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Seismic Vibration Control of Structural System using Interval Type2 Fuzzy Logic Controller and genetically tuned PID Controller

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Abstract

In this paper, the problem of active vibration control of multi-degree-of-freedom structures is considered. Interval Type2 Fuzzy logic and genetically tuned PID controllers are designed to suppress structural vibrations against earthquakes under the non-linear soil-structure interaction. The advantage of the interval type2 fuzzy logic approach is the ability to handle the non-linear behavior of the system. Non-linear behavior of the soil is modeled in the dynamics of the structural system with non-linear hysteric restoring forces. One of the main shortcomings of the type-1 fuzzy systems is their inability to consider uncertainty in fuzzy rules. IT2FLS has the ability to handle this problem. The IT2FLC is designed for getting the maximum response reduction under different types of earthquake excitations. A structural system was simulated against the ground motion of the destructive Gadha earthquake (M*w* = 6.9) in Jabalpur, India on 21 May 1997. At the end of the study the time history of the storey displacements and accelerations and the frequency responses of both the uncontrolled and the IT2FLC based controlled structures are presented. These results show that the proposed interval type2 fuzzy logic controller and genetically tuned PID controller has great potential in active structural control.

Keywords

Seismic vibration control, Interval Type2 Fuzzy logic controller (IT2FLC), genetic algorithms, genetically tuned PID controller, non-linear structure, earthquake induced vibration.

1. Introduction

Natural hazards such as earthquakes and high winds pose a serious threat to multi-degree-of freedom structures. Recent earthquakes, such as the 1996 Gadha (Jabalpur), India, the 1994 Northridge, USA_ the 1995 Kobe, Japan and the 1999 Kocaeli, Turkey earthquakes resulted in extensive destructive damage to structures. A variable solution to safeguard the civil structures against these natural hazards is the use of structural control systems. Over the past few decades, a number of structural control strategies have been developed and practical applications have been realized. Schlacher et al. (1997) used a class of hybrid control systems for earthquake-excited high raised buildings, which consists of a base isolation and an additional active damper, and the mechanical model of building is a shear wall structure with non-linear hysteretic restoring forces. Al-Dawod et al. (2001, 2004) applied fuzzy logic control (FLC) for active vibration control of tall buildings in two papers. Yagiz (2001) applied sliding mode control for a multi-degree-of-freedom structural system. Guclu (2003) designed a fuzzy logic based controller and PD controller for an active control device considering a five degrees of freedom structure against the ground motion of the destructive earthquake. Yang et al. (2006) applied a neural network designed for system identification and vibration suppression in a building structure with an active mass damper. In this study, interval type2 fuzzy logic (IT2FLC) and genetically tuned PID controllers are proposed and designed to suppress structural vibrations against earthquake. This earthquake motion is obtained using the seismic data of the destructive Gadha(Jabalpur),India earthquake (M*w* = 6.9), which resulted in disaster in the vicinity of Jabalpur.

There are a couple of reasons to use fuzzy logic control in reducing earthquake excited structural response. It is well known that civil structures are complex and large structural system. They generally have distributed parameters and are of complex geometries making them difficult to model and analyze. They are subjected not only to static loading but also to a variety of complex dynamic loading, including winds, and earthquakes. The complexity in these structures generally arises from uncertainties in structural models, parameters and geometries. Some uncertainties are not random in nature. Normally, a precise mathematical model is difficult to be obtained for describing an entire large structural system. Conventional structural analysis models are built based on many simplifications and assumptions on structural system to reach the goal of precision. All these provide the motivation to use fuzzy logic technique in design of earthquake resistant structures.

One of the main shortcomings of the type-1 fuzzy systems is their inability to consider uncertainty in fuzzy rules. IT2FLS has the ability to handle this problem[17]. It also takes into account uncertainty in loading and structural behavior. To evaluate the efficiency of the proposed control method, an 11-storey realistic shear building is used. The IT2FLC is designed for the first mode characteristics of the mentioned structure for getting the maximum response reduction under different types of earthquake excitations[17].

To illustrate the effectiveness of the proposed interval type2 fuzzy logic controller and genetically tuned PID controller[17], data bsed simulation was implemented for a structural system in MATLAB/Simulink environments. It is shown that the controller provides robust performance when large parameter variations in structural system are presented.

2. The PID Controller

PID control has been widely used in industry. In general the closed loop diagram of the feedback system is shown in Figure 1. Here, $x_{r2}(t)$ is the desired value for the output of the system. $x_2(t)$ is the output and $e(t)$ is error[1].

$$e(t) = x_{r\,2}(t) - x_2(t). \qquad (1)$$

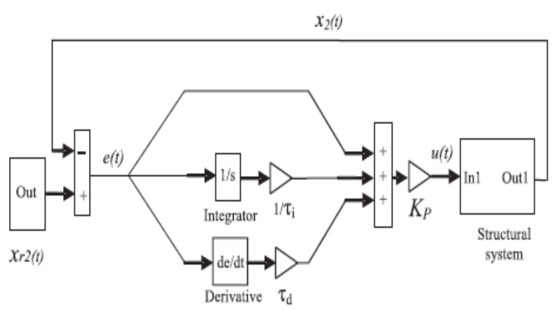


Figure 1. Closed loop block diagram with PID controller.

The control input u(t) is obtained as follows:

$$u(t) = K_P\left[e(t) + \frac{1}{\tau_i}\int_0^t e(t)d(t) + \tau_d\frac{de(t)}{dt}\right] \qquad (2)$$

where, KP, τ_i and τ_d are the proportionality constant, integral time and derivative time, respectively.

3. Interval Type-2 Fuzzy Logic Systems

A type-2 fuzzy set in a universal set of X is defined as $\tilde{A}$ and can be determined by[17]:

$$\tilde{A} = \int_{x\in X}(\mu_{\tilde{A}}(x)/x)$$

$\mu_{\tilde{A}}(x)$ indicates the secondary membership function and is defined by:

$$\mu_{\tilde{A}}(x) = \int_{u\in J_x}(f_x(u)/u),\ J_x \in [0,1] \qquad (3)$$

Where fx(u), Jx and u, are secondary grade, domain of secondary membership function and a fuzzy set in [0,1], respectively. When $f_x(u) = 1 \quad \text{for} \quad \forall\ u \in J_x$, then secondary membership functions are as interval sets and the obtained fuzzy set can be called an interval type-2 fuzzy set (IT2FS). It can be shown as below:

$$\tilde{A} = \int_{x\in X}(\mu_{\tilde{A}}(x)/x) = \int_{x\in X}\left(\left(\int_{u\in J_x}(1/U)\right)/x\right),\ J_x \in [0,1] \qquad (4)$$

Eqn 4 implies that IT2FS illustrates a uniform uncertainty in the primary membership. An IT2FS is defined based on its upper and lower membership functions. In IT2FLS, footprint of uncertainty (FOU) is defined based on the upper and lower membership functions as:

$$\mathrm{FOU}(\tilde{A}) = \cup_{x\in X}\left(\overline{\mu}_{\tilde{A}}(x), \underline{\mu}_{\tilde{A}}(x)\right) \qquad (5)$$

Figure 2 shows an interval type-2 fuzzy membership function with footprint of uncertainty (FOU), upper and lower bounds, and its standard deviation. The general structure of an IT2FLC is illustrated in Figure 3 in which the components are denoted as follows:

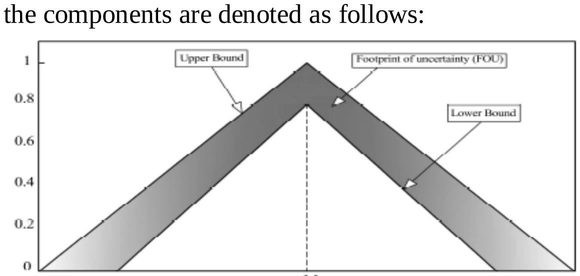


Figure 2. Interval type-2 fuzzy MF

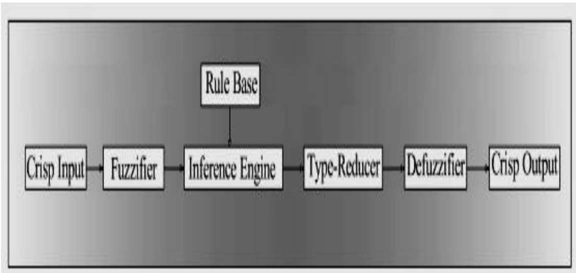


Figure 3. IT2FLS structure

3.1 Fuzzifier

Fuzzifier maps the measured inputs into fuzzy linguistic values with the help of fuzzy reasoning mechanism. In the present study, singleton fuzzifier was used which its output is a single point of a unity membership grade[2].

3.2 Rule base

In this part which is a set of IF-THEN rules, the knowledge of experts will be placed. Jth rule in IT2FLS can be written as:

$$Rj: If\ x_1\ is\ \tilde{F}_1^j\ and\ x_2\ is\ \tilde{F}_2^j\ and \ldots x_n\ is\ \tilde{F}_n^j\ then\ y\ is\ \tilde{G}^j \tag{6}$$

Where xi(i=1,2,…,n) and y are IT2FLS input and output, respectively and also show the type-1 or type-2 antecedent and consequent sets, respectively.

3.4 Inference engine

In IT2FLS, the inference engine combines rules and represents a mapping from input to output IT2FLS. Using input and antecedent operations, the firing set is obtained as:

$$F^j(X) = \prod_{i=1}^{n} \mu_{F_{i^j}}(x_i) \tag{7}$$

Where, t-norm is assumed to be product. Since the present study discusses IT2FLS, the firing input sets are defined based on the upper and lower membership functions as:

$$F^j(X) = \left(\underline{f}^j(X), \overline{f}^j(X)\right) \tag{8}$$

Where * shows the t-norm and $\underline{f}^j(X)$ and $\overline{f}^j(X)$ j are the jth upper and lower membership functions, respectively and can be determined by:

$$\underline{f}^j(X) = \underline{\mu}_{F1^j} * \underline{\mu}_{F2^j} * \ldots * \underline{\mu}_{Fn^j} \tag{9}$$

$$\overline{f}^j(X) = \overline{\mu}_{F1^j} * \overline{\mu}_{F2^j} * \ldots * \overline{\mu}_{Fn^j} \tag{10}$$

3.4 Type reducer and Defuzzifier

Since the output of the inference engine is an IT2FS, a type reducer is needed before defuzzification to convert IT2FS into type-1 fuzzy set[17]. Type reducer was first proposed by Karnik & Mendel [36,39]. In [39], five different methods of type reduction have been suggested. Among these methods, center of sets (COS) has been extensively used due to easy calculation with the help of Karnik & Mendel's iterative algorithm [3]. The COS type reducer is an interval set which is determined by left-end point (yl) and right-end point (yr) and can be written as:

$$Y_{cos}[y_l, y_r] = \int_{\theta^1} \cdots \int_{\theta^M} \int_{f^1} \cdots \int_{f^M} \left(1 / \left(\left(\sum_{j=1}^{M} f^j . \theta^j\right) / \left(\sum_{j=1}^{M} f^j\right)\right)\right) \tag{11}$$

Where $f_j \in F_j = \left(\underline{f}_j(X), \overline{f}^j(X)\right)$ and f_j is the centroid of jth consequent set. In general, there is no closed-form formula for calculating yl and yr. However, Karnik and Mendel [34] have proposed two algorithms for calculating end-points which are known as KM iterative algorithms. In case of using singleton fuzzifier, product inference engine and COS type reducer, yl and yr can be written as:

$$y_l = \left(\left(\sum_{j=1}^{M} f_l^j . \theta_l^j\right) / \left(\sum_{j=1}^{M} f_l^j\right)\right) \tag{12}$$

$$y_r = \left(\left(\sum_{j=1}^{M} f_r^j . \theta_r^j\right) / \left(\sum_{j=1}^{M} f_r^j\right)\right) \tag{13}$$

Where θ_l^j and θ_r^j are related to left-end point and right-end point of jth consequent set, respectively. Finally, the obtained set from type reducer can be defuzzified by using the average of yr and yl [37], as below:

$$y = \left[(y_l + y_r)/2\right] \tag{14}$$

4. Design of Interval Type2 Fuzzy Logic based Control System

Fuzzy logic control is knowledge based control system. It can mimic human thinking using natural language to produce the control commands for a dynamic system. In fuzzy logic control system, the uncertainties in the ground motion data and structural dynamic response can be easily treated by fuzzy sets using linguistic variables. Figure 4 shows the architecture of an interval type2 fuzzy logic controller for seismically exited building. Fig.5. shows example of the membership function for antecedent.

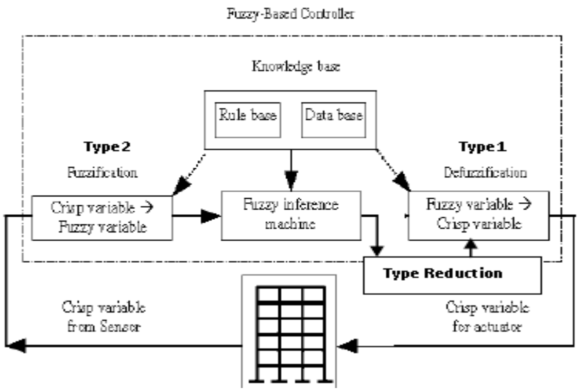


Figure 4. Architecture of interval type2 fuzzy logic controller for seismically exited building

Fuzzification, type reducer and defuzzification interfaces are to transform data between crisp and fuzzy sets, because measurements of dynamic excitation and response and control actions are still designed for crisp data in the control system[4]. Whereas, knowledge base unit containing a rule base (fuzzy IF-THEN rules) and a data base (membership functions used in the fuzzy system). In our study, the dynamic response of building roof in term of x, the displacement, $\dot{x}$ and $\ddot{x}$, the velocity and acceleration, respectively; are used as input variables to the fuzzy controller Fuzzy sets represent the grade of crisp input items in antecedent parts of rules. Figure 5 depicts examples of such fuzzy sets (membership function). The following lingual variables are used: NB = negative big, NM = negative medium, NS = negative small, ZR= zero, PB = positive big, PM = positive medium, PS = positive small.

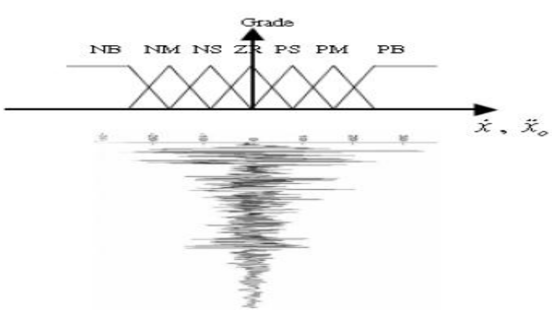


Figure 5. Example of the membership function for antecedent

Karnik and Mendel expanded the centroid of an interval type-2 fuzzy logic set. Firstly, IT2FLC is designed for a SDOF system for getting the maximum response reduction under different types of earthquake records including both far field and near-field ground accelerations. The mass, stiffness and damping constants of the proposed system are chosen as the first mode characteristics of the realistic 11-storey building. Then, the designed IT2FLC for the SDOF system is used with the genetically tuned PID controller of the 11-storey building. The obtained results by the proposed control method were compared with those of uncontrolled structure[17]. The results show that IT2FLC along with genetically tuned PID controller is an effective control method among the other control algorithms for reducing the structural response and also the response of SDOF system driven by the designed IT2FLC has a good agreement with the response of realistic building when the same controller is used.

An analysis of a seismic response of structures using semi-active MR (magnetorheologic) and ER (electrorheologic) bracing systems is performed[6]. The authors showed that placing dampers near the base of a structure, as opposed to the upper levels, gives a better response reduction[16]. The control method used here is a linear generation of the control forces based on ground acceleration[9]. A damper controller is used to generate and adjust the command voltage to track the desired damping force determined by the system controller based on the desired and the actual damping forces. One of the implementations of actuators for this control strategy is the one using smart fluids (MR or ER)[14]. These are fluids with controllable viscous behavior, given a small electric or magnetic input. Interval type2 Fuzzy logic control has the advantage of not requiring a strict mathematical model for design. The nonlinearities of the plant are inherently included in the controller and little knowledge of the plant model is necessary[7]. However, these controllers are usually based on human expertise. Fuzzy logic is centered on linguistic terms and non-crisp coding of the process variables. Thus, each input and output variable is described in linguistic terms, as a human expert would. For the Mamdani fuzzy controller, the inputs need to pass through a fuzzification procedure[8], while the commands sent into the system need to be defuzzified, as the actuators currently used require numerical control signals (either discrete or continuous)[5]. Figure 6. shows physical model of the structural system[15].

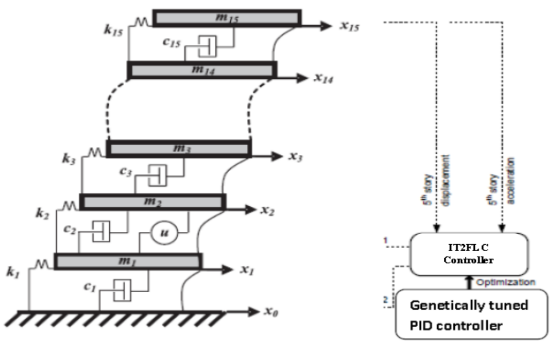


Figure 6. Physical model of the structural system.

4.1 System Description

The building selected for this research was obtained from Yeh *et al.* (1994). It has a mass of 345,600 kg

Table 1. Characteristics of Selected Earthquakes

Earthquake	Date	Magnitude	Peak Acceleration(g)
Elcento,CA	May 18,1940	7.1	0.3495
Hachinohe,Japan	May 16,1968	7.9	0.2294
Northridge,CA	January 17,1994	6.8	0.8428
Kobe,Japan	January 17,1995	7.2	0.8337
Gadha,India	May 21,1997	6.9	0.8269

, a stiffness of 3.4 x 107 N/m and a damping ratio of 0.02 and will be equipped with two large-scale 20-ton MR dampers. The acceleration data of Gadha-India earthquakes widely used in structural control research were employed. Their characteristics are presented on Table 1

The equation of motion for seismically excited SDOF structures with a controller can be written as:

$$m\ddot{x} + c\dot{x} + kx = -f - m\ddot{x}_g \qquad (15)$$

where $x, \dot{x}, \ddot{x}$ are the floor displacement, velocity and acceleration, respectively, $\ddot{x}_g$ is the ground acceleration, and *f* is the control force.

4.2 IT2FLC control system Diagram

An IT2FLC controller is presented in Figure 7. The input variables to the fuzzy controller were selected as floor displacement (*d*) and velocity (*v*) and the output as applied current to the MR damper (*i*). The membership functions for the inputs were defined on the normalized universe of discourse [-1,1] and selected as three identical triangles with 50% overlap. For the output, they were defined on the universe of discourse [0,1] and selected as seven identical triangles with 50% overlap. The labels NB, NM, NS, ZO, PS, PM, PB refer to the linguistic values: negative big, negative medium, negative small, zero, positive small, positive medium and positive big, respectively.

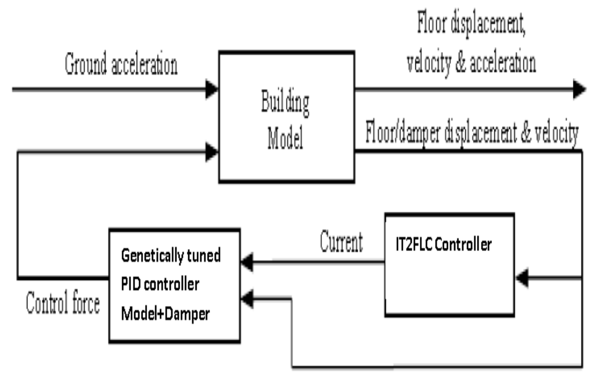


Figure 7. Diagram of the interval type2 fuzzy control system

4.3 Design of IT2FLC Controller

Fuzzy logic controller is designed based on the crisp data directly received through the structure. This data is mapped on to fuzzy sets through the fuzzification process. In the present study, IT2FLC has been designed using two input variables each one having three upper and three lower membership functions (MFs), and one output variable with seven upper and seven lower MFs. The upper and lower MFs chosen for the input and output variables are triangular shaped and have been defined on the common interval [-1,1].

In this study, displacement and velocity of the roof level of the SDOF system are chosen as input variables of controller for the IT2FLC design[11][17]. In real applications, some sensors must be installed on the floors to measure the acceleration responses of building and an integrator is used to convert the acceleration measurements to the displacement and velocity responses. The main purpose of using two input variables for the IT2FLC is to show the efficiency of the fuzzy approach in the control problem. These input variables help in generating the inference rule base. If displacement is zero and velocity is not zero, control action with small intensity should be applied to maintain the structure close to its neutral position[13]. If displacement and velocity are of the same sign, the structure is moving toward its extreme position and a control force with high intensity should be applied. If velocity is zero and displacement is not zero, or displacement and velocity are of the opposite sign, the structure is returning to its neutral position and a relatively small control force is applied.

4.4 Genetic Algorithms for PID Tuning

Here an internal loop for control of the output actuator force has been considered, with a conventional PID control algorithm, with parameters obtained by means of genetic algorithms (figure 8). The fitness function minimizes the error between the desired control force (fed into the loop as a set point) and the output control force of the damper[10]. The performance index is to be minimized, and the algorithm returns the best set of PID tuning parameters with the lowest performance index at the moment the stop condition for the algorithm is met.

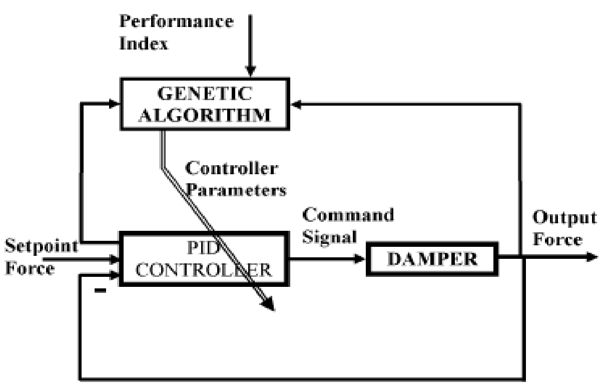


Fig.8. Genetic tuning of PID controllers for dampers

5. IT2FLC for Base Isolation

The interval type2 fuzzy controller (IT2FLC) implemented in this paper is of Mamdani type and is part of the control strategy presented in figure 9, where: *x* is the displacement of the structure; $\dot{x}$ and $\ddot{x}$ are the velocity and acceleration of the structure, respectively; *F* is the control force; u_{FLC} is the desired control force, *u* is the command signal (either voltage or current), ε is the control error of the inner loop; *a* and *v* are

Fig.10. Genetic tuning of PID controllers for dampers

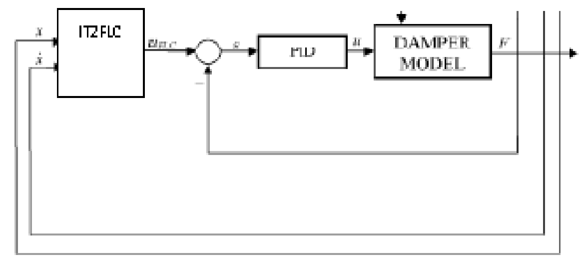


Fig.9. Interval Type2 Fuzzy control strategy

the earthquake induced ground acceleration and velocity, respectively. The controller input variables are the displacement and velocity of the structure and the output is the command voltage or current used for the dampers, respectively. The discourse universes for each input variable are normalized to the interval [-1, 1], while the output is generated in the normalized interval [0, 1]. The scaling factors used were obtained by analyzing the structure output[12][16].

The input and output variables are triangular membership functions, with a 50% overlap. The linguistic terms are coded as follows: E - displacement (deviation from zero), D - velocity (derivative of first input), C - command (output), N - negative, P - positive, L - large, M - medium, S - small, Z - zero. Table 1 also presents the rule base.

A second fuzzy controller (FLC) was implemented in order to obtain better reduction of the structural displacement. While the triangular membership functions are widely used, they sometimes lack in precision[18]. When the considered plant is sensible to small variations of input, then a higher resolution in generating the control signal is required. The second FLC in this paper was designed by assigning gaussian membership functions to the linguistic variables, while using the same rule base.

6. Simulation

In this study, Matlab Simulink with Fuzzy Toolbox is used. The aim of the fuzzy logic control system for the structural system uses the errors in the second storey motion $(\varepsilon = x_{r2} - x_2)$ and the derivatives of it as the input variable while the control voltage (u) are their outputs. Reference values are considered to be zero in Figure 10.

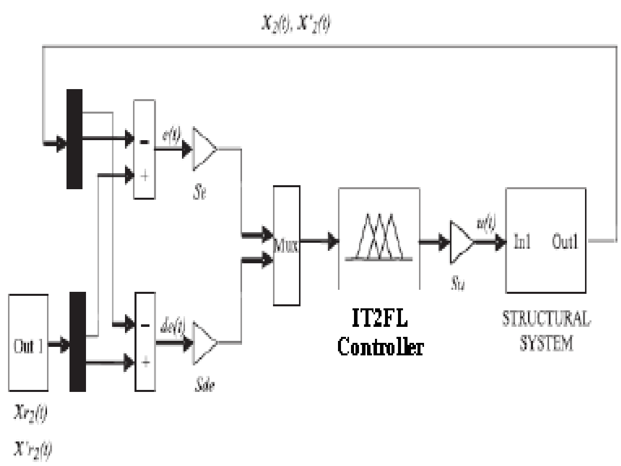


Figure 10. Closed loop model of the structure with fuzzy logic controller.

The membership functions for both scaled inputs (*e*, *de*) and output (*u*) of the controller have been defined on the common interval [–1, 1]. Scaling factors (*Se, Sd, Su*) are used to set *e*, *de* and *u* (Figure 10) (Mudi and Pal, 1999). The first rule in Table 1 is given below:
If e is XNB and de/dt is V N THEN u is UNB.

All the rules are written using the Mamdani method to apply to fuzzification. In this study, the centroid method is used in defuzzification. A structural system has been simulated against the earthquake ground motion of the destructive Gadha earthquake (M*w* =6.9). Earthquake ground motion is used as an input to a building structure. Accelerations were recorded at the Gadha (Jabalpur) Observatory and Earthquake Research Institute strong motion station at the IIT Rurki, India.

It is seen from the Table 2 that IT2FLC reduces the uncontrolled peak displacement response of the top floor about 49% and 61.1% for first and eleventh storey respectively for the Gadha earthquake[17]. This feature of IT2FLC is revealed in the time history responses of the top floor compared to uncontrolled response when subjected to Gadha earthquake.

Another criterion for comparison of uncontrolled and IT2FLC is RMS displacement of stories. This parameter is obtained for the realistic building in case of using uncontrolled and IT2FLC under Gadha ground accelerations as shown in Figure 11. As expected, IT2FLC decreased the RMS displacement responses of floors more than that of obtained by uncontrolled and it can be understood that a superior improvement in terms of RMS reductions observed when using IT2FLC[17].

Table 2: Peak response and peak response reduction using different control systems in Gadha Earthquake

Floor	Peak response of displacement		Percentage response reduction
	Uncontrolled	IT2FLC	(%)
1	0,013	0.007	49.0
2	0,027	0.012	50.0
3	0,040	0.018	52.0
4	0,052	0.023	54.3
5	0,065	0.025	57.5
6	0,072	0.029	58.0
7	0,086	0.031	59.8
8	0,094	0.033	60.1
9	0,98	0.037	60.9
10	0,101	0.039	61.0
11	0,103	0.040	61.1

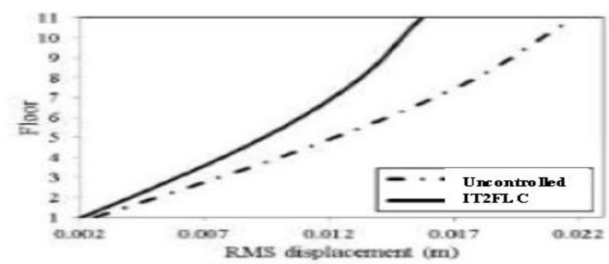
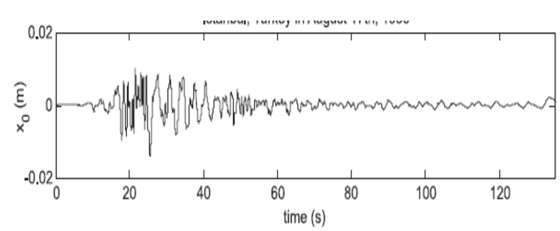
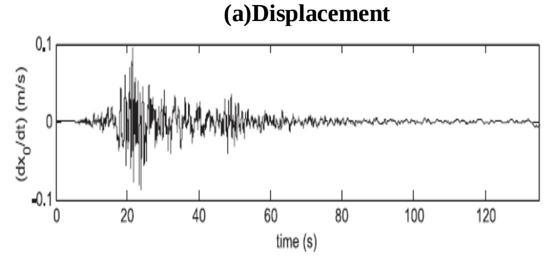


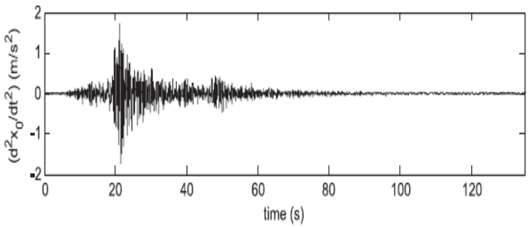
Figure 11. Comparison of RMS displacement of stories in case of uncontrolled and IT2FLC



(a)Displacement



(b) Velocity



(c) Acceleration

Figure 12. Gadha(Jabalpur) earthquake excitation input to the structure.

Figure 12. shows Gadha(Jabalpur) earthquake excitation input to the structure. The displacements of the related storeys are planned to estimate through displacements on them after online integration. This integration includes the necessary high–low pass filters to get rid of the effects of noise and other unmodeled dynamics. Figures 13 and 14 shows the time responses of the second storey displacements and accelerations, respectively, for both controlled (PID & IT2FLC) and uncontrolled cases. Figures 15 and 16 shows the time responses of the fifteenth storey displacements and accelerations, respectively, for both controlled (PID & IT2FLC) and uncontrolled cases. It is observed that there is an important improvement with interval type2 fuzzy logic controller when the horizontal displacements of the structure are considered. Against earthquake excitation, vibration amplitudes of storeys were decreased. When the response plots of the structural systems with interval type2 fuzzy logic controllers (IT2FLC) are compared, a superior improvement in terms of magnitudes with the fuzzy logic one has been witnessed (Figures 9 and 10). Therefore, at the resonance values of the response of the storeys with fuzzy logic controller, satisfactory results are reached.

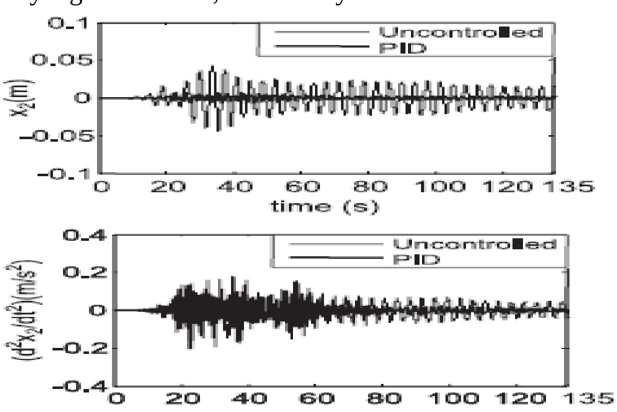


Figure 13 Uncontrolled and PID of displacement and acceleration time responses of Second storey

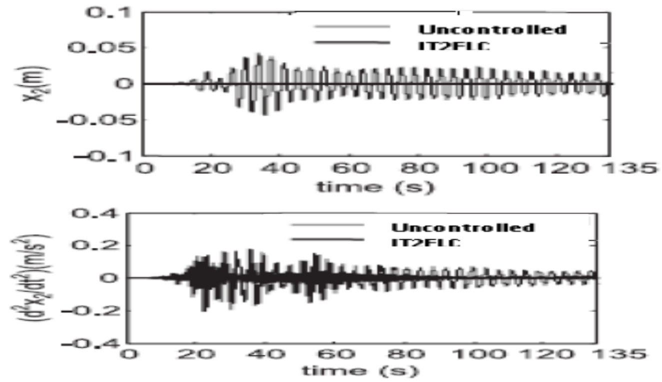


Figure 14 Uncontrolled and IT2FLC of displacement and acceleration time responses of Second storey

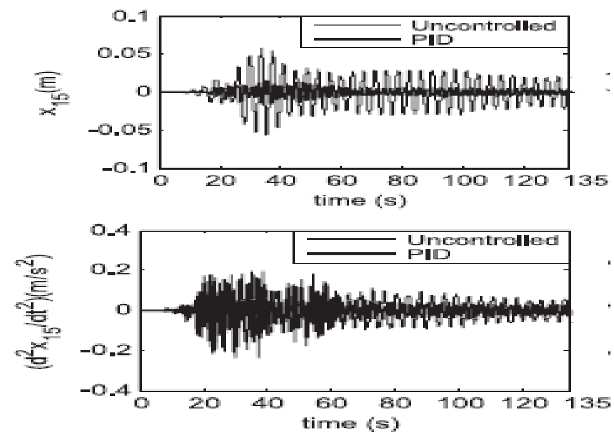


Figure 15 Uncontrolled and PID of displacement and acceleration time responses of fifteenth storey

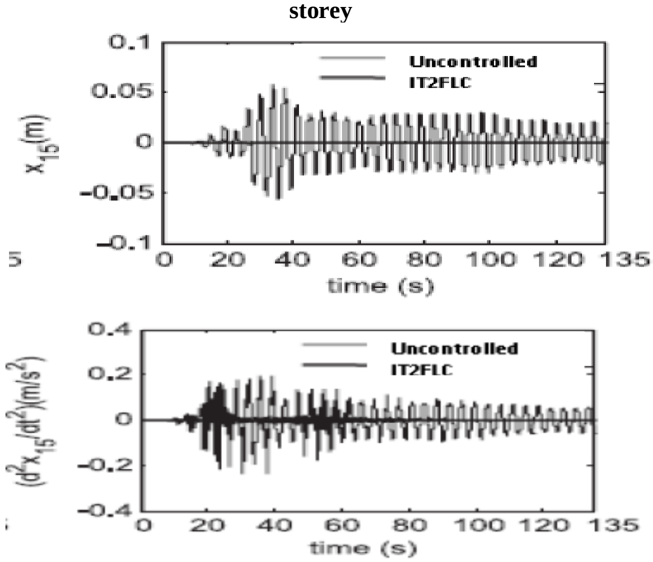


Figure 16 Uncontrolled and IT2FLC of displacement and acceleration time responses of fifteenth storey

7. Results discussion

A Simulink model of the system, which consisted of the selected building, was created and simulations were performed using MATLAB, version 6.5. The time response of the floor displacement and acceleration under the different seismic excitations were studied. These figures show that both control algorithms successfully reduced the building responses under the different earthquake loads and that they were more effective in reducing displacements than accelerations for all loading situations. It can also be observed that the interval type2 fuzzy controller performed better than uncontrolled, producing larger reductions for both structural responses. The greatest reductions for both responses were observed for the Gadha earthquake, with values of 67.78% for displacement and 46.57% for acceleration, using the algorithm presented in Liu *et al.* (2001) and of 76.45% and 48.12%, for displacement and acceleration, respectively, using the interval type2 fuzzy control algorithm presented in this paper. For all seismic excitations, the interval type2 fuzzy controller was found to perform better than the controller proposed by Liu and colleagues. Root mean square (RMS) responses are also considerably reduced by the algorithms studied. Reductions for RMS displacement ranged from approximately 40 to 86%, while those for RMS acceleration ranged from roughly 18 to 67%. The greatest reductions were obtained under the Gadha earthquake load, with values of 69.67% for displacements and 59.06% for accelerations with the algorithm developed by Liu *et al.* (2001) and of 85.67% and 59.68% for displacements and accelerations, respectively, with the interval type2 fuzzy controller.

8. Conclusion

The safety of the structures and comfort level for the user are the essential performance requirements. The safety of the structures mainly depends on the displacement response, while the comfort level of the occupants depends on the acceleration response. To ensure that both responses are within permissible limits, interval type2 fuzzy logic controller and genetically tuned PID controller have been designed for a multi-degree-of-freedom system having the parameters of a real structure under the non-linear behavior of soil-structure interaction, and simulation results have been presented. The main idea behind proposing interval type2 fuzzy logic controller is its success and the ability of using these types of controllers on structural systems. Because the destructive effect of earthquakes is a result of horizontal vibrations, in this study the degrees of freedom were assumed only in this direction. The system is modeled including the dynamics of a linear motor which is used as the active isolator, and the structural system is then subjected to Gadha earthquake vibration effects, which are treated as disturbance. The simulation results indicate that the implementation of interval type2 fuzzy logic controller shows a good response as far as absorbing the vibration due to earthquake effects. Essential performance requirements for the safety of the structures and comfort level for the user are achieved. The displacements of the fifteenth storey are minimized successfully using the interval type2 fuzzy logic controller. The designed IT2FLC shows high performance. A designed interval type2 fuzzy logic controller brought better active control performance than a PID controller. The improvement in resonance values and the decrease in vibration amplitudes support this result and the proposed fuzzy logic controller has great potential in active structural control.

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