connection of the pair of observing stations is perpendicular or inclined to the FOs trajectories, then no false targets can be found.

3.3. Model III

There are three typical cases shown in Fig.12a-c – dispositions of the FOs and stations, where the false targets appear. The FO's trajectories are translated[6], parallel and have

[6] Previously, this disposition of flaying objects and their trajectories is called "in a formation".

tical speed. Thereby, FO a_2 is ahead of FO a_1, at distance Δv. FOs are moving obliquely in relation to the connection of stations A and B. Since two targets a_1, a_2 and two stations A and B, define a plane (the connection a_1a_2 is horizontal – parallel to "0 horizontal" AB), the false targets *l* and *L* appear. When speaking in geometrical terms,"0 horizontal" is the *trace* of the inclined plane, in fact, in all considered cases, a connection line of the pair of monitoring stations. If dynamic aspect included, the geometrical locus (glt) of the false recognized FOs are two horizontal straight lines.

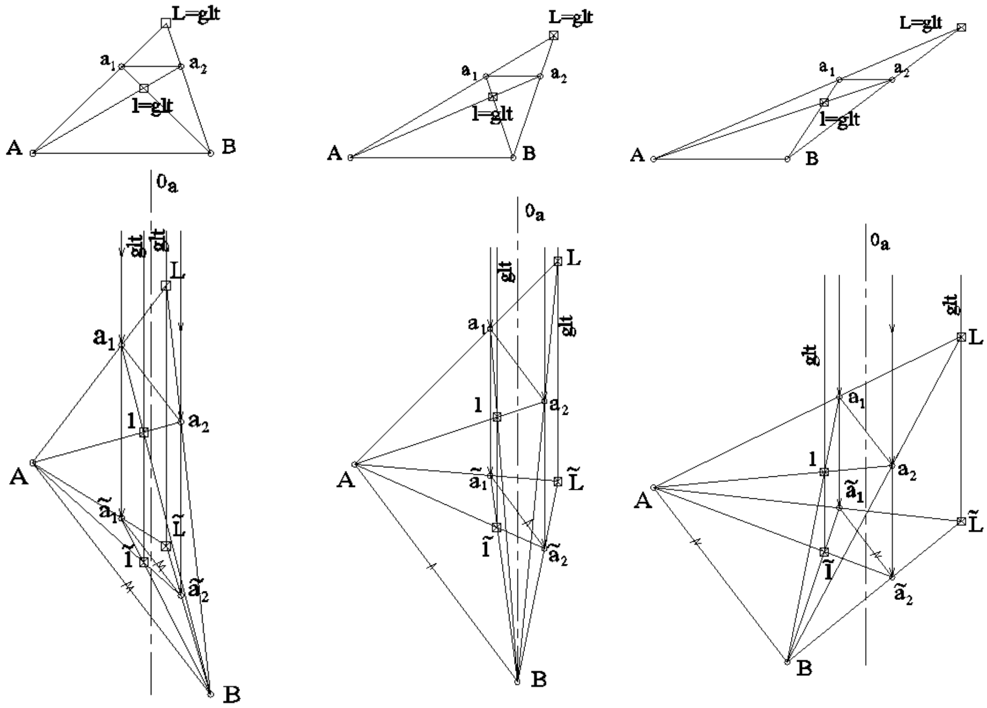

Fig.12 a b c

The Case 1

FOs are moving between stations A & B, where the axis (0a) of symmetry of the two FOs crosses the connection line AB (Fig. 12a).Two parallel lines, false targets (glt),at different altitudes, pass by, between FO's trajectories.

The Case 2

FOs are moving between stations A & B, in a way that the axis (0a) of two FOs passes through the point B (Fig. 12b). One of the false targets lines (glt), is between FOs trajectories and the other, is in the external space.

The Case 3

FOs are moving off from the connection AB, i.e. off from the axis (0a), not meeting it (Fig. 12c).The pair of false targets lines (glt) is beyond "flying" space, from the opposite sides of the FO's trajectories.

When analyzing of the three above mentioned cases, it is noticed that while moving of station B, in relation to the axis (0a) of the FOs trajectories, the locuses of the false targets (glt) have a tendency of moving from "inner" (between FO's trajectories) towards the area of the "outer" space. The boundary cases will be a subject of special analyses on given presumptions.

The variation of previous models is established in Fig. 13, with such settings, where two stations A&B are "aligned" with targets $_1$ and $_2$. For the pair of monitoring stations A & B, two false target locuses *glt* were determined, and additionally inserted station C, for the confirmation of the targets.

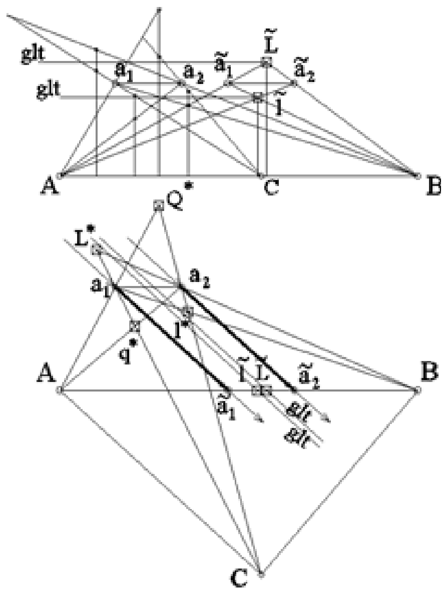

Fig. 13

Conclusion for the Model III:

- False targets appear in the case when connection of monitored pair of targets – FOs (a_1& a) is parallel, or "aligned" with connector of the pair of monitoring stations (A& B).
- By introduction of the third station C, anywhere on the terrain in front of the stations A & B, the exact target position can be determined.

3.4. Model IV

This is the case when two FOs fly in the formation, at different altitudes, monitored from stations A & B (Fig. 14), such as connector AB is parallel to the FOs trajectories, and additionally, all six points – targets and stations are coplanar. Front view is perpendicular to FOs trajectories and connector of the stations A and B, as well. Hence they appear as points, while the inclined plane containing them appears as a line.

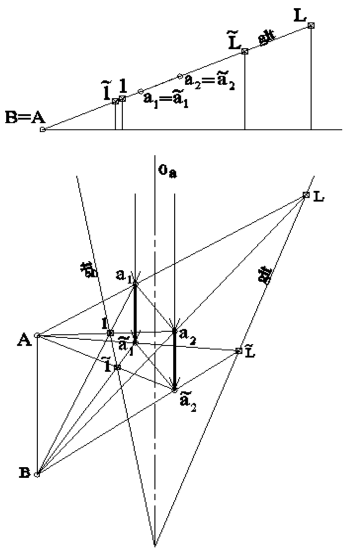

Fig. 14

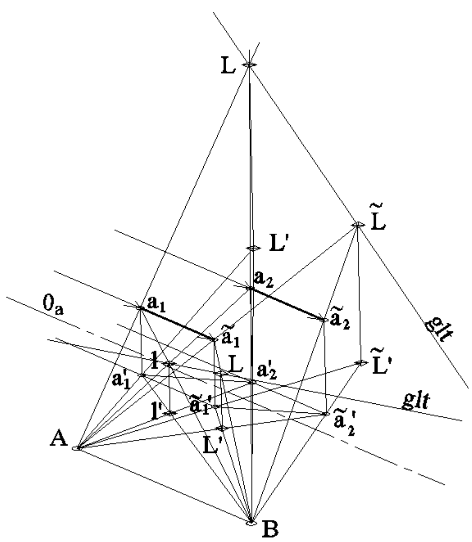

Fig. 14a

The false target locuses (glt) are straight inclined lines meeting in the plane of symmetry of FO's trajectories. Since FOs trajectories are horizontal lines, then the connection of stations A & B must be '0' horizontal of the inclined plane, i.e. it's *trace*.

Conclusion for the Model IV:

- The false targets appear only in the case when connection of two monitoring stations is parallel to the FOs trajectories and additionally if all six points – targets and stations are coplanar.
- By introduction of the third station C, anywhere in front of the stations A & B (with exception of direction AB) the exact coordinates of targets can be determined.
- The false targets won't appear if target monitoring straight lines are bypassing, in fact, if two stations A & B are not coplanar with four targets.

4. Model Applicability

Contemporary topics of "remote sensing" [1] and human ecology care, in the future, are actual for a long time, in the scientific research. Many scientific disciplines gave their contributions to these themes in the field of: cosmic research, peacetime military demands, modelling of climatic conditions, etc., in domain of ecological vision of the world. "Lidar" techniques [2,p.1] (active tasks, such as: emission, creating of the beam of signals, their reception and processing) which enable "data collecting" from atmosphere (temperature, atmospheric pressure, chemical composition....) with precise description of location of "event" and it's prediction, in the problems of monitoring of flying targets, need a strict solutions in Mathematics, Physics and other theoretical disciplines.

From the interdisciplinary point of view, in narrow range of monitoring of flying objects, as "friendly program", Descriptive geometry [4] has found its role in introspection and solutions of spatial aspect of the problem. With its dynamical geometrical models, illustrated in this paper, Descriptive geometry gave solutions - data base for the algorithms useful for the IRST (Infra Red and Tracking) systems [3].

5. Conclusion

The considered models give solutions for geometric false targets locuses for the several possible dispositions of stations and FOs trajectories in the observed air space. Detailed conclusions were given at the end of each model explanation. Each of the above presented models can be considered as "mechanism" which has general, peculiar and border cases, within specific disposition of the observing stations. Obtained solutions could function as the basis for development of corresponding numerical models.

Model solutions indicated that system of triangulation [3] makes sense. Valid for all the cases is that introduction of the third station provides solution for exact determination of the true targets.

For the practical applications, in the problems of "determination of the locus of multiple detected point objects" [3] the following factors are of the special significance: how quickly FO's coordinates could be defined, reliability of method and error tolerance for chosen geometry[7]. For each pair of assumed FOs, in concrete "tracking" problem, is necessary to determine the critical distance – orthogonal or inclined (D_{min}).

R e f e r e n c e s

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ПРИМЕНЕНИЕ МЕТОДОВ ПРОЕКЦИОННОЙ ГЕОМЕТРИИ В ЗАДАЧАХ ПРОСТРАНСТВЕННОЙ ТРИАНГУЛЯЦИИ ДЛЯ ВЫЯВЛЕНИЯ ОШИБОЧНО ИДЕНТИФИЦИРОВАННЫХ ОБЪЕКТОВ

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Данная статья посвящена вопросу определения пространственных координат в ограниченном пространстве в общих условиях. Для контроля воздушного пространства используются мобильные станции, связанные с системой пространственной триангуляции. В результате «сканирования» воздушного пространства, объекты отображаются в адекватных представлениях, характеризующих положение идентифицируемого самолета или другого летательного объекта (ЛО). Основная задача состоит в интерпретации и обработке собранных данных, с тем, чтобы с высокой степенью надежности определить координаты воздушного судна. Проблема ошибочной идентификации объекта имеет место в том случае, если анализируются данные, полученные только с двух станций. Предлагается решение этой проблемы путем использования метода начертательной геометрии для построения плоскостей, содержащих лучи, направленные от станции к летающим объектам, как в классических ортогональных проекциях, так и в виде 3D-модели. Динамическая 3D- модель состоит из двух летательных объектов, отслеживаемых с двух станций в течение заранее определенных периодов времени. Конструктивные 3D-решения представляют собой геометрическое место траекторий ложных объектов для нескольких вариантов взаимного положения летательных объектов и станций мониторинга. Исследования показали влияние геометрического положения третьей станции на точность определения координат ЛО. Геометрическое решение может служить основой для развития численного метода, который приведет к прикладному программному решению.

КЛЮЧЕВЫЕ СЛОВА: пространственная триангуляция, координаты объекта, геометрическая модель, ложные траектории объекта.