Precise efficiency of autonomous navigation ergatic transport complexes

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Abstract: Selected air transport accepts characteristics without crew systems of air objects which are about to move in selected corridor when the requirements of newly created legislation for relevant object have been fulfilled. The first technical requirement of applicability is to particularize the kinesis of an air transport object (ATO). The paper focuses on primary research, the aim of which is to create a premise of applicability of a navigation ergatic complex NEK. Criteria of applicability of the definition methods of autonomous navigation ergatic transport complexes effectiveness [1],[7] are the premise. From the viewpoint of systematic approach, the usability of objective precision effectiveness, which is by relation defined by probability, has been widely discussed. Air transport object controlled by process, along the determined flight trajectory is determined in time by the probability of not leaving the corridor.

Keywords: Random, Markov process, sensor error mathematical model, correlation function, objective precision effectiveness, corridor borders, probability, navigation precision criteria, observation time, correction, Doppler aerometric inertial complex.

1 Introduction

ATO flux along the defined borders or flight corridor (Fig. 1) is supposed.

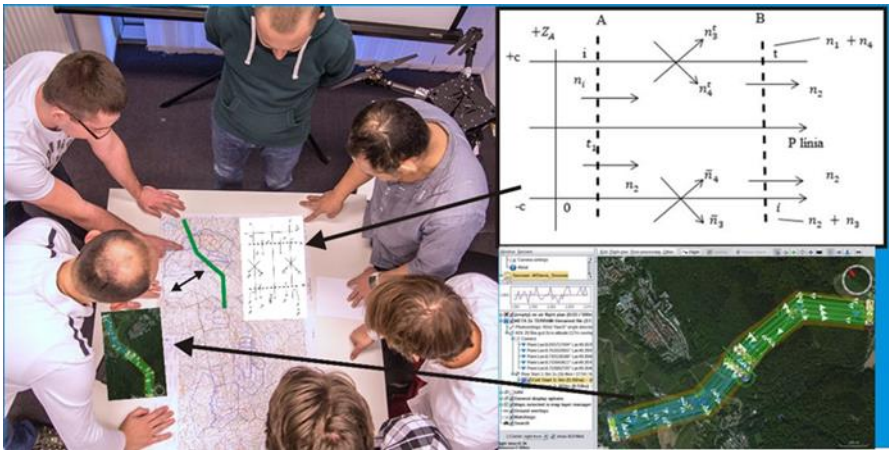

Figure 1

a) Location of hypothetical scheme into actual map environment; b) hypothetical model with transitions across corridor borders +/- c; c) track in real-world in-site corridor; [1], [9],

Probability according to which no flying object crosses its borders is considered. Actual probability can be determined by relation of the number of 'n' ATO, which has not crossed the corridor border to the number 'N' which have moved with control in the observed section. Movement speed of observed objects as well as the conditions of technosphere do not change. From the total number of 'N', 'n_1' ATO returned to the corridor [1] on the border after performing the correction. It means that 'N-n_1' ATO have reached the corridor border or crossed it for a short time. To sum up (see fig. 1), at the time of observation, t(0,T) out of the number ATO 'n_1', 'n_3' have crossed the border and (n4) have returned. In total sum, in final time Tk there have been 'n_2' ATO on the corridor readout and 'N-n_2' outside. Then: $n_1+n_4 = n_3+n_2$. Ratio number of ATO in observed time t(0,T) has been: $(n_1/N) *(1-n_3/n_1)$; after adjustment there are formed probabilities P1, P3. The difference: f/F = Pp.e = P1-P3, can be defined as the criterion of precision effectiveness, where:

$$P1 = \frac{n_1}{N};\ P3 = \frac{n_3}{N}; \tag{1}$$

The criteria used: P2=n2/N increases the value of precision effectiveness navigation ergatic complex (NEC):

$$P2 = P_p\,.e + P4; \tag{2}$$

Criterion: 1-P3 (probability of not crossing of corridor border from inside) increases the estimation of precision effectiveness (NEC):

$$(1 - P3) = P_p . e + (1 = P1); \quad (3)$$

Physical importance:

After substitution (2) into (3), after adjustment the following can be stated:

$$P1 + P4 = P2 + P3; \quad (4)$$

Summary probabilities (4) express lengthwise and side movement of ATO in the observed corridor [5] by indexes. Identity (4) creates premises about the precision effectiveness of autonomous ATO as the bearers of NEC [5]. The criteria of precision effectiveness f/F=Pp.e (the used form f/F replaces the symbol of Greek alphabet Φ) agree with the requirements which are scrutinized by statistic analysis [2],[3],[4],[7].

Let us concentrate on the usability (4) when determining probability characteristics of ATO which is moving inside the corridor, the width of which is *'c'*. Process navigation is performed by NEC and together with ATO they create intelligent autonomous *SCOPE system (Sky Control-Object-Power-Enviroment).*

2 Combined experiment – results

The process NEC has been used to measure ATO movement error inside the corridor (see Fig.1) *c = +/-0.2 km*. Sensor reading errors have been accepted for measurement. Environment influences have been ignored. The precision of measured data has been determined by technological system level [5], [7], [8]. Characteristics approximation, their balancing have been tied by MATLAB methods. Time demandingness is decreased if the order of probability calculations P1,P2, which are presented by 2D ATO migration density in the corridor, is used. The process advances as follows: let P1 be the probability of ATO random movement on level *+c* (from corridor center upwards) and P2 be the probability of random movement on level *-c* (from center towards bottom border). The calculations in time t are performed. Then [1]:

P1=FI[c/sigmaz(t)]; *(5)*

P2=FIi[c/sigmaz(t+T)]; *(6)*

where *FI (Φ)* is the function of regular standard distribution [2],[3].

sigmaz(t), sigma(t+T) – are semi-quadratic divergences in the first section and next in a timely (t+T) shifted corridor section. In the presented case, model semi-quadratic divergence 'sigmaztm' has been used, which is square root of dispersion

Dz(t). Multiterm Dz(t) contains measured values, sensor reading errors, mutual correlations. Mutuality are important at errors [1] (gradually: labelling; meaning):

ssigmazk – initial value of system error of side divergence measurement,

ssigmapsi0 – system KS error (KS – course system),

ssigmaus – system error of measurement of drift angle, Doppler system

nyomega – degree of influence of random value for a KS flywheel break-out,

sigmaomega – KS flywheel error,

nyus – degree of influence of random value on drift angle,

alfaomega – observation speed of KS system platform,

alfaus – observed value of drift angle after one-time integration,

The influence of measurements (one and double integration) of angle errors of course flywheel have been primarily observed, ..., other [1],[5],[6],[8]. Calculation possibilities of MATLAB [6] environment have enabled to realize the following calculations: P1,(1),(3),(4),(5):

Observation time:
t=0:0.5:5;
*sigmaztm=5.4e-006.*t.^2+0.034.*t+0.14;*
figure,1;stem(t,sigmaztm,'g:','LineWidth',2),grid on
title(' Recording the side deviation values sigmaztm','FontSize',12),
ylabel(' Side deviation values sigmaztm [km]','FontSize',12),
xlabel('Observation time','FontSize',12),hold off,
Table values:
[t;sigmaztm];
Evaluation (5),for +c=0.1[km]:
With the aid of literature [2]page 235,
Achieve find in stage FI=P1:
u=(0.1./[sigmaztm]);
P1=[0.76 0.73 0.71 0.70 0.68 0.67 0.66 0.65 0.64 0.63 0.625];
Graphic record of the probable location of the ATO who uses those parameters NEC is
figure,2;stem(t,P1,'k','LineWidth',2),grid on
title('Probability input ATO P1 into corridor','FontSize',12),
ylabel(' Probability values P1','FontSize',12),

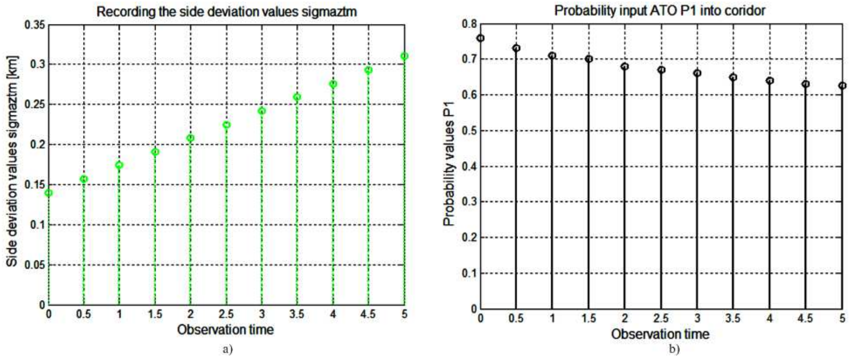

Figure 2

a) Recording the side deviation values sigmaztm'; b) Probability input ATO P1 into corridor

Calculation P2,(2),(4),(6). Probability of helicopter flight in *"c"* on the exit from corridor P2. After correcting NEC let us determine the probability P2 of the position of helicopter flight path in determined corridor in time t+T,. Let us determine the probability in known time: T=3;[min];

Current flight time was:
ta=0:0.8:8;Side errors will be changed to:
*sigmaztam=5.4e-006.*ta.^2+0.034.*ta+0.14;*
figure,3;stem(ta,sigmaztam,'b','LineWidth',2),grid on,
title(' Recording the side deviation values sigmaztam','FontSize',12),
ylabel(' Side deviation values sigmaztam [km]','FontSize',12),
xlabel('Observation time ta','FontSize',12),hold off,
Table value:
[ta;sigmaztam];
At the known corridor width:
c=0.1; is the argument of the distribution function of the normal standardized FI distribution:
u=c./sigmaztam;
P2=[0.57 0.25 0.03 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00];
figure,4;stem(ta,P2,'m','LineWidth',2),grid on
title(' Probability of entering ATO P2 into the corridor ','FontSize',12),
ylabel(' Probability values P2','FontSize',12),
xlabel('Observation time','FontSize',12),

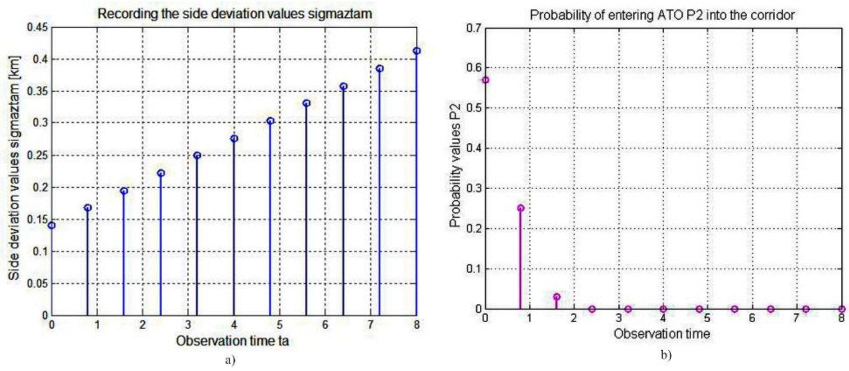

Figure 3

a) Recording the side deviation values sigmaztam ; b) Probability of entering ATO P2 into the corridor

Conclusion

The performed analysis of NEC precision effectiveness which consists of Doppler, aerometric, inertial complex has accepted the flight corridor of the width *+c = 100m*. Corridor width and inertial system correction performed in suitable time will considerably influence ATO navigation precision. Continuing research performed a priori has shown that for *+c = 800m*, observation time t=0:5:60[min] the probability on the entry into the corridor will be (estimated for two decimal places):

P1=[1 0.99 0.95 0.89 0.83 0.78 0.75 0.72 0.70 0.68 0.66];

Observed value on the exit from corridor P2 in shifted time T=3 min has been:

P2=[1 0.99 0.94 0.87 0.82 0.77 0.74 0.71 0.69 0.670 0.66 0.64];

According to familiar method [2],[3] the probability of not crossing corridor border has been calculated:

P3=[1 1 1 0.99 0.91 0.83 0.72 0.57 0.44 0.30 0.2];

Then according to (3) the value of identified precision effectiveness will be:

Pecplus=(P1-P3);Dynamic changes expresses graph:

figure,5;plot(ta,(P1-P3),'b','LineWidth',3)

grid on,

title('Identified accuracy of NEC in the corridor +c','FontSize',12),

ylabel('Values of NEC accuracy identified in the corridor +c','FontSize',12),

xlabel('Observation time ta','FontSize',12),

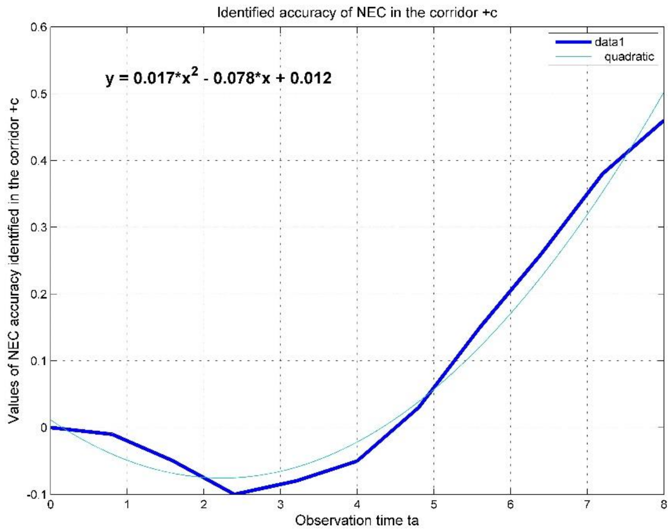

Figure 4 Identified accuracy of NEC in the corridor +c

In conclusion, the justification of the use of method to determine ATO navigation precision in the selected corridor by NEC requires the knowledge of its statistic parameters and corridor values. Data about precision characteristics are the output into the calculation of suggested NEC technical effectiveness.

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