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AUTOMATED WORKSTATION FOR TRYOUT OF ESTIMATING ALGORITHMS OF POSITION OF AIRCRAFT UNDER APPROACH AND LANDING OPERATIONS

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Для багатопозиційної радіодальномірної навігаційно-посадкової системи обґрунтований і обраний метод математичного моделювання процесу обробки алгоритмів оцінювання місцезнаходження повітряного судна, показана апаратно-програмна структура його реалізації.

Ключові слова: повітряне судно, навігація, посадка, багатопозиційна система, автоматизоване робоче місце.

For multiposition radio rangefinding navigation and landing system is justified and chosen method of mathematical simulation of estimation algorithms o location of the aircraft, shown the hardware and software structure for its implementation.

Keywords: aircraft, navigation, landing, multiposition system, automated workstation.

Introduction

One of the versions of the navigation orientation of the aircraft in areas such as routes and airfields of regional airlines, where, for whatever reasons, the application of complicated and expensive stationary navigational equipment is undesirable or impossible, is to determine the location by the method of three or more ranges [1], which are measured from the aircraft up to small (portable) radio beacons, the location (position) of which are known, including the coordinates of the runway.

Such mobility radio rangefinding interrogation-response system for light aircraft landing (hereinafter MPLS) is structured on the basis of signal-generating technologies DME (Distance Measuring Equipment), described in [2], where are justified its parameters.

The principle of MPLS operation in the aircraft landing mode, is on board aircraft measurement of distances $D_{1,2,3}$ to transponder beacon *TB* and re-transmitters $RT_{1,2}$ with their known position on ground relative to the runway, and then on-board aircraft calculating of its location, see fig. where $RL_{1,2,3}$ — radio line. Information is given to the pilot in analog form, required for manual flight control and/or digital — for further processing in automatic flight control modes [3].

Parameters characterizing MPLS: operating zone of the system in the approach mode of aircraft to the runway (at altitudes up to 6000m) — 75 km range and 360 degrees in azimuth, in flight (at altitudes above 6000 m) — 240 km (according to the documents ICAO — DO 189).

For systems of such functional purpose, including MPLS, accuracy of aircraft location in landing mode, in standard sector, should be sufficient for performing it in 1 category (in accordance with the documents ICAO, — RNP 0.02/40).

Problem statement

In domestic and foreign practice, creation of electronic systems to ensure the regulated operations of the aircraft near the runway [1], and in particular airborne equipment of aircraft location measurement [2], program-technical complexes (referred to as working out program complexes) working out algorithms for estimating location, based on modern computing facilities, began to be applied relatively recently. Previously created complexes have software in computing codes of previous generations, what makes them unwieldy.

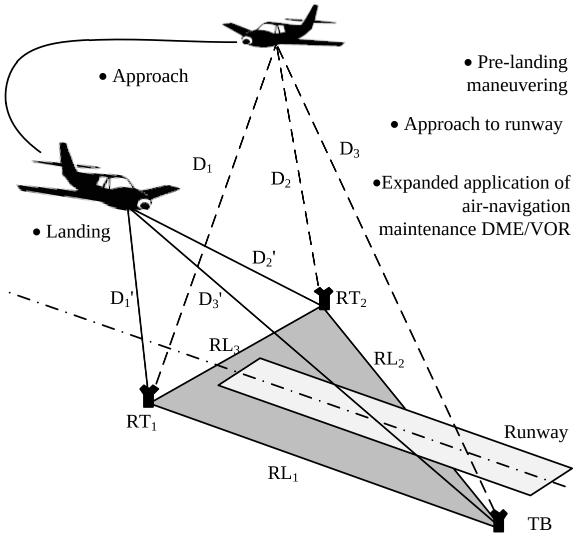

Fig. MPLS operating principle

In addition, the limited ability of such complexes in the number of worked out algorithms and graphical presentation of results makes the actual problem of creating a workstation that uses high-level language with well-developed software and advanced graphics capabilities, allowing work in at least five or six types of coordinate's estimating algorithms.

Absence of software and hardware complex for working out of algorithms of aircraft coordinates measuring by multipositioning radio range finding navigation and landing system [1], hold back the time-frame of their establishment and force hardware engineers to task researchers work in creation of workstation, that providing:

- testing of at least 4 types of algorithms in Fortran-2003 language;
- time spent on testing of an algorithm is not more than 2 hours;
- advanced graphics for display aircraft flight;
- operational definition of aircraft flight trajectories and a number of other service programs.

This raises the need to study the possibility of creating a single shell that can satisfy the sometimes conflicting requirements of the program from each of the algorithms to be working out. Consequently, this work has ***relevance***.

The novelty of problem of approaching to program synthesis of algorithms estimation, proposed in task, is stated in the creation of methods on the basis of which it is possible to construct the required shell.

Creating a workstation with universal shell would be very useful when working using the workstation or its components as a tool for obtaining new knowledge about the processes in the multiposition systems that are relatively not profoundly studied.

Backgrounds of creation of workstation for the algorithms of aircraft location estimation during its approach and landing to the runway

Technology of algorithms development includes itself such steps:

1) problem statement and the choice of way of solutions;

2) the synthesis of algorithm or a group of algorithms;

3) creation of mathematical model;

4) processing and comparative analysis of algorithms on a mathematical model;

5) operation of flight tests through the analysis of specific situations on a mathematical model.

At least the steps of 3,4,5 require a convenient mathematical model, and although this is often required in the first two steps.

The mathematical model includes: a model of the environment with significant impacts for work out of algorithms, software implemented work out algorithms, software elements for recording and displaying of results obtained in the simulation process.

Creation of such a mathematical model is a complicated and laborious process. In addition, if from the first no focus on relatively universal model, and this greatly increases the amount of work, the mathematical model obtained is usually very narrow, covering a limited number of variations and situations.

Upgrading of model by including of additional options leads to difficulties in working with such model.

The way out from this situation is the creation of object-oriented system for developing algorithms. The structure of such a system, which can be called automated workstation, includes input/output system of information, database that includes mathematical models of the environment, working out algorithms database, registration and displaying system.

During the mathematical modeling, such structure allows the system to form a task, i.e. choose kind of environment, algorithms, recording and displaying, and perform modeling of the selected variant of the problem. In this case can be created a database of simulation results of different variants of the problem and comparison them with each other.

It is obvious that such approach to the algorithms work out appreciably simplifies the task and allows analysis and comparison of variants of algorithms without large time-consuming for creation of mathematical model.

Structure and functional capabilities of the automated workstation for tryout of estimating algorithms of the location of aircrafts in the mode of their approach and landing on the runway

Into the composition of automated workstation AW is entered a technical means — personal computer IBM PC/AT with peripherals (printer, mouse), which allow to implement the requirements specified in the task, and software tools that provide solution of service and application programs.

Application software product (ASP), constituent to AW, is built on the block principle, allows an interactive mode of operation and includes itself: block of trajectories, block of algorithms, display block.

It is provided a possibility of forming of different variants of the trajectories, algorithms and information displaying.

It is possible to include to ASP of programs that implement other types of trajectories of aircraft and new versions of the location estimating algorithms.

Block structure of the ASP allows to create the problem for solving, i.e. to choose or to form the trajectory of aircraft, sets the number and location of the beacons, include into the task either selected or new algorithm, choose the type of displaying of simulation results.

Block of trajectories is designed for consistent development of the aircraft location coordinates, belonging to the standard trajectory with set the initial parameters, or the trajectory of a special type defined in the formation of the task. Movement of the aircraft may begin and end at any point of the trajectory.

Block of algorithms includes separate blocks that implement various algorithms: coordinate descent, statistical approximation, nonlinear filtering, calculation algorithms with information about the altitude. It is possible to connect the "empty" blocks, into which can be entered programs that implement some other algorithms of estimation of the aircraft location.

Display block is designed to process the recording and displaying of the simulating results of problem. The form of information display is chose during forming of the task.

Formation of problem, i.e., assignment of initial parameters, of trajectory type, of algorithm type, of displaying type is performed interactive mode and completely determines the whole task from beginning to end of the process.

Necessary for the task formation input information includes:

- the motion parameters (aircraft speed and the time interval between the range estimation);
– trajectory parameters (altitude, turning radius, slip angle);
– amount and coordinates of beacons;
– algorithm used in task (number, σ_R — range estimation).

As a result of simulation, the following output information is represented:

– data array of trajectories (X, Y, Z);
– trajectory displaying the in the coordinates (X, Y); (Y, Z); (X, Z);
– data array of differences of true values of the coordinates with estimations (ΔX, ΔY, ΔZ);
– displaying of differences of true values of the coordinates and estimations in coordinates (X, Y); (Y, Z); (X, Z).

It is possible to save the simulation results on the disk in a data file to display results in future.

Purpose and structure of the AW software

Software for AW implements software support of hardware and represents an application package (AP). AP is designed to run on the operation system MS Windows on a personal computer compatible with IBM PC/AT. For correct functioning the AP requires 300kb of memory and a color VGA-monitor.

AP gives the possibility of algorithms modeling of aircraft control during landing on different trajectories. The AP implemented two types of trajectories and five types of algorithms. It was provided the possibility of a partial upgrading of the AP, which includes the following software:

– module of AW integrated environment, CAACS.EXE;
– two modules of trajectory calculation, TRACK#1.EXE and TRACK#2.EXE;
– five modules of algorithms computing, FLIGHT#1,EXE,FLIGHT#2,EXE,FLIGHT#3,EXE FLIGHT#4,EXE, FLIGHT#5,EXE;
– full screen text editor, EDITOR.COM;
– six modules for creation new tasks written FORTRAN2003, F1.EXE, F2.EXE, F3.EXE, LINK.EXE, LLIBFOR7.LIB;
– two modules to support fonts in graphics mode, COURB.FON, SCRIPT.FON.

Integrated environment CAACS

Work on the AW passes within the scope of integrated environment CAACS, which organize work of the entire AP. Enter into integrated environment (IE) is performed through the launching of the program CAACS.EXE by standard methods of the operating system. Mode of operation is full screen, interactive.

During IE operation display screen is divided into three zones: the zone of operation mode choice, the zone of results display and information zone.

Zone of operation mode choice is a string with a list of available modes: TRACK, FLIGHT, GRAPHICS, REPORT, QUIT. If one of the names has dark background, it means that this area is currently active, i.e. all commands entered from the keyboard of computer, refer to this area. Mode is selected by cursor keys → and ←, and the activation of the selected mode — by pressing ENTER key.

Results display zone is an area on the screen, designed for placement the results obtained in the simulation. Column entitled Xt, Yt and Zt — coordinates of the trajectory points, the column entitled Xf, Yf and Zf — coordinates obtained from the algorithm operation, the column entitled dX, dY and dZ contain information about the differences of algorithmic and trajectory coordinates. If the headline of zone is highlighted by bright white, this zone is active. In this case, the cursor keys ↓ and ↑, and keys PgUp and PgDown allow viewing that part of the results, which did not fit in the display zone. The possibility of "paging" is indicated by arrows ↓ and ↑, located in the upper corners of zone. The transition from zone to zone is implemented by pressing TAB.

Information zone is designed to display the current date and time and can’t be activated by the user.

Modes of operation

Integral environment implements five main modes of operation:

- calculation of trajectory with parameters presetting (TRACK mode);
- algorithm modeling for calculation of trajectories with parameters presetting (FLIGHT mode);
- viewing simulation results in graphical mode (GRAPHICS mode);
- work with the result log (REPORT mode);
- IE shutdown (QUIT mode).

TRACK mode

Mode is used to calculate the trajectory by preset parameters.

During selecting this mode the user has opportunity to select one of two groups of parameters. The first group includes the velocity in m/s and discrete time interval in msec. The group has a name PRECISION. The group included PARAMETERS: number of trajectory variants (from 1 to 3), turning radius in m, altitude in m, angle of descent in degrees. The last three parameters only apply to internal trajectory variants (#1 and #2). Work with user trajectory (variant #3) is described in paragraph 4.

The choice of parameters is realized by cursor keys ↓, ↑ and ENTER. To change the numeric parameters (except the variant number) it is needed to mark the appropriate parameter by dark background, using the cursor keys ↓ and ↑, and then press ENTER. Instead of a dark background will appear a blinking cursor, which characterizes the mode of entering a new value. Entering is completed by pressing ENTER, or pressing ESC. In the first case, the new value is stored in the second is ignored and kept the old value. To change the alternative parameter — number of trajectory variant — it is necessary to mark it by dark background, using the cursor keys ↓ and ↑, and then set the desired number by pressing ENTER. Each click on button ENTER changes the variant number by one.

The key ESC is used to stop operating with parameters group or with all parameters of trajectory. In addition, if parameters were changed or for some reason, the results of trajectory calculation are absent, the trajectory is automatically calculated in accordance with the established parameters. Successful trajectory calculation accompanies changing of content in display zone and its activation.

FLIGHT mode

In FLIGHT mode algorithm modeling is performed by desired trajectory on basis of algorithms and environment selected parameters. After selecting of FLIGHT mode it is necessary to select a group of settings that need changing. These groups are three:

– mode and coordinates of beacons in m (BEACONS group);

– coordinates of the beginning and end of trajectory working zone in m (WORK ZONE droup);

– algorithm variant number and parameter of range noising in m (PARAMETERS group).

The last parameter refers only to the internal algorithms (1—5).

Selection of desired parameters is performed by cursor keys ↓,↑ and ENTER. Changing of beacons mode and algorithm variant presented as alternative rows, is the same as selecting of trajectory variant. Assignment of numerical values of the beacons coordinates and noise parameter is similar to assignment of numeric values in TRACK mode.

Input of coordinates of start and end points of trajectory working zone has difference associated with the need to guarantee hitting of specified values on trajectory. Interested point is selected by cursor keys ↑ and ↓, then ENTER is press. On the screen trajectory is visualized in relative form and position of the selected point is indicated as a percentage of the total trajectory duration. The position of the point is changed by cursor keys → and ←. For the initial point, it ranges from 0 to 98 %, for ending point — from 2 to 100 %. Position increment is 2 %. If the choice ends by pressing ENTER, than recalculation of relative position into absolute coordinates in accordance with the chosen path occurs. If the choice ends by pressing ESC, then the recalculation does not occur, preserved the old values.

Termination of work with this group of parameters is initiated by pressing ESC. Termination of work with algorithms and environment parameters is initiated also by pressing ESC. If in this case parameters were changed, or for whatever reason, there are no results of the algorithm simulation, or trajectory was changed before, then the end of FLIGHT mode accompanies calculation results of the established algorithm and set parameters on the current trajectory.

Working in FLIGHT mode is allowed only with presence of calculated trajectory.

GRAPHICS mode

GRAPHICS mode presents the simulation results in graphical form. Permitted one of the following interpretations:

- projection on the YX plane,
- projection on the YZ plane,
- projection on the ZX plane,
- isometric view,
- graphs of errors (dX, dY, dZ).

The choice of interesting interpretation is similar to the choice of parameters in TRACK and FLIGHT modes.

Returning from a graphical mode — is implemented by pressing ESC.

Working in GRAPHICS mode is possible only by presence of results. If there is only the trajectory, and the algorithm was not simulated, then full trajectory working zone and beacons location are interpreted. ERRORS submode does not work. In the case of presence of complete set of results the trajectory is interpreted within the scope of working zone, the results of the algorithm and beacons location.

REPORT mode

Integral environment CAACS provides the opportunity to work with the result log. When REPORT is selected, access to three submodes is opened, the selection of one of which is carried with cursor keys ↑ and ↓ and pressing ENTER. In PRINT submode the printed output of result log is implemented (hard copy). In SAVE submode saving of results to a file on disk occurs with the name specified in response to the request of IE CAACS. File type is automatically installed as .RPT. Load submode is designed to load log of previous simulation into memory of IE CAACS from a file on disk, a previously saved in SAVE submode. The filename is specified in response to the request of IE CAACS, file type is automatically installed as .RPT. After loading the log, all variables and results are set according to how they were stored in file and can be used as usual input data and results for further work.

QUIT mode

QUIT mode has two submodes, selectable in the usual way. SHELL submode allows temporarily leave IE CAACS and return to the operating system environment. To return to the IE CAACS, the EXIT command must be entered. EXIT submode is completion of work in an integrated environment CAACS, deleting temporary work files, storing the results of the last simulation, a return to the operating system MS Windows.

Working with user programs

IE CAACS, v1.0 allows for expansion of the AP by one trajectory calculation module and algorithm simulation module described by the user. The interface to these modules is implemented through installation of trajectory variant number — 3, and the algorithm variant number —6.

When trajectory number is installed as 3 and exiting from TRACK mode in response to the request of IE CAACS it is necessary to specify a file name with the text of programs written in FORTRAN2003 and contained the procedure of the trajectory calculation. File type is automatically installed as .FOR. IE CAACS establishes full-screen editing of source code. After editing the IP CAACS creates an exe file named TRACK#3.EXE, with the help of which trajectory is calculated. The trajectory recalculating is not performed when refusing to name input.

When using non-standard trajectory calculation procedure the IE CAACS allows the use of three parameters, described as RADIUS, HEIGHT, and ANGLE, but which may carry a different meaning.

IE CAACS interface with non-standard trajectory calculation procedure is implemented through including in procedure text the following statements:

```
* reading of speed, temporary discrete step and
three arbitrary parameters
READ(5,1) IV, IDT, IP1, IP2, IP3
1  FORMAT (5I6)
. . .
* print the number of trajectory points
PRINT 2, N
2  FORMAT (I6)
* print of simulation results
PRINT 3, (ITX(I), ITY(I), ITZ(I), I=1,N)
3  FORMAT (3I6)
. . .
```

Variable names and formats numbers can be changed. The principal is the size of input/output format and sequence of actions. The number of trajectory points should not exceed 512, all transferred parameters must be INTEGER∗2 type.

Using non-standard algorithm calculating procedure is similar to using non-standard trajectory calculating procedure. Interface is implemented through inclusion in procedure text of following segments:

```
*  reading of parameter number of beacon and
trajectory points
READ(5,1) IS, NB, NT
1  FORMAT(3I6)
*  reading of beacons coordinates
READ(5,1) (IBX(I), IBY(I), IBZ(I), I=1,NB)
. . .
*  print of trajectory coordinated
READ(5,1) (ITX(I), ITY(I), ITZ(I), I=1,NT)
. . .
* print of number of used trajectory points
PRINT 2, NT
2  FORMAT(I6)
*  print of algorithm simulation results
PRINT 1, (IFX(I), IFY(I), IFZ(I), I=1,NT)
. . .
```

Transmitted parameter is known in IE as a noised parameter, but the non-standard procedure may have other meaning. Number of beacons is not more than 4, the number of trajectory points not more than 512. Return of number of used points can be used to monitor the successful algorithm simulation. All parameters must be of INTEGER∗2 type.

Using "mouse" device

IE CAACS supports interface with a device as mouse. In presence of the apparatus and loaded device driver, it can be used for working in IE on the following principles:

- pressing the right button always correspond pressing the ESC key on keyboard;
- pressing the left button of device corresponds to choice of element pointed by cursor, i.e. sequence of clicks on the cursor keys and ENTER key (if such clicks sequence makes sense). Using the "mouse" device greatly facilitates the work in IE CAACS.

Features of IE use

1. AP and user programs must be in current section of file system.
2. In case of fatal error the additional information is placed in file TRACK.ERR and FLIGHT. ERR. Access to them is possible in QUIT mode.
3. The software module CAACS.EXE protected from copying and unauthorized distribution.

Conclusion

AW for tryout of estimating algorithms of aircraft location under approach and landing on the runway can solve many problems arising in the algorithms development: to tryout an estimating algorithm for different parts of trajectory, to make a comparative assessment of features of several algorithms variants, promptly include into software of the new trajectories and estimating algorithms, save results for more detailed analysis.

The AW structure allows using it for other purposes, for example: debugging parts of complex mathematical models, analysis of complex systems functioning in different situations, etc.

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