THE ITERATIONS STUDY IN THE DESIGN PROCESS, BASED ON THE DSM METHOD AND THE MARKOV CHAIN MODEL

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Abstract: *This paper presents a methodology to analyze and to simulate the design iteration in the design process.*

The first research method used in this work relies on observation of the design process.

The second research method is based on the DSM (Design Structure Matrix) representation of the tasks of the design process. In our work, a model based on Markov chain was used to simulate a group of design tasks.

For this purpose a laboratory experiment was used. The results could be used to make recommendations for the designers to improve the performances of the design process.

Keywords: Markov chain model, DSM, design process, design experiment.

INTRODUCTION

The design process is a creative activity, during which many solutions necessary to the development of a product are generated.
The design process is also a decision-making activity, as far as certain solutions are chosen from among the ones that have been generated. This approach leads to continuous interactions, or, more specifically, to iterations between the various design tasks. The iteration treatment is crucial for the improvement of the design process performance, for the cost reduction and for the decrease of the product launch period. For this purpose, methods that could emphasize these iterations and their treatment with the purpose of reducing their consequences should be developed.
In this article, we are presenting a research methodology for the design process iterations, mainly concentrated on the research of the sources generating such iterations and on the participants' intervention. The first stage consists in the identification of the tasks that must be fulfilled. Then the dependences between these tasks are determined and a matrix of their connections is made (DSM – Design Structure Matrix). After applying an algorithm, the DSM matrix will be rearranged (by taking into account the constraints), and the number of iterations will be diminished (the ones related to the interdependence of the activities), is such a way as to minimize their impact. During the design process, unpredictable iterations generated by miscalculations, change in the used solutions or objectives may occur.

THE DESIGN PROCESS AND ITS RELADED ITERATIONS

The product design process is a dynamic and complex process, during which designers use information, financial, technological and knowledge resources in order to create a product. This product includes tasks meant to solve a number of problems. An iterative process [1], [2], [3], [4] is necessary for the development of a number of solutions, i.e. some activities must be entirely or partially repeated within certain tasks, figure 1.

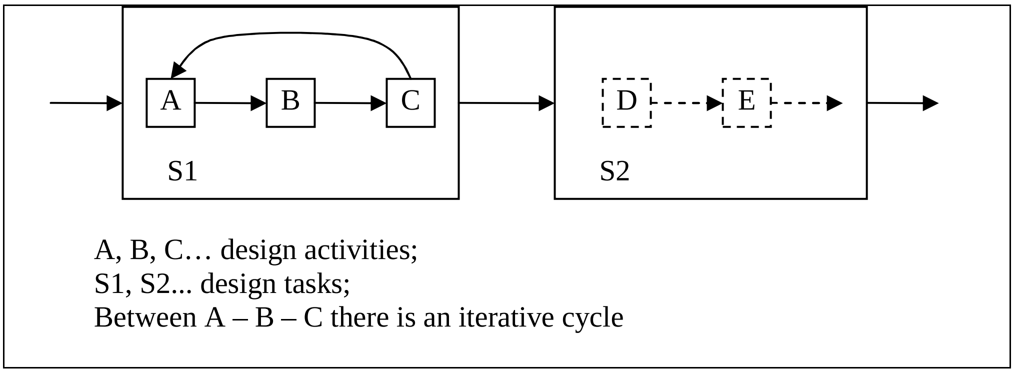

Fig. 1. Example of iteration across the activities of a design task

THE MARKOV CHAINS METHOD

Markov chains method is based on the method DSM (Design Structure Matrix) and assumes that each design task (denoted in the matrix with A, B, C ...) has a fixed and known duration, but it must be repeated a number of times to resolve the priority conflicts. The probability of repetition is a function of how the tasks are coupled (in series, parallel or interdependent).
Since the main purpose of the method of Markov chains is to determine the forecasted duration of the design will be presented algorithm for calculating the duration.

	A	**B**	**C**
A	4	0.2	0
B	0.4	7	0.5
C	0.3	0.1	6

Fig. 2. Iterative matrix 3x3

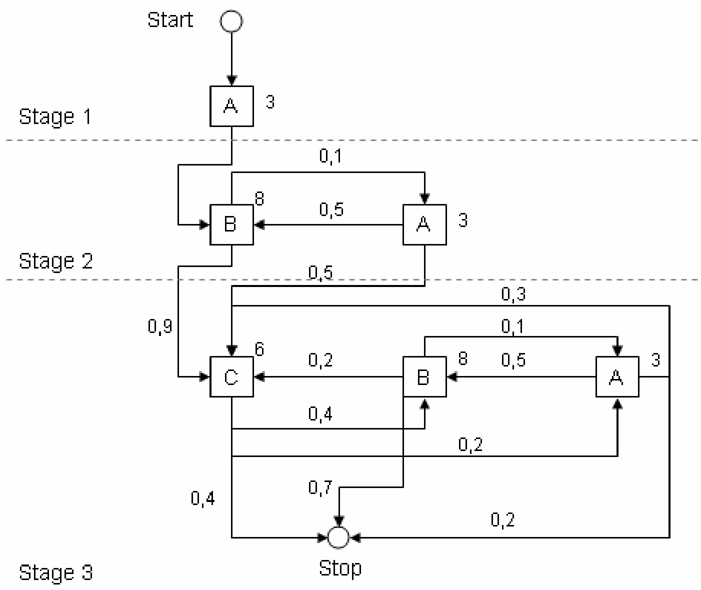

Fig. 3. The Markov chain for a 3X3 matrix

The chain is divided into three stages. The work is performed with a probability of 1, then activity B is executed with a probability of 0.8. The activity should be repeated with a probability of 0.2. Tasks A and B should be repeated until the results are compatible, while the activity of C will be executed first. After execution of C there is a probability of 0.5 to conclude the process, but the probability of 0.5 and that between A, B and C to be an iterative process.

Algebraic calculation is similar to Gaussian elimination, projected standings can be written as a set of linear equations.
Be r_A, r_B and r_C periods remaining in each of the three nodes in the third stage of the chain. These will be given by the equations:

Equations can be written as:

$$\begin{bmatrix} 1 & -0.4 & -0.3 \\ -0.2 & 1 & -0.1 \\ 0 & -0.5 & 1 \end{bmatrix} * \begin{bmatrix} r_A \\ r_B \\ r_C \end{bmatrix} = \begin{bmatrix} 4 \\ 7 \\ 6 \end{bmatrix}$$

After the Gaussiene removal, we have:

$$\begin{bmatrix} 1 & -0.4 & -0.3 \\ 0 & 0.92 & -0.16 \\ 0 & 0 & 0.91 \end{bmatrix} * \begin{bmatrix} r_A \\ r_B \\ r_C \end{bmatrix} = \begin{bmatrix} 4 \\ 7.8 \\ 10.23 \end{bmatrix}$$

The value of the parameter r_C is:

$$r_C = \frac{10.23}{0.91} = 11.21$$

For the two nodes of the second stage of the Markov chain, where s_A and s_B are the standings for this stage, we have:

$$\begin{bmatrix} 1 & -0.4 \\ -0.2 & 1 \end{bmatrix} * \begin{bmatrix} s_A \\ s_B \end{bmatrix} = \begin{bmatrix} 4 \\ 7 \end{bmatrix} \Rightarrow \begin{bmatrix} 1 & -0.4 \\ 0 & 0.92 \end{bmatrix} * \begin{bmatrix} s_A \\ s_B \end{bmatrix} = \begin{bmatrix} 4 \\ 7.8 \end{bmatrix}$$

Iteration starts in node B in the second stage, so it will retain value sB.

$$s_B = \frac{7.8}{0.92} = 8.48$$

For the first stage we have only one node to the length of A, $t_A = 4$.
The total duration for the Markov chain (A-B-C) is 23.69 (sum of c_R, s_B and t_A).
Observe that the equations for the r_C, s_B and ta are expressed in Gaussian elimination for equations of the third stage. r_C foreseeable time, s_B and t_A values are on the right side column matrix calculation. This property is true in general since the first parts of iterations are without influence on the final stage. This special structure is exploited to establish an efficient algorithm for calculating the total length.
Depending on the duration forecast and the probability of recurrence for each activity will choose a convenient arrangement.
For the 3x3 matrix in example considered, the ordering of all possible tasks to get the situation shown in Table 1 and in Figure 5 shows the optimal order for the 3x3 matrix.

Table 1. Possible variations to accomplishing the tasks

Order of executions of tasks	Time forecast
A-B-C	23.69
A-C-B	20.43 (min)
B-A-C	22.66
B-C-A	28.54 (max)
C-A-B	22.23
C-B-A	25.54

	A	C	B
A	4	0	0.2
C	0.3	6	0.1
B	0.4	0.5	7

Fig. 4. 3x3 matrix rearranged by the Markov algorithm

THE DESIGN EXPERIMENT

In the case of a design experiment, the tasks are performed by one or several participants, who may work in a synchronized or unsynchronized manner.

The monitoring of this experiment and of the activity performed by each participant represents an important source of information that can help us understand the designers' creativity and behavior in various situations.

For this experiment, the proposed theme is "*Designing a drilling device, necessary for making 6 open end holes of 6 mm, with a production of 30,000 units/year*".

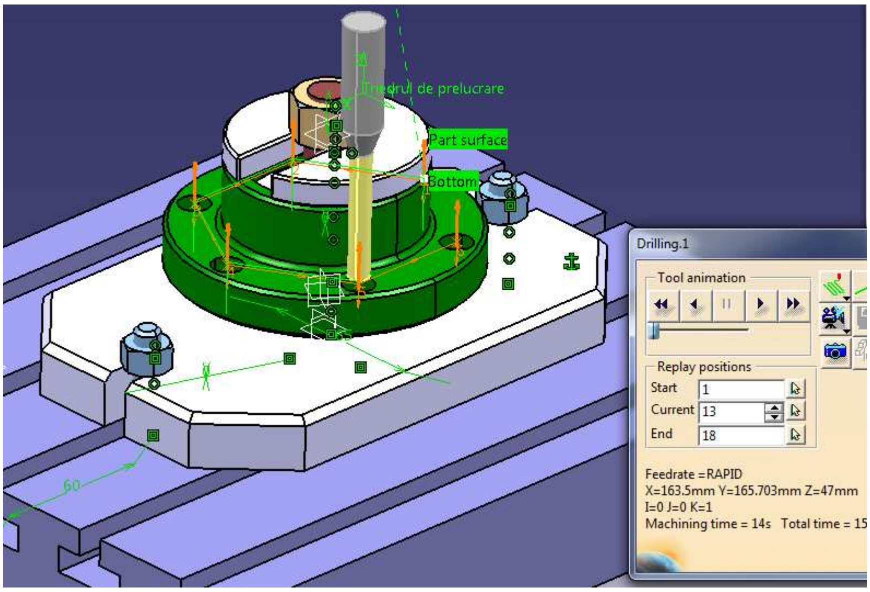

Fig. 5. The drilling device

The design team is made of 3 members:

- *TL – The Team Leader;*
- *DD – The Device Designer;*
- *MS – Material Specialist.*

In order to be able to monitor the experiment, tasks required for its performance have been identified. These tasks are as follows:

1. *Establishing the data necessary for the device design;*
2. *Setting the dimensions that must be achieved and the dimension basis systems;*
3. *Setting the guiding base system and the guiding elements;*
4. *Setting the fastening system of the piece;*
5. *Designing the piece guiding elements;*
6. *Designing the device body;*
7. *Choosing the materials;*
8. *Designing the guiding elements for the cutting tool;*
9. *Designing the piece fastening elements;*
10. *Designing the auxiliary elements;*
11. *Setting the device operating parameters.*

In order to reduce the number of iterations, the DSM (Design Structure Matrix) [5] of the process was rearranged, figure 2, and then the matrix rearranging algorithm was applied, and the matrix in figure 3 was obtained.

	1	2	3	4	5	6	7	8	9	10	11
1											
2	1										
3	1	1									
4		1	1			2					
5		1	1								
6	1				1			2	2	2	
7					2	2		1	2	2	
8		1				2			2		
9				1	2	2					
10	1					1		2			
11		1			1			1			

Fig. 6. Original DSM Matrix

	1	2	3	5	4	6	8	9	10	7	11
1											
2	1										
3	1	1									
5		1	1								
4		1	1			2					
6	1			1			2	2	2		
8		1				2		2			
9				2	1	2					
10	1					1	2				
7				2		2	1	2	2		
11		1		1			1				

Fig. 7. Rearranged DSM Matrix

Material and information resources: 3 personal computers, one for each participant, connected to the network and to the Internet; one database concerning types of steel, 3D design software allowing for the usage of shared drawings so that any of the participants may be able to add his input, at any moment; specialized books and treatises, etc.

FINDINGS

The tasks of the design process can be run in different series. With the arrangement using DSM has been the most favourable sequence in terms of duration. In reality, due to various additional constraints, some unforeseen April, it is recommended to resort to running tasks after another scenario, different from the one established with the DSM. Thus, the simulation method Markov chains can be made a series of forecasts of the total length of the project, depending on the scenario chosen progress. Only if recommended by the DSM method. To estimate the total length of the iterative process is necessary to know the terms above tasks and the likelihood of achieving iterations. Builds the corresponding 11x11 matrix (see Figure 8) and Markov chain 1-2-3-5-4-6-8-9-10-7-11

	1	**2**	**3**	**5**	**4**	**6**	**8**	**9**	**10**	**7**	**11**
1	0.25										
2	0.8	0.25									
3	0.8	0.7	0.30								
5		0.8	0.6	0.30							
4		0.9	0.9		0.10	0.9					
6	0.5			0.5		1	0.7	0.4	0.8		
8		0.3				0.7	0.30	0.9			
9				0.9	0.9	0.8		0.30			
10	0.9					0.4	0.8		0.10		
7				0.9		0.9	0.9	0.9	0.8	0.30	
11		0.9		0.8			0.7				0.20

Fig. 8. Matrix iterative process

Will build a new matrix, which's the elements will be the negative values of transposed DSM, and the main diagonal will have value 1.

	1	2	3	5	4	6	8	9	10	7	11
1	1	-0.8	-0.8	0	0	-0.5	0	0	-0.9	0	0
2	0	1	-0.7	-0.8	-0.9	0	-0.3	0	0	0	-0.9
3	0	0	1	-0.6	-0.9	0	0	0	0	0	0
5	0	0	0	1	0	-0.5	0	-0.9	0	-0.9	-0.8
4	0	0	0	0	1	0	0	-0.9	0	0	0
6	0	0	0	0	-0.9	1	-0.7	-0.8	-0.4	-0.9	0
8	0	0	0	0	0	-0.7	1	0	-0.8	-0.9	-0.7
9	0	0	0	0	0	-0.4	-0.9	1	0	-0.9	0
10	0	0	0	0	0	-0.8	0	0	1	-0.8	0
7	0	0	0	0	0	0	0	0	0	1	0
11	0	0	0	0	0	0	0	0	0	0	1

Fig. 9. Transposed Matrix

With the calculation algorithm presented above the project duration is calculated as the sum of Ni. Each element is Ni duration for each successive stage of the chain, given that the input node and no node in the previous stages.

$$Durate = \sum_{i=1}^{11} N_i = 0.25 + 0.25 + 0.3 + 0.3 + 0.1 + 1.09 + 2.08 + 1.42 + 0.58 + 0.3 + 0.2 = 6.87$$

CONCLUSIONS

The two methods presented in the paper presents a particular importance in the design, analysis and treatment are recommended. DSM and the method of Markov chains method provides the possibility of organizing a convenient design process, avoiding as much as possible disturbances of the latter. The two methods can be seen as ways to improve the performance of the design process, which along with other methodologies is a key to reducing the development time and release time on the market a product.

REFERENCES

[1] Anghel D.-C., Belu N., Boudouh T., «Management of design process based on the analysis of intermediary objects », The 3rd International Conference on INTEGRATED ENGINEERING C2I 2008, May 8th-10th 2008, Timisoara, Romania.
[2] Blanco, E., (1992). L'émergence du produit dans la conception distribuée, Thèse de doctorat, Institut National Polytechnique de Grenoble.
[3] DeGROOT, Morris H., Probability and Statistics, Addison Wesley, Reading, 1986.
[4] Ogata, Katsuhiko, State Space Analysis of Control Systems, Pretice Hall, Englewood Cliffs, N.J., 1967.