Methods and Program Environment for Structure Optimization of MIMO Automates

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Abstract: *In the work has been suggested a methods for structure optimization in the synthesis of MIMO automat without memory. In the functional description are implemented multiplexer circuits. The methods has deal with the optimization in a sequence of steps on them are used different functions (criteria) for decisions optimization. It is developed a program environment for the synthesis realization, which can successfully applied in student learning. The aim of this paper is to create methods and to project an adequate computer aided environment for it.*

Keywords: *Automat, MIMO, decision tree, criteria for optimization of the decision, program environment*

INTRODUCTION

In a lot of digital devices there are blocks, which are constructed with circuits from small-scale (SSI) and medium-scale integration (MSI). They must have an optimal structure because of the space restrictions on the main board system. These blocks often are logical devices like combinations circuits or MIMO automats without memory, which have descriptions in finite sets. Same kind of structures exists in the automats with memory. Their synthesis is made by applying of classical methods and using optimization procedures for the mathematical presentation.

The tasks for the design of logical controlled objects in the contemporary control systems [2] applied controllers or develop program for such control, which is based on one chip microcomputers. They require solving similar problems.

Using controllers and blocks in the computer aided control systems it is possible directing of analyzers to the problem of structural automat synthesis for their work without any optimization. But the problem of optimization has validity for all cases even if there are used programs on one chip microcomputers and microprocessors. It can point successfully arguments for support of the idea, that the simple logical function really decreases the amount of used program memory and the time for program execution for objects, which have a logical control necessity [4, 5, 6, 7].

It is interesting to make synthesis of MIMO blocks with middle integration degree circuits. Some advantages for this purpose have multiplexers. They multiplied signal on their data inputs with combination which are for its choice or it is simple to make conjunctions. With them it is easy to make synthesis by using optimization procedure in the appropriate program environment.

METHODS FOR SYNTHESIS OF AUTOMAT WITH OPTIMAL STRUCTURE

The synthesis of the MIMO automat without memory, applying scheme with middle integration degree, is well known in the literature [1, 3]. The aim of this work is to develop a new methods and program environment by using different conditions for structures optimization of the automatic device.

Decision tree

The methods is develop in the meaning of the tasks for decision making by using familiar descriptions with decision trees. The decision tree has one root and two kind of vertexes – vertex case ○and vertex, in which make a decision Δ.

For the aim achievement is necessary to know a number of digital variables **n,** which take part in the logical functions with them is made functional description (in conjunctive normal form) of the automat. As a rule this number is limited [2], if we are foreseeing possibilities for synthesis of arbitrary complexity functions for programmable devices. It became clear that they have restrictions. By this reason it will work with at most eight numbers of binary variables. This number is placed on the decision tree root. There are used multiplexers with 16, 8 and 4 data inputs, which are selected with 4, 3 and 2 control inputs.

The tree consists of some consecutive choices - in the beginning is selected multiplexer for a scheme realization and after that a variable configuration (combination) for control inputs. There are several possibilities in a set of decisions.

For each value of **n** there are three alternatives. It is possible to choose circuits with 4, 3 or 2 control inputs. Very likely choice in decision making $\mathbf{D_1}$ for $\mathbf{n > 4}$ is to use multiplexer with 4 control inputs or probabilities are in a proportion $\mathbf{p_3 > p_2 > p_1}$ **(**$\mathbf{p_3}$ is for multiplexer with 4 control inputs**,** $\mathbf{p_2}$ - for 3 and $\mathbf{p_1}$ **–** for 2**)**. This is right decision because by the number **n** of variables greater or equal of 5 the best usage is the maximal number for control inputs – 4. It leads to receive lower rank of the residual functions, which are place on data inputs and less number of used logical circuits.

In the general case this choice has to be connected with satisfying criterion *minimal rank of the residual function.*

If follow the tree for $\mathbf{n = 4}$ the arc leads to the vertex – decision (Fig.1). With the choice of third alternative - 4 control inputs, the residual function cannot consist of binary variables, because of the participation four binary variables in the control forming on which one data input. Therefore it blocks realization of the residual function. Hence the probability of choice for this output is zero ($\mathbf{p_3 = 0}$). If is used a circuit with three control inputs the probability choice is $\mathbf{p_2}$**,** and the residual function consists of only one binary variable. By the choice of two control inputs, the residual functions rank increase to 2 and the probability has notation $\mathbf{p_1}$. The sum of probabilities is one and it is foreknow, that $\mathbf{p_2 >> p_1}$. Even are suggested in the definite cases, that $\mathbf{p_1 \approx 0}$ and therefore $\mathbf{p_2 \approx 1}$**.**

After that is going to the next vertex – decision $\mathbf{D_2}$ for the choice of a variable combination $\mathbf{C_n^r}$, which are placed on control inputs of the multiplexer – for analyse case $\mathbf{C_n^r = C_4^3 = 4}$. Here are four alternatives with the same probability choice by the criterion absence for a result evaluation of the combination choice. The selection of an option directs to one decision.

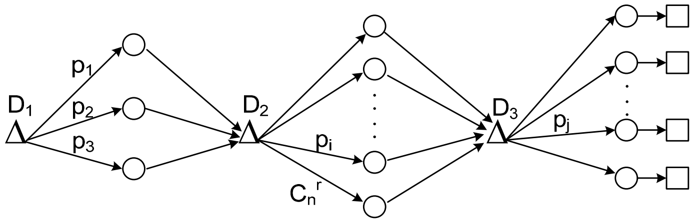

Fig.1. Decision tree for optimization of the structure choice

Criteria determination for evaluation of the decision

- *The minimal rank of the residual function, which are applied to data inputs*

If is noted the rank of residual function with $\mathbf{C_1}$, then this value will estimate first decision making in the tree - $\mathbf{D_1}$:

$$\mathbf{C_1 = n - r = min,}$$

where **n** is the number of binary variables in the logical function and **r –** is the number of control inputs of the multiplexer.

The decision for which $\mathbf{C_1}$ is minimal will receive the high rating applying this criterion.

- *The minimal number of data inputs, on which are placed binary variables*

This criterion is satisfied in dependence with the loading of signals receivers, which are represented binary variables.

If note the number of data inputs for the multiplexer with **S** then $\mathbf{S = 2^r}$. The number of inputs with residual function will be $\mathbf{S' \leq 2^r}$ $\mathbf{(S' = \{1, 2, 3, \dots, 2^r\})}$. The criterion for a decision evaluation $\mathbf{D_2}$ will be

$$C_2 = S' = \min.$$

- *Maximum number* of *data inputs with minimal rank of residual function*

Let **t** is a rank notation for of the residual function placed on the data input $\mathbf{I_j}$, then $\mathbf{t = n - r}$. The criterion will have meaning by evaluation of decision $\mathbf{D_2}$ in the decision tree, when there is case for which $\mathbf{t > 1}$ and the minimal number of used data inputs with binary variables $\mathbf{S' = min}$ is defined.

Criterion $\mathbf{C_3}$ estimates the most high this decision $\mathbf{D_3}$, for which is *maximum number of data inputs of multiplexer, on which the rank of the residual function is minimal*. Decreasing of the rank of the residual function is in the connection with its minimum. The set of ranks of these functions, placed on the data inputs is

$$T = \{ t_1, t_2, \dots, t_i, \dots, t_{S'} \}.$$

In the common case $\mathbf{t_i \leq n - r}$ by one or many conjunction on the **i – th** input. Therefore the set of data inputs with minimum rank of the residual function **T'**, is the subset of **T**. The number of elements of this set (cardinality of a set), according the third criterion must be maximal, i.e.

$$C_3 = | T' | = \max.$$

Such criteria formulation for evaluation of the chosen decision is conveniently for a program realization of the structure choice of an automat, when its synthesis is made by multiplexers.

The last one of criteria requires bigger attention, because of the problem for minimization of residual function. This was mentioned early.

For each of the data inputs of the already chosen multiplexer it is possible to compose for example a Karnaugh map in which place those ones, according to the conjunctions in the residual function. Its minimal form depends on their location.

It is possible to apply a simple variant for the decision analysis. For this purpose can be introducing coefficient **K,** defined with next analytical expression:

$$K = (2x_2 + 3x_3 + 4x_4 + \dots + 16x_{16}) / (x_2 + x_3 + x_4 + \dots + x_{16}),$$

where $\mathbf{x_2}$ is the notation of input number with two conjunctions in the residual function, $\mathbf{x_3}$ **–** for three and etc**.** The subscript 16 relates to the case $\mathbf{n = 8}$ and the chosen multiplexer has 16 inputs (4 control inputs).

When used data inputs have only one conjunction, $\mathbf{K = 1}$. In the case with two decisions with different coefficients $\mathbf{K_1}$ and $\mathbf{K_2}$ better decision has high coefficient **K.** It is possible two decisions to be with equal coefficients. For this case the choice is those variant, which has an input with most number of conjunctions in the residual function.

From the reasoning can be seen, that specified coefficient **K** combines two of pointed criteria for decision evaluation – minimum number of data inputs on which are pass binary variables and maximum number of data inputs with minimum rank of the residual functions.

STRUCTURE OPTIMIZATION FOR SET OF FUNCTIONS SYNTHESIS

The MIMO automat, in the general case, has a set of outputs each of them is described with logical function defining its work. Let for every one of the function was made analysis and received the possibility for optimal choice of a combination of binary variables, placed on the data inputs of chosen multiplexers for its realization. This is a precondition for finding the best complete decision for an automat with many outputs **{ Y }.**

Let $\mathbf{D_{yi}}$ is notation for the set of possible optimal decisions for the output $\mathbf{y_i \in \{ Y \}}$. Then the optimal decision will be the intersection of these sets:

$$D = D_{y1} \cap D_{y2} \cap \dots \cap D_{yi} \cap \dots \cap D_{ym}$$

The received decision set is possible to be an empty set, namely **D = Ø.** In this case must search quasi optimal decision and in order to expand sets $\mathbf{D_{yi}}$. It will add variants,

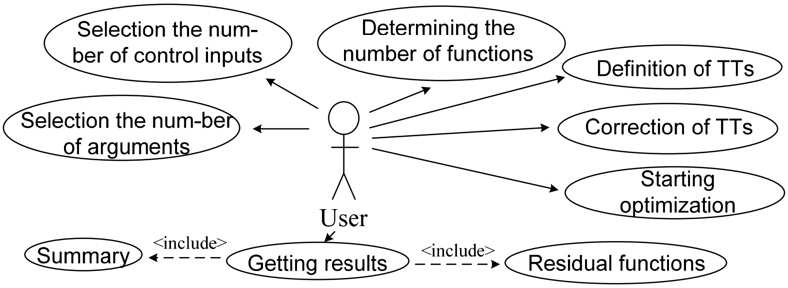

Fig.2. Use case diagram of the application environment

which are slightly different from the optimal decision. For example will accept to enter in the decision set those, for them the number of used input with binary variables are with one more than the optimal cases with minimal number of used inputs (according to the criterion $\mathbf{C_2 = S' = min}$**).** Obviously this decision will be made compromise for some cases.

THE MODEL OF THE PROGRAM ENVIRONMENT

The functionality of the environment is presented by means of the use case diagram shown in Fig.2. The user selects the number of arguments of the functions and the number of control inputs of the multiplexers. Then he determines the number of functions and their truth tables. If there are errors in functions' definitions the user corrects them and starts the process of optimization. At the end the user has the results of the optimization as a list of all possible residual functions and a summary in the form of the number of all data inputs with signal zero for all possible combinations of signals for control inputs.

The main classes of the environment and implemented interactions between them are presented in sequence diagram in Fig.3. At the beginning StartOptMx class instantiates DefinPnl and OperationalPnl classes. There are 2 combo boxes in DefinPnl. By means of the first one called argsNbrsCombBox the user chooses the number of functions' arguments that can be between 2 and 8. The second one – addrrsInpsNbrsCombBox is for determination of multiplexers' control inputs number, which depends on the number of arguments in the following way: at 3 arguments – 2 control inputs, at 4 – 3 or 2, at 5,6,7 or 8 arguments the control inputs can be 4, 3 or 2. At the beginning only argsNbrsCombBox is visible. There are 2 buttons – changeBtn for the change of the made decisions and nextBtn for the depiction of OperationPnl panel. In a corresponding text field in OperationPnl the user determines the number of function for optimization. The event handler of funcNbrBtn provides text field for every function and fills them with randomly generated truth tables for every function. The user can edit this field and determine her/his own functions. When the functions' definitions are correct the user can start the optimization by clicking on the optimizBtn button. Its event handler instantiates Optimization class, where the optimization takes place. The method setCombFuncsInfValsFourArr with arguments combNbr, funcNbr, infInptsNbr and funcValsNbr, which are integer variables for the number of combinations, the number of functions, the number of data inputs of the multiplexers and the number of sets of residual

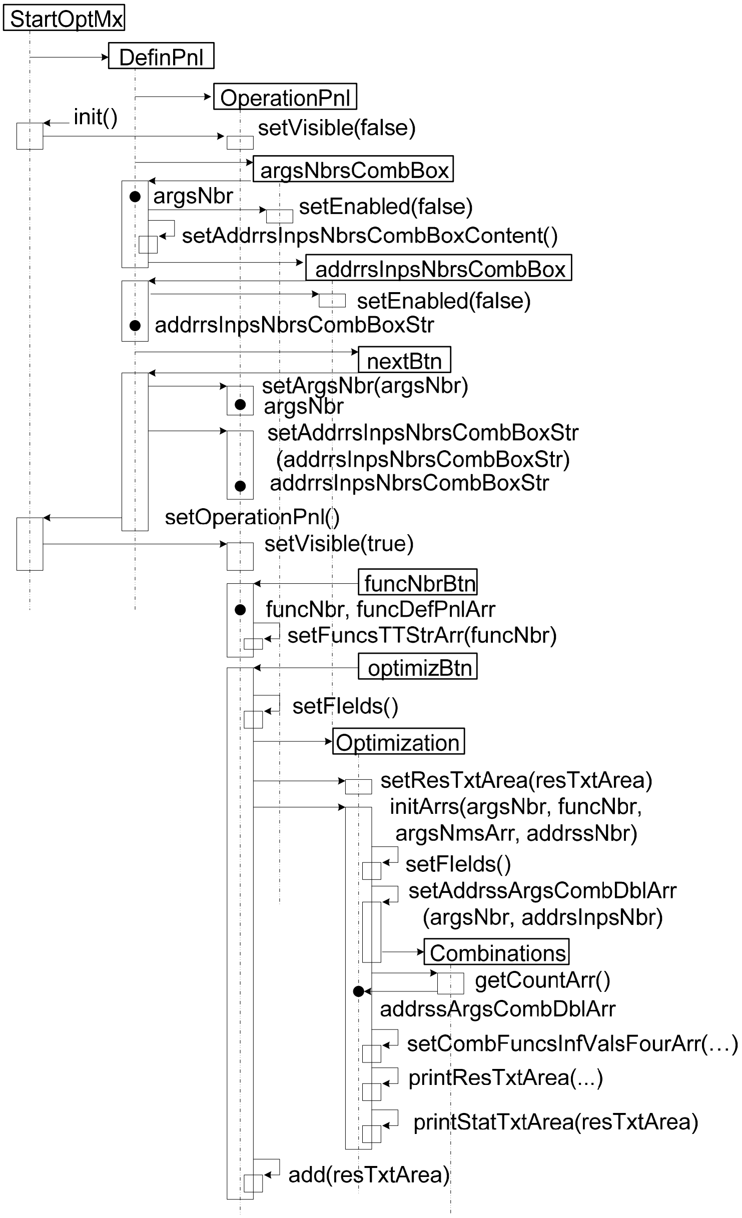

Fig.3. Sequence diagram of the application environment

functions accordingly instantiates and initializes an four dimentional integer array combFuncsInfValsFourArr with truth tables of the residual functions of all data inputs, for all user-defined functions at all possible combinations of arguments passed to the control inputs of the multiplexers. The method PrintResTxtArea with arguments combFuncsInfValsFourArr array and resTxtArea text area prints in resTxtArea the residual

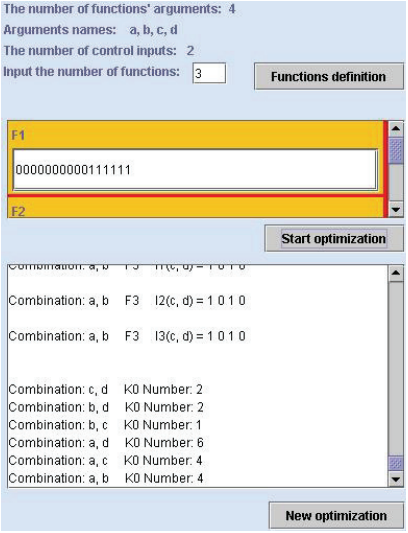

Fig.4. Optimization's result

functions for all data inputs of the multiplexers, for all functions defined by the user and for all combinations of arguments submitted to the control inputs of the multiplexers.

SCREENSHOT OF THE PROGRAM ENVIRONMENT

The interface of the application when the number of arguments is determined to 4, the number of control inputs – to 2, and the number of functions – to 3 is presented in Fig.4. The truth tables of the functions can be seen in the upper scroll area. In the bottom scroll area the result of optimization appears.

CONCLUSIONS

In the paper a method for synthesis of MIMO automat is suggested, some criteria for the optimal decision choice of its structure are applied and a program environment for automat synthesis was developed.

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The paper has been reviewed.