BASIC APPLICATION OF EVOLUTIONARY ALGORITHM FOR CIRCUIT DESIGNING

Ricardo Francisco Martínez González

Instituto Tecnológico de Veracruz

imag@itver.edu.mx

Marcos Alonso Méndez Gamboa

Instituto Tecnológico de Veracruz

lmarcosalonso@itver.edu.mx

José Luis Fernando Palomeque Loyo

Instituto Tecnológico de Veracruz

jlfpl@hotmail.com

Abstract

The evolutionary algorithms are a mixture of techniques based on natural process; they are vast and varied as the same nature. However, there are some invariant elements in each algorithm: initial population creation, selection, reproduction, and the current work cover all of them. At first, the evolutionary algorithm can be considered complicated or confusing; although, the current work shows that this kind of algorithms are simple once the principles are understood. The proposed application for the developed algorithm is the solution of an electric circuit; even though, it is quite simple, since it only has resistances and voltage source, it can show the applicability of the evolutionary algorithm at the search of solutions, no matter the problem origin.

Index Terms: Auxiliary mutation, evolutionary algorithms, mitosis based reproduction, passive circuit.

1. Introduction

The evolutionary algorithms offer interesting and practical solutions for engineering problems. They are based on heuristic search assumptions; the first researcher who proposed them was Holland [1].

Opposite to other optimization or searching methods, the evolutionary algorithms examine a set of probable solutions at the same time [2]. They emulate biological processes that are commonly implemented by nature. A flowchart appears in [3], it is an evolutionary algorithm; it has 4 stages or phases. At the first phase, the first population is initiated; and then, each individual is randomly varied [4].

Afterward, the varied individuals are evaluated to determinate its fitness; the evaluation is used to select the fittest individuals of the population. To close the loop, the fittest individuals are used for breeding a new generation. The loop is repeated until generate one or more individuals whose characteristics solve the initially proposed problem [5-6].

Pseudo random number generators are usually used to give origin the first generation. Those generators use different method to produce each number; ideally, the statistical distribution of the random generated numbers is uniform and it covers the whole available universe.

Other of the evolutionary operators is the reproduction; for it, there are basically two ways: Mitosis and Meiosis [7]. At mitosis, the same genetic information from an individual is copied to the next one. On the other hand, meiosis process consists in to divide by 2 genetic information of the selected individual. Such information is mated with another's one to breed a completely new individual.

Even thought, the natural selection looks fittest individuals; there are other artificial selection mechanisms as: Random, Roulette wheel, Rank, Tournament and Boltzmann. Each of the selection mechanisms has their pros and cons, in order to found more related information, see [3].

Review works

The idea for designing analog circuits is not new; Fernandez et al [8], at 1991, stand for a useful form for automatic designing after a symbolic representation of the circuit. Nowadays, the usage for genetic algorithms in analog designing continues; Madeleine Fort at August 2014 [9] proposed an algorithm for determining topology as well as elements values in an analog circuit. Besides, the

current manuscript goes for analog designing, the application for genetic algorithms in circuit designing transcends analog barriers, and they are also use for digital designing. Vijakumari et al [10] use them for digital designing optimization.
This introduction was used to give a brief background to the evolutionary algorithm world. On next section, the proposed algorithm will be depicted.

2. Circuit to be resolved

In the electric circuit, there are two kinds of elements: pasive and active. The active elements enpower the circuit, and the pasive ones consumes power. For the active elements, the most common ones are voltage and current sources. Meanwhile, resistance is the most common pasive element. The proposed circuit is integrated by a voltage independent source and resistances, as it is shown on figure 1.

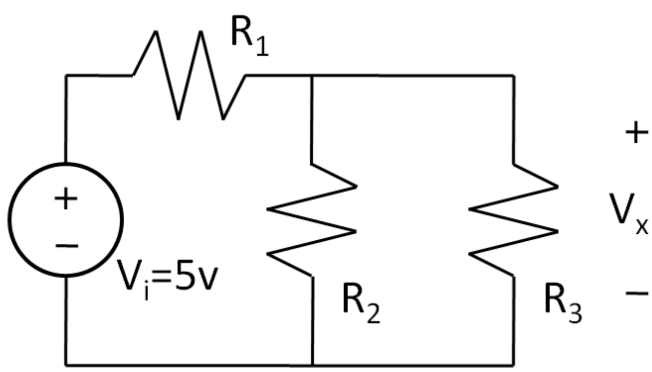

Figure 1 Test circuit for the current algorithm.

The circuit is analyzed by mesh method, since it has two clearly identified meshes. First mesh consists of V_i, R_1 and R_2; R_2 and R_3 are part of second mesh. Voltage at R_3 is the desired parameter for optimization.
Once the meshes were determined, each mesh is used to produce an equation; therefore, circuit produces two equations that are shown on next.
For first mesh, equations 1, 2, 3 y 4.

$$R_1 I_1 + R_2(I_1 - I_2) - V_i = 0 \quad (1)$$

$$R_1 I_1 + R_2 I_1 - R_2 I_2 = V_i \quad (2)$$

$$R_2(I_2 - I_1) + R_3 I_2 = 0 \quad (3)$$

$$-R_2 I_1 + R_2 I_2 + R_3 I_2 = 0 \quad (4)$$

Integrating both equations into a whole system, it gives equation 5.

$$\begin{bmatrix} R_1 + R_2 & -R_2 \\ -R_2 & R_2 + R_3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_i \\ 0 \end{bmatrix} \quad (5)$$

According to the figure 1, the evaluation parameter is the output voltage. It is determined as equation 6.

$$V_x = I_2 R_3 \quad (6)$$

The V_x value is set at 3.5 volts, the value was arbitrary and it does not have any meaning. Once the circuit conditions have been established, it is time for the proposed algorithm presentation.

3. Proposed Evolutionary Algorithm

Present work was inspired by the cellular reproduction known as mitosis. In this kind of reproduction, the original entity is copied to give origin other two new and independent entities. Those entities have the same characteristics as their parent entity; however and for the solution searching, each new entity must suffer a mutation. With it, any entity is a little different from the rest; no matter, if all of they were originated by the same parent entity.

As it was mentioned in the introductory section, a good part of algorithm success relies on initial population selection. As the proposed scheme was implemented in Matlab, initial population was generated using rand function. This function produces uniformly distributed sequences; such uniformity improves chances for solution finding.

Another parameter that drastically enhances algorithm chances is highly populated generation. The algorithm was firstly proved using 64 individuals for the first generation; afterward, the algorithm was modified to produce first generations with 216 individuals. The modification had good acceptance since the 64 individual generations sometimes do not converge in a correct solution, but the generations with 216 individuals drastically improves its convergence.

After the initial generation was produced, it is evaluated. Each individual is used to solve the proposed circuit. For circuit solution, the matrix on equation 5 is solved using the Gauss Jordan elimination with partial pivoting method. This method is called in Matlab as rref function; the function output is taken to evaluate individual performance. Calculating its absolute error, the error is associated to specific individuals for future selection process.

With each evaluated individual, the complete generation is segmented in two. The more suitable half is used for reproduction and the less suitable one is disposed. Each individual at the more suitable half is used to generate two new individuals by the mitosis and mutation process previously described.

The newly generated population is evaluated once again and cycle is repeated until one individual has an absolute error lesser than a minimum allowed error. This allowed error is a parameter determined by user. Nevertheless, it is important to be cautious; the lower error is allowed, the more time the algorithm requires for solution finding. Another collateral effect of using a lower allowed error is an increment of the non-satisfaction possibilities.

4. Result for the proposed algorithm

The first result to be considered is statistical distribution for initial generated chromosomes. To give origin to 216 individual in first generation, six individual chromosomes were needed; ideally, the statistical distribution for chromosomes must be uniform; however, the number of chromosomes is not large enough for appreciation of such distribution. The phenomenon is shown in figure 2.

Non-uniformity of distribution for the initial generation should be partially fixed if more individual are included in it. Unfortunately after generating an empirical initial population with forty individual chromosomes, the non-uniformity stills. If this behavior remains, the number of individual chromosomes does not matter. However, problem relays on the generating algorithm of pseudo random numbers. In order to establish the point, statistical distributions of 40 and 100 individual chromosomes generated by rand function are presented at figure 3.

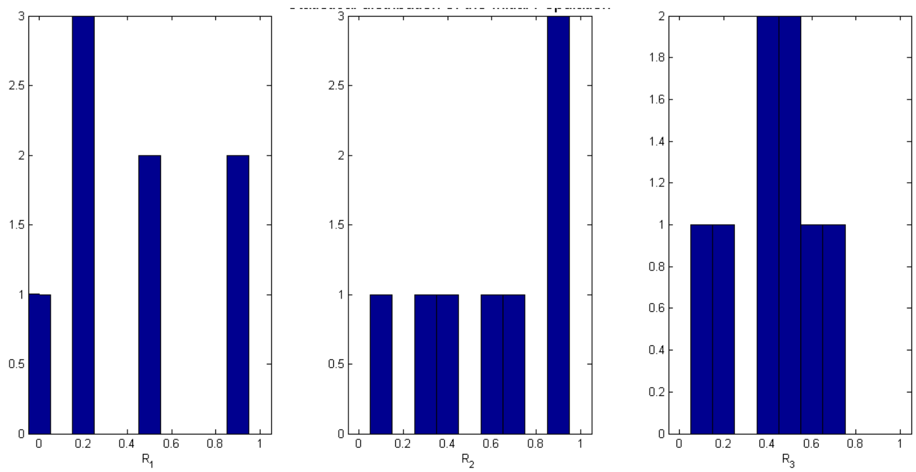

Figure 2 Statistical distribution for the firstly generated chromosomes.

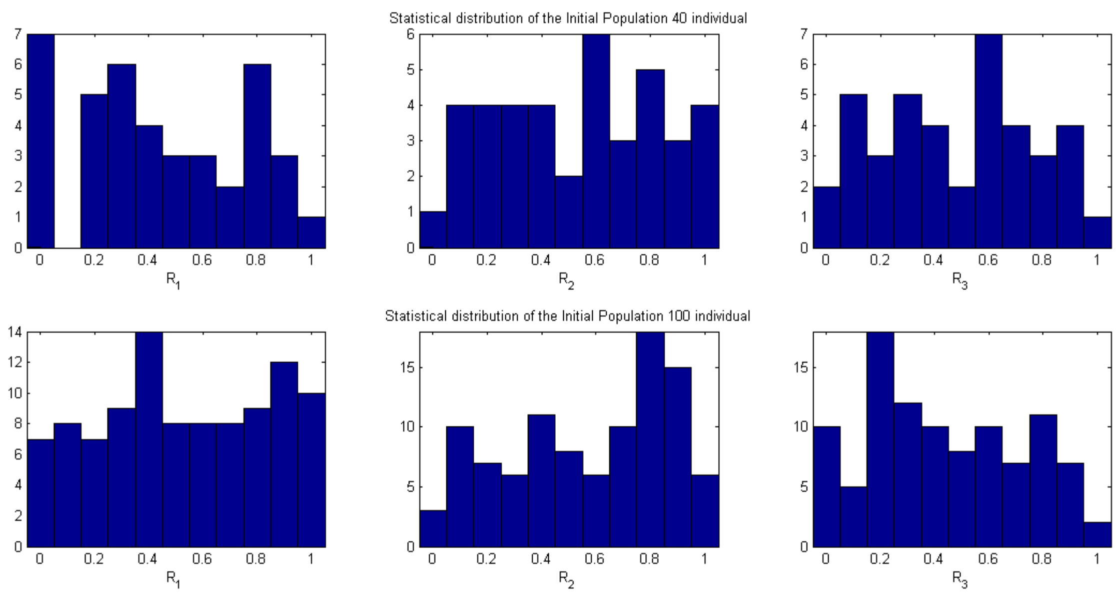

Figure 3 Statistical distribution of the initial chromosomes with different number, 40 chromosomes (top) and 100 chromosomes (bottom).

At first sight, distributions are not uniform. In consequence, if better initial chromosomes are required, non-uniformity phenomenon must be reduced; and the most obvious solution is to use a better generating algorithm, but the current work only uses rand function.

The initial population is established combining every individual chromosome up; in other words, one chromosome for R_1 is put together with one for R_2 and other one for R_3. Process is repeated until have completely covered the chromosome pool of each resistance.

The next step for procedure is to measure fitness grade of recently made generation; for it, a deviation from desired value of output voltage is calculated. For calculation, absolute difference is determined following equation 7.

$$\varepsilon = |V_x^0 - V_x'| \tag{7}$$

Where ε is absolute error for the individual, V_x^0 is the desired output voltage, and V_x' is output voltage obtained from tested individual.

Using equation 7 a graph was obtained. Such graph shows the absolute errors of each tested individual, and it gives evidence of how fitted the individual is. Additionally, the errors are ascending sorted; it eases selection process to give birth next generation. In figure 4, both graphs are presented; on left, the error graph as each individual gets so, and on right, the sorted errors graph.

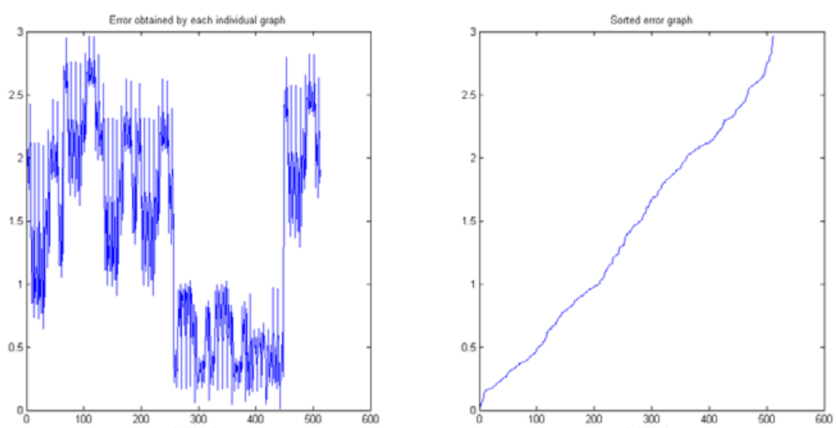

Figure 4 Errors obtained by each individual; (left) as they were obtained, (right) sorted.

The sorted errors drastically help selection process out, since only the fitter half of individuals is chosen for giving birth to next generation. As it was explained in the previous section, the reproduction recalls the mitosis reproduction. For this kind of reproduction, each individual of the fitter half is copied twice. In each copy, the genomes suffer a slight mutation produced by the function rand limited by a factor. The expression that was used for the copied and mutation process is

$$i'_{a,\frac{n}{2}+a}[R_1 + m_1, R_2 + m_2, R_3 + m_3] = i^0_a[R_1, R_2, R_3] \quad (8)$$

Where i^0 is the individual that belongs to the fitter half of previous generation, *i'* is the new mutated individual, *a* is a consecutive number that starts at 1 and ends on half of the complete population; m is mutation value, it is determined by a random value multiplied by an elicited factor, and it is independently generated for each copying process.

The first generation is created from six values for each chromosome, resulting at 216 individuals. The second generation is the result of 108 individuals, each of them is mutated and copied twice; as consequence, now each chromosome has 216 values. This can result evident at see the figure 5, where the top histograms are for the first generation chromosomes and the bottom histograms are for the second generation ones.

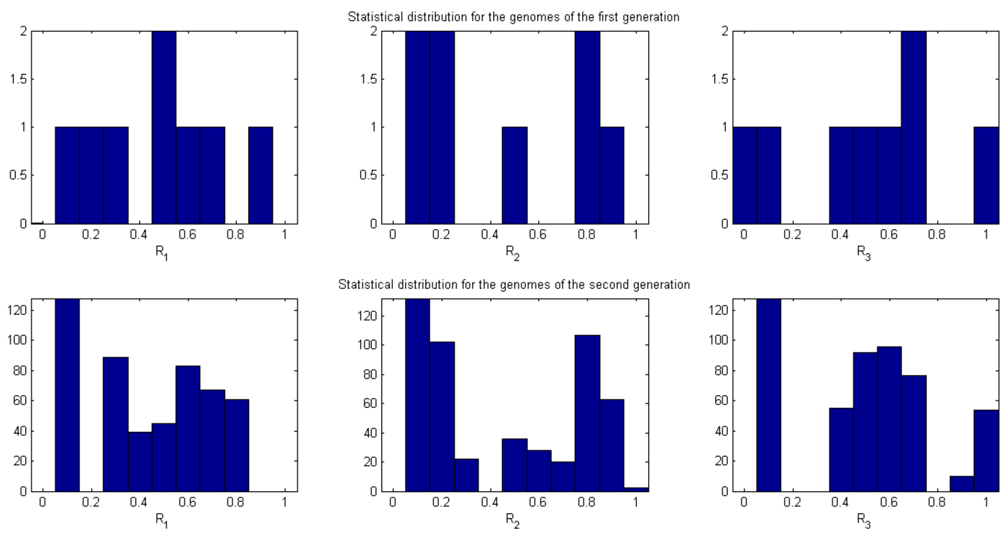

Figure 5 Histograms for the first (top) and second (bottom) generation genomes.

With the second generation created, the proposed process is iterated until reach the desired output; however, an exact output is extremely hard to achieve, so a safe parameter is established for saving malfunctions. For the current work, safe parameter was established at 0.1 volts.

Finally when any individual of population satisfies the output parameter, then iterating loop is broken up. The number of iterations depends on many factors as:

initial generation, desired output, safe parameters and mutation factor. Nonetheless, since this application is quite simple its convergence is soon, typically less than 10 iterations are required for finding a satisfying result. In each plot of figure 6 are shown the accumulative and minimum error respectively obtained by each generation. In those plots can be observed that the error decreases after every generation.

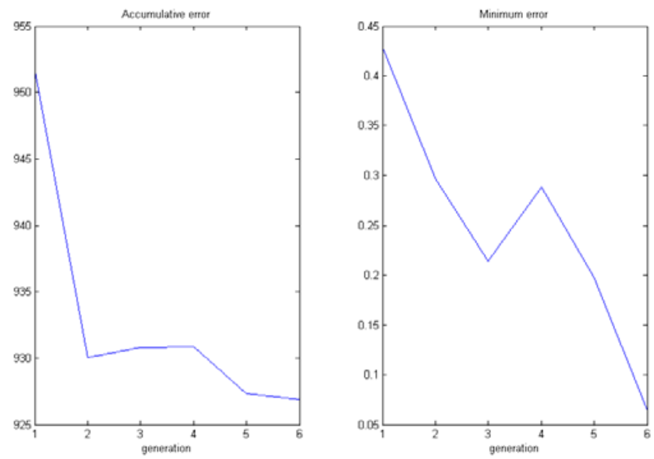

Figure 6 Accumulative (left) error plot and minimum (right) error plot obtained by each generation.

This results section was presented in order to review effectiveness of the proposed algorithm; now on next section, we will talk about the conclusions and knowledge let behind after this work

5. Conclusions

The proposed circuit and evolutionary algorithm are simple, and they were chosen in that way in order to have a closed milestone in this kind of algorithms. The knowledge after this first milestone is satisfactory, because it proves that evolutionary algorithm actually works for real circuit problem solutions and they do not have to be messy nor tricky.

Mitosis method can be used as reproduction mechanism; however, it necessarily requires a mutation process in order to achieve an individual who satisfies the required parameters.

6. Future work

With the good experience obtained from this work, next step is to rise evolutionary level up. In other words, enhance the proposed algorithm in order to satisfy multiple parameters. Other goal is to generate a more uniformly distributed population.

The final achievement is to stop Matlab need, and translate the algorithm to C or Python and use it as embedded part of a more sophisticated system.

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8. Authors

Ricardo Francisco Martinez-Gonzalez. He was born on Veracruz, Mexico. He received his Bachelor of sciences degree from Instituto Tecnológico de Veracruz. Next on, He studied his M.Sc. degree at Instituto Nacional de Astrofísica, Óptica y Electrónica; where he also obtained his PhD degree; applying his knowledge on chaos applications. Nowadays, He works at Instituto Tecnológico de Veracruz.

Marcos Alonso Méndez Gamboa. He received his Bachelor of Science degree from Instituto Tecnológico de Veracruz at August 27, 2004. Afterwards, he studied his Master´s Degree at Centro Nacional de Investigación y Desarrollo Tecnológico (CENIDET), and he got it on February 29, 2008. He started working in Instituto Tecnológico de Veracruz at that year´s summer.

José Luis Fernando Palomeque Loyo. He got his Bachelor of Science degree in Electronically Industrial Engineering from Instituto Tecnologico de Veracruz at 1982. At 2002, He got a Master’s of Science degree in Science Teachings by CIIDET. He also had some remarkable chairs on Sistema Nacional de Instituto Tecnológicos. Since 1987 He is professor of Electrics and Electronics Engineering Department at Instituto Tecnológico de Veracruz.