Integrating sustainable development in morphological synthesis and selection of optimal engineering solutions

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Abstract. The selection of optimal engineering solutions is one of the main tasks in the development of any project. When choosing engineering solutions, you need to consider factors such as project goals and requirements, budget, deadlines, available resources, and the ability to scale and support the selected technologies. The analysis should take into account parameters such as performance, reliability, security, usability, and cost and complexity of implementation. The article discusses the formation of a morphological set of engineering solutions, their analysis, synthesis and subsequent clustering. On the one hand, the multiplicity of solutions must be representative, and on the other hand, limited, since the resources for their modelling are limited. In conclusion, it is concluded that the average estimates increase to 18% when generating 4% of variants and 20% when generating 20% of options. This allows you to limit the number of solutions that can be generated. The use of the approach is seen as part of computer aided innovations and IT technologies. Thus, when applying the proposed approach, it is possible to conduct a comparative analysis of many engineering solutions and choose the one that will be the most effective and convenient for a particular project.

1 Introduction

The properly selected engineering solutions (ES) will help ensure the successful implementation of the project and the achievement of its goals. It is important to choose those ES that will best meet the needs of the project and allow you to achieve your goals. Optimal ES allows you to achieve the required results with maximum efficiency, minimum time and resources. When choosing the best ES, the following factors should be taken into account:

- Goals and requirements of the project. It is necessary to understand what tasks need to be solved, what are the functional and non-functional requirements for the project in order to choose the appropriate ES.
- Technical capabilities. It is necessary to evaluate the technical capabilities of the development team and the available technologies in order to choose the best tools and platforms for the implementation of the project.

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- Timeline and budget. It is necessary to assess the available time for the implementation of the project and the budget in order to choose the optimal ES that will allow you to achieve the goals in the established time and cost.
- Performance and scalability. It is necessary to evaluate the performance and scalability of the selected ES to avoid problems with system overload as the load increases.
- Security. Security considerations must be taken into account when choosing a ES to protect the confidentiality and integrity of data.

Optimal ES helps to increase the efficiency of project development, improve product quality and meet user needs. Value engineering is widely used to evaluate ES [1,2].

2 Morphological analysis in the synthesis of engineering solutions

Morphological analysis (MA) of ES is a method of system analysis, which involves the decomposition of engineering analysis into constituent elements and the analysis of these elements in order to determine their interrelations, functions and features [3,4]. To carry out MA ES, specialists identify the main characteristics and parameters that determine its functionality and operational characteristics. These characteristics are then decomposed into smaller components, which in turn can be analyzed. Morphological analysis allows you to identify various options for the implementation of ES, analysis their advantages and disadvantages, and choose the best solution to the problem. This method is widely used in the development of new technologies, products, systems and processes [5,6].

In the morphological synthesis of engineering solutions, the number of generated options can depend on various factors, such as the complexity of the task, available resources, customer requirements, etc. When it comes to choosing the number of generated options, it is important to take into account the specific needs and goals of the project. For example, if you want to find the best solution, you may need to generate more options for further analysis and selection of the best one. On the other hand, if the task is limited in time or resources, then you can limit the number of options generated, focusing on the most promising and potentially successful options. In any case, it is recommended to analyse and evaluate the potential benefits of generating additional variants in order to make a more informed decision on the number of generated options in the morphological synthesis of ES. The following problems may arise during the generation of variants in the morphological synthesis of engineering solutions:

- Limited capabilities of algorithms. Some complex TPs may be difficult for morphological synthesis algorithms, and they may not be able to generate all possible variants.
- Some algorithms may not take data into account, which can lead to incorrect or inapplicable ES.
- Uncertainty and ambiguity. In some cases, there may be situations where the TR may have several possible interpretations, which makes it difficult to generate variants.
- Insufficient data. Successful generation of variants in morphological synthesis requires large amounts of qualitative data, which may not be available or sufficient.
- Difficulty evaluating options. Once the different solutions have been generated, it can be difficult to identify and select the best one, especially if there are many parameters and selection criteria involved.
- Limited resources. It is possible that generating all possible options will require significant computational and time resources, which can be problematic in real-world working conditions.

3 The optimal number of solutions in the morphological synthesis

The optimal number of ES in the morphological synthesis of ES may be different depending on the specific task and conditions. However, in general, it is considered optimal to have enough options to choose the best solution, but not too many to avoid unnecessary complexity and time spent on analysis. Often, for effective morphological synthesis, it is recommended to conduct a preliminary analysis and assessment of quality criteria that will be used to select the optimal solution. Based on this analysis, it is possible to determine the optimal number of options that will be considered in the synthesis of the solution. It is also important to take into account the specifics of the task and the preferences of the customer in order to select such options that will best meet the requirements and expectations. Thus, the optimal number of options in the morphological synthesis of ES may be different for different tasks, but it is important to strive to ensure that it is sufficient to choose the best solution, but at the same time not excessively large.

Clustering of ES in a decision space is the process of grouping similar ES into specific clusters or categories. This allows you to highlight common characteristics and features in different solutions, which helps to simplify their analysis and comparison. As a result of clustering ES, it is possible to gain a more complete understanding of different approaches to solving technical problems, which allows you to make more informed decisions and optimize the processes of developing and implementing new technologies.

Initially, a morphological matrix (MM) is generated (Table 1) [3]. The morphological set XM is a subset of all ES:

$$X_M \subset X \tag{1}$$

Table1. Morphological matrix.

	Options P^k							
Attributes P_n		P^1	P^2	P^3	…	P^j	…	P^{mmax}
	P_1	P_1^1	P_1^2	P_1^3	…	P_1^j	…	P_1^{m1}
	P_2	P_2^1	P_2^2	P_2^3	…	P_2^j	…	P_2^{m2}
	P_3	P_3^1	P_3^2	P_3^3	…	P_3^j	…	P_3^{m3}
	…	…	…	…	…	…	…	…
	P_i	P_{i1}^1	P_{i2}^2	P_{i3}^3	…	P_i^j	…	P_i^{mi}
	…	…	…	…	…	…	…	…
	P_n	P_n^1	P_n^2	P_n^3	…	P_n^j	…	P_n^{mn}

The power of the morphological set of solutions is equal to

$$|\, X_M| = \prod_{i=1}^{n} m_i \tag{2}$$

where m is the number of elements in the i-th row

Morphological set of solutions:

$$XM = \{Xmi,\ i = 1,\ p\} \tag{3}$$

where X_{mi} - i-th variant of ES and

$$p = |XM| \tag{4}$$

n the future, they generate ES solutions. At this point, many rational X_{Mr} solutions are generated for later analysis. For each variant of ES $X_{m1}, X_{m2}, \dots, X_{mn}$, contained in the MM, additive convolution is performed, and each ES is evaluated depending on the assessment of feature elements and normalized weight coefficients $w_{c1}, w_{c2}, \dots, w_{ci}$:

$$U = \sum_{k=1}^{n} w_{ck} \ w_i^j \tag{5}$$

where n is the number of criteria.

The greater the value of the U estimate, the more preferable the solution, i.e. if $U(X_{mj}) > U(X_{mj+1})$, where $U(X_{mj})$ is the value of the U estimate for the solution $X_{mj} \epsilon X_R$, then the solution is $X_{mj}$is preferable as X_{mj+1}. The newly generated solution X_{mj} is with a grade of U_j is compared with the previous generated solutions. In the case of ES selection at a higher level of evaluation, it is entered into the set of X_R, at the worst level it is discarded. The set of rational X_{RR} variants is selected from a set of randomly generated and selected X_G variants and is given as the sum of the sets of variants - rational X_R, reference X_{Ro} variants having the maximum scores for each X_{Rk}:

$$X_{RR}=X_R+X_{Ro}+X_{Rk} \tag{6}$$

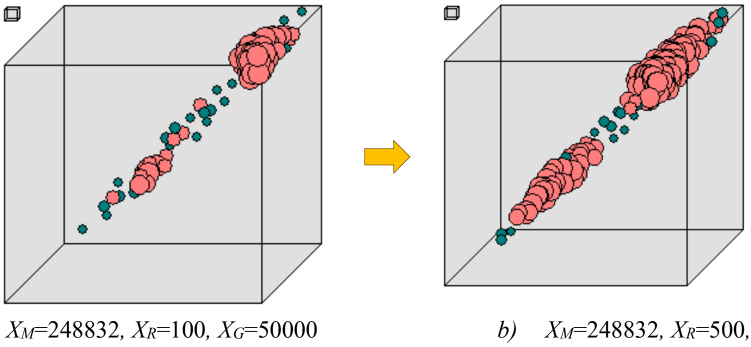
The mean score $\overline{U}$ ES X_{RR} is calculated:

$$\overline{U} = \frac{\sum_{i=1}^{n} U_i}{n} \tag{7}$$

where n is the number of ES in the X_{RR} set. The similarity measure of all ES is also calculated using the Hamming distance.

4 Results

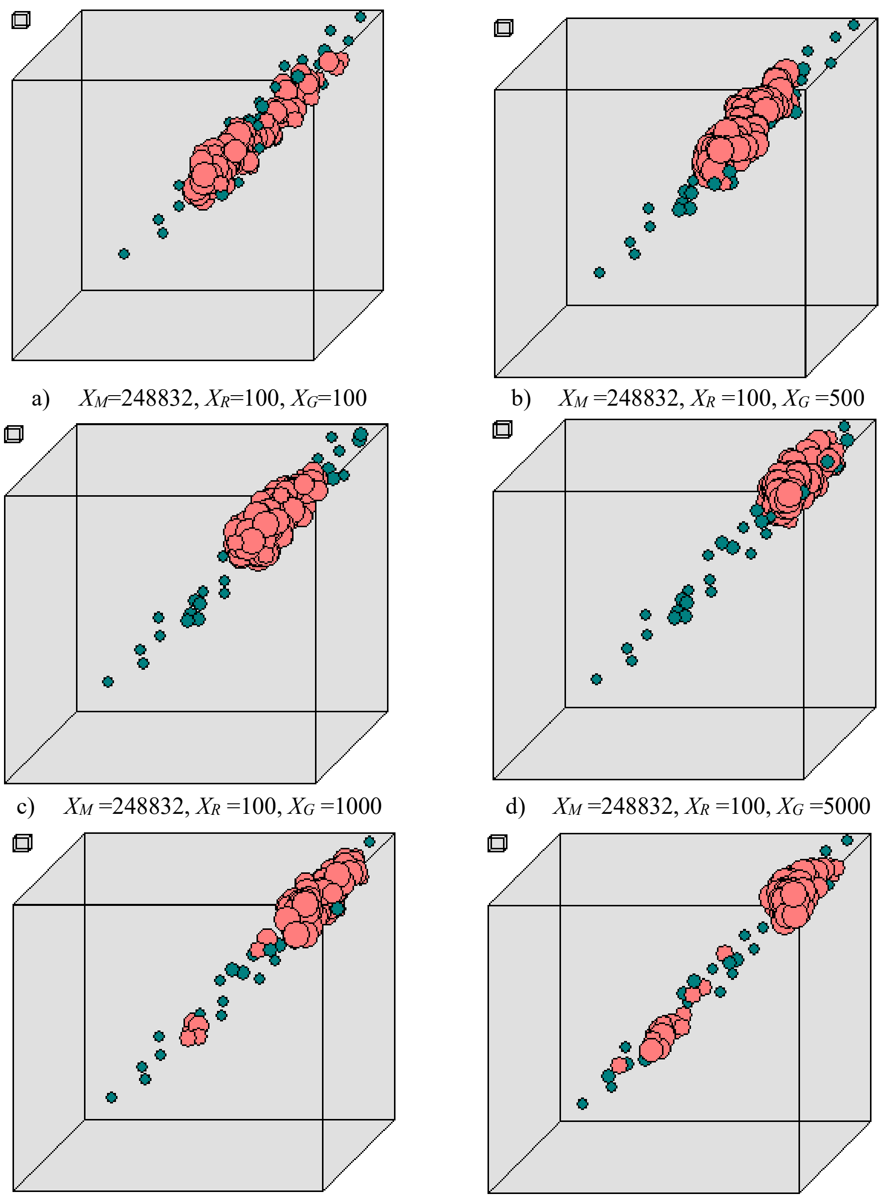
A number of solutions were generated using the developed methodology [7.8]. In the course of the work, the process of constructing solution clusters was analyzed. In particular, we considered the issues of changing the solution space when the number of generate ES X_G is fixed but the number of selected ES X_R is different. As can be seen in Fig. 1, we can state the formation of two groups of solutions, at that, when the number of solutions is large, these groups of solutions are approximately equal, and in the first case the group of solutions with higher characteristics prevails over the second group.



a) X_M=248832, X_R=100, X_G=50000 *b)* X_M=248832, X_R=500, X_G=50000

Fig. 1. The solution space with different X_G.

Figure 2 shows the generated solution spaces of the same morphological matrix with the same number of selected variants X_R, but with different numbers of generated solutions X_G. It can be seen that the centers and clusters of solutions change during the process. The average scores of the generated options were also determined. As the number of generated solutions X_G increases, the average score increases sharply at first, and then the curve of increase takes a gentler monotonic character (Fig.3).



a) X_M=248832, X_R=100, X_G=100

b) X_M =248832, X_R =100, X_G =500

c) X_M =248832, X_R =100, X_G =1000

d) X_M =248832, X_R =100, X_G =5000

e) X_M =248832, X_R =100, X_G =10000

f) X_M =248832, X_R =100, X_G =50000

Fig. 2. The solution space with different X_G

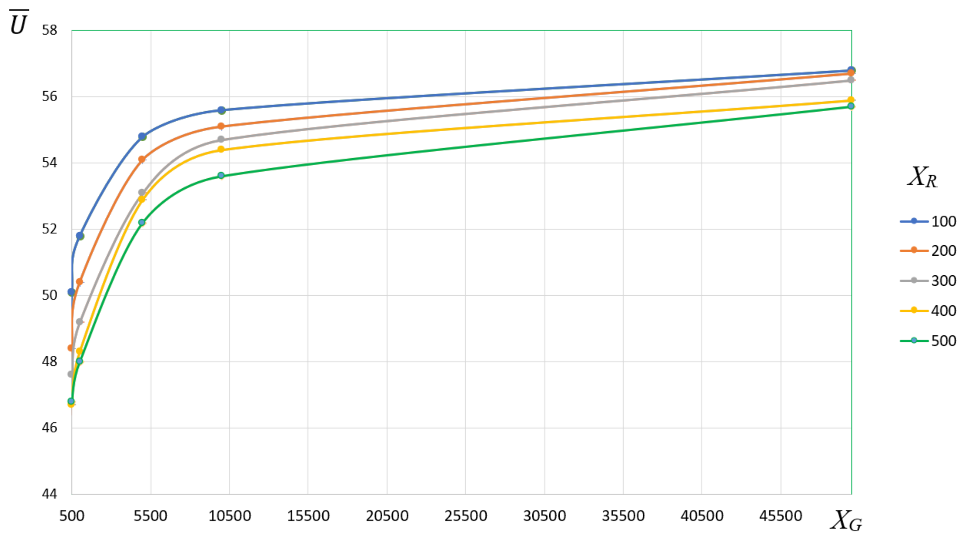


Fig. 3. Change in average score as a function of the number of solutions generated X_G and selected X_R

5 Conclusions

The selection of multiple optimal ES is one of the main tasks in the development of any project. It is important to select those ES that will best meet the needs of the project and achieve the objectives.

On the one hand the set of solutions should be representative and on the other hand limited, because the resources for modelling them are limited. It can be concluded that the average estimates increase to 18% when generating 4% of the options and 20% when generating 20% of the options. This allows limiting the number of generated ES.

When applying the proposed approach, it is possible to conduct a comparative analysis of multiple ES and choose the one that will be the most effective and convenient for a particular project. Ultimately, the right choice of ES will help to ensure the successful implementation of the project and achievement of its objectives.

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