Decision making support system for electronic devices design

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Abstract[1]

The approach to metric evaluation of electronic devices architecture efficiency is offered with the purpose of their automation choice in concrete applications. The decision-making support system is offered for control system calculator architecture engineering.

1. Introduction

The development of modern electronic control systems (ECS) is characterized by high complexity and plural-component. An advanced stage of the development of modern manufacturing techniques of electronic computing systems component base is so high that spectrum of possible architectures of electronic computing systems is essentially expanded. It allows to design and to use more effectively functioning electronic computing systems.

Modern technologies allow to realize a required set of ECS functions in the various ways. These ways differ from each other both on used resources and on received benefits. In conditions of various industrial and operational requirements ECS realization will be multiple. However it results to complication of choice process. Increase of complexity results increase of criticality of used calculator architecture choice. In these conditions the results of an expert way of their choice are bad motivated. In this case the problem of uniform optimum designing intensifies. So, there is a need of automated management of designing process. For satisfaction of this need it is expedient to create new classification of computing systems architectures. This classification should consider both classical and perspective kinds. It underlies in a basis of decision-making support system (DMSS) creation and it also demands the development of specialized software.

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1. ECS Classification

Modern technologies allow to project and realize a wide ECS spectrum. There are many different classifications but in some cases they do not consider perspective architecture and componental base. New classification based on the analysis of three classification factors: architecture, operation and componental base, is offered. This classification bases on three aspects of designing: architectural realization, features of operational use, type of used components. Thus, general ECS classification will consist of a combination of three private classifications basing on various aspects of designing.

First factor of classification is offered to use ECS architectural realization (their architectural maintenance). On fig. 1 private ECS classification by an architectural principle is resulted.

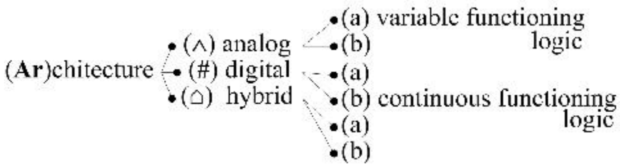

Fig. 1. Private ECS classification by an architectural principle

Each branch of classification resulted in figure is designated by alphabetic or symbolical identifiers resulted in brackets. The first level of architecture classification considers distinction of computer architecture as the used information: analog, digital and hybrid. Thus the computer of each type can be realized by two ways: with use of changeable logic of functioning or constant logic. The sequence of identifiers determines the following subclasses of electronic computers:

Ar∧a – Perspective architecture of analog computers basing on Field-Programmable Analog Array (FPAA). Functional possibilities of this type of devices are insignificant now. They are applied in a radio engineering preferably. The changeable logic of functioning consists of full or partial change of analog circuit during functioning or change of some elements characteristics.

Ar∧b – Classical analog computer facilities described by weak ability to updating, low accuracy but high speed.

Ar#a – Digital computers. Their structure and set of executed functions can be changed while service. For their structure operational programming is typical. As an example it is possible to result modules of supercomputer Cray XD1 [1] build on the basis of microcircuits FPGA.

Ar#b – Digital computers. Their structure and set of executed functions can not be changed while service. Today it is the most widely distributed kind of computer devices.

Ar#m – Digital computers containing reconfiguration elements and elements with constant logic of functioning. As an example we can mark devices on Field-Programmable System-Level Integration Circuts (FPSLIC) base containing both PLD core and invariable microprocessor core.

Ar⌂a, Ar⌂b – Hybrid computers building on the basis of the other principles determined by application specificity.

As another factor of classification it is offered to use features of ECS operational use. On fig. 2 private ECS classification by a principle of operational use is resulted.

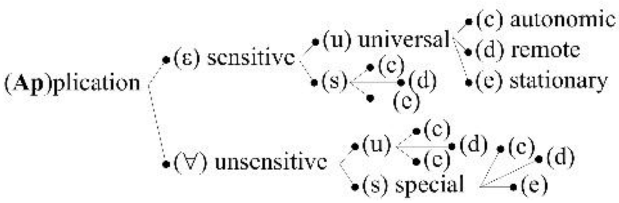

Fig. 2. Private ECS classification by a principle of operational use

For the description of this private classification it is better to consider in details the factors of classification instead of its classes. ECS of critical application differ from ECS of noncritical application by heavy consequences of their refusal. According to this the functions of fault tolerance maintenance become complicated.

The next used factor is ECS character of use: universal and specialized. In case of universal application ECS is characterized by an opportunity of operational change of a set of executed functions (software) for universal maintenance. As advantage of universal calculators it is possible to specify operational convenience: wide spectrum of solved tasks and an opportunity of fast adaptation under changing requirements. As lacks it is possible to allocate the dependence on human factor and low reliability.

The third factor of classification is the character of operational service. In case when ECS belongs to subclass of independent use it is not require participation of the personnel (designers and operators) in its service. These functions are assigned to it. In case of remote use service is carried out far off and does not demand personal presence of the personnel. Service of stationary ECS assumes personal participation of the personnel.

From the listed subclasses independent ECS (Apεuc, Apεsc, Ap∀uc, Ap∀sc) are perspective. Now given classes could be attributed to empty but essential researches on their creation however are conducted. As an example it is possible to result the program of independent calculations (Autonomic Computing Initiative) of IBM [2]. It is possible to characterize Apεse class by a set of embedded (including - onboard) ECS of critical application. For example, an onboard unattended computer. Class Apεue is similar in general to Apεse but distinguish from previous one by person participation. ECS of Apεud and Apεsd classes also cannot be characterized by wide application because of problematical character of fault tolerance maintenance at remote service. ECS of Ap∀ud and Ap∀ue classes are the most widespread and are characterized by use of personal computers (both personal and remote management) at their realization. Calculators of Ap∀sd and Ap∀se classes are widely applied in embedded control systems where high reliability of functioning does not demand.

The last factor of classification we offer the types of used integrated components of ECS. It is necessary to notice that given classification is not considered as the closed system and in future its classes can be exposed. It can occur in case of necessity to account new qualifying factors. On fig. 3 private ECS classification is resulted by used integrated components.

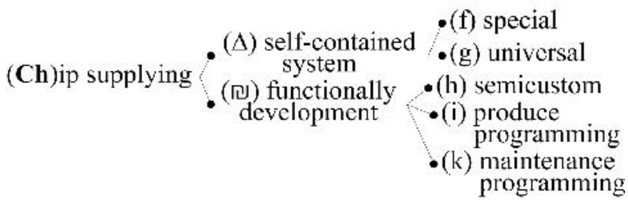

Fig. 3. Private ECS classification by used integrated components

At comparison of this private classification with private classification by architectural principle (fig.1) it can be noticed that questions of executed functions updating are mentioned in both of them. However at classification by architectural principle the componental base is not regulated and change of functioning logic can be realized multi-versionaly - both with application of functionally-developed component maintenance and without it. And in case of classification by component base the factor of functional development precisely divides classes of integrated devices. Thus emptiness of some classes of resulting classification can take place but it does not remove need of separate classification of componental base.

The next identifiers determine the following subclasses of electronic computers:

ChΔf – The componental base does not demand updating because of invariance of management laws during ECS operation time. At its ending ECS life cycle simply comes to the end. Functionality of these computers is determined by their manufacturer. As an example it is possible to result specialized IC for concrete object management (IC for step-by-step engine management).

ChΔg – The difference from ChΔf consists of possibility of given integrated devices functionality changing. Mostly it is realized on the base of program management principle. As an example it can named IC microcontrollers. Their functionality depends on their software.

Ch₪h – The componental base is close in use to ChΔf class however its functionality is determined by the consumer not the manufacturer. The information on IC functionality is passed the manufacturer further making functionally constant production. An example of given class are Application Specific IC (ASIC).

Ch₪i – Functionality of componental base of given class is determined by the user. As against Ch₪h the user independently brings the configuration information in IC. Further it can be changed (in most cases) only in process of equipment reengineering.

Ch₪k – The device with operational programming which functionality is updated each time during initial ECS start. Advantage of this IC class is flexibility and readiness for internal structure updating (as far as updating during functioning). Example of this IC class is Field Programmable Gate Array (FPGA).

General classification is set of three resulted private classifications. It is the most convenient to present it as the three-dimensional table where each element corresponds to one of the classes. This three-dimensional table is submitted on fig. 4.

Each element corresponds to the set of three classes on architectural, operational and componental private classifications. So, the element «Ch₪h|Ar∧a|Apεuc» (marked on figure in parameter "Lcc1") corresponds ECS representing independent analog computer working in critical conditions of operation created on the basis of semicustom IC with changeable logic of functioning. Designing and use of such ECS will demand essential material inputs. It causes large value of life cycle cost index. Now given class is empty.

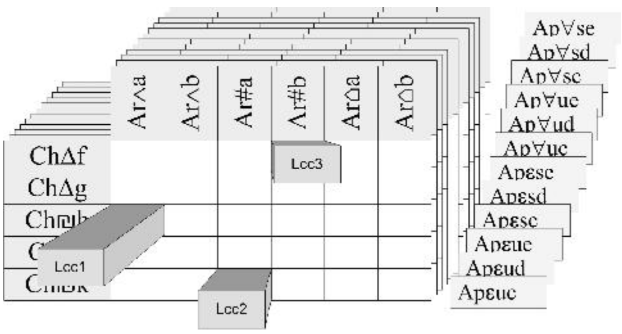

Fig. 4. General ECS classification

The second selected for example class is «Ch₪k|Ar#a|Apεuc». It is digital universal computer maintaining in critical conditions and created on the basis of componental base with operational programming. The cost of such device life cycle will be less than of «Ch₪h|Ar∧a|Apεuc». The probability of such device creation is higher than at previous, however modern technologies still do not allow to create effective ECS in «Ch₪k|Ar#a|Apεuc» class.

The third selected class: «ChΔf|Ar#b|Apεuc». It is digital universal computer with constant logic of the functioning working in critical conditions and constructed on the base of functionally complete IC. The cost of such ECS development and operation is even lower. As an example of given class it is possible to result an independent industrial computer build on the basis of classical microprocessor.

Each element of this table is characterized by parameter Lcc (life cycle cost) chosen according to standards [3]. This parameter most naturally can be used as a criterion at a choice of the most1effective way of ECS realization possessing the minimal Lcc value.

2. Decision-Making Support System at Computer Architecture Choice

Offered computer classification consists of 648 classes. Consideration of such amount of variants by the person is inconvenient (especially for semi-structured and not structured tasks). For simplification of decision making person work it is offered to use decision-making support system (DMSS). Its use during ECS development is shown on fig. 5.

The saved up data and knowledge of previous variants of processes of realization ECS are united in the base of precedents. On the basis of the technical project given ***by the Customer*** and base of precedents DMSS gives ***System analytics*** a vector of values Lcc_i metrically estimating the predicted cost of life cycle on each of *m* classes. On the basis of Lcc_i vector analysis decision making person gets out ECS realization in the most effective class. The choice is carried out in a direction of Lcc value minimization however system analytic has to choice one variant among similar values. Further ***the Developer*** carries out ECS designing within the framework of the chosen class. On the basis of received while service data the base of precedents is supplemented and modified.

However the question of Lcc value calculation encounters essential complexities. Its metric estimation is characterized by influence of some factors such as: type of designing route, its characteristic; time expenses; direct material inputs; expenses of calculator resources for solving a task of management; auxiliary expenses and etc. Assumed by standard [3, 4] additive ways of Lcc value calculation often base on group of analytical (frequently intuitive) methods of various stages of life cycle cost definitions.

At use of given structure the technical project suggested by the customer is used as the initial data for DMSS. After corresponding formalization and metric evaluation

DMSS gives system analyst a vector of used criterion of choice (Lcc) values. On the basis of this vector and some additional data (statistical, expert or analytical) analyst makes a choice of the most effective realization of control system. It is possible to assume that a leading class will be a class possessing minimal Lcc.

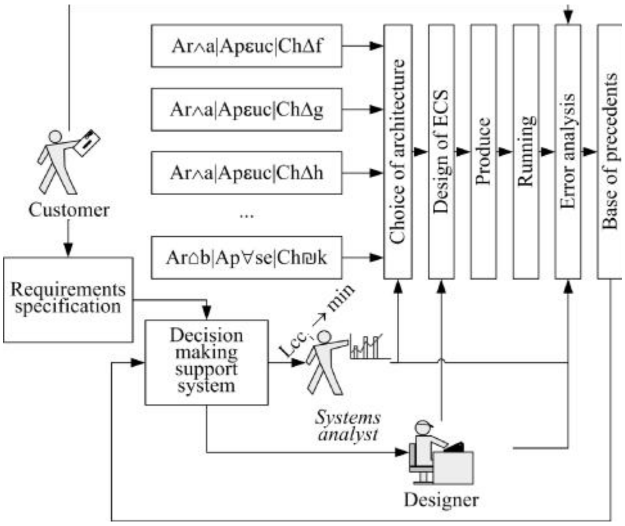

Fig. 5. DMSS use in ECS development

During produced ECS service mistakes revealing is possible. It will demand carrying out the additional analysis both on the part of ECS developers and on the part of the customer. Its results are used for the base of precedents updating. Actually the base of precedents is a source of knowledge for construction and updating of life cycle models used for definition of Lcc value. A source of mistakes can be both the erroneous or incomplete technical project and erroneous analytics or the developer decisions. These mistakes can reduce to inefficient ECS work and to repeated designing and manufacturing of electronic product. As a rule the last is a blunder and inadmissible that assigns special requirements to process of ECS architecture choice during designing.

Lcc value of each class consists of several components. Their quantity can be designated *n*. As an example it is possible to result the most probable expenses determining these values: direct material costs, probability of a mistake and cost of its consequences, cost of mistake correction, life cycle duration and so on. Thus it is possible to construct both analytical and statistical models. Analytical models turn out on the basis of the class of objects features analysis. For example, they are functional models of designing routes individual for each class [5]. Statistical models are constructed on the basis of the saved up operational data. They can be sold on the basis of the multi-factorial analysis or indistinct, neuro-indistinct approaches [6]. Both kinds of models answer one question: how partial expenses (U) are characterized depending on metric of technical project (x): U=f(x). Both types of models have entitlement for existence and effective utilization. Therefore it is offered to carry out a choice from the values received on the basis both analytical and statistical models of life cycle. In the most elementary case it is a choice of the worse variant - i.e. variant characterized by maximal Lcc value.

Received as aggregate of models of both types DMSS structure for ECS development is submitted on fig. 6.

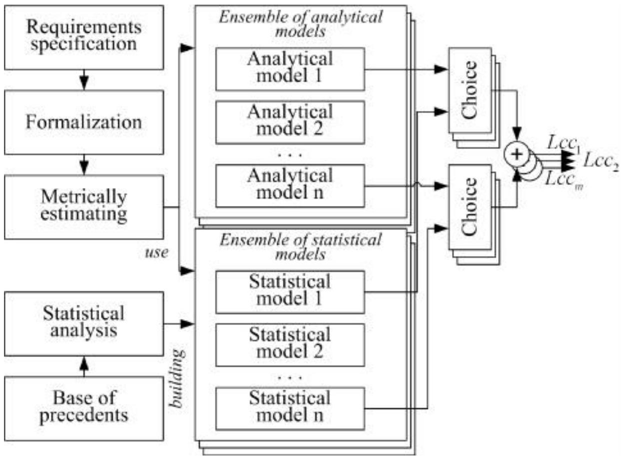

Fig. 6. DMSS structure for ECS development

Received from ***requirements specification*** on ECS development the requirements are exposed to ***formalizations*** and subsequent ***metric evaluation***. These data move on two ensembles of models (analytical and statistical). There are *n* elements in the structure of models set (corresponding to each class) depending on the number of Lcc components are examined. For each pair of models the worst Lcc rating is chosen and its value includes an additive combination of values of all models pairs are carried out. In case when construction of separate model is impossible or is problematic the function of a choice is reduced to a choice of a unique value. Lcc_i vector received thus is used during process of ECS realization.

As a result of offered classification and life cycle modeling the significant set of models turns out: ensembles of models have *m* layers in total, each of them corresponds to each of 648 classes of offered classification.

In turn each layer consists of two types of models (analytical and statistical) consisting of *n* models of expenses (material inputs, expenses for designing, qualification, cost of a mistakes, etc.). If for example amount of kinds of expenses is equal to five the power of variants set comes to 6480 models. However some models may be trivial or some classes can be rejected on the first steps of the analysis of technical project. Reasoning from it offered DMSS realization structure is represented on fig. 7.

Process of DMSS functioning is represented as two stages: process of examined classes set truncation and process of outline designing. It is necessary to note that the offered set of classes can be subjected according to universal development of ECS construction technological base. DMSS is realized in two variants: «DMSS I» and «DMSS II».

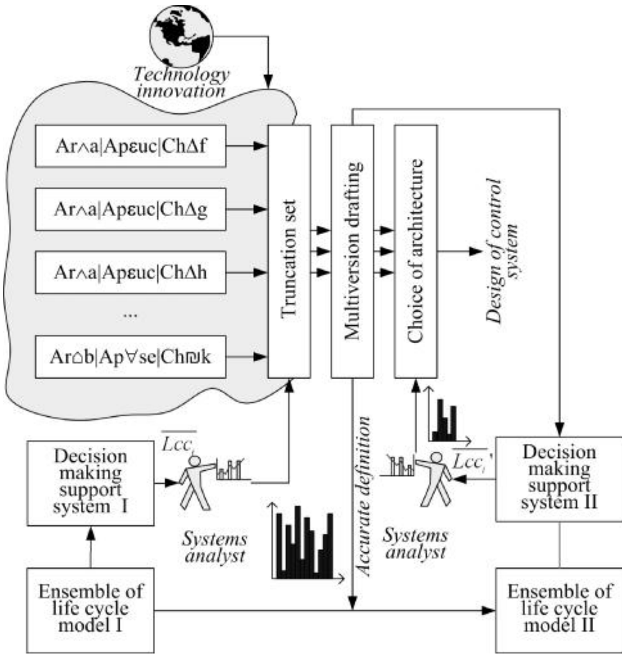

Fig. 7. Detailed elaboration of architecture choice during DMSS functioning

Their difference consists of a level of elaboration details of used models and their updating during outline designing. During outline designing there can be changes of life cycle models. It results to ***accurate definition*** (transformation of «Ensemble of life cycle models I» into «Ensemble of life cycle models II»). At the first stage of DMSS functioning the analyst on the basis of technical project requirements (in figure it is not shown) and the first ensemble of models carries out truncation of examined classes set. Those classes which are essentially unsuitable are rejected or have high Lcc value. Further outline designing is made during which the parameters of models are specified. On the basis of specified models and results of outline designing there is a calculation of elements of truncated Lcc_i` vector. The amount of classes and factors at this stage is less than at the initial stage. It allows to construct life cycle models with greater detail. On the $Lcc_i$` vector values basis the resulting architecture choice is made.

4. Conclusion

Offered classification of electronic calculators and DMSS allow to formalize process of modern computing systems architecture choice and also to automate this process. Offered classification is based not only on classical architectures of computing systems but also on their perspective variants.

The following results are received:

- Offered computers classification considers a wide spectrum of modern and perspective electronic devices (including atypical architecture). It allows to formalize the process of optimal variant of their realization choice.
- On the basis of offered classification decision making support system for electronic devices design is developed. Its internal structure and structure of its software are described.

The results of these researches promote in solving the next problems: development of structure and a technique of electronic technics operation; construction of specialized metrics of developed devices efficiency estimation; forming of ensemble of life cycle cost models; increase of ECS performance at the expense of a choice of the most adequate architecture for solving tasks. DMSS and offered complex of mathematical models allow to formalize process of architecture choice. Consequence of it is an improvement of ECS operational qualities at the expense of their optimum architecture choice.

Acknowledgments

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