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Earth Quake Prediction Feasible More Efficiently with Fuzzy Preview Control Design

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***Abstract:*— This paper proposes a technique of efficiently determining the impact of earthquake by considering the motion of the dynamics of a three story building. The comparative analysis with existing methods show that the method proposed is a feasible, practical and low cost alternative for possible detection and warning of earthquakes. Typical earthquake transducer is a second order plant which picks up the vibrations. In this paper, an integrated plant mode is proposed which is evolved with time delays taking earth as a dynamic system which passes on information to the plant and detects the impact of the earthquake.**

***Index Terms*:— Earthquakes, Preview Control, fuzzy logic, Integrated time delay models, state space models**

I. INTRODUCTION

Earthquake detection, immediate steps for survival, aid processes are an area of utmost importance in the every changing context of the technologies leading to weak lands. The structures and the structures of control laws are to be defined with utmost care and attention. The world is prone to more earthquakes for various reasons such as global warming. The problem with earthquakes and associated implications have become issues of serious concerns worldwide which have been investigated by researchers.

Qiu et al [1] have elaborated on a methodology of using fuzzy logic technique for earthquake excited structural control is proposed keeping in view of the uncertainty involved with the construction of the pendulum system. Srikanth et al [2] have discussed about a method of using particle swarms and studying the dynamics of double inverted pendulum for understanding earthquakes. Patwardhan [3] explains how the earthquakes map the Earth's internal structure and reveal what it is made of studying it as a dynamic system. Spencer et al [4] indicated the first criterion on which controllers will be evaluated is based on their ability to minimize the maximum rms intense drift due to all admissible ground motions. Certain parts of peninsular India that have suffered ground motion of magnitude 3-4 units on the rector scale may be identified as 'earthquake prone'. The Himalayan seismicity is a matter of concern for Earth scientists, engineers and environmentalists as the Himalayan region is more prone to earthquakes than the peninsular India[3]. Movements associated with earthquakes are described as primary, secondary or sympathetic. Lai [6] has highlighted the technique of granular computing and have highlighted the significance of granular computing which in one sense would speed up the processing of the data. Tarun[7] has applied the technique to a single inverted pendulum and Nidhika et al [8] has elaborated on preview control with a discussion on how future information can be used. Srikanth et al [9] have used the same logic for control of a humanoid robot during staircase stepping which is used in this work. Yang et al [10] have discussed on demonstration and analysis of buildings under numerous earthquake ground motions, with repair costs aggregated.

Huaguang [11] has discussed about the general aspects of fuzzy logic and fuzzy control which could be applied to the system like the robogymansts or humanoid robots. Min et al [12] has discussed about the general aspects of time delay sytems and the issues in dealing with time delay systems in terms of robustness and stability which are incorporated into the studies of the triple inverted pendulum system studies. Lai et al [13] have discussed about the granular computing technique where scaling down information into granules would help with the better study of a system in general and how it could be used in conjunction with fuzzy logic for improvising system studies. Drainkov et al [14] have discussed about the basic aspects of fuzzy control and how it could be extrapolated and tested for large scale systems. Yao et al [15] has elaborated on the system

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identification aspects using fuzzy control.
A control structure for such a high impact such as an earthquake impulse is difficult to be designed. However, the prediction of the signal can be studied like an open loop response of the system. The proposed method here investigates the studies based on a preview control logic which presumes there is some information available about the earthquake in an advance and a security network is activated and a signal generated indicating for possible threats to life and property for necessary security measures. In section 2, methodology is elaborated taking the case of the building and then designing a transducer which is approximated with a fuzzy preview controller.

II. PROBLEM FORMULATION WITH DYNAMICS OF BUILDINGS

James et al [5] have proposed a representation for a three story building modeled by a lumped mass system. The dynamics in equations 1 and 2 are enhanced to consider the time delay parameter as an integrated model in equation 3. The ground acceleration is considered as the input for the plant and the effect of delay would indicate the intensity of distortions. The modified dynamics of the plant to accommodate the time delay and integrate the new state space formulation so that the state space formulation is given by equations 3.

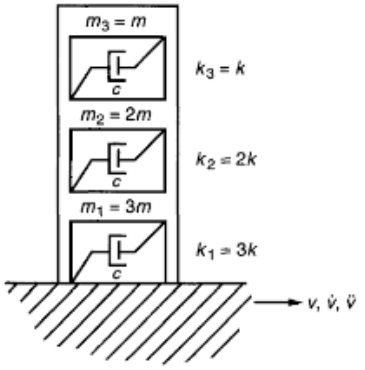

Figure 1: Representation of Dynamic system of three story building[5]

$$\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\\ \dot{X}_4\\ \dot{X}_5\\ \dot{X}_6\end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0\\ -\frac{k_1+k_2}{m_1} & \frac{-2c}{m_1} & \frac{k_2}{m_1} & \frac{c}{m_1} & 0 & 0\\ 0 & 0 & 0 & 1 & 0 & 0\\ \frac{k_2}{m_2} & \frac{c}{m_2} & -\frac{k_3+k_2}{m_1} & \frac{-2c}{m_2} & \frac{k_2}{m_2} & \frac{c}{m_2}\\ 0 & 0 & 0 & 0 & 0 & 1\\ 0 & 0 & \frac{k_3}{m_3} & \frac{c}{m_3} & \frac{k_3}{m_3} & \frac{-c}{m_1}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\\ x_5\\ x_6\end{bmatrix} + \begin{bmatrix}0\\ -1\\ 0\\ -1\\ 0\\ -1\end{bmatrix} u \quad (1)$$

$$\begin{bmatrix}y_1\\ y_2\\ y_3\end{bmatrix} = \begin{bmatrix}1 & 0 & 0 & 0 & 0 & 0\\ -1 & -1 & 0 & 0 & 0 & 0\\ 0 & 0 & -1 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\\ x_5\\ x_6\end{bmatrix} \quad (2)$$

$$\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\\ \dot{X}_4\\ \dot{X}_5\\ \dot{X}_6\\ \dot{X}_7\end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0\\ -\frac{k_1+k_2}{m_1} & \frac{-2c}{m_1} & \frac{k_2}{m_1} & \frac{c}{m_1} & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & 0 & 0 & 0\\ \frac{k_2}{m_2} & \frac{c}{m_2} & -\frac{k_3+k_2}{m_1} & \frac{-2c}{m_2} & \frac{k_2}{m_2} & \frac{c}{m_2} & 0\\ 0 & 0 & 0 & 0 & 0 & 1 & 0\\ 0 & 0 & \frac{k_3}{m_3} & \frac{c}{m_3} & \frac{k_3}{m_3} & \frac{-c}{m_1} & 0\\ 4/Tuo & -2/Tuo & 0 & 0 & 0 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\\ x_5\\ x_6\\ x_7\end{bmatrix} + \begin{bmatrix}0\\ -1\\ 0\\ -1\\ 0\\ -1\\ 0\end{bmatrix} u \quad (3)$$

The modified equation represents the linear transformation that took place which is to be controlled with the help of the controller. The practical controller/transducer could possibly be represented as shown in figure 2.

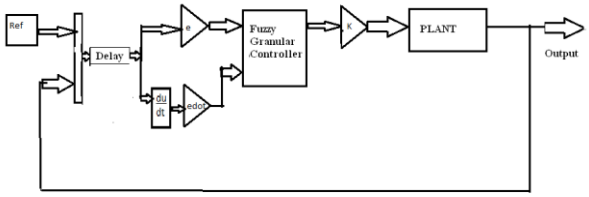

Figure 2: Representation of fuzzy logic controller [2]

III. FUZZY PREVIEW CONTROL

Preview based logic is the study of methods and principles of reasoning in abstract manner with the knowledge of future, where logical reasoning means obtaining new propositions from existing propositions that are predefined[16]. The systematic framework for fuzzy modeling and fuzzy control of nonlinear systems with uncertainties is based on three types of models mostly which could be the mamdani model or Takagi Sugeno model and fuzzy hyberbolic model. The mamdani model constructs a bridge

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between the operator's knowledge and conditions statements that are framed. The preview based fuzzy controller is designed for the triple inverted pendulum taking into consideration the highly unstable triple pendulum on cart as shown in figure 1.

A Type-1 Fuzzy Logic Controller has been designed with 2 inputs – error and rate of error, and 1 output – F. The controller uses traditional lookup tables which are defined based on fuzzy members for the fuzzy memebership values defined based on the possible inputs. The rate of error is additionally differentiated for further granular computing. The analysis is to be done by taking the time derivative of error and error itself and passing on to the fuzzy lookup table where the lookup table has data which is a set of possible fuzzy numbers defined for each of the adjectives of distortion of the pendulum from the unstable equilibrium position which decides the deviation. The output of the fuzzy lookup table is given as the input to the plant model as shown in figure 2 and then a feedback gain matrix defined is used for controlling the plant.

IV. RESULTS

Figure 3 indicates the typical response of the plant modeled in equation 1 of the three story building controlled with a LQR controller for a delay of 0.4 seconds and figure 4 indicates for a delay of 4 seconds. The variation of delay in 0.4 seconds cycle shows that the memory less controller will not cause much variation in the transients observed over 10 step duration. This possibly being because of the lack of variation of Q and R matrices which are static and which will not vary causing the system to respond similarly for all the test cases.

However, if the fuzzy preview control is used for evaluating the system, the states show how the plant responds to a small disturbance which could be attributed to understanding the impact of earthquake. It depicts an insight into the control strategy of such a structure. The peaks show the impact of the delayed plate displacements causing the impact on the building. This directly can be used for understanding the impact of the plant in the sense of understanding the stability margins on the impact margins causing failure of the structure. The control structure is static and shows how the integrated delays when evolved into the system would guide in deciding the impact of the structure. Figure 5 indicates the response under the impact of a wave of earthquake which possibly distorts the controlled parameters. The response noted in figure 5 indicates the level of impact and significantly helps in giving a thoughtful insight into the level of impact based on the technique.

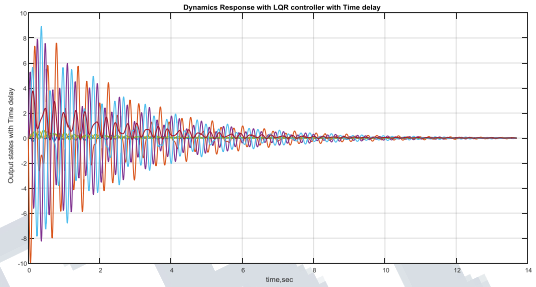

Figure 3: Dynamic response with LQR controller for the plant with delay 0.4 seconds

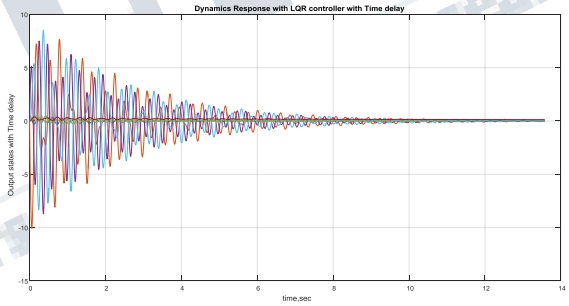

Figure 4: Dynamic response with LQR controller for the plant with delay 4 seconds

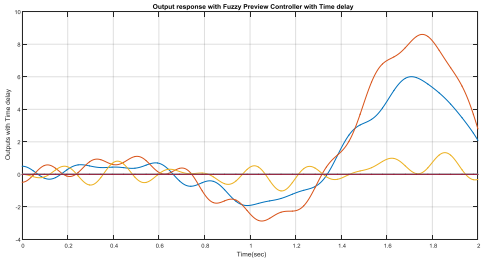

Figure 5: Response with fuzzy preview controller

Table I. Structural Earthquake Analysis

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CaseID	Impact	Damage Level
1	Normal	No significant damage
2	Normal	No significant damage
3	High	Building collapses

Table I indicates the cases drawn from figures 3, 4 & 5 respectively as cases 1,2 &3. As it can be observed the impact with a low time delay of the vibration on the building will not effect the building and cause damage to property but however if as shown in figure 5 which shatters the building and indicates the possible collapse of the building.

V. CONCLUSION

The following conclusions can be drawn from the analysis done

- Fuzzy logic controller with preview estimates the impact of the earthquake with less logical steps than classical algebraic ricatti equation solutions.
- A physical model of the proposed logic can be used for alarming the systems for possible operations for helping people.
- Earth Quake prediction feasible more efficiently with under actuated dynamic system prototype with anticipated time delays integrated into the system matrix.
- The studies help in doing a preventive analysis of structures subject to vibrations
- Safety and management of structural safety can be better analyzed to certain extent by doing this analysis.

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