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PROGRAM SUPPORT FOR RELIABILITY ALLOCATION FROM A STANDPOINT OF TECHNICAL REQUIREMENTS

Abstract: *Reliability allocation represents an integral part of reliability design of technical systems and their parts. The detailed explanation of a computer program refers to reliability allocation methods from a standpoint of technical requirements are given in this paper. Reliability allocation is shown on a specific example using the AGREE method. Advantages of an automated approach to reliability allocation and the direction of further development of the presented program are shown in the conclusion of the paper.*
Keywords: *Reliability allocation, Allocation methods, Software, AGREE method*

1. INTRODUCTION

Modern technical systems, addition to requirements in terms of performance, price and maintenance, etc., must meet user expectations in regard to reliability and readiness [1]. This creates a need of application of various methods in the system development phase, which will enable that a desired level of reliability is built into individual parts, as well as into the entire system [2].

Reliability design starts with a specified system reliability which is determined as a result of researching user requirements and expectations, achieved level of reliabilities of similar competitor products and other relative data. In the following step, the specified system's reliability should be distributed on the integral elements. The process, in which the reliability of integral parts is determined, to satisfy the required system's reliability, is called reliability allocation [3].

Numerous methods have been developed for reliability allocation which are based on various criteria [1, 3, 4]. All these methods can be sorted into two basic groups.

The first group consists of methods in which allocation of reliability is done from the standpoint of technical requirements and system element properties. In this group of methods is neglected the influence of expenditures, ie "effort" required to develop a system with default reliability, but it provides completely satisfaction not only the desired level of reliability, but also other technical requirements and limitations.

The second group consists of methods in which primary importance is the system's cost, in other words, they optimize expenditures. In doing so, the impact of specific technical requirements and properties of the system is ignored, but they provide a favorable economic effect.

The process of reliability allocation with different methods can be automated using computer programs in order to reduce the possibility of human error, reducing the time required for calculation and greater accuracy of results. With that in mind, a program has been developed in Visual Basic for the group of reliability allocation methods, which take into

account technical requirements. This program will be explained in this paper.

2. RELIABILITY ALLOCATION METHODS IN TERMS OF TECHNICAL REQUIREMENTS

The largest number of reliability allocation methods from a technical requirement and system element's properties standpoint is based on assumptions that the failures of system elements are independent of other elements, the failure of any element results in system failure and the operating times up until element's failure can be described by exponential distribution law. All other influential factors are also ignored including specified reliability costs[1, 3, 4, 5].

Methods of reliability allocation have been developed for serial, parallel and combined element's connections, such as:

- EQUAL allocation method,
- ARINC allocation method,
- AGREE allocation method;
- EFTES allocation method,
- M-1 allocation method etc.

The EQUAL allocation method is the simplest method of reliability allocation. Its simplicity lies in the fact that in the process of allocation, specified sustem's reliability or whole's allocated reliability of the lower structural levels than the system is distributed equally between the components. Under the assumption that all parts are of similar complexity i.e. all parts can be assigned the same values of reliability. The ARINC method was named after the abbreviation for Aeronautical Radio, Inc. [5]. It was developed in the research sector of this corporation in the early 1960s. This method can also be found in literature under the name "Distribution based on timeframe state data of similar systems" [3]. Based on the analysis of the ARINC procedure it can be concluded that this method tends to distribution system's reliability in components comply with the real possibilities of their realization. However, this implies having at least rough orientation values of the failure intensity for all system elements.

Name of the AGREE method of allocation represents an abbreviation for Advisory Group on Reliability of Electronic Equipment, which developed this method in 1957 for the purposes of the US Army [5]. In literature of the subject area, it can also be found under the name "Distribution by significance" [3]. The method has been developed primarily for use in electronic systems. Within this method the complexity of certain parts of system is taken into account as well as the total number of parts and their influence on the successful operation of the system. The AGREE allocation method is somewhat better than previous mentioned models. Its major advantages are reflected in the appreciation of the relative importance and complexity of individual system's parts, i.e. their inner structure (in the case of sub-systems and components).

Starting from facts that previously discussed methods for reliability allocation intended primarily for the use in electronic systems and do not take into account requirements and properties of mechanical systems, the authors of [3] developed the EFTES procedure for reliability allocation of mechanical systems. The abbreviation EFTES applies to name of the scientific conferences in the field of Efficiency of technical systems, held in Novi Sad, Serbia. A good characteristic of the EFTES method is that it can be applied to systems whose reliability cannot be easily defined by intensity of failures (eg, rockets and other systems of one-time use).

The M1 method for reliability allocation takes into account the complexity of the system, i.e. the number of components, operation time of the system elements and the importance of proper operation of system elements [4].

3. AGREE ALLOCATION METHOD

According to the suggestions of the advisory group on reliability of electronic equipment, the maximum of acceptable failure intensity for the *i*-th subsystem is calculated using the formula [1, 3]:

$$\lambda_i = \frac{n_i \cdot [-\ln R_S(t_S)]}{N \cdot E_i \cdot t_i}, \qquad (1)$$

used variables are:

n_i - number of integral elements of the *i*-th subsystem,

$R_S(t_S)$ - required system's reliability for the specified operating time t_S,

E_i - importance factors for the *i*-th subsystem,

N – total number of integral system parts ($N = \sum_{i=1}^{n} n_i$), and

t_i - operational time of the *i*-th subsystem.

To determine the reliability allocation of the *i*-th subsystem, for a given operation time t_i, use the espression:

$$R_i(t_i) = 1 - \frac{1 - [R_S(t_S)]^{n_i/N}}{E_i}. \qquad (2)$$

This equation for reliability allocation gives satisfactory solutions only if importance factors E_i for all parts of the system approximately equal to one [1]. Otherwise, with the reduction of the importance factor's value, the result's accuracy is also reduced.

4. RELIABILITY ALLOCATION PROGRAM

The program code for reliability allocation was written in Microsoft Visual Studio 2010 VB, using Visual Basic program language [6].

The program for reliability allocation in terms of technical requirements is designed to work in all Windows platforms. Instalation of the program is initiated by starting the Setup.exe file and following short and simple instructions. Starting the program from its installed location opens the basic interface of the program (Figure 1).

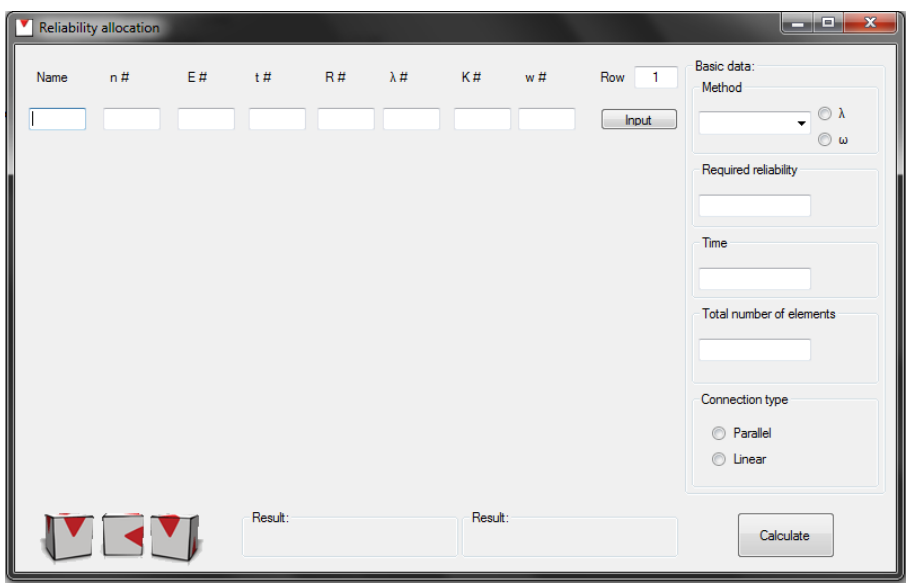

Figure 1 - Basic program interface „Reliability allocation"

The reliability allocation program begins with the selection of the allocation's method. In the upper-right corner of the operating environment (Figure 2), in the drop-down menu which refers to available method, user selects the preferred method for the allocation among five possible options.

After the first step, regardless of the chosen reliability allocation method, data for the desired (specified) reliability, system operation time and total number of subsystems is entered.

Choosing the type of connection subsystem within the system is done by clicking on the appropriate connection name in the lower-right corner of the basic window. A further procedure of data entry and result's acquisition varies for each selected method in the program. Selection of specific allocation method allows the user to enter data into columns of variables in the upper segment of the basic program window, which are designed for calculation using this method. Other fields are tinted and are not operational.

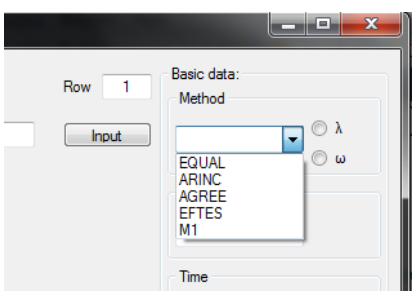

Figure 2 - Selection of the preferred allocation method

The situation is similar in the selection of serial or parallel connection of subsystems within the system (bottom right corner of the program workspace in Figure 1). The selection of method automatically changes the type of subsystem's connection, if the previously selected type of connection is not provided within the method. In addition, if you choose the method that is valid only for the serial connection of subsystems within the system, and then choose a parallel connection in the "Connection Type" program initiated notification window (Figure 3). In this case, after confirming the warning by clicking the OK button, the user manually chooses a different type of connection. Otherwise, with every user's attempt to perform calculation, this notice appears.

Figure 3 - Notice that the selected method does not support the connection type

After the selection of the reliability allocation's method and the subsystem connection's type within the system, the numeric values of subsystem parameters', characteristic to the preferred method can be entered. Entering parameter values is performed by rows for each subsystem respectively (Figure 4). In case of an error during the data entry process, each row can be reedited by inputting the desired row which needs to be changed in the "Row" input box in the upper-right corner. Changing between input boxes can be done by pressing ***Tab*** on the keyboard.

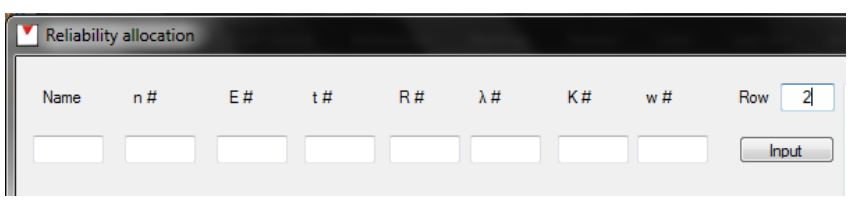

Figure 4 - Data input into columns

When the row of required data for one subsystem is complete, by clicking the ***Input*** button user enters data for next subsystem and counter of the row that is entered automatically changes to the next sequential number. The current row which is being edited is shown in the "Row" box above the Input button. It is possible to change data in any column by changing the number of row in counter, re-entering the data values in raw and by re-clicking on the ***Input*** button, which automatically updates the table.

Calculating the value of the reliability allocated of subsystems, for the entered values of characteristic parameters is done by clicking the ***Calculate*** button. The calculated results, depending on the method used, are shown in the marked fields in the bottom part of the window of basic interface or in the appropriate columns with a popup window (see Fig. 1 and 5).

5. EXAMPLE OF PROGRAM APPLICATION FOR AGREE METHOD

The system, which consists of four serially connected subsystems, should have a reliability of 0.95 for a period of 100 hours in operation. The first subsystem has $n_1 = 70$ parts, the second $n_2 = 25$, third $n_3 = 40$ and fourth $n_4 = 25$ parts. For an effective operational time of subsystem, should take values: $t_1 = 80\,\text{h}$, $t_2 = 80\,\text{h}$, $t_3 = 90\,\text{h}$ and $t_4 = 100\,\text{h}$. The estimated values of influence factor of subsystems are $E_1 = 0.9$, $E_2 = 0.9$, $E_3 = 0.95$ and $E_4 = 1$.

By using the AGREE method for reliability allocation to determine the subsystem's reliability, that will satisfy the required reliability of the system. In addition, you need to determine the maximum allowed intensity values of subsystem's failure in a given period of time.

Figure 5 shows the program interface with the example data. The order of data entry is as follows. After starting the program, in the group of basic data, from the drop-down menu selects the AGREE method. After that, the value of system reliability, operation tyme and number of subsystems are entered.

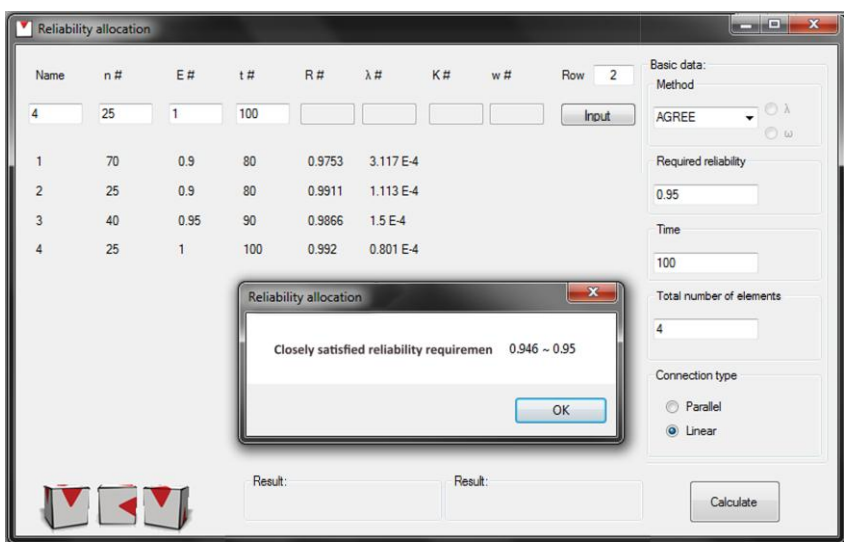

Figure 5 - Example of input values with the calculated results displayed

Since the AGREE method is only used for serial connection of subsystems, the ***Linear connection*** button in a lower-right corner is checked.

As already explained, the serial number of the subsystems, the number of elements *n#*, influence factor *E#* and effective operation time *t#* is entered by raws for each subsystem individually. In this way are obtained the columns of corresponding values.

After required data entry is complete, by clicking on the ***Calculate*** button in the column for the reliability *R*, based on equation (2), allocated values for reliability are calculated, and in the failure intensity column λ, according to function (1), the maximal allowed subsystem's failure intensity values are obtained too. In addition, the program provides two more separate windows that open sequentially, first reliability allocated with respect to the required reliability (show in Figure 5), and than after click on OK button, the failure intensity of the system and the sum of subsystem's failure intensity (Figure 6).

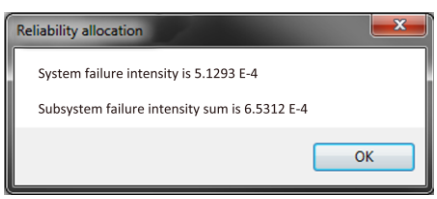

Figure 6. Failure intensity result window

Upon revision, the calculated system reliability's value should be greater than or equal to the required value. However, the calculated reliability of the system is slightly less than the required because the influence factors of subsystems, 1, 2 and 3 are less than 1. This type of error is typical for the AGREE method and is found in almost all the examples cited in the literature in this area [4].

6. CONCLUSION

The program presented in this paper for reliability allocation from the aspect of technical requirements allows the automated data processing, a decrease of calculation time and increase the accuracy of calculations, reducing the possibility of human error during calculation, etc.

The program code for reliability allocation from the aspect of technical requirements is written so that there is a possibility of adding new methods of reliability allocation just by appending them to the list, without requiring changes in the existing program code. As a result, in the further development of the program, there is the possibility of inclusion of new methods for reliability allocating. From the aspect of optimal solutions' selection, the possibility of collecting and comparative displaying the results of the allocation of a number of methods is a significant.

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