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MATHEMATICAL OPTIMIZATION MODEL OF AVIONICS COMPLEXATION PROBLEM ON EARLY STAGE OF DESIGNING

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The article is the sequel of another one of this digest of authors "Approximate optimization solution by Pareto of discrete extremal problem of complexation of new generation avionics" and its development in the direction of creating optimization model and organization under synthesis of avionics structure.

Vindication of optimization criteria and formation of mathematical optimization problem

The solution of integer-valued discrete programming tasks is usually realized by such methods: intercepting method, branch and bound method, dynamic programming method.

In intercepting method the additional limits are input, depending on which there is a precision of algorithms. The essential singularities of branch and bound method are: the need in creating variants tree, identification of limit value for each vertex and cutting out non-prospective vertexes.

The searching of large amount of vertexes leads to increase of solution time. But when using the dual simplex-method there is a need in determine of simplex matrix for each vertex and at the same time the requirements to capacity of on-line storage gets higher.

The solving of discrete programming problems is based on formally-logical scheme of consecutive variants analyses of complex system designing subject to reliability criterion [1–3].

The criteria selection of multicriterion optimization was founded for aircraft instrumentation complex with known aircraft performance characteristics and operational characteristics: new variants and basic variants ("B" index):

$$G_C^B,\ \Delta G_C;\ \Delta G_C = \Delta G_C^{EC} + \Delta G_C^{\grave{I}} + \Delta G_C^F;$$

$$\gamma_C^B,\ \Delta\gamma_C;\ \ \Delta\gamma_C = \Delta\gamma_C^{aut};$$

$$V_S^B,\ \Delta V_S;\ \ \Delta V_S = \Delta V_S^w;$$

$$T_{run}^B,\ \Delta T_{run};\ \Delta T_{run} = \Delta T_{run}^w + \Delta T_{run}^{AC};$$

$$\overline{C}^B,\ \Delta\overline{C};\ \Delta\ \overline{C} = \sum_{i\in I}\left[\frac{\mathring{A}_d}{(1+\mathring{A}_d)^{\grave{O}_{si}}-1} + \mathring{A}_n\right]x_i + k'\mathring{A}_n;$$

$$C_{f.fh}^B,\ \Delta C_{f.fh};\quad C_{f.fh} = C_{f.fh}^* - \frac{RC_i}{\grave{O}_{run}},$$

where G_C is highest possible commercial load; γ_C is commercial load coefficient; V_S is average run speed; T_{run} is annual run, *h*; $\mathring{A}_d$ is discounting degree; $\mathring{A}_{\grave{i}}$ is normative e coefficient of investments' comparative efficacy; x_i is variable of model, 0 – N, that means (0 – system isn't chosen, 1,2,3…N – reserve degree).

The main components of efficiency criterion use two values:

The annual aircraft work content:

$$B = G_C\gamma_C V_S T_{run}$$

and total annual costs for one aircraft:

$$Z = C_{cr}(R+E_n) + C'_{ann} + E_n I',$$

where C'_{ann} is annual maintenance costs in operation; I' is attendant investments in civil aviation branch, penetrating the aircraft with avionics complex.

In market exchange relations this criterion can be expanded and thus perform the comparative analysis of variants of avionics complexes more seriously. We use four criteria to compare the complexes cost efficiency:

– annual aircraft work content in tonne-kilometers $\hat{A}$;
– total annual costs Z;
– first cost of 1 tkm *S*:

$$S = Z/B;$$

– annual profit *P*, where t_s is published tarifr for 1 tkm:

$$P = \hat{A}_{ts} - Z.$$

The formula

$$R = E_n/(1+E_n)^{T_{oi}} - 1$$

and product $C_{cr}(R+E_n)$ we use, where C_{cr} – cost of purchase of specified complex is designated as *C* for Z_i:

$$Z = \overline{C} + C'_{ann};$$

$$\overline{C} = \sum_{i \in I} C_i \left[\frac{E_d}{\left(1+E_d\right)^{T_{si}} - 1} + E_n \right] + k'E_n;$$

$$C'_{ann} = C_{fh} T_{run},$$

where C_i is cost of separate complex; T_{si} is service life of complex; C_{fh} is first cost of flight hour without depreciation reserves for avionics novation:

$$C_{fh} = C^*_{fh} - \frac{RC_i}{T_{run}}.$$

The general formula for calculation of B, Z, P of new variants of complex:

$$Y_a = Y_a^B + \sum_{w=1}^{6} K_w^a \Delta x_w$$

where $a \in \{I, II, III, IV\}$ is choosing of one the indexes; $w \in \{1...6\}$ is sequence number of criterion; K_w^a is coefficient that is appropriate for variant of complex.

Since it is important to measure the changeable part when comparing, optimization criteria can be shown for new variants as:

$$Y_a = Y_a^B + \sum_{w=1}^{6} K_w^a \Delta x_w^0 + Y'_a - Y_a^B$$

The values of basic indexes Δx_w^0, x'_w are determined under existing method.

Classification of variable parameters for calculation of indexes of offered and basic criteria:

– variable parameters of avionics and aircraft of basic equipment set:

G_C^B, γ_C^B, V_S^B, T_{run}^B, $\overline{C}^B$, C_{fh}^B;

– fixed characteristics of basic aircraft:

$t_p^{\max}, \Delta g^G, \Delta g^H, \Delta V_{iec}, g_{tm}, \hat{E}_n$;

– airway system characteristics of basic variant: $L_{FS}, t_p, \mu_i, \mu_2, \mu_3$;

– general technical and economic parameters:

C_{iec}, $\grave{I}_{iec}$, $\hat{E}_G$, $\grave{I}_i$, $\hat{E}_{L\hat{A}}$, $\tilde{N}_{mai}$, $\mathring{A}_n$;

– maintenance characteristics of avionics:

γ, $\hat{E}_G$, $\grave{a}$, $\hat{E}_C$, $C_{\acute{O}}^{\acute{o}}$, t_r, $\hat{E}_{nav}$;

– data assigned for basic variant:

$\hat{E}_{mai}^B, K_{mai}, \hat{E}_{\acute{O}}^B, \hat{E}_{\acute{O}}$;

– index difference:

$\Delta t_{\eth}^w$, Δg^w, $\hat{E}'^B$, $\hat{E}'$, ΔV_{FNE}, Δn_{ec};

– characteristics of another systems for calculation:

G_i, C_i, W_i, T_{oi}, T_{si}, T_{pi}, T_{mpi}, t_{ro}, τ_i.

As the maximization task P is equivalent to maximization task $\ln(P)$, then for greater amounts of argument t (while t=3, inaccuracy is not more than 10%), P_n criterion takes the form of:

$$\min\left\{\left(\sigma_{xDec}^2 + \sigma_{zDec}^2\right)\left(\frac{1}{\grave{a}^2} + \frac{1}{\hat{a}^2}\right)\right\} = \left\{\frac{\sigma_{xDec}^2}{\frac{\grave{a}^2\hat{a}^2}{\grave{a}^2+\hat{a}^2}} + \frac{\sigma_{zDec}^2}{\frac{\grave{a}^2\hat{a}^2}{\grave{a}^2+\hat{a}^2}}\right\}.$$

In model values y_i, x_i at $\grave{a}^2 + \hat{a}^2$ $y_i \in \{0,1\}$, $y_i \le x_i$, define the participation of parameters in criterion forming, and x_i defines the avionics reserve. For correct calculation of criterion the limitation is put into the problem situation:

$$\sum_{i \in I_p} y_i = 1$$

where I_p is system ensemble, defining P value.

Vindication of limitations in the synthesis of avionics structure

The effectiveness of solution optimizing depends on developing software, which is peculiar. The general properties limitations are determined by indexes of: weight, cost, power consumption, error-free running time:

– by weight:

$$\sum_{i \in I} m_i x_i \le SM;$$

– by cost:

$$\sum_{i \in I} C_i x_i \le SC;$$

– by direct current consumption:

$$\sum_{i \in I} W_i^G x_i \le SW^G;$$

– by alternating current consumption:

$$\sum_{i \in I} W_i^f x_i \le SW^f;$$

– by cooling consumption:

$$\sum_{i \in I} V_i x_i \le SV;$$

– by failure running time:

$$\sum_{i \in I} \frac{1}{T_{ci}} x_i \le \frac{1}{ST}.$$

For each system of complex it is quite difficult to input the limitation on backup degree:

$$0 \le x'_t \le x_i^{\max}.$$

For synthesis of avionics structure the main limit is limitation on reliability of performing of complex functions for flight control, in terms of tolerance probability, i.e. probability of failures. Creation of "chains" is realized with usage of algorithm of aircraft functions performance.

The "chains" define the in equation:

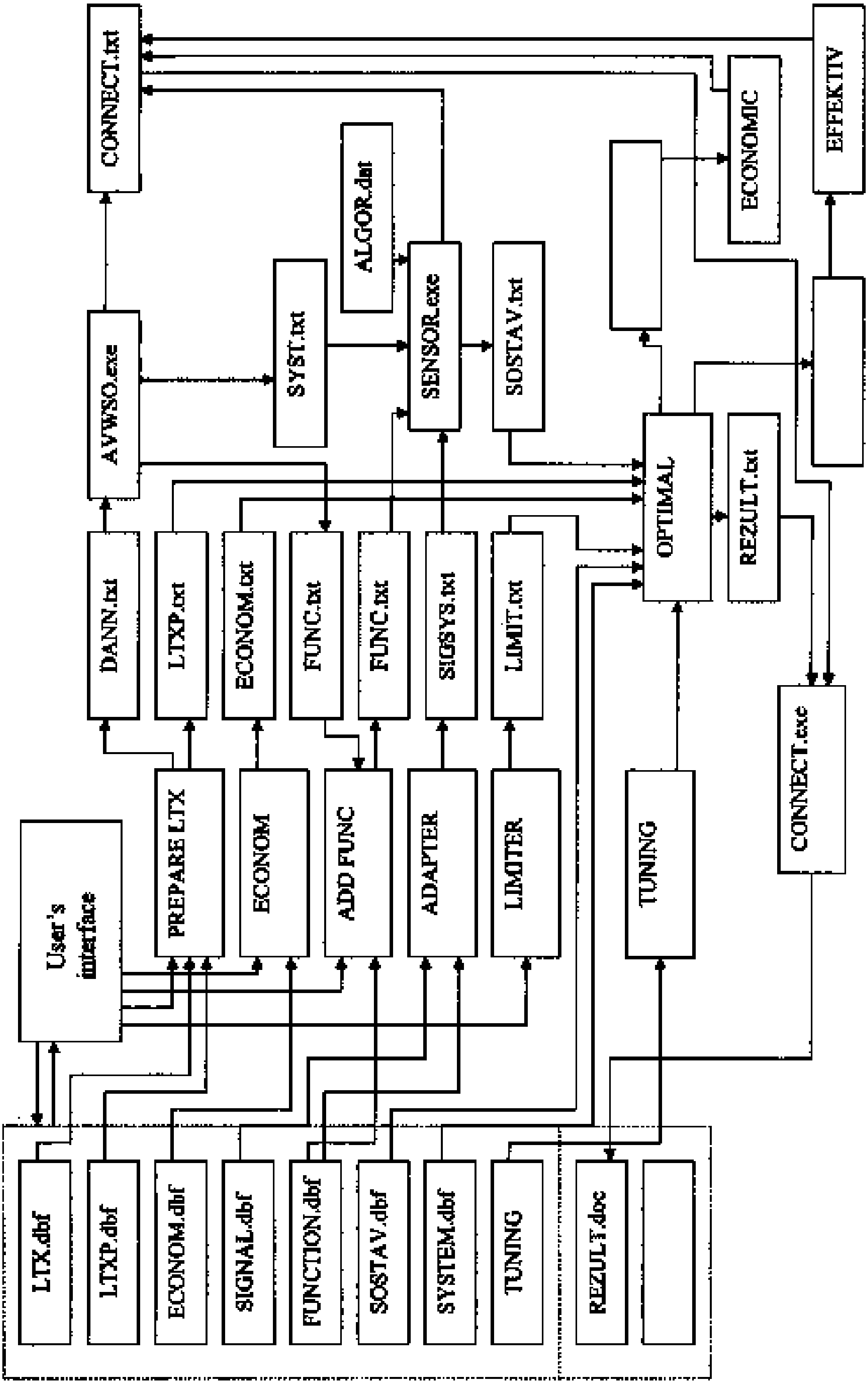
$0 < \text{number} < 1$, $\text{DUBL} > 1$,

realization variants: $VV_i = V_1 V_2 ... V_k$

where the list $V_1 ... V_k$ is logical sum of SS_j elements;

$$V_i = SS_1 + SS_2 + ... + SS_{nj};$$

$$VV = \{\{S_0, S_j\} + \{S_2, S_3, S_4\} S_5 + \{S_6, S_7, S_8\}\}.$$



The structure chart of application package functioning of «ARM constructure»

For variant of system with reserve degree x_i the failure probability on flight time is:

$Q_i(x_i) = (1 - e^{-\lambda_i t_n})x_i$, and if $0 \le \lambda_i t_n << 1$;

$Q_i(x_i) \approx (\lambda_i t_n)^{x_i}$; $P_i(x_i) \approx 1 - (\lambda_i t_n)^{x_i}$,

where $P_i(x_i)$ is probability of functional task performing during the flight.

In examined criteria and limitation the optimal complexation of avionics task has a view:

$$\sum_{i \in I} C_i^{a^0} x_i + \sum_{w \in W} \sum_{r \in R} C_{rw}^{a^0} y_{rw} \to \text{extr}; \ \sum_{r \in R} S_i y_i \to \min .$$

The realization of linear model solution of optimal complication of avionics by applications of ARM constructor

The application package of ARM constructor includes: database (DB), interface complex, the text files block, the composition of avionics determination block, optimization programs block (figure).

The realization of application package is performed in the following way:

– database and interface complex – by means of “FOXPro”;

– filename extension, interface complex – AVIA.prg program;

– block of avionics programs is realized on PASCAL language with software: the list of functions AVNSO.exe; the formation of avionics variants AVIA.prg with txt-files, FUNC.txt and SOSTAV.txt; optimization of complexation – PASCAL language with software of data TASK.exe, optimization module TASK_LP.exe, results registration TASK_R.exe.

The result of task-OPTIM.res file characterizes the discovered solution or its absence (REZULT.txt file).

The database files:

– LTX.dbf – aircraft performance characteristics;

– LTXP.dbf – economic characteristics (variable and fixed);

– LTXPT.dbf – parameters of economic characteristics of aircraft;

– ECONOM.dbf – economic characteristics of environment (airway system, avionics data, accuracy estimation);

– SYSTEM.dbf – characteristic on avionics system; SOSTAV.dbf – structure data, weight, block dimensions;

– SIGNAL.dbf – input and output signal;

– FUNCTION.dbf – functions of systems, complexes and avionics as a whole;

– ALGORITM.dbf – signals and functions of systems for performing of avionics function;

– TUNING.dbf – optimization module tuning;

– REZULT.dbf – ARM results;

– OPERATOR.dbf – list of ARM users;

– IMVAR.dbf – description of task variant.

Conclusion

The multicriterion model of optimal avionics complexation task is an approximate model on criteria of maximization of technical effectiveness and minimization of reduced costs under parameters limitation. The algorithm is based on principles of decomposition of building of ε-chain of Pareto-optimal solutions for separate complexes by force of consecutive combination of solutions and sifting of not Pareto-optimal. The practical output of modeling is development and realization of application package “Automatized system of choice of optimal avionics structure”.

References

1. *Воробьев В.М., Захарченко В.А., Вашку Ж.О. Воробьев А.В.* Системная эффективность комплекса «экипаж–ВС–среда» // Кибернетика и вычислительная техника: Сб. науч. тр. – К.: Ин-т кибернетики им. В.М. Глушкова НАН Украины, 2000. – Вып. 126. – С. 48–76.

2. *Белых Т.В., Кузьменко В.Н.* Алгоритм генерации ε-сети компромиссных решений для многокритериальной целочисленной задачи // Методы исследования экстремальных задач АН Украины. – К.: Ин-т кибернетики им. В.М. Глушкова НАН Украины, 1994. – С. 35–41.

3. *Белых Т.В., Головнев Е.А., Кузьменко В.Н.* Линейная модель задачи оптимальной комплектации электронного бортового оборудования самолета // Теория оптимальных решений. – К.: Ин-т кибернетики им. В.М. Глушкова НАН Украины, 1994. – С. 45–50.

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Рассмотрено приближенное оптимизационное по Парето решение дискретной экстремальной задачи комплексирования авионики нового поколения и ее развитие для создания оптимизационной модели и организации ограничений при синтезе структуры авионики.

Розглянуто наближений оптимізаційний за Парето розв’язок дискретної екстремальної задачі комплексування авіоники нового покоління і її розвиток для створення оптимізаційної моделі й організації обмежень при синтезі структури авіоники.