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Research paper

Comparison optimization Computational model between Cellular Automata and Genetic programming in dynamic response of guyed tower under vibration force

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Abstract

In the telecommunication industry, guyed towers are one of the important structural subsystems. They support a variety of antenna systems at great heights to transmit radio, television and telephone signals over long distance, thus preserving them in events of natural disasters such as earthquake is of high priority. Also, domes and transmission stations functions depend on transmitted information by guyed towers. In this paper, seismic behavior of guyed towers are studied. For that, one guyed tower in 9 clusters of guys is studied under earthquake force. This research was accomplished on the base of wind and earthquake forces and tower interaction to these forces. Here, the effect of earthquake force and tower response to seismic events are studied. At first, time history analysis is used in determination of towers vibration natural modes, then, under time- acceleration components of El-Centro earthquake, spectral analysis are accomplished. Analysis outputs are two parameters including frequency and maximum lateral displacement which are provided using ANSYS software. The results are used in comparing two different calculation models: genetic programming and cellular automata.

1. Introduction

Cellular automata (CA) is a decentralized computing model providing an excellent platform for performing complex computation with help of only local information [1]. In this paper, using 1- D two and three state in CA some samples of towers are studied to find rules of simulation for frequency and maximum lateral displacement of towers[2]. For that, using provided algorithms of two and three state 1-D CA and using 5 parameters-horizontal state between guyed cables on the earth (X1), the height of the first tower guy and the earth (x2), the height of guy cable and tower (x3), the height of antenna on the tower (x4) and the number of guy levels surface (n) and maximum deflection-for 50 towers in programmed CA (C++ programming language) and after one billion accomplishments for two state rules and 20 million three state rules, some models were provided for each tower. These models were tested to other 50 tower sample and in terms of the error percent for frequency and maximum lateral deflection, there was comparison with obtained results via ANSYS software [3].

Genetic programming (GP) is an evolutionary algorithm-based methodology which is branch of genetic algorithms [4]. Genetic programming creates computer programs in scheme computer languages as the solution. Genetic algorithms create a string of numbers that represent the solution so they have ability to optimize complex structures and can use in different problems [5]. GP model was provided for 50 guyed towers on the basis of X1, X2, X3, X4 and n parameters which are provided using ANSYS software. Then using genetic operators such as generation, crossover and mutation, the final population was provided which is maximum lateral displacement in guyed towers [6]. Finally, genetic programming algorithm has been introduced to dynamic response of guyed towers under earthquake force.

2. Materials And Methods

2.1. Guyed Tower

Guyed Towers are lightweight to heavyweight towers supported by guy wires and are designed with the ability to carry light to heavy antenna loads. Guyed Towers are typically made of a mast in triangular cross-section and hinged support[7]. A cluster of guy lines are used at various elevations and angles to tower shaft. These guy lines maintain the stability of tower and provide tower (MAST) lateral stiffness. The various components of a typical tall guyed tower are shown in Figure1. The structural behaviour of guyed towers is complex; this arises from significant geometric nonlinearity, in the first order, the sagging tendency of the guy cables and the interaction between the cables and the towers; and in second order, the slenderness of the mast[8].

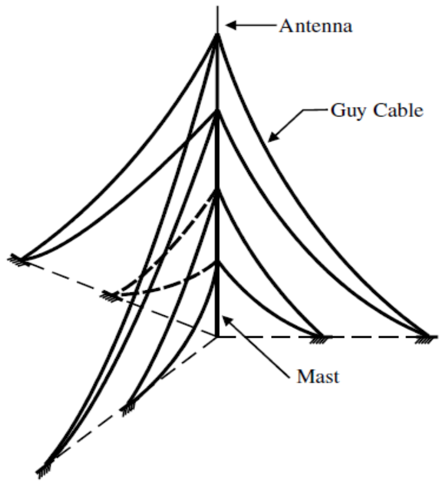

Figure 1: Guyed tower

2.2. Guyed Tower Modeling Using ANSYS

At this phase, analysis of guyed towers using ANSYS may be performed and different samples for CA and GP computing models are provided (Figure 2).

Variable modeling parameters in ANSYS software are described as follows[9]:

X1: horizontal distance between guy lines on the earth (12m)

X2: The distance from the first guy line to the base tower (11.4m)

X3: the distance between guy lines on tower (9.6m)

X4: the height of antenna on the tower (1.8m)

n: number of guy lines (9 level)

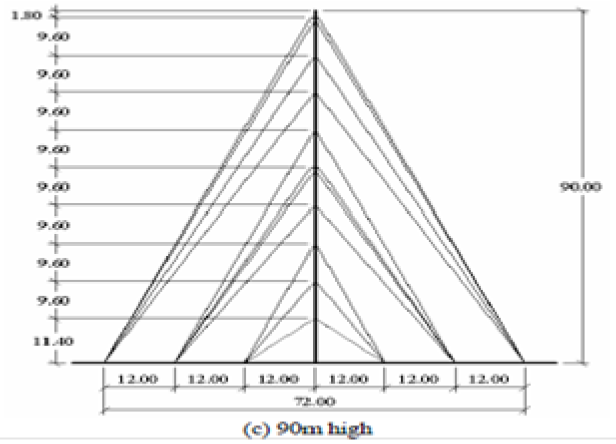

Figure 2: Geometry of 90-m guyed tower

All the above mentioned parameters are used to provide different guyed tower samples, X1: 7-12 m, X2: 11-14 m, X3: 8-11 m, X4: 1-3 m and n:7-12 m. All towers have a truss type geometry with a square cross section. Angles are connected to each other using bolt. Effective self weight in analysis includes self weight if structure, stairs, antenna, guy lines and etc. Also in modeling, the beam 3-D finite element with rigid connection is used. Vertical elements in four points of square section are solid and are 25 cm in diameter. Horizontal elements are varied by height of towers and include L 80×80×8mm, channel beams No. 300 and 120. Diagonal elements are used as truss bracing in which elements section change by tower height. They are made of thin casting pipe (No. 3.75×70mm and 3.25×76mm) and angle of 120×120×80 L mm. Young's modulus and steel materials density are 2.88×10^6 kg/cm^2 and 7.85×10^{-3} kg/cm^3, respectively. All of angle elements (section No. 12) are made of steel ST32 and tensile strength equal 3600 kg/cm^3. Also, section angles (No. 8) are made of steel ST37 and tensile strength equal 2400 kg/cm^3. All of cables are 40 mm in diameter and Young's modulus, ultimate strength and permissible strength are 688×1010kg/m^2, 10460kg/cm^2 and 4700 kg/cm^2, respectively.

3. Results And Discussion

3.1. Dynamic analysis of guyed tower

To find of earthquake effects on guyed towers and their maximum lateral deflection, horizontal component of north- south El- Centro earthquake (1940) has been studied in which time, maximum acceleration, maximum speed and maximum deflection are 31.98s, 0.31g, 33 cm/sec and 21.4 cm, respectively (Figure3).

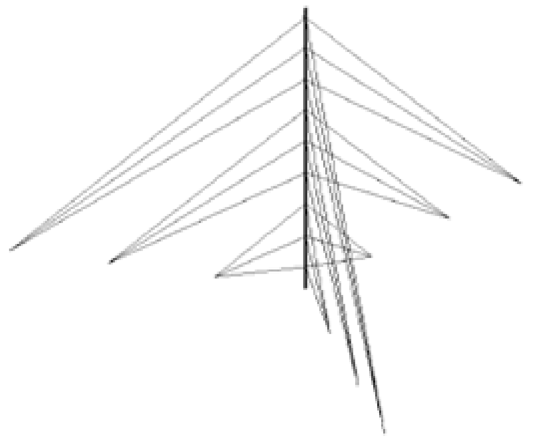

Figure 3: Accelerogram component of El- Centro earthquake

3.2. Data modeling using GP

At the second phase, using C++ programming language, the main GP steps are performed[10]:

1- Initial population of rules including potential solutions is provided potentially.
2- Provided rules are valued using fitting function in training collection.
3- Some of rules are chose on the basis of valuation of previous stage to provide reproduction mechanism.
4- Crossing over, reproduction and mutation operators are applied on current rules.
5- New generation choose to provide new generation.
6- Stages 3 to 6 will repeat to find suitable classification rule or provide maximum determined reproduction.
7- Stage 2 to 7 will repeat to find a suitable rule in data collection.
8- In training and experimental collection, each sample belong to a specific group.

These process is shown in Fig. 4.

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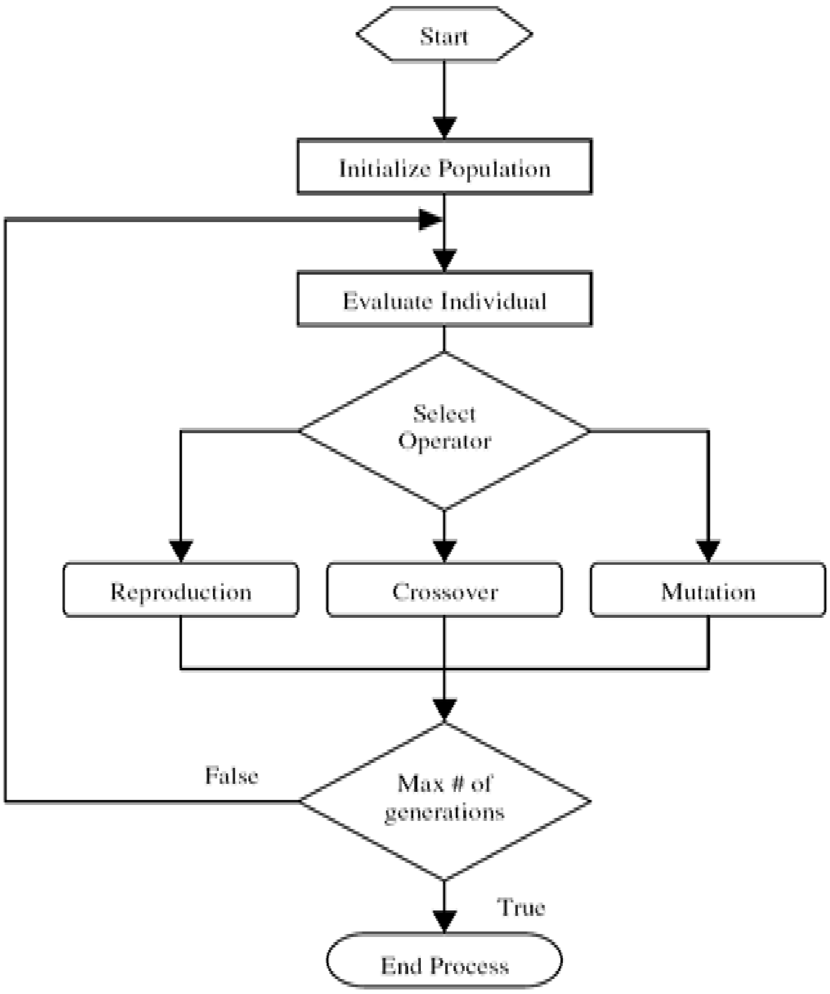

Figure 4: GP programming process

Using ANSYS, top maximum lateral displacement data (50 samples) of guyed tower were provided in which initial population are determined by X1, X2, X3, X4 and n. Also, details of mathematic formula, gen expression tree and the codes of the best GP model in top maximum lateral displacement modeling on the basis of mathematic operators are introduced as output. Then using GP modeling programming codes in C++ programming language, other 50 analyzed samples (secondary population) are analyzed by ANSYS and the error percent of maximum lateral displacement and the best GP model is determined. Details of mathematic formula are output which determine tower maximum lateral displacement using X1, X2, X3, X4 and n.

Briefly, the second phase of paper deals with GP regarding to geometric parameters such as horizontal distance between guy lines, the height of the first guy lines on the tower, height of antenna on the tower and the number of guyed level surface. After few generations and using GP operators, final population is provided which determine tower maximum lateral displacement [11,12]. In modeling using GP, it is necessary to determine suitable frame including primary regulation (App. I) and determination of mathematic operators (App. J). At the beginning of modeling using GP, 50 guyed towers are analyzed.

4. Test of models

To test of GP models, it is necessary to provide secondary population of data which don't belong to initial population. Then the results of analysis of top lateral displacement using ANSYS and the best GP model are compared (Fig. 5 and 6).

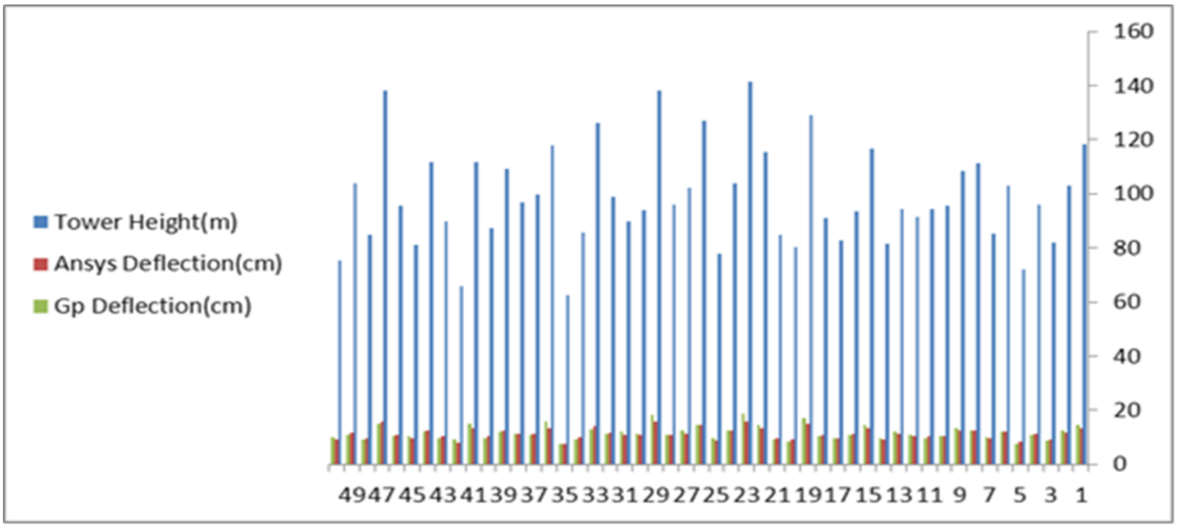

Figure 5: Comparison of maximum lateral displacement using ANSYS and GP on the basis of height of tower

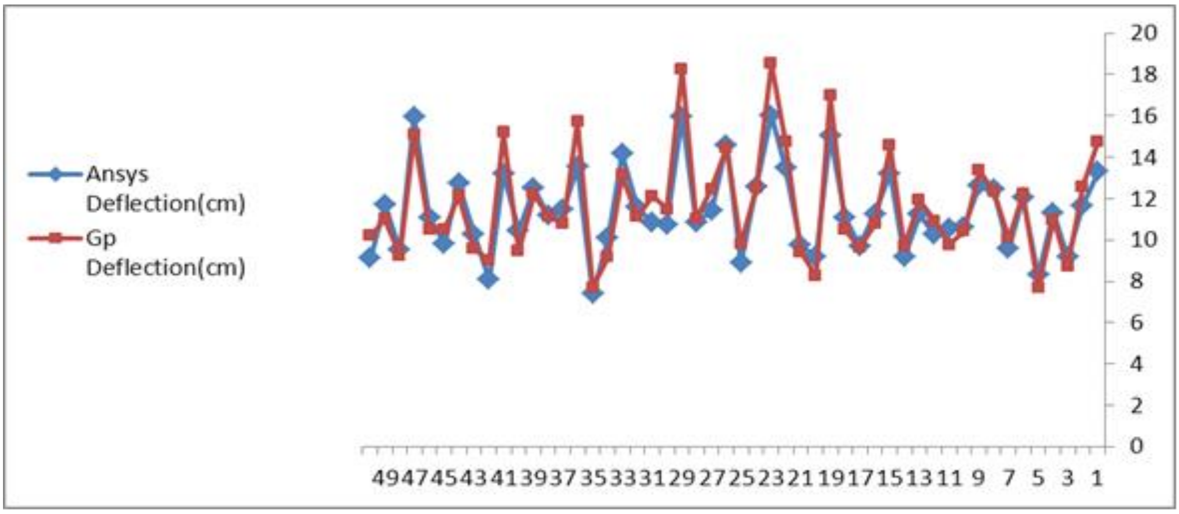

Figure 6: Comparison of maximum lateral displacement using ANSYS and GP

5. Data modeling using CA

Cellular automata (CA) are discrete, abstract computational systems[14]. The consists networks of similar and distinct places which includes finite sets of integers. According to algebraic rules, integers are depends on different steps. CA can use as an idealization of partial differential equations and usually describes natural systems. In addition, their partial natures leads to providing an important scale with the aid of digital computers. CA can be evaluated as a computer-like processing with a simple design[15,16]. CA includes two parts:

cellular space and local transition rules. Different types of each cell and cell type in time are shown with I index and S_i^t. In cellular automata, there are neighbors surrounding a central cell. For each cell, a set of cells called its neighborhood is defined relative to the specified cell. Cell neighbors (i) in time (t) and neighborhood radius of each cell are indicated in η_i^t and r, respectively[17]. Local transition rule is a function of η_i^t which is applied in cells simultaneously ($\phi(\eta_i^t)$). Finally, for each CA, there is a formula:

$$CA = (\varepsilon, d, V, \emptyset) \qquad (1)$$

in which Σ, d, V and ø are Possible conditions of cell, CA dimension, CA neighborhood structure and Local transition rule, respectively.
One- dimensional CA is shown in Figure 7.

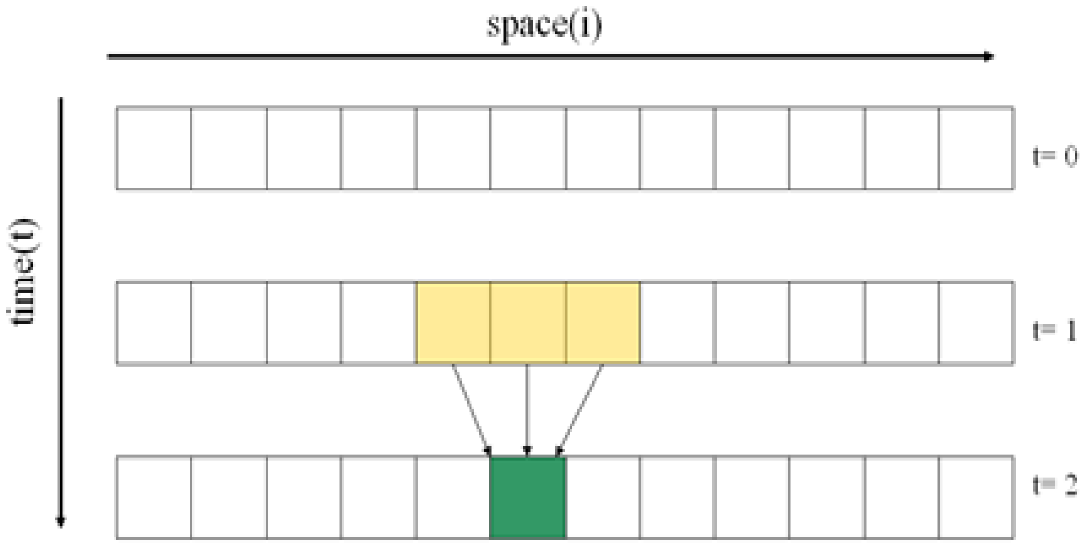

Figure 7: 1-D cellular automata

In this phase, using 1-D two and three state CA, provided tower samples in ANSYS are analyzed to find rules for simulation of maximum lateral displacement of guyed towers[18]. For that, by using 1-D two and three state CA algorithms and considering 5 parameters (X1, X2, X3, X4 and n) and calculated maximum displacement by ANSYS in C++ programming, one billion accomplishments for two state rules and 10 million rules for tree state rules, some tower models were provided. Then, these models were compared with other 50 samples and the error percent was determined for each analyzed tower in ANSYS. Analysis and modeling process by using cellular automata are shown in Figure 8.

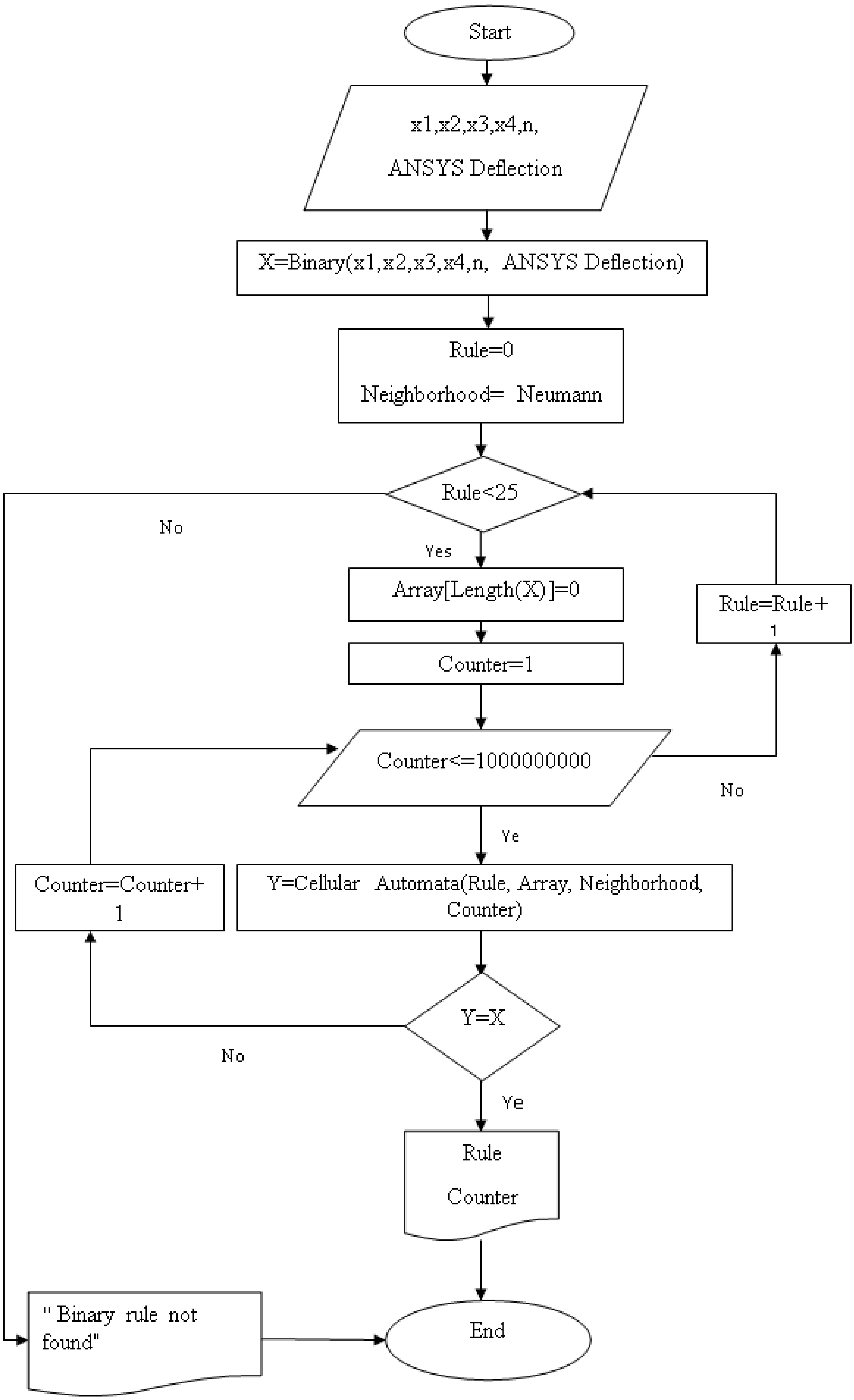

Figure 8: CA programming process

6. Analysis of guyed tower using CA

By using 50 data obtained by calculation of maximum lateral displacement in ANSYS, CA model was provided and after one billion accomplishments for 256 two state rule and one trillion performance three state rule follow data were provided. (figure 9 and 10)

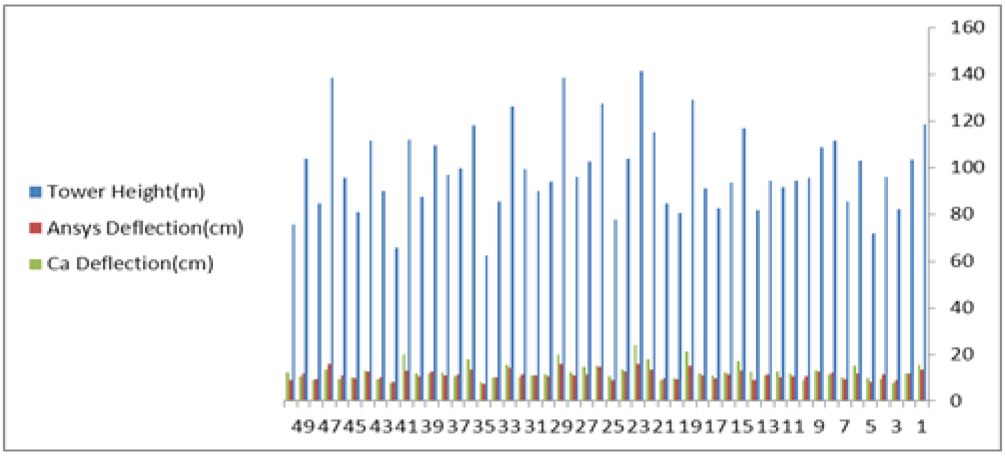

Figure 9: Comparison between maximum lateral deflection by ANSYS and CA due to height

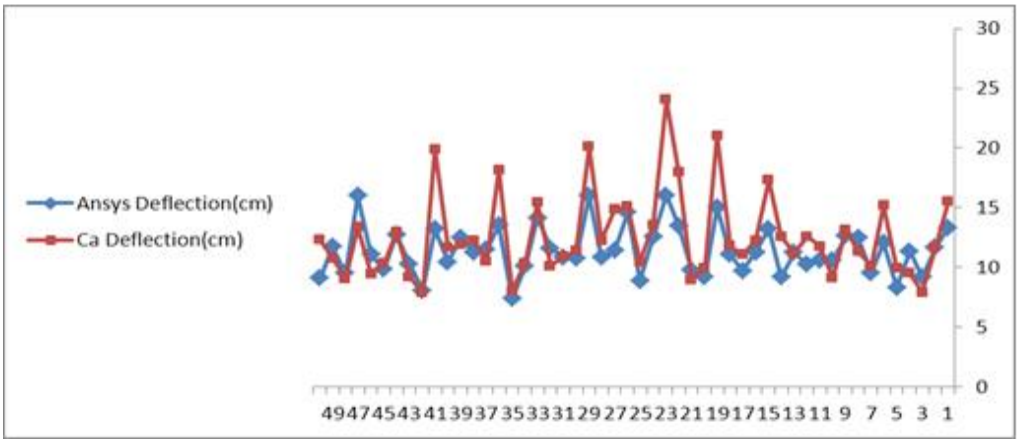

Figure 10: Comparison between maximum lateral deflection using ANSYS and CA

8. CONCLUSION

According to analysis of top displacement in guyed towers by using CA and GP, the average of error percent in GP and CA are 6.81 and 12.86 percent, respectively. The results are shown in figure 11 and 12.

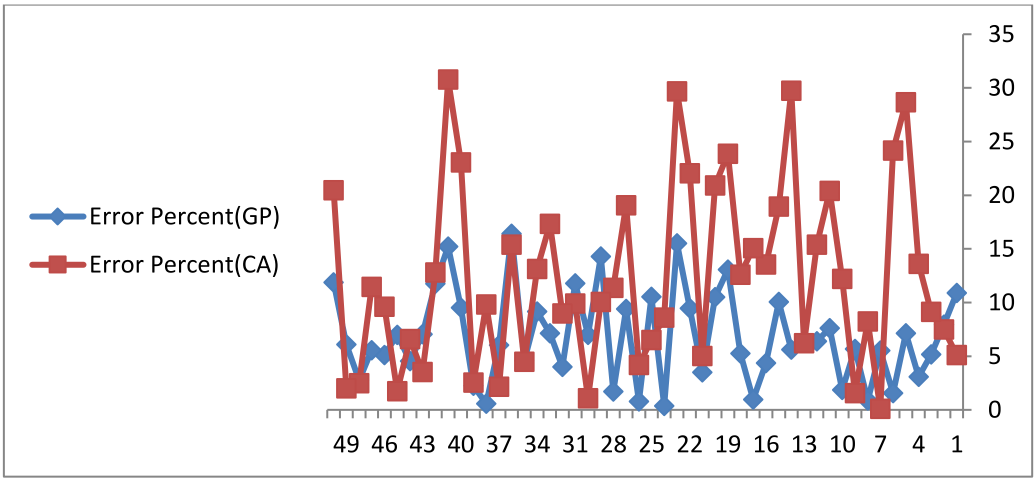

Figure 11: Comparison between error percent in calculation of maximum lateral deflection of guyed tower using CA and GP

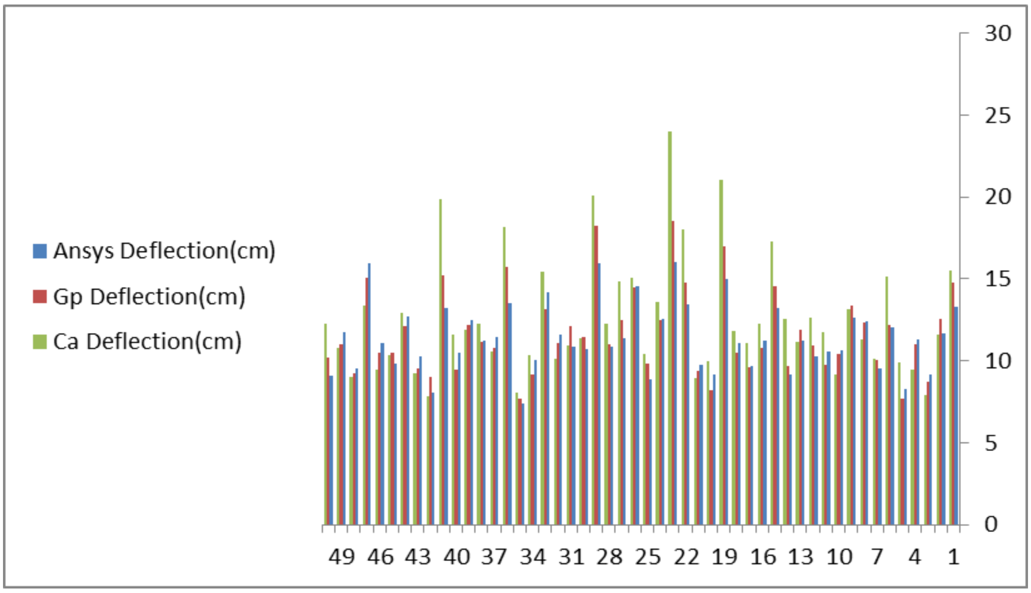

Figure 12: Comparison between maximum lateral deflection using CA, GP and ANSYS software

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