UDC 621.32

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# RESOURSE-ORIENTED DIVERSIFICATION OF FAULT-TOLERANT PLD-SYSTEMS

The analysis of methods for increasing reliability during designing the fault-tolerant digital systems with programmable logic (PLD-systems) in terms of diversity principle is given. The concepts of internal and external diversification of PLD-systems are introduced. Approaches to the projects diversification of such systems based on using the opportunities of computer-aided design (CAD) and genetic algorithms (GA) technology are represented.

**PLD-systems, reliability, diversity, designing, genetic algorithm**

## Introduction

Modern experience of designing and exploiting digital systems shows that more complicated problem of automation and more important area where such systems are used cause the properties of fault tolerance, survivability, safety, availability become more and more critical.

The basic problems with assurance of these requirements arise while exploiting so-called critical systems such as airborn control systems, atomic power plants safety systems and others. The reasonable decision during designing such systems is the use of programmable logic devices (PLD), which have sufficient resource-intensiveness and computational power, reconfiguration capable architecture. They also implement system-on-a-chip (SoC) idea [1, 2].

It is very important for the critical digital systems not to allow the occurrence of latent design faults. This problem can be solved by application of multi-version approach to designing such systems [3].

The performed analysis of existing works shows that previously developed methods of DSPL (digital systems with programmable logic) projects diversification [3 – 5] grounded on different approaches to designing allow to significantly decrease level of design faults appearing. These approaches are generally based on the life cycle diversity within the one designing concept. Also taking into account the rapid progress of designing methods this limits ability while developing the DSPL projects. Therefore the actual problem is to develop the elements of methodology of creation the most diversified DSPL project.

The purpose of this paper is to analyse various levels of fault-tolerant DSPL design diversity and to consider diversification approaches based on various designing methods.

These approaches are founded on use of different recourses during designing process.

## External and Internal Diversification

Application of multi-version approach to designing digital systems assumes obtaining version redundancy by varying the set of resources used in designing process. Hence the main task is to obtain the most alternate versions of the same project.

For example, using several development groups, several CAD packages etc. it is possible to significantly decrease correlation level of release versions. Therefore implementing the most diversified n-version project it is necessary to isolate n subsets of resources that allow implementing the same functionality. At that versions obtained from different subsets will be less correlated than obtained by varying characteristics within one subset. Thus it is possible to reach lesser correlation

level using several CAD packages than changing characteristics of one CAD package.

Therefore as used here we can speak of two design diversity levels – internal and external.

The internal design diversity assumes obtaining alternative versions from only one isolated subset of resources used in designing process; the external one assumes application several sets of resources.

For example, obtaining project variations using several CAD packages is the illustration of the external design diversity relative to compiler adjustments of one CAD system; still within the general approach the using of several CAD packages is the internal design diversity. Therefore the most important developer's task while creation multi-version project of digital system is to isolate subsets with maximal cardinality for subsequent formation of release versions, as well as to select diversity metrics, which allow comparing obtained versions.

It should be emphasized that while isolating resources subsets for external design diversify of DSPL project the developer should pay particular attention to risk analysis concerned with estimating compatibility of obtaining versions. Nevertheless currently many large vendors of CAD packages are taking an active part in developing software products which support EPLD produced by different vendors. This allows developing algorithms suitable for implementing on not only different families of EPLD but also from different vendors. Examples of such systems are FPGA Express family by Synopsys, OrCAD Express by OrCAD, products of VeryBest, Aldec, Cadence Design Systems and many others. Practically it seems the most effective to exploit external design diversity based on different approaches to DSPL designing. This approach significantly increases cardinality of less correlated versions variations set. The difference of graphs topologies characterizing the EPLD logic cells connections has been obtained as the diversity metrics. Also the possibility of internal design diversity remains.

## CAD-based and GA-based Diversification

Several methods of EPLD-based projects diversification can be isolated within discussed above approach. These methods are grounded on different concepts of DSPL designing. The most popular method is so-called CAD-based one, which is closely related with life cycle phases of designing system using common CAD packages. This approach allows exploiting the internal diversification on phases of selecting EPLD, entering, compiling, testing and verifying project.

The second EPLD projects diversification method allows the developer using new approaches to designing DSPL, which are directed to obtaining new and often non-trivial decisions implementing such systems [6 – 8]. This method is grounded on exploiting genetic algorithms (GA) [9], which have been actively developed last decade. The GA-based approach to DSPL projects diversification can be utilized on abstract level as well as on physical level of system development [7]. Regardless of selected level GA handles finite set of decisions (population), which is combination of binary sequences that encode different variants of DSPL implementations. GA generates new decisions combining parts of population individuals by means of genetic operators like selection, crossing, mutation and inversion. Fig. 1 illustrates methods of diversity introduction to obtain diverse models within this approach.

DSPL projects can be diversified at stages of GA presetting, selection, crossing, mutation and inversion of individuals. GA presetting means choosing the distribution law that forms the individuals of an initial population, probabilities of genetic operators application, complexity of GA. At a stage of selecting intermediate decisions the developer can also define the selection method: roulette wheel, rank, tournament, steady-state or elite selection. At the crossing phase new versions of project can be generated by choosing the

crossover type (single point, two point, uniform, etc.) and/or its fashion (haploid or diploid).

Reception of additional versions at the next stage is possible by using either single point or uniform mutation and inversion of individuals.

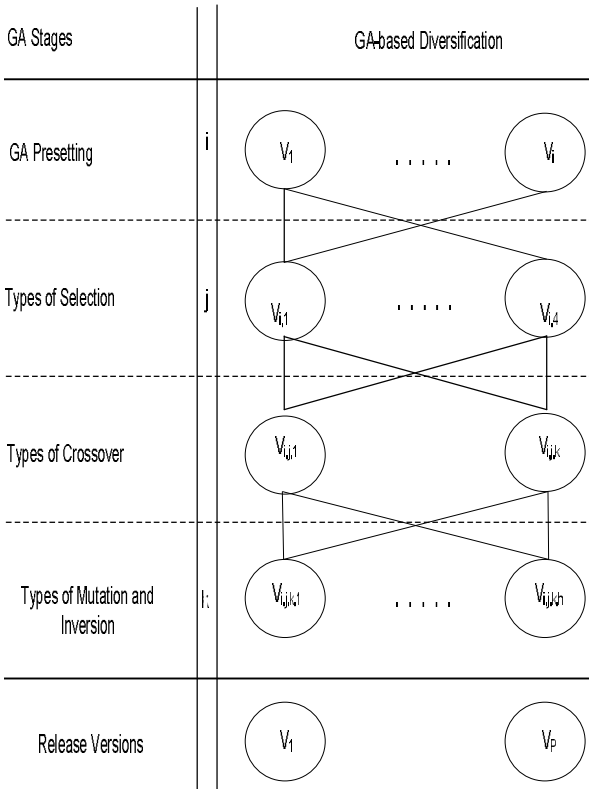


Fig. 1. Means of alternative versions reception within the GA-guided approach to designing

It should be emphasized that the internal diversification of DSPL projects can be implemented during either whole CAD- and GA-guided design process or during one or several stages.

As a result the necessary number of release versions are finally selected from the set of obtained versions by "reliability-cost" criterion.

In case of GA-guided designing the best decisions are selected among the final set of versions in last population according to their fitness (the design equation for calculation of this factor depends on specificity of a solved task [8, 9]).

Application in various combinations of the given methods allows generating a number of schemes for internal and external diversification of DSPL projects (fig. 2, 3).

Thus the internal diversification assumes reception of alternative versions by CAD- or GA-guided design method and the external one applies combinations of both methods.

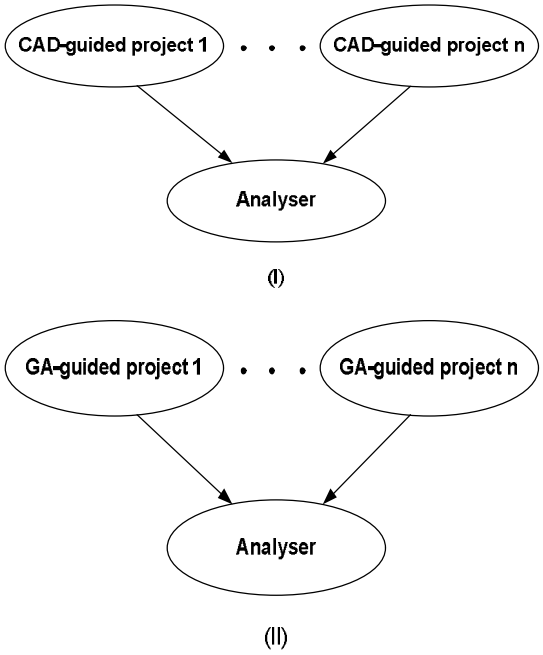


Fig. 2. Flow of internal CAD-guided (I) and GA-guided diversification (II) of PLD-projects

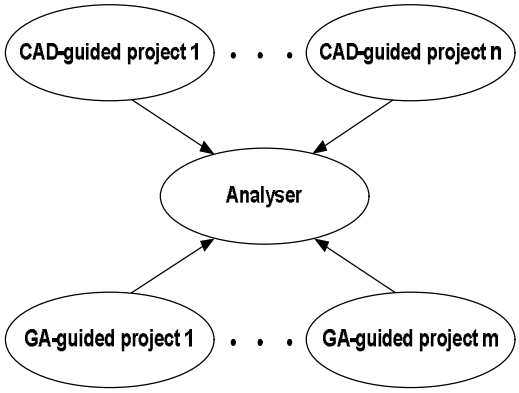


Fig. 3. Flow of external diversification of PLD-projects

## Conclusion

As a result of the lead analysis two levels of diversification of DSPL projects have been proposed – external and internal ones. These approaches are based on exploiting the various resources providing by CAD- and GA-guided design methods. Proposed variants of

their joint use represent different methods of recourse-oriented diversification of DSPL. Thus the internal diversification of PLD-projects is possible within the each approach.

The internal diversification based on GA-guided design approach has been worked out in detail. So the diverse models have been received at various stages of GA during developing PLD-systems.

In our opinion the main directions of future researches within the recourse-oriented approach are:

– development of detailed technique for designing digital systems with external diversification on the basis of two considered approaches;

– development of algorithms to generate the pairs of versions received by internal diversification using the external diversification flow;

– determination of diversity metrics to estimate diversification degree of different PLD-projects.

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*Поступила в редакцию 14.03.2006*

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