Gene Express Programming in optimum shape of concrete ogee arch under earthquake loads

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Abstract

The main goal of this research is determination of optimum shape concrete ogee arch under earthquake loads by Gene express programming. In this paper, samples of semi-circular, obtuse angel, four- centered pointed, Tudor, ogee, equilateral, catenaries, lancet and four-centered ogee arch are modeled. Then they are analyzed and optimized under acceleration–time components of Elcentro earthquake. For arch response optimization, the results were used in Gene express programming computational model. Then using provided rules for modeling, the mentioned ogee arch are analyzed and optimized. The results of error range and time of analysis in Gene express programming model and FEM software compared. Finally comparing the results of GEP (Gene express programming) method and FEM (Finite Element Method) method, shows that although precision is less in GEP method, but the time of analysis and optimization is so much smaller in it.

Key words: Optimum Shape, Ogee Arch, Concrete, Earthquake Load, Gene Express Programming.

1.Introduction

Traditionally, arch is defined as a part of circle or bow, but Heyman's definition (1982) of arch is as follows: it is a curve surface for covering that its span is higher than its depth. Concrete ogee arch have been used to span covering of considerable length in many different applications.Transferring of vertical forces gives a rise to both horizontal and vertical reactions at the abutments. The curvature of the arch and its restraint by the abutments cause a combination of flexural stress and axial compression in it.

Regarding to importance and application of ogee arch in traditional structures,. Also, Kumarci., Ziaie, Koohikamali and Kyioumarsi (2008) have studied concrete under earthquake loads. Dynamic or time history analysis is an analytical method for determining reflections during the earthquake in structures. Dynamic analysis and optimization of ogee arch need to consume a long time; so gene express programming, analyze and optimization of ogee arch perform in less time and obtains more acceptable results. Ferreira (2001, 2006) believes that It is a good method for computation and simulation of complicated behaviors by local data. The main importance of this research is showing the ability of analyzing and optimizing of every arch in shorter time.

2. Research Methodology

2.1 Modeling, analyzing and optimizing arch shape using FEM software

At the first step arch modeling has been conducted by FEM software. Furthermore, dynamic analysis has been conducted applying north-south horizontal accelerations of Elcentro earthquake in which the time, maximum acceleration, maximum velocity and maximum displacement are 31.98(s), 0.31(g), 33 (cm/sec) and 21.4 (cm), respectively (fig.1) and SOLID65 is used for analysis in this stage. In FEM software, the base and top thickness, maximum tensile stress and weight of structure have been defined as design variable, state variable and objective function, respectively. Optimum shape of ogee arch in FEM software has been shown (fig.2). Crisfield (1985) has used this method for solving many engineering problems.

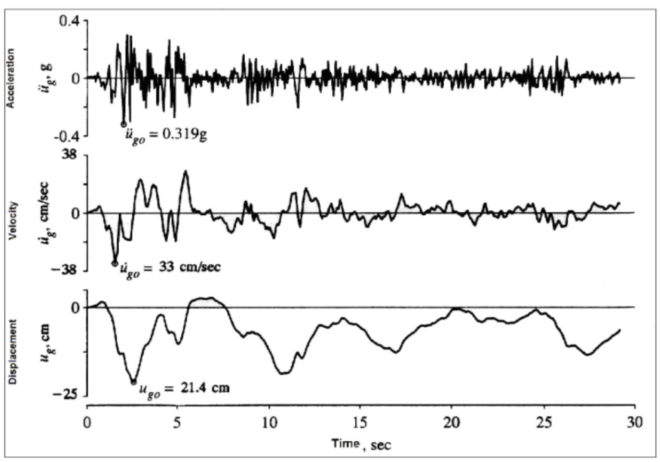


Fig.1: North-south horizontal component of Elcentro earthquake

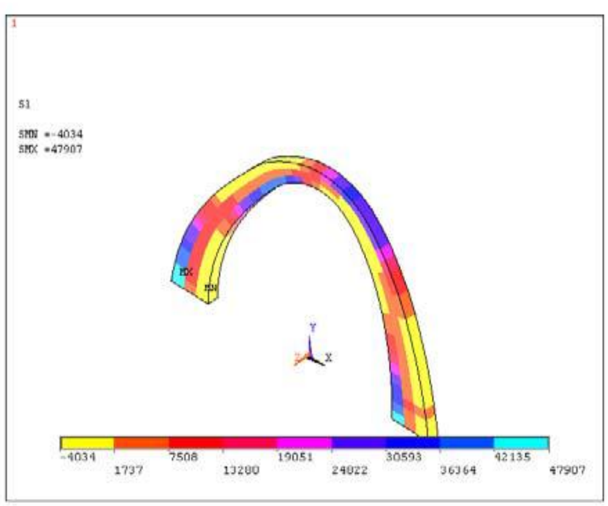


Fig.2: optimum shape of ogee arch using FEM software

Abruzzese, Como and Lanni (1995) have explained that in arch modeling, tolerance increases because the thickness decreases from base to top. It should mention that in modeled arch, the thickness decreases from base (t_0) to top (t_1) linearly and also arch thickness of axis is 20 (cm) in the length direction. The motion of support nodes is zero and dynamic force has no effect on them. In addition, concrete made by water and cement homogenous material (table1). The efficient factors in the inelastic nonlinear analysis have been shown in table 2. In the present paper, arch radius limit (R), maximum tensile stress, base and top thickness in optimum state are considered as 4-8 (m), 48000-5000 (KN/m^3), 0.9- 1.34 (m) and 0.3-0.36(m) respectively for all modeled arch.

Density(ρ) (Kg/m^3)	Elastic Modulus (MPa)	Poisson Ratio (υ)
2400	3.1×10^4	0.2

Table1. concrete characteristics

Allowable Tension Stress(f_t) N/mm^2	Allowable Compressive Stress(f_c) N/mm^2	Modulus Of Rupture N/mm^2
2.4	28	4.1

Table 2. Effective coefficient in non elastic and nonlinear analysis

3. Results and Analysis

3.1 Arch Modeling Using GEP Approach

We are going to exploit the GEP approach of (Ferreira, 2001, 2006), In this stage, regarding the definition of GEP, the data for each arch will be analyzed to find the simulation models of each arch behavior. To achieve this aim, 1000 samples of each arch radius, base and top thickness and maximum tensile stress were chosen and analyzed by GEP algorithm.

3.2 Gene express programming Configuration

Related parameters for the training and testing of the GEP model like general setting and genetic operators and are given in Table 3, 4.

Chromosomes:	30
Genes:	4
Head Size:	16
Tail Size:	54
Dc Size:	39
Gene Size:	78
Linking Function:	Addition

Table 3. GEP General Settings

Mutation Rate	0.066
Inversion Rate	0.1
IS Transposition Rate	0.1
RIS Transposition Rate	0.1
One-Point Recombination Rate	0.4
Two-Point Recombination Rate	0.4
Gene Recombination Rate	0.1
Gene Transposition Rate	0.1

Table 4. GEP Genetic Operators

3.3 Gene express programming Model

We have exploited the GEP approach of Ferreira (Ferreira, 2001), as described above using GEP Algorithm. Therefore, we have exploited the three features for modeling. The system calculates the feature weights using Gene express programming. To do this we use GEP finding function method. For training GEP models, we use 1000 samples of each arch was produced by FEM software and after one Million repetitions, some models were provided for each arch. Then for testing each arch model we produce Maximum tensile stress for 50 samples has been provided and error percent has been compared with another analyzed samples in FEM software.

3.4 Evaluation GEP model

We used 1000 Ogee arch samples for training and 50 Ogee arch samples for testing GEP model and the results are given in table 5 and 6.

Best Fitness	100
Max. Fitness	100
Accuracy	100%

Table 5. Statistics - Training

Best Fitness	83.45
Max. Fitness	100
Accuracy	86.50%

Table 6. Statistics - Testing

Maximum tensile stress was achieved for 50 samples of ogee arch by GEP. Figure 3 define comparison between maximum tensile stress in FEM and GEP model**.** The mean of error percent in ogee arch is 13.50%.

4. Arch Optimization Using GEP

In this stage, by means of GEP model for each arch top and base thickness were optimized. Considering optimized maximum tensile stress which is 51000(N/m^2), the range of radius, top thickness and maximum tensile stress in each arch are considered as input, so arch base thickness will be provided. In the next stage, size of arch radius, base thickness and maximum tensile strain are considered as input. So arch top thickness will be provided.

4.1 Top thickness optimization in ogee arch using GEP

In this stage, 50 ogee arch samples were chosen for top thickness optimization. Their optimum maximum tensile stress range, arch radius and base thickness were 49000 to 51000 (KN/m^3), 4~8 meter and 0.8 to 1.44, respectively. After ward, the top thickness was calculated and compared with top thickness in FEM software (Figure 4). The mean of error percent of top thickness calculation was 11.18%.

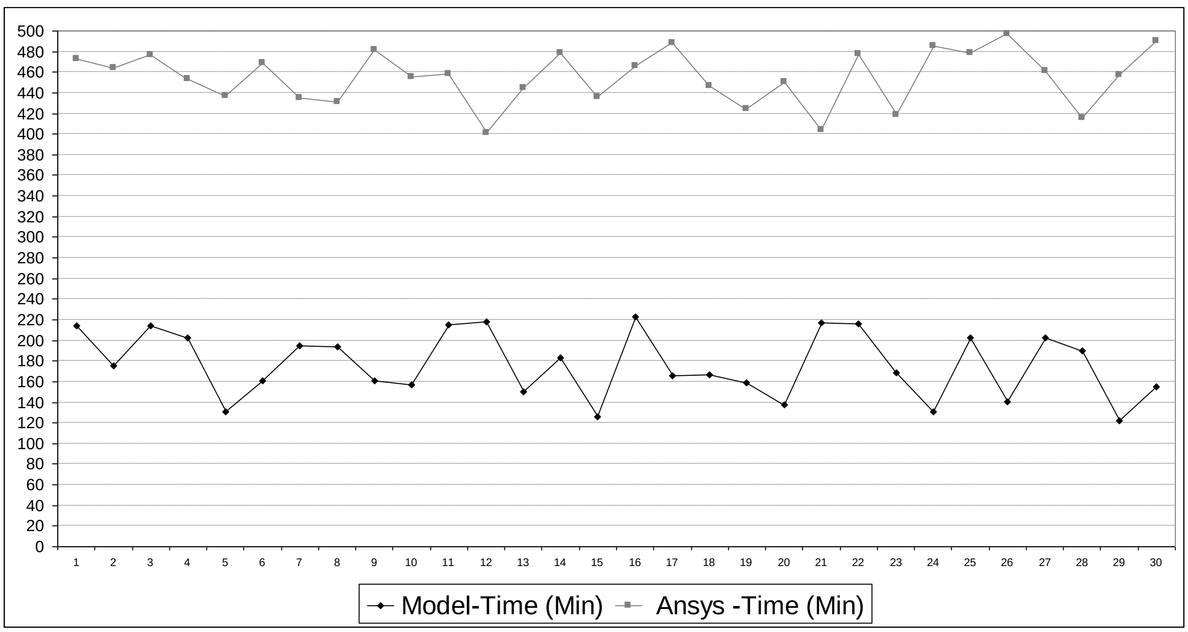


Fig.3: Comparison between time of computing maximum tensile stress of ogee arch using FEM software and GEP model

4.2 Base thickness optimization in ogee arch using GEP

In this section, 50 ogee arch samples were chosen for top thickness optimization. Their optimum maximum tensile stress range, arch radius and base thickness were 49000 to 51000(KN/ m^3), 4~8 meter and 0.2 to 0.35, respectively. After calculation of base thickness, the results were compared with base thickness in FEM software (Figure 5). The mean of error percent of base thickness calculation was 11.93%.

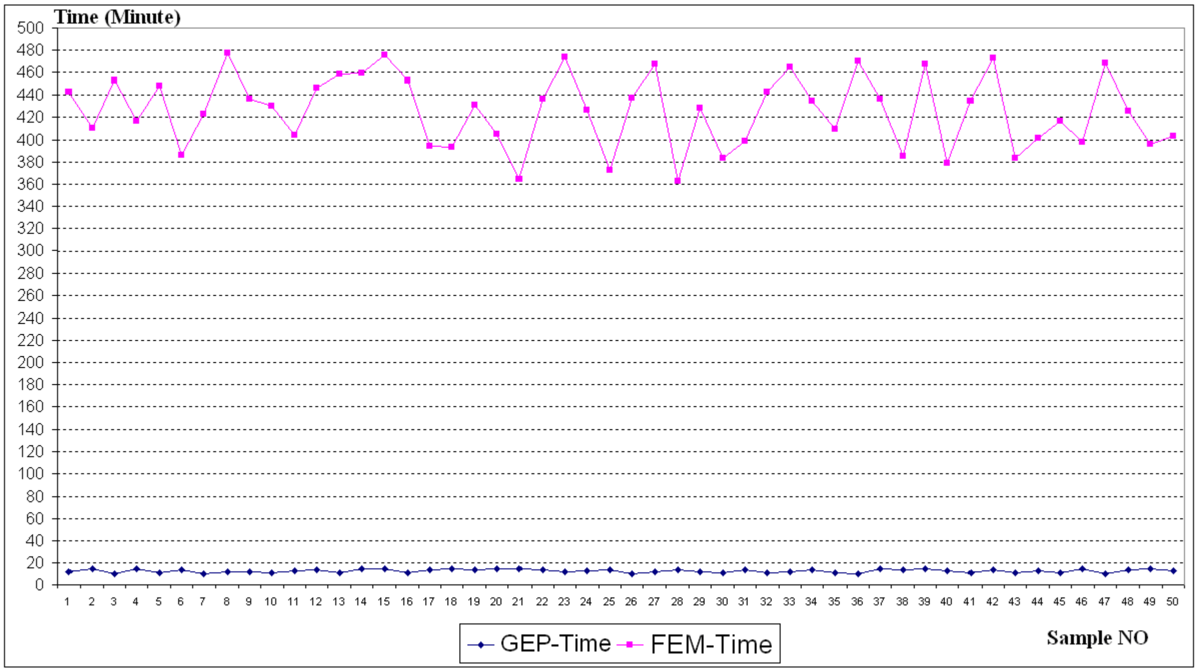


Fig.4: Comparison between optimization time of base thickness in ogee arch using FEM software and GEP model

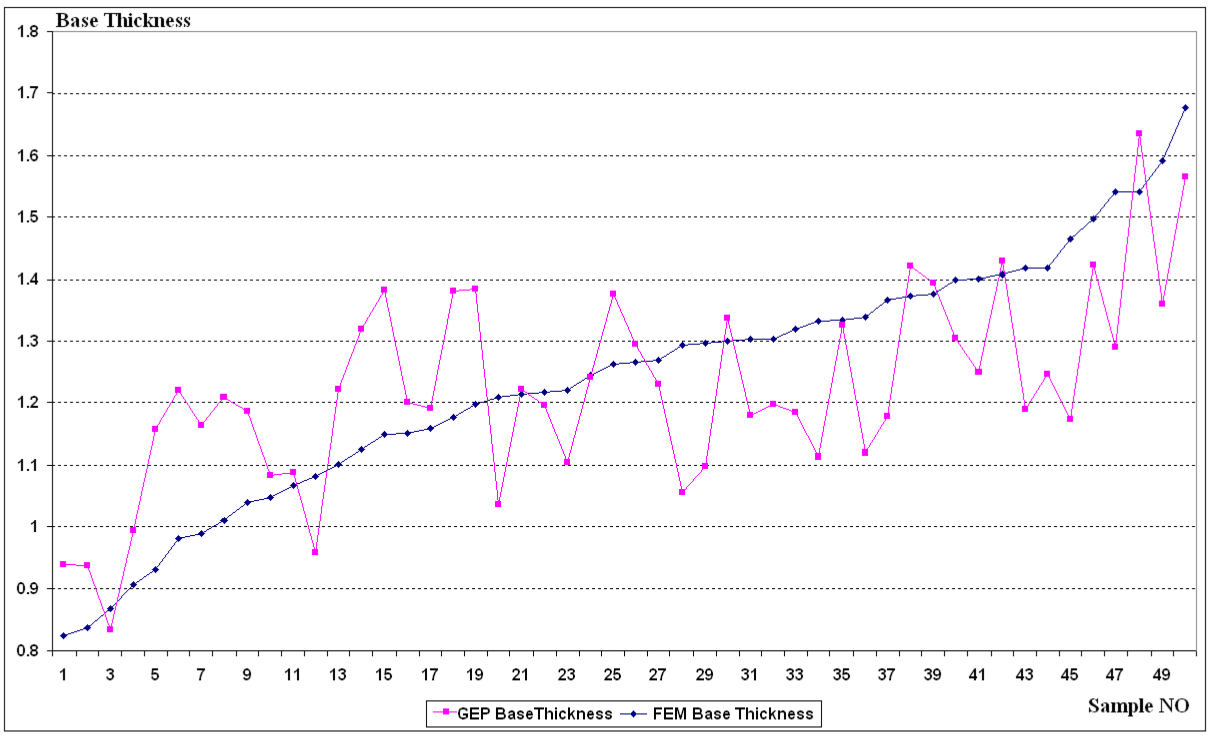
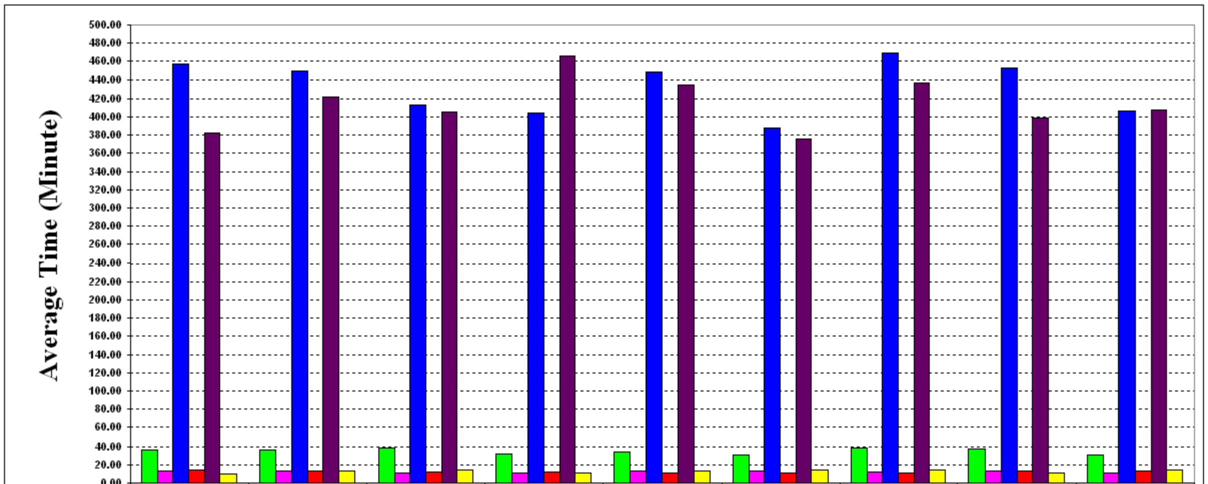


Fig. 5: Comparison of optimum range of arch base thickness using GEP model and FEM software

5. Conclusions

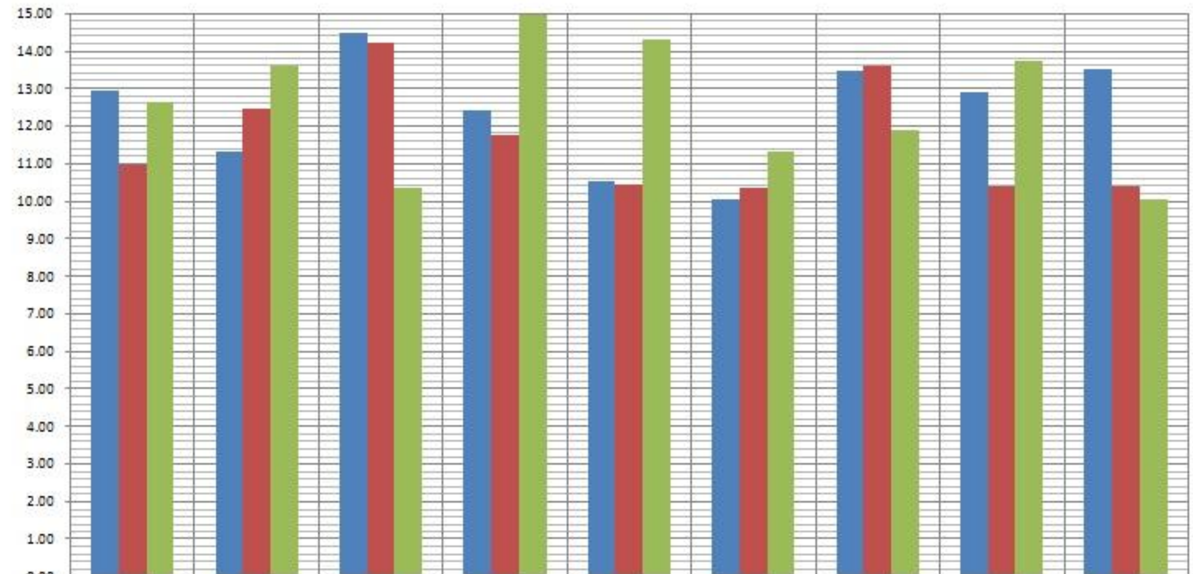
In the present paper, nine ogee arch- semi-circular, obtuse angel, four- centered pointed; Tudor, ogee, equilateral, catenaries, lancet and four-centered ogee arch- were modeled using FEM software and GEP model. Figures 6 and 7 show analysis and optimization time, the results which are provided by GEP in arch modeling and the mean of error percent for arch analysis and its optimization, respectively.

Considering results, GEP model can be used in simulation of all ogee arch. Therefore, the time of calculation decreases. Also, it can be used in dynamic response, natural frequency and response of structure under different dynamic loads. To increase GEP models precision, we can increase the number of chromosomes which are larger than 30 and repeated more than 1000000 times are needed.



	Catenary arch	Equilateral arch	Four centered pointed arch	four-centered arch	Lancet arch	Ogee arch	Optuse angle arch	Semicircular arch	Tudor arch
FEM Analyzing Average Time	36.51	36.09	38.29	31.63	33.53	30.93	38.58	37.72	30.50
GEPAnalyzing Average Time	13.70	13.14	11.48	11.03	13.43	13.33	12.13	13.11	11.37
FEM Top Thickness Optimizing Average Time	456.62	449.91	413.26	404.88	448.70	387.77	469.05	452.51	406.11
GEP Top Thickness Optimizing Average Time	14.70	12.85	12.04	11.60	10.62	10.87	10.86	13.35	13.32
FEM Base Thickness Optimizing Average Time	382.80	421.85	404.97	466.42	435.47	375.96	436.88	399.04	408.07
GEP Base Thickness	10.39	12.81	14.58	11.16	13.16	14.47	14.00	11.01	14.28

Fig. 6: Comparison between mean of analysis and optimization time of all discussed ogee arch using FEM software and GEP model



	Catenary arch	Equilateral arch	Four centered pointed arch	Four-centered arch	Lancet arch	Ogee arch	Optuse angle arch	Semi circular arch	Tudor arch
Base Thickness Error Percent AVG	12.96	11.33	14.50	12.41	10.52	10.03	13.46	12.92	13.53
Tensile Stress Error Percent AVG	10.98	12.45	14.23	11.76	10.43	10.37	13.62	10.38	10.42
Top Thickness Error Percent AVG	12.66	13.58	10.35	14.95	14.30	11.32	11.88	13.73	10.04

Fig.7: Comparison between the mean of error percent of analysis of tensile stress and optimization of base and top thickness for discussed ogee arch using GEP model toward FEM software

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References

Abruzzese D, Como M, Lanni G. (1995). "Some results on the strength evaluation of vaulted masonry structures". In: Brebbia CA, Leftheris B, editors. *Structural studies of historical buildings* IV—vol. 1: *architectural studies, materials and analysis*. Computational Mechanics Publications; p. 431–40.

Crisfield MA. (1985). *Finite element and mechanism methods for the analysis of masonry and brickwork ogee arch*, Research report 19. Crow Thorne: Transport Research Laboratory.

Ferreira, C., (2001). Gene express programming: A New Adaptive Algorithm for Solving Problems, *Complex Systems*, 13 (2): 87-129.

Ferreira, C., (2006). *Gene express programming: Mathematical Modeling by an Artificial Intelligence*, 2nd Edition, Springer-Verlag, Germany.

Kumarci K., Ziaie A., Koohikamali M., Kyioumarsi A. (2008). "Optimum Shape In ConcreteOgee arch Under Static And Dynamic Loads", *International Journal Of Mathematics And Computers In Simulation*, Wseas Transactions On Mathematics Volume 7, ISSN: 1998-0159, 171-178.