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EXTENDED ABSTRACT

Studying the effect of model predictive algorithm parameters on vibration control of structures

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1. Introduction

In this research, the simultaneous effect of the prediction horizon (Np) and control horizon (Nc) parameters on the efficiency of MPC controller for the structure equipped with MR damper is studied. The model structures are two three- and five-story shear frames equipped with MR dampers that have been subjected to earthquake excitation (Xu and Li, 2011). In the control process, in order to check the effect of the parameters, first the states and control force weight matrices have been adjusted and then the combined effect of the Np and Nc has been investigated. The results of the simulations show that choosing the value of the Np as Np$\simeq(10\times\mathrm{DOF})\pm 10$ and the Nc as Nc$\simeq(10\times\mathrm{DOF})$ has a better performance in terms of achieving the control goals, and choosing higher values only increases the calculations.

2. Methodology

At first stage, the formulation of the MPC is presented (Mei et al., 2004). In the following, the weight matrices of the controller are adjusted based on trial and error in the case of Np=Nc=1, and these weights are assumed to be fixed during the study. Programming is done in MATLAB software. A simple bang-bang control law is used to command the voltage to produce the required force in the MR damper (Jung et al., 2023). Next, with the aim of studying the effect of Np and Nc parameters, different values of these parameters are applied and the MPC controller is designed for different combinations of Np and Nc. The maximum values of displacement response and control force of the top floor are reported for different values of Np and Nc. The effect of the Nc is bold on the amount of control force and its effect on the response values is insignificant. For this reason, in this research, the impact of the Np has been studied first. Next, in order to check the effect of Nc values on the controller's performance, the value of Np equal to the result obtained from the previous section is adopted and by keeping the Np constant, different values of the Nc are used in the controller design.

3. Results and discussion

According to the results, for three-story structure, it can be seen that increasing the value of Np from 40 does not lead to a significant change in the responses and only increases the amount of calculation (Table 1). In the case of five-story structure, the maximum displacement response did not decrease with the increase of the prediction horizon from Np = 70, and therefore, in the five-story structure, Np = 60 seems suitable for the prediction horizon, and adopting larger values will increase the calculations (Table 2).

Table 1. The maximum responses and control force of top floor of the three-story structure for different Np and Nc.

Controller	Displacement(m)	Velocity(m/s)	Acceleration (m/s^2)	Control Force (kN)

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Uncontrolled			0.0428	0.7796	15.0548	-
MPC	Nc = 10	Np = 20	0.0204	0.3998	7.5888	1.5312
	Nc = 15	Np = 30	0.0177	0.3625	6.9635	1.8940
	Nc = 20	Np = 40	0.0158	0.3309	6.3991	1.9236
	Nc = 25	Np = 50	0.0162	0.3294	6.3468	1.9453
	Nc = 30	Np = 60	0.0158	0.3215	6.1425	1.9996
	Nc = 35	Np = 70	0.0155	0.3179	5.9472	2.0461
	Nc = 40	Np = 80	0.0153	0.3131	5.8769	2.0455

Table 2. The maximum responses and control force of top floor of the five-story structure for different Np and Nc.

Controller			Displacement(m)	Velocity(m/s)	Acceleration (m/s²)	Control Force (kN)
Uncontrolled			0.0435	0.7963	18.9390	-
MPC	Nc = 10	Np = 20	0.0256	0.4264	10.1431	4.1658
	Nc = 15	Np = 30	0.0221	0.3809	8.2847	5.5466
	Nc = 20	Np = 40	0.205	0.3772	7.8089	5.9954
	Nc = 25	Np = 50	0.0197	0.3736	7.5677	6.3179
	Nc = 30	Np = 60	0.0187	0.3650	7.1052	6.8813
	Nc = 35	Np = 70	0.0188	0.3652	7.1235	6.8649
	Nc = 40	Np = 80	0.0187	0.3642	7.0759	6.9557

Table 3. The maximum responses and control force of top floor of the three-story structure for different Nc.

Controller			Displacement(m)	Velocity(m/s)	Acceleration (m/s²)	Control Force (kN)
Uncontrolled			0.0428	0.7796	15.0548	-
MPC	Nc = 10	Np = 40	0.0153	0.3249	6.3002	1.9813
	Nc = 15	Np = 40	0.0153	0.3257	6.3244	1.9696
	Nc = 20	Np = 40	0.0158	0.3309	6.3991	1.9236
	Nc = 25	Np = 40	0.0163	0.3370	6.4812	1.8968
	Nc = 30	Np = 40	0.0165	0.3397	6.5138	1.8925
	Nc = 35	Np = 40	0.0165	0.3402	6.5191	1.8930

Table 4. The maximum responses and control force of top floor of the five-story structure for different Nc.

Controller			Displacement(m)	Velocity(m/s)	Acceleration (m/s²)	Control Force (kN)
Uncontrolled			0.0435	0.7963	18.9390	-
MPC	Nc = 30	Np = 60	0.0187	0.3650	7.1052	6.8813
	Nc = 35	Np = 60	0.0190	0.3671	7.2101	6.7609
	Nc = 40	Np = 60	0.0190	0.3676	7.2414	6.7350
	Nc = 45	Np = 60	0.0190	0.3677	7.2455	6.7277
	Nc = 50	Np = 60	0.0191	0.3680	7.2617	6.7079
	Nc = 55	Np = 60	0.0191	0.3681	7.2686	6.7007

Considering the desired goal, which is the simultaneous reduction of responses and control efforts, it can be stated that considering Nc=30 by achieving this goal can be the desired value for the control horizon in the design controller for three-story shear frame (Table 3). For the five-story structure, if the priority is to simultaneously reduce the dynamic response and control force, Nc = 50 seems more reasonable and appropriate than other values (Table 4). The MPC has been successful in reducing the structural response compared to the uncontrolled state. By initially adjusting the weights and keeping them constant in the process of studying the effect of the prediction and control horizon, it was observed that the selection of the Np value is about 10 times the number of dofs of the structure (with about ±10 tolerance) and the Nc is ($10 \times \mathrm{DOF}$) has a better performance in terms of achieving the control goals, and choosing higher values does not have better effect on improving the control performance and only increases the MPC calculations.

4. Conclusions

The results of this study are briefly presented below. The MPC algorithm has been successful in reducing the structural response compared to the uncontrolled state. By initially adjusting the weights and keeping them constant in the process of studying the effect of the Np and Nc, it was observed that the selection of the Np value is about 10 times the number of dofs of the structure (with about ±10 tolerance) and the Nc is ($10 \times \mathrm{DOF}$) has a better performance in terms of achieving the control goals, and choosing higher values does not have better effect on improving the control performance and only increases the amount of MPC calculations.

5. References

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