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# Use of Analytical Hierarchical Process for the Selection of Bio-inspired Algorithm in Design of Triangular Frequency Selective Surface

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## ABSTRACT

The objective of this article is to evaluate which bioinspired optimization method has the best performance in the design of frequency selective surfaces. To this end, this article reports the continuation of the work carried out in the article: Statistical Study of Bioinspired Metaheuristic Algorithms Applied to the Optimization of Triangular Frequency Selective Surface Parameters [1]. The statistical data (mean, standard deviation and interquartile distance) used to evaluate the convergence of the bioinspired methods, which optimized the parameters to design a frequency selective surface, were implemented in the hierarchical analytical process to discover which of the methods is the best to use in solving this type of problem. The results obtained are reported in the final considerations.

**KEYWORDS:** Bioinspired Optimization Method, Hierarchical Analytical Process, Statistical Data, Frequency Selective Surfaces.

## 1 INTRODUCTION

The effectiveness of a frequency selective surface (FSS) is due to design parameters of the FSS itself as manufacturing material, structure dimensions and geometric format [2-4]. The efficiency of the FSS in resonating at a desired frequency mainly caused by the length of its dimensions, constituting one of the main challenges (problems) in the FSSs design.

This problem was solved by optimization algorithms. An example of such algorithms are bio-inspired metha-heuristics, which have been successfully implemented in the FSSs project [2-4].

However, since FSSs have different geometric shapes, a given algorithm may be efficient for a structure with a certain geometric shape, whereas for a different geometric shape it may not be as efficient. This issue needs to be analysed in order to provide some advancement in the field. Regarding the relevance of this discussion, the present article studies the evaluation of these algorithms used in the design of FSSs of triangular format, strip printed on fiberglass substrate, by means of statistical tools, since the metha-heuristic algorithms work in a stochastic way, as they generate the candidates for optimal solution in a random manner.

Thus, it is necessary to study the behavior of such algorithms, since randomly generated values have no guarantee of convergence for an optimal value, however, statistical tools can evaluate the behavior of these algorithms by conducting the randomly generated value to the optimal value. Such investigations done on optimization algorithms have been the object of researches, such as the work of PESSIN et al (2013) who working on a robotic problem using bio-inspired algorithms and evaluates the effectiveness of algorithms using statistical tools [5].

Considering the importance to define which of the algorithms should be best applied for the situation we want to discuss, a decision had to be made. For this, the hierarchical analytical process as a metric for the selection has been used. The hierarchical analytical process is a methodology used in decision-making problems. It was proposed during the 1970s by SAATY (1976) [6], being well defined and widespread in the literature and being used for decision-making in problems of engineering, such as the problem of the Civil Engineering area in pipeline design [7], in the area of telecommunications to for decision making on the best performance of a network for certain scenarios [8]. The AHP method has been used for several applications in the industry [9].

## 2 METHODOLOGY

In order to reach the fobjective of evaluating optimization algorithms, the Xi-Che-Yang (2010) article methodology was used, [10], where it is suggested to simulate each algorithm 100 times for the same problem, thus generating sample data for the evaluation.

After obtaining this sample of 100 data, we subjected this data to statistical analysis, calculating the mean, standard deviation and interquartile distance of the data. We then applied the hierarchical analytical process to verify which of the two algorithms performed better, based on the data generated by the statistical analysis.

Figure 1 shows the methodology flowchart.

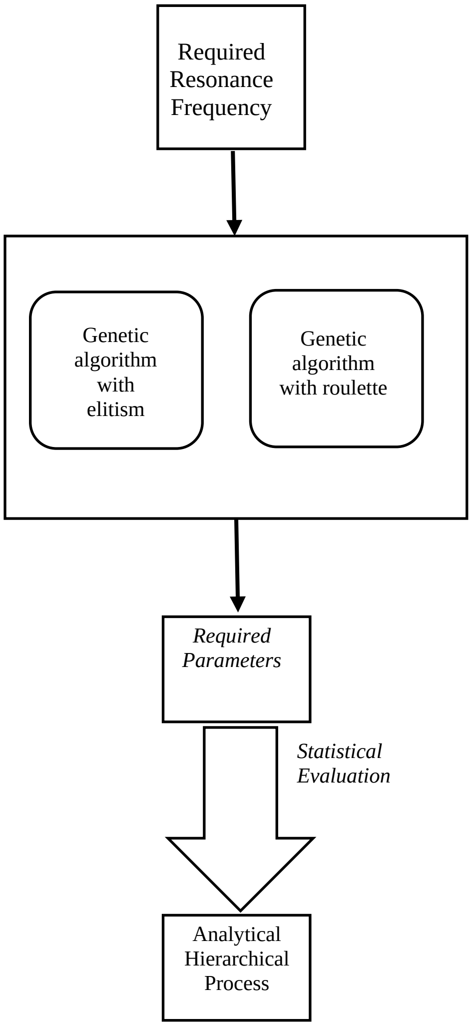

Figure 1: Flowchart of the methodology utilized

## 3 ANALITIC HIERARCHY PROCESS

In decision-making processes, the analytical methods are used in order to define the best choice to be made by established criteria. One of these methods is the analytic hierarchy process (AHP). This method is based on a weighting process in which several relevant parameters are represented by their relative importance.

This method has been used in several decision-making problems, for example in the design of ducts in civil engineering and for the selection of first-mile access technology in ISDB-T standard.

The method consists of constructing an array with weights $a_{ij}$ associated with the parameters used in decision making $c_i$ and $c_j$. The comparison of the dosages is done as follows: if they are equal in importance, the weight $a_{ij} = 1$ is assigned, if $c_i$ is a little more important than $c_j$, the weight 3 is assigned, if $c_i$ is more important than $c_j$, the weight 5 is assigned, if $c_i$ is much more important than $c_j$, the weight 7 is assigned and if $c_i$ is much more important than $c_j$, the weight 9 is assigned. The relation $a_{ij} = {}^{1}\!/_{a_{ji}}$ gives us the value the elements below the main diagonal of the matrix. The following is an example of the matrix.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & \cdots & a_{ij} & \cdots \\ \cdots & a_{ij} = {}^{1}\!/_{a_{ji}} & \cdots & \cdots \\ a_{n1} & \cdots & \cdots & 1 \end{bmatrix}$$

These matrices must have an index of consistency less than 0.1. The descriptions and other formalities of the method can be found in [6, 11].

## 4 RESULTS

With the results obtained in the simulations using the bio-inspired algorithms, the AHP method was applied to select the best algorithm. The criteria establishing the hierarchical structure of the process were $C_1$, $C_2$ and $C_3$ (mean, standard deviation and interquartile distance) and the alternatives are the two bio-inspired algorithms $A_1$ and $A_2$ (Genetic Algorithm with Elitism and Genetic Algorithm with Roulett). The execution of the hierarchical analytical process is represented in the flowchart of figure 2.

Defined the hierarchy comparison of process the matched comparison matrices were constructed. The construction of these matrices was made based on the study realized in this study. The pairs were compared at all hierarchical levels according to the fundamental SAATY scale [6].

$$\begin{array}{cccc} C_1 & C_2 & C_3 & \\ \left[\begin{matrix} 1 \\ {}^{1}\!/_{7} \\ {}^{1}\!/_{3} \end{matrix}\right. & \begin{matrix} 7 \\ 1 \\ {}^{1}\!/_{5} \end{matrix} & \left.\begin{matrix} 3 \\ 5 \\ 1 \end{matrix}\right] & \begin{matrix} C_1 \\ C_2 \\ C_3 \end{matrix} \end{array}$$

$$C_1 = \begin{array}{ccc} A_1 & A_2 & \\ \left[\begin{matrix} {}^{1}\!/_{1} \\ {}^{1}\!/_{3} \end{matrix}\right. & \left.\begin{matrix} {}^{3}\!/_{1} \\ {}^{1}\!/_{1} \end{matrix}\right] & \begin{matrix} A_1 \\ A_2 \end{matrix} \end{array}$$

$$C_2 = \begin{array}{cc|l} A_1 & A_2 & \\ \hline {}^{1}/_{1} & {}^{1}/_{3} & A_1 \\ {}^{3}/_{1} & {}^{1}/_{1} & A_2 \end{array}$$

$$C_3 = \begin{array}{cc|l} A_1 & A_2 & \\ \hline {}^{1}/_{1} & {}^{1}/_{3} & A_1 \\ {}^{3}/_{1} & {}^{1}/_{1} & A_2 \end{array}$$

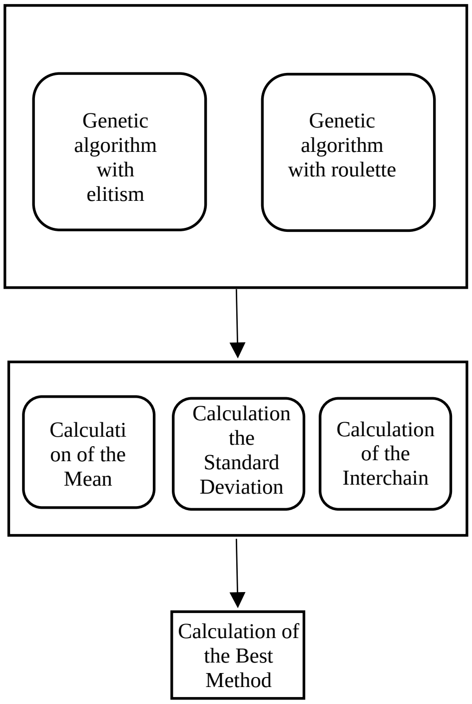

Figure 2: Flowchart of the analytic hierarchy process

Then, the matrices were normalized, the arithmetic mean for each row of the normalized matrix was obtained and the result of consistency (RC) verified for each case.

The values 0.5445 and 0.4555, respectively, represent the numerical results for $A_1$ and $A_2$.

According to the results based on the previously mentioned criteria, it can be see that the best algorithm was the genetic algorithm with elitism.

## 5 CONCLUSION

Among the results presented, those with a distribution closer to the normal curve have a willingness to concentrate around the central tendency values, thus, they are those that become closer to actually converging to an optimal value.

Given the different behavior of each distribution generated randomly by the bio-inspired methods, the one that best adapts to the problem of optimizing the dimensions of a triangular geometric FSS with the aid of the AHP decision making technique was determined. The most suitable algorithm is genetic algorithm with elitism.

Thus, we solve the problem of which bioinspired algorithm is most effective for designing frequency-selective surfaces that was presented in [1].

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