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Performing Dynamic Analysis of the Conceret Structures using Genetic Algorithm and Determining the Optimal Range during a Natural Hazard Crisis (Tempe, Arizona, U.S.A)

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Abstract

The approach employs a binary genetic algorithm alongside natural numbers. Given the differences between accelerometers and scale coefficients, the genetic algorithm introduced herein is a hybrid, featuring two chromosomes. A key factor influencing the accuracy and effectiveness of these programs is the precise estimation of their parameters. When these parameters are determined accurately, the gap between the average response spectrum and the design spectrum is significantly minimized. This program operates with two genetics that run concurrently, yielding results that closely approximate the optimal solution. The program itself is capable of offering users a range of desired coefficients, as well as values for the covariance and mutation of each chromosome. The algorithm detailed in this article can generate a new generation of individuals from an infinite array of ground motion records, utilizing processes such as natural selection, mating, and mutation, and continue this cycle until an individual meets the desired characteristics. This paper presents a novel method for optimally selecting accelerometers and scaling them for dynamic time history analysis, aiming for an average response spectrum that closely aligns with the target spectrum, reflecting the expected seismic activity for the structure in Tempe district in Arizona State. Given the relatively high number of parameters involved, reliance on trial-and-error methods is significantly influenced by the user's skill set; thus, the hybrid genetic algorithm presented here addresses this limitation.

Keywords: Dynamic Analysis, Genetic Algorithm, Earthquake, Cnceret structure

1. Introduction

The genetic algorithm is the best evolutionary method and does not need gradient information. The implementation of genetic algorithms starts with the creation of an initial population of chromosomes. Then these initial structures are evaluated and they are allowed to reproduce according to their merit (Aghazadeh, M. *et al*., 2017) [2]. Usually, the degree of desirability of the solutions is determined according to the current population. The structure of the genetic algorithm is such that it must have at least one member in its initial population. This member is responsible for generating a new population and growing it to meet the final condition. In the genetic algorithm, the first stage of evolution is the production of people (Zakerhaghighi *et al*., 2015) [36].

In these algorithms, after generating the initial population, it is time to select two parents and combine them in the form of one or two children, and finally, the children mutate. The new offspring replaces one of the weaker individuals in the population. A genetic algorithm is an iterative procedure that includes a population with a fixed size (Khanian, M., *et al*., 2013) [19]. Each individual of this population is presented according to a limited string of symbols, which are referred to as the genome. Each of these genomes encodes a possible solution in the problem space.

The problem space is interpreted as the search space, which includes all possible solutions to the problem. Generally, genetic algorithms are used for problems whose search space is very large and the usual search methods do not apply to them (Sadigh Sarabi, M., *et al*., 2023b) [34]. According to the main goal of this research, which is to obtain the set of ground motion by genetic algorithm, it is by the scope of Iran's 2800 regulations**.** The genetic algorithm can select and scale from the population of real ground maps for a specific area with a specific soil type to obtain a suitable combination of ground motions, according to the range of plans introduced in Iran's 2800 regulations (Karimimansoob *et al*., 2024b) [17].

The research process is that, first, based on the characteristics of different earthquakes that have occurred in the world based on the type of soil, and the distance of the station from the specific earthquake source, a database is selected, and then this data is expanded for different types of soil. Will be given (Sadigh Sarabi, M., *et al*., 2023). Then the genetic algorithm will select the response spectrum of the combination of these records by comparing the spectrum of the code, and if the convergence criterion is satisfied, that set will be selected as an individual for the earthquake record**.** The results show that the genetic algorithm produces accurate results in selecting and scaling the main earthquake sets according to the design spectrum.

The results of this research can be used in design and consulting offices when dynamic analysis is necessary**.** The effect of distance on the source of energy release has been investigated by different researchers (Norouzian, M. M., & Sarabi, 2023) [29]. In most studies, the maximum ground motions are plotted as a function of distance**.** In such a way, a suitable curve is fitted to the data points and the equation of this curve is used to determine the maximum ground movements at different distances (Kahvand, M., *et al*., 2015) [15]. These relations, which are called attenuation, were initially proposed independently of the magnitude of the earthquake, but later researchers included the effect of this parameter in the relations**.** The results of the research show that the maximum acceleration of the earth with the increase of the distance to the source of the release of the energy of the earthquake is effective in the reduction relationship (Karimimansoob, V. *et al*., 2024c).

But near the fault, only earthquakes with small magnitudes are in the relationship of Gausar reduction, and earthquakes with large magnitudes do not have much effect on these relations**.** The effect of local soil conditions on earthquake waves: It seems that there is a general agreement among different researchers about the great influence of soil conditions on the speed and location of the earth's movement (Maleki, M., *et al*., 2024) [21]. According to Bor, Sayed, and Idris, it is possible to create greater maximum horizontal velocities on soil than on rock, it should be noted that this was done in a statistical study on the movement of the earth (Norouzian & Gheitarani, 2023) [23].

The average speed-to-acceleration ratio for maps recorded on alluvium is larger than the same ratio for rock. This shows that soil conditions affect the speed of ground movement**.** Earthquake waves are reflected and refracted when passing through different layers of soil, and when the wave reaches a softer layer, its extension is closer to the vertical axis**.** On the other hand, when the vibration is introduced from the rocky layer to the softer layers, according to a normal dynamic rule, the vibration amplitude increases, and for this reason, the earthquake coefficient is usually higher for soft soils than for hard ones (Norouzian & Gheitarani, 2024) [28]. Theoretical studies show that this increase occurs gradually in the path of the wave passing from the rock bed to the ground surface.

Experience shows that structural damage in soft alluvial land can be more severe and this has been proven in numerous earthquakes. Of course, this effect also depends on the type of structure, its cycle time, and its distance from the earthquake center, for example, it can be expected that low-rise brick buildings on soft ground will be less damaged**.** Effect of ground material: The effect of softening the ground material appears as a decrease in the acceleration resonance coefficient at high frequencies and an increase at low frequencies. For soft soils, compared to hard soils, the maximum ground acceleration parameter remains constant, but the maximum values of ground speed and displacement increase (Aghazadeh, M. *et al*., 2019) [1].

The reason for this phenomenon is that the soft soils yielded in the earthquake and therefore the basic acceleration remained constant, while the speed and displacement increased**.** As a result of this change in the base curve of the design spectrum, the values of the spectral values in the region of constant speed and displacement in soft soils increase compared to hard soils, while they remain almost unchanged in the region of constant acceleration**.** In this research, according to assumptions such as comparing the response spectrum with the design spectrum (Sadigh Sarabi, M., *et al*., 2023a) [33].

2. Theoretical

Genetic algorithm: A genetic algorithm is a special type of evolutionary algorithm and artificial intelligence that uses biological techniques such as inheritance and mutation to find the answer**.** A genetic algorithm is a tool by which the machine can simulate the mechanism of natural selection**.** This action is done by searching the problem space to find the superior and not necessarily the optimal solution (Naghibi Iravani, S., *et al*., 2024b) [25]. In the book Genetic Algorithm and its Applications, Mahdavi defines the genetic algorithm as a search method according to the structure of genes and chromosomes**.** Genetic Algorithm is a computer simulation program of natural evolution process to search for solutions and optimization problems**.** The close conjecture of adaptive systems in machines goes back to the anachronistic stage of computer software and hardware development (Norouzian & Sarabi, 2023) [29].

A lot of time has been spent, though, until it's perfected enough to be used as a usable tool**.** The availability of high-speed computers has paved the way for applications of genetic algorithms in engineering (Karimimansoob *et al*., 2024a) [16]**.** The book Genetic Algorithm and Optimization of Composite Structures calls the Genetic Algorithm a search method that is based on the observation of the characteristics of children of successive generations, and the selection of children based on the principle of survival of the fittest (Sadigh Sarabi, M., *et al*., 2024a) [30].

The general process of optimization and problem-solving in the genetic algorithm*:*

Start**:** Random generation of a population that includes a large number of chromosomes (problem-solving methods).

Correctness assessment**:** Correctness assessment for the function f(x) for each chromosome x in the population.

Creating a new population: Creating a new population by doing all the sub-groups below until a new population is created.

Replacement: Replacing the new population instead of the previous population and using the new population in the next stages of the algorithm.

Test: If the optimal conditions are established in solving the problem, we announce that we have reached the best solution and exit the algorithm, otherwise, we go to step 2 and repeat the same process. The power of the genetic algorithm lies in its inherent ability to adapt itself. In natural systems, species adapted to the environment through successive interactions and generations are related to the environment (Gheitarany, N., *et al*., 2013b).

After several successive generations, only those species that can adapt well to the environment remain and the rest disappear. In mathematical terms, people are like the variables of the problem, and the environment is the nature of the problem. The last generation of strings of variables that can be adapted to the problem are problem solutions. Genetic algorithms provide the necessary tools to mimic this natural process (Gheitarani, N., *et al*., 2013a). The correspondence between natural evolution and genetic algorithm is summarized in Table 1.

Table 1: Correspondence between natural evolution and genetic algorithm

genetic algorithm (GA)	Natural evolution
Problem to solve	environment
A set of alternative answers	population
Repeat step	production
Volunteer answer	the person
Selected answers	parents
fitness value (evaluator function)	Compliance size
Selection of parents according to fitness value	survival
Encrypted answer	Genotype
The answer is decoded.	Phenotype
Position in the field	Gene
A value at a specific position in the string	allele
The process of getting from the current population to the next population	Production frequency

The general trend of genetic algorithms: Before a genetic algorithm can be implemented, a suitable encoding (or representation) for the given problem must first be found.

The most common way of displaying chromosomes in the genetic algorithm is in the form of binary strings. Each decision variable is binary and then by putting these variables together, a chromosome is created. Although this method is the most widespread coding method, other methods such as representation with real numbers are expanding (Khanian, M., *et al*., 2019) [20]. Also, a fitness function should be devised to assign a value to each coded solution. During execution, parents are selected for reproduction and combined using the fusion and mutation operators to produce new offspring. This process is repeated several times until the next generation of the population is produced. Then this population is examined and if the convergence criteria are met, the above process is terminated (Ghadarjani *et al*., 2013b).

Using genetic algorithm to scale records: The selection and scaling of earthquake records to match the design spectrum can be formulated with engineering optimization problems such as the mean squared distance between the code response spectrum and the selected and scaled average response spectrum within an arbitrary period range. The current methods of the regulations, which lead to the same scale coefficients for a set of accelerometers, will not necessarily lead to the closest matching of the average spectrum resulting from the selected accelerometers with the spectrum of the standard design, but the achievement of such a goal should be sought in the form of optimization of the combination coefficients (Norouzian, M. M., 2024) [27].

Several algorithms, which can be classified as deterministic or stochastic, have been developed to solve engineering optimization problems. Gradient-based deterministic algorithms are local search methods that require significant gradient information to find a solution (Aghazadeh, M. *et al*., 2018) [3]. Finding the overall optimum using gradient-based algorithms is not easy unless the resulting space is known. For this reason, the interest in using stochastic optimization algorithms to solve engineering optimization problems has increased. Among the stochastic optimization algorithms used, genetic algorithm and... can be used (Gheitarani, N., *et al*., 2024b).

The purpose of this research is to use a genetic algorithm to solve the problem. The error obtained from the objective function with the mean square is the error between the root of the sum of squares of the average of the scaled spectrum and the target spectrum so that the results of the scaled average spectrum be placed above the target spectrum in the range of T0 to Tn. The search process retrieves the best seven earthquake pairs and their corresponding scale factors. There is also no limit to the number of records and scaling factors that the algorithm may choose.

The basic elements of the genetic algorithm applied to these problems:

Population: A set of assumed variables is the solution. In most programs, there are thousands of "persons" in the population. These individuals are binary strings that, after decoding, evaluate real numbers representing the problem variables for "natural selection of parents." The initial population is usually provided randomly. Generations of children are multiplied by applying genetic algorithm operators (intersection and mutation) to parents in the population. In this research, the population of people was selected respectively 50, 100, and 300 in separate programs and finally, the appropriate population size for this problem was introduced (Sadigh Sarabi, M., *et al*., 2024b) [31].

Fitness function: It is a mathematical expression to evaluate the fitness of individuals across generations. The main rule in defining a fit function is that for those near optimal it should have values greater than yield. As a result, more fit individuals can receive a higher chance of being selected as a parent in the next generation. The fitting function of the problem raised in this research is given in the problem formulation section of this chapter (Norouzian M. M., *et al*., 2024) [28].

Interbreeding: This process takes place by the intercourse of two individuals for the reproduction and reproduction of individuals. This is done by changing and sharing parts of the parent's profile. Several models of intersection have been introduced, such as single-point intersection, multi-point intersection, uniform intersection, etc. In this study, uniform intersection is used for the binary part of the genetic algorithm, and mixed intersection is used for the real part of the genetic algorithm. Also, the intersection rate for three values 0.6, 0.65, and 0.9 has been checked (Gheitarani, N., *et al*., 2020) [11].

Mutation: Is a necessary mechanism to ensure diversity in the population. When an individual is randomly selected to undergo mutation (by enabling mutation probability), the algorithm randomly selects bits along the range of 0 and 1 or in the opposite direction of a fixed pattern of solutions to reproduce. It reproduces among all future generations (Dizaji, A. *et al*., 2023) [6]. It is necessary to perform a broad search of the entire search space. A very large jump probability, however, can optimize the process to adapt and converge early. In this problem, the mutation rate has been investigated for three values of 0.001, 0.01, and 0.025.

Natural parent selection: This is a probabilistic method of selection based on individual fitness. To ensure the survival of the fittest, individuals with a higher fitness function value have a greater chance of being selected as parents to reproduce in the next generation. In this study, the type of selection is a competition (Gheitarani, N., *et al*., 2024c).

Selection of accelerometers for seismic design: As explained earlier, the structural design cycle requires earthquake loads to be compared with a smooth response spectrum as input in dynamic analyses. Input motions should be chosen to be representative of the seismicity of the region. To predict the details of how an earthquake will occur use it in the framework of transient dynamic analysis (Naghibi Iravani, S., *et al*., 2024a) [24]. In this research, a set of records of 374 pairs of modified accelerometers related to the horizontal component of 24 real earthquakes with 5% damping has been extracted from the Pierre site. The average velocity of the shear wave at the recording location of these accelerometers is 360 to 750, which according to the 2800 standard is placed in the type 2 soil category with a very high relative risk of seismicity of 0.35g. The genetic algorithm selects the records from this collection and the combined response spectrum of this pair of accelerometers is compared in the interval time range of 0.25 to 1.86 seconds with the interval dT=0.1. The selection and scaling of earthquakes according to the spectrum given in the 2800 regulation is proposed as an optimization problem.

How to collect and analyze data. The genetic algorithm operators selected here are as follows:

The variables of the problem (people of the population) in this research are considered as an optional combination of 7 records and 7 separate scale coefficients as an individual or chromosome. Therefore, each individual has 14 subsets to represent each variable (a total of 14 variables, 7 to identify the record in the set and 7 to identify the corresponding scale coefficients). Therefore, a binary string of length 10 is assigned to each subsection, which makes the total length of each person equal to 140 binary codes. Of course, the length of these strings can be changed, larger binary strings may be used in larger sets (Kazembeyki, M., *et al*., 2021) [18]. The first seven binary strings provide the positions of the seven records in the database.

The remaining seven strings show the correlation of scale coefficients. Since the number of records are integers and the scale coefficients are real numbers, the required optimization method is a combination of real and exact number processes. In this research, the binary and true genetic algorithm program examines the objective function of the problem individually with the proposed clause. The binary genetic algorithm of this program with uniform covariance and competitive selection and the real genetic algorithm with permutation covariance and weighted average and competitive selection analyze data (Ghadarjani *et al*., 2013a). The input data includes the spectrum of the target acceleration scheme, the period range of the structure to match, the upper and lower limits of acceptable values for the scale factors, and a set of genetic algorithm parameters.

Genetic algorithm parameters include population size, number of generations, crossover percentage, and mutation percentage. The program is very fast and takes only a few seconds to converge the optimal results on a regular PC. The selection of accelerometers and the effect of the population size of the Maps First, a set of 136 records including two horizontal components of modified accelerograms has been extracted from the Pierre site (Berkeley University). According to regulation 2800, the response spectrum of the average acceleration of each pair of scaled accelerometers is compared with the spectrum of the standard design by applying a damping ratio of 5%, in the range of T0.2 and T1.5 interval times (Dehghan S. *et al*., 2024) [5].

This collection is stored as a database in Excel software, according to the results of the genetic algorithm, the author considers enlarging the set of records as an effective factor in improving the results of the presented algorithm. Therefore, in the presented research, the record set of 374 horizontal components of modified accelerograms, all of which are extracted from the type 2 soil for the ground with a very high relative risk, the acceleration ratio based on the design is 0.35, was extracted from the Pierre site. According to the 2800 regulations, in the analysis of the time history, the average of 3 to 7 records in the mentioned interval is compared with the target spectrum. In this research, the goal is to choose the best combination of 7 with the lowest amount of error compared to the standard spectrum.

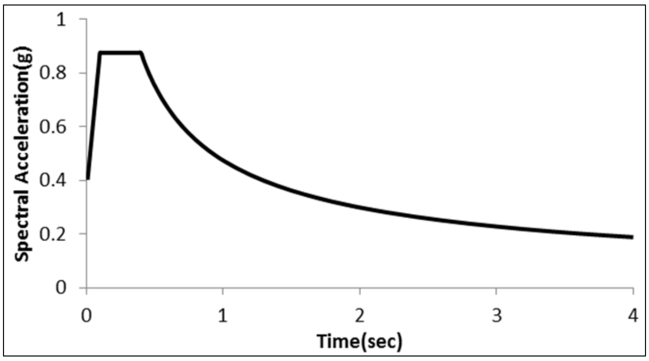

Fig 1: Spectrum of earthquake code design 2800 for land type 2 with a high and very high relative risk

3. Methodology

In this part, the codes written for two real and binary genetic algorithms are compared with each other. In this study, firstly, in the first part, the values of the parameters are considered according to the reference's proposal, and in the second part, the values of the parameters are considered according to the reference. Running the program with the variable values suggested by the reference for the Binary ***Genetic Algorithm***. The binary encryption program with table values (1) has been run five times, each run takes about 20 seconds. The results of five executions of the program are given in Table 1, the minimum error obtained in these five executions is equal to 1.5%. Table 2 shows the scale coefficients of each earthquake above its number for the fourth implementation of the binary genetic program with the values of Table 2. In Table 2 the value of the genetic parameters of the program suggested by Naeem *et al.*

The results of binary encoding with table values (3) for five implementations of the binary genetic algorithm program are shown in Table 4.

The lowest error is obtained from the fourth execution of this program with the mentioned values, which can be displayed in the Table 5.

Table 2: Parameters of reference genetic algorithm

Scaling range	Number of people	Number of generations	Shipping rate	Mutation rate
0.5-1.5	200	300	0.65	0.025

Table 4: The results of running the binary program with the values of the recommended reference parameters

Execution Number	Scale Coefficients							Earthquake Number							Error
1	1.4	0.5	0.6	0.7	1.2	0.7	1.3	296	37	39	176	168	78	53	0.016
2	0.77	1.5	1.1	1.5	1	1.3	0.9	264	183	37	233	347	296	313	0.021
3	1.5	1.1	1.4	1	1	1	1.4	296	176	53	78	39	142	168	0.016
4	1.48	0.8	1.4	1.1	1.1	1.5	1.1	296	78	168	176	39	53	142	0.015
5	1.36	0.7	1	1.4	1	1.2	1.1	53	37	10	296	103	168	78	0.019

Table 5: Scale coefficients and number of records of the best implementation of the binary genetics program with values

Minimum error obtained=1.5							
Scale coefficients	1.482405	0.820626	1.370968	1.09042	1.092375	1.469697	1.104106
Number of earthquakes	296	78	168	176	39	53	142

Fig 1 shows the comparison between the average response spectrum of the fourth implementation of the program, with the target spectrum of Regulation 2800 for soil type 2 with very high seismicity.

4. Findings and Results

First, two binary and real encryption programs were implemented separately with the values suggested by the reference authority, and the results obtained from them were compared with the results of the work of Naeem *et al*. with the results of the SAFE program. The shape of the improvement process of the merit function of each program and the spectrum of the average response compared to the spectrum of the regulation plan are drawn in graphs Zaker Haghighi *et al*., 2014. Then the values and graphs of the average spectrum of the root of the sum of squares of the best result obtained from these comparisons, as well as the graphs of previous researchers, if any, are given for comparison.

In the following, according to what was said above, to check the effect of the genetic algorithm optimization control values, each parameter has been tested with three different values five times in the binary genetic algorithm program (because it provides better results than the real genetic algorithm). Also, the diagram of the best response spectrum of the root mean square set in each run among three different values for each parameter compared to the spectrum of the regulation design is drawn in graphs (M. M. Norouzian & N. Gheitarani, 2023) [23]. At the end, the results of the hybrid genetic algorithm program executions, the values of the optimization parameters of the genetic algorithm obtained from the genetic program itself, are given in tables. As said, these results are close to optimal and are reasonable results for beginner users.

After that, the graph comparing the response spectrum with the target spectrum of Naeem *et al*.'s article is given in Fig 2. The percentage of error obtained by Naeem *et al*. in the solved problems as the mean squared error at different intervals is 3.1, 7.7, and 4.3, respectively. As can be seen in figures (2) and (3), the result obtained from the proposed program of this research has very little difference compared to the reference program.

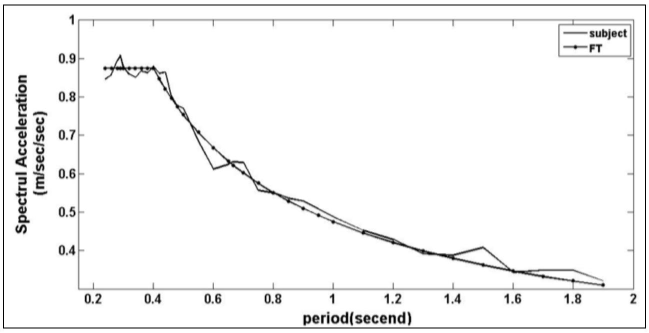

Fig 2: Compares the average spectrum of the root sum of squares of binary encryption with the spectrum of the regulation plan

Comparison of the response spectrum of the root mean sum of squares (with the least error) with the spectrum of regulation 2800, for soil type 2 with very high seismicity, which is shown by the binary encoding program with the values of the parameters of the genetic algorithm of the Table 1 in the Fig 2. The difference between the error of the proposed program and the error of Naeem *et al* is 1.6%, which indicates the high power of the algorithm.

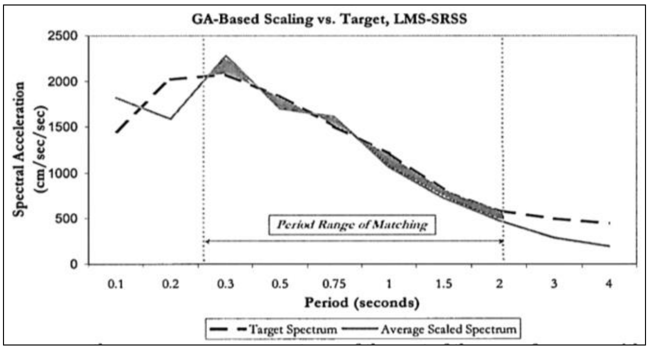

Fig 3: Compares the average response spectrum of the root of the sum of squares with the target spectrum

Implementation of the program with variable values suggested by the real genetic algorithm: The program presented by Naeem *et al*. is only implemented as a binary genetic algorithm. Considering that this research has two programs;

1. Binary genetic algorithm. 2- Real genetic algorithm. Presented, to observe the performance and usefulness of these two programs and compare their results with each other, the real encryption program with table values (5) has been executed.

Each performance takes about 20 seconds. The results of all five executions of the program are given in Table 6, the minimum error obtained in these five executions was equal to 1.9% of the first execution. The table of real encryption results with the values of Naeem and colleagues for five implementations of the genetic algorithm program:
In Table 7, the lowest error obtained from the first execution of this program with the mentioned values is displayed.

Table 6: The results of running the real program with the values of the suggested reference parameters

Execution number	Scale coefficients							Record number							Error
1	0.86	0.91	0.8	0.9	1.4	0.6	0.9	39	53	176	168	296	142	233	0.01
2	0.94	0.97	1.4	0.8	0.79	0.8	0.8	37	39	296	233	120	147	49	0.028
3	1.3	0.85	1	1.3	0.93	1.1	0.9	4	39	176	296	78	53	10	0.03
4	1	1.06	1	1.4	0.62	0.9	1	168	53	78	296	353	142	37	0.022
5	1.1	0.91	1.3	1.4	1.05	0.6	0.8	39	176	4	296	233	214	53	0.021

Table 7: scale coefficients and number of records of the best implementation of real genetics program with variable values suggested by Naeem *et al*

Minimum error obtained = 1.86%							
Scale coefficients	0.856412	0.913092	0.796013	0.941645	1.401997	0.594166	0.946393
Number of earthquakes	39	53	176	168	296	142	233

Fig 4, shows the comparison between the average response spectrum of the first run of the program with the target spectrum of Regulation 2800 for soil type 2 with very high seismicity. The difference between the error of the binary program and the real program with the parameters of the genetic algorithm of Naeem *et al* is 0.4%, this result is indicative of this problem. In this research, the binary genetics program is more appropriate for selecting and scaling the records for the combined response spectrum. Of course, considering the smallness of this difference, it can be concluded that both programs presented in this research work well.

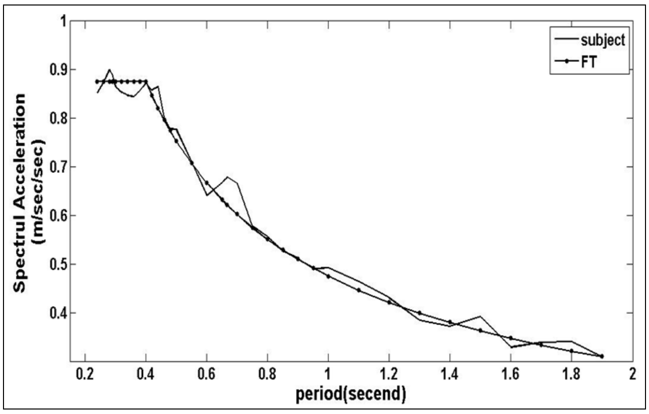

Fig 5: Comparison of the average spectrum of the root of the sum of squares of the real encoding with the values of the proposed reference variables

Implementation of the program with variable values proposed by Seif for the binary genetic algorithm.
The proposed values of the genetic algorithm variables by Seif, have been tested for selection among 136 accelerometers with the current program. These values for the binary genetic algorithm are in the Table 8. After running the program five times, using these values for the parameters of the binary genetic algorithm, the best result was obtained in the third run of the program, which had an error of 3.7%.

Table 8: Parameters of the binary genetic algorithm proposed by Seif

Range of coefficients	number of people	Number of generations	Shipping rate	Mutation rate
0.5-1.5	50	300	0.6	0.002

Table 8 shows the results of 5 implementations of the binary genetics program with the mentioned values, and Table 9 shows the scale coefficients and the number of earthquakes of the third implementation of this program. In his thesis, Saif obtained the minimum error of 3.98% by binary program. The results of five executions of the binary genetics program are given in the Table 8. It can be seen that this time the results obtained by the presented program are less compared to the reference and this problem shows the strength and accuracy of the presented program of this research.

Table 9: Binary encryption implementation results with suggested values of CIF parameters

Execution number	Scale coefficients							Number of earthquakes							Error
1	1.24	1.16	1.5	1	0.51	0.5	0.7	104	37	49	78	81	34	39	0.046
2	1.25	0.99	1.2	0.7	0.5	1.3	1	37	53	49	104	120	78	81	0.052
3	0.5	0.94	1.2	1.5	0.75	1.4	0.7	81	53	10	49	37	104	9	0.037
4	0.76	1.48	1.1	0.5	0.5	1.4	1.1	34	49	78	112	5	37	53	0.045
5	0.5	1	1.4	1.5	0.99	1.3	0.6	5	81	37	49	55	53	85	0.045

Table 10: Scale coefficients and number of records of the best implementation of the binary genetic program with genetic values suggested by CIF

Minimum error obtained = 3.7%							
Scale coefficients	0.500978	0.937928	1.152004	1.498045	0.751222	1.372923	0.746334
Number of earthquakes	81	53	10	49	37	104	9

Above Table 10 shows the lowest error obtained from the third execution of the binary genetic program with the suggested values of CIF.

Fig 6 shows the average response spectrum with the genetic values proposed by Seif for binary encoding compared to the design spectrum.

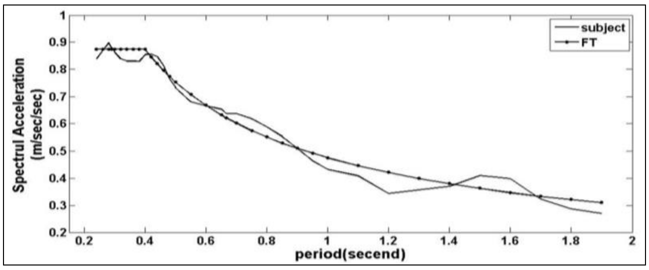

Fig 6: Comparing the average spectrum of the square root of the binary encoding with the values of the variables proposed by CIF

Following the suggested values of binary genetic algorithm variables by Seif to choose from among 136 acceleration maps, this time the suggested values of real genetic algorithm variables in the Table 11 have been tested by the real genetics program presented in this research (Naghibi Iravani, S., *et al*., 2024c) [26]. Again, after running the program five times using these values for the parameters of the real genetic algorithm, we reached the best result in the fifth run of the program, which had an error of 4.9%**.** Seif has obtained the minimum error of 3.19% by the real program.

The results of five executions of the binary genetics program are given in the Table 12.

In Table 13 of scale coefficients above the number of its records, as can be seen, the lowest error obtained from the third execution of the binary genetic program with the suggested values of CIF is displayed.

Table 11: Parameters of the real genetic algorithm proposed by Seif

Range of scaling factors	**Number of people**	**Number of generations**	**Shipping rate**	**Mutation rate**
0.5-1.5	50	600	0.9	0.1

Table 12: Of the results of the real encryption implementation with the suggested values of the safe parameters

Execution number	**Scale coefficients**							**Number of earthquakes**							**Error**
1	1.17	0.72	1.2	1	1.15	1.1	1	49	11	21	37	49	37	78	0.0779
2	1.1	0.51	0.7	1.3	0.9	1.1	1.1	78	81	10	53	59	37	26	0.0608
3	1.16	0.74	1	1.1	0.82	0.6	1.1	40	81	53	120	55	39	78	0.0667
4	1.12	1.16	1.1	0.9	1.34	0.8	1	78	106	49	21	112	39	37	0.0975
5	0.89	0.7	1.2	1.1	0.71	1.2	1.1	77	5	53	78	3	37	49	0.0499

Table 13: Scale coefficients and number of records of the best implementation of the real genetic program with the suggested genetic values of CIF

Minimum error obtained = 4.9%							
Scale coefficients	0.892131	0.696177	1.193522	1.145187	0.71419	1.170112	1.114723
Number of earthquakes	77	5	53	78	3	37	49

Fig 7 is a comparison chart between the response spectrum obtained with the genetic values of the Table 13.

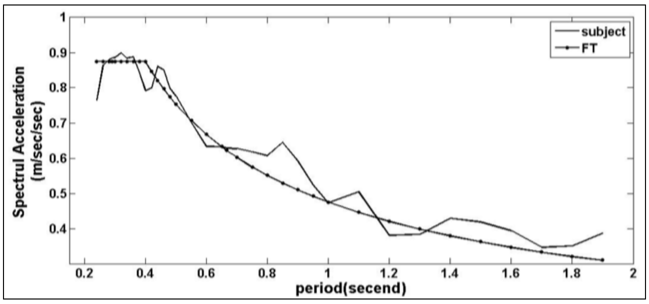

Fig 7: Comparison of the average response spectrum of the root of the sum of squares of the real encoding with the values of the variables proposed by CIF

It can be seen that the Binary Genetic Algorithm program has performed better than the real Genetic Algorithm and also this program has significantly reduced the error rate of the objective function compared to previous research**.** In Table 14, the names of the records along with their scale coefficients obtained from the binary genetics program with reference genetic values are shown. The fitting diagram of its merit function is drawn in Fig 7.

Table 14: Results of the best implementation of the binary genetic algorithm program with the values of the suggested reference parameters

Number of records	**Names of earthquakes**	**Scale coefficients**
296	Northridge at W15180	0.148
78	Northridge at Castaic Old Ridge	0.82
168	Landers at the Fire station	1.37
176	Landers at W1580	1.09
39	Landers at Duarte station	1.09
53	Loma Prieta at Gilroy Gavilan	1.47
142	Lander at Baker Fire Station	1.1

The graph of the improvement process of the merit function is drawn in Fig 8 for the fourth implementation of the binary genetic algorithm program, which achieved the least error with the values suggested by Naeem.

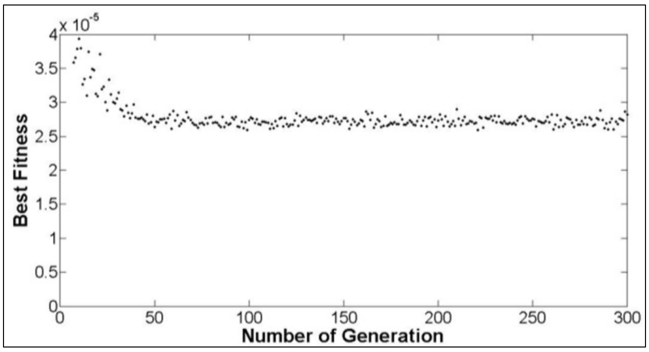

Fig 8: Fitting diagram of the merit function of the binary genetic algorithm

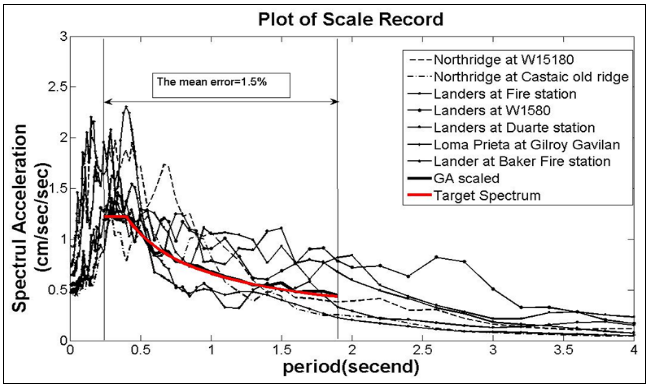

Fig 9: Scaled response spectrum of accelerometers obtained from the binary genetics program and the average spectrum of the root of the sum of squares compared to the spectrum of the 2800 regulation

5. Discussion

In the first step, a comparison was made between the error of the program and the error of previous researchers. It was observed that both the binary and real genetic algorithm codes caused a significant reduction in the error of the objective function of the problem compared to previous research. Also, the presented binary genetic algorithm performed slightly better than the real genetic algorithm of this research. As mentioned before, the program written by the researcher was able to overcome the shortcomings of the previous researchers by using two chromosomes, one chromosome for selecting the scale coefficients which is in the form of natural numbers, and one chromosome for selecting the earthquakes which is binary.

Also, the use of two genetic algorithms at the same time, in which the values of the variables are selected by the program's suggestion, allows the user not to make a mistake in making a decision. The first opinion is that Naeem's proposal is a binary encryption program that selects and scales accelerometers at the same time, while the nature of the two is completely different from each other. Because the scale coefficients are in the form of integers and the number of records is in the form of natural numbers, in the binary coding program, the user is forced to use the correct component to select the number of records, which causes us to have a rounding error. The second opinion specifies the ability of the program to select its variables automatically. By using the best values obtained for each of the programs, a comparison was made between the results of binary and real encryption.

This comparison shows that the binary encryption program is more powerful than the real encryption program because it was observed that the binary program reaches the desired answer with a smaller number of people and several generations, which is very effective during the execution of the program. Considering how the genetic algorithm works and the complete search of the design space by the operators of the algorithm, the time required to obtain the optimal shape in each step is significant.

Therefore, providing codes with a faster calculation process for use in the genetic algorithm can be an effective step in the development of the genetic algorithm user. The presented program can reach the desired results in less than 20 seconds. Loads caused by earthquakes for different constructions are usually expressed according to the range of proposed designs of seismic loading regulations. As long as the behavior of the structure remains in the linear range, the maximum values of the seismic response of the structure can be obtained using the spectral analysis method. However, these regulations require that in the seismic analysis of irregular and special structures such as power plants, dams, tall buildings and structures with unusual components resistant to earthquakes such as energy-consuming devices, from linear time history analyzes and be used non-linearly.

Regardless of the reasons for the need to perform a dynamic analysis of the time history, incoming earthquakes in these analyses should be introduced in the form of earthquake accelerometers. However since the seismic risk in a building is expressed in terms of a smoothed design spectrum, the accelerometers used in the time history analysis must be compatible with this spectrum. One of the most suitable methods for estimating the seismic behavior of buildings is the use of nonlinear time history analysis. For this purpose, the considered earthquake records should be scaled. The time history method has been introduced as a more accurate method than spectral and static analysis in seismic design regulations, including the 2800 standard. For cases such as quantitative assessment of vulnerability, it is necessary to use this method for detailed dynamic and sometimes non-linear analysis of the structure using maps of the time history of excitation.

However, the application of this method for analysis and especially design in many practical cases is faced with uncertainties in determining the loading or identifying the building, which hinders the trust in making decisions from the answers obtained from a specific accelerometer, even related to the past earthquake. To perform a time history analysis, several accelerometers are needed that represent the expected earthquake of the building. In most regulations, scaling of selected accelerograms is required to ensure that the response spectrum meets or exceeds the target spectrum within a given range of periods.

6. Conclusion

In this research, an effort was made to select from a data set of the response spectrum of the accelerometers available in the Pierre site for soil type 2 and scale its records using weighted average coefficients to the average response spectrum of the square root of the records, which is a good match. And have a little difference with the range of the standard 2800 design**.** Therefore, to solve the shortcomings of previous researchers, we were able to achieve this goal by using two chromosomes for the genetic algorithm program, one chromosome for selecting scale coefficients which are natural numbers, and one chromosome for selecting earthquakes which are whole numbers. Also, the use of the hybrid genetic algorithm in which two genetic codes are executed simultaneously to select the values of the genetic variables with the suggestion of the program allows the user to obtain close to optimal results. In the first step, each of the two binary and correct genetic codes was executed with the values of the genetic parameters of Naeem *et al*. in the Table 14 and then with the suggested values of Seif in the Table 15.

Table 15: Compares program error with reference

Program error			
Naeem *et al*		**The present research**	
Binary genetics	**True genetics**	**Binary genetics**	**True genetics**
4.30%	-	1.50%	1.90%

The values obtained from both codes have a very small error compared to the error of the objective function of Naeem *et al.*

Table 16: Compares program error with reference

Program error			
Sif		**The present research**	
Binary genetics	True genetics	Binary genetics	True genetics
3.98%	3.19%	3.70%	4.90%

In Table 16, by checking the results, it can be concluded that the binary genetic code of this program has a better performance compared to the integer genetic code. Therefore, a comparison between the results of binary and real encryption shows that the binary encryption program is more powerful than the real encryption program because it was observed that the binary program reaches the desired solution with the number of people and the number of generations, which in time The implementation of the program is very effective. In the next step, by checking each of the parameters, we finally reached an error of 1.45% by using the values in the Table 15, and the results were expressed in the Table 16. At the end, the hybrid algorithm program, whose process is as follows:
Two genetic codes are executed at the same time and introduce optimal values for genetic algorithm parameters. Which allows a beginner user to work, was introduced and implemented. The results of the parameters obtained from it were shown in Table 16 and the results of the program implementation with the introduced values of the genetic algorithm were shown in the Table 16.

The obtained results show that:

1. If there is a possibility of low coercivity, it leads to the selection of repeated accelerograms.
2. The number of generations is large, if the number of people is small, good results are not obtained.
3. The number of people in the population in the real genetic algorithm achieves good results in the range of 200 to 500.
4. The mutation rate in an integer genetic program is more flexible than binary.
5. The greater the range of coefficients, the greater the dispersion in the answer.

The bigger the database of accelerometers, the bigger the search space of the algorithm, and the more favorable results are obtained.

Suggestions and areas for further research. According to the results obtained in this research, it can be seen that the use of optimization methods is very effective in reducing the final costs of a structure. Accordingly, it is recommended to continue this research in one of the following fields:

- Application of genetic hybrid algorithm along with harmony search algorithm.
- Application of other optimization algorithms and comparison of results.
- Application of a method that can select and scale records according to a specific value for the difference between the response spectrum and the design spectrum.
- Investigation of different seismicity for different types of soil.

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