Australian National University

(Research Project)

Active Building Controller

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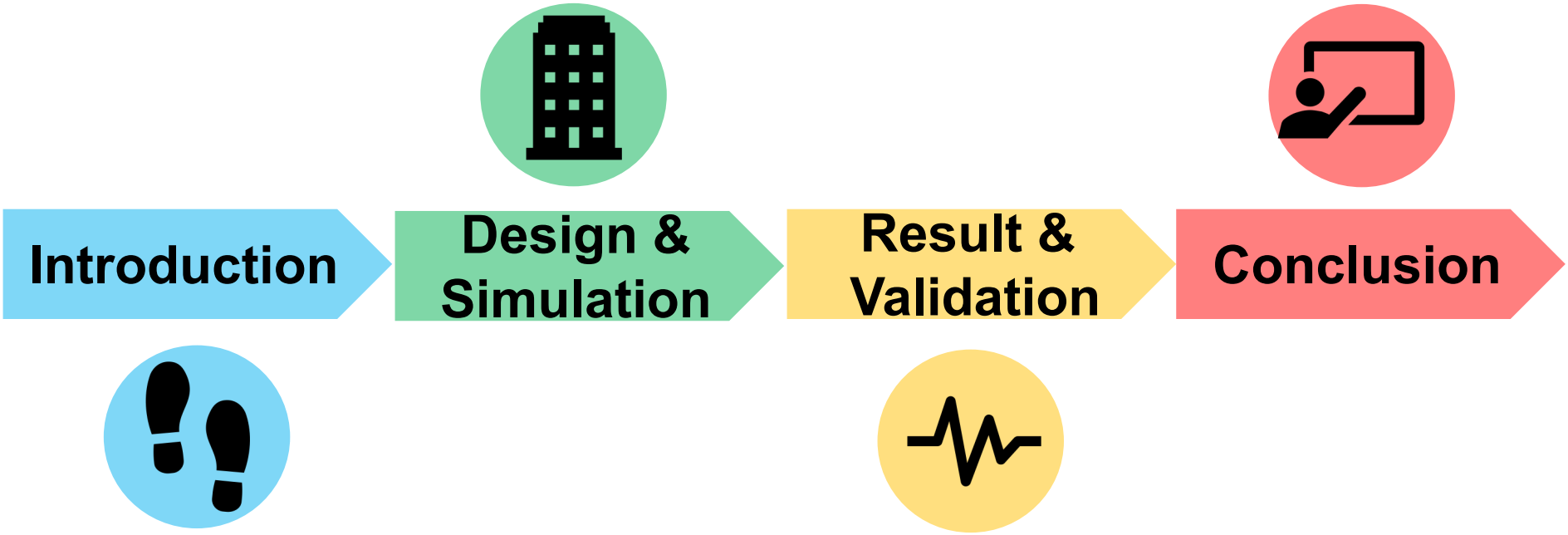
Project Flow



Project Flow

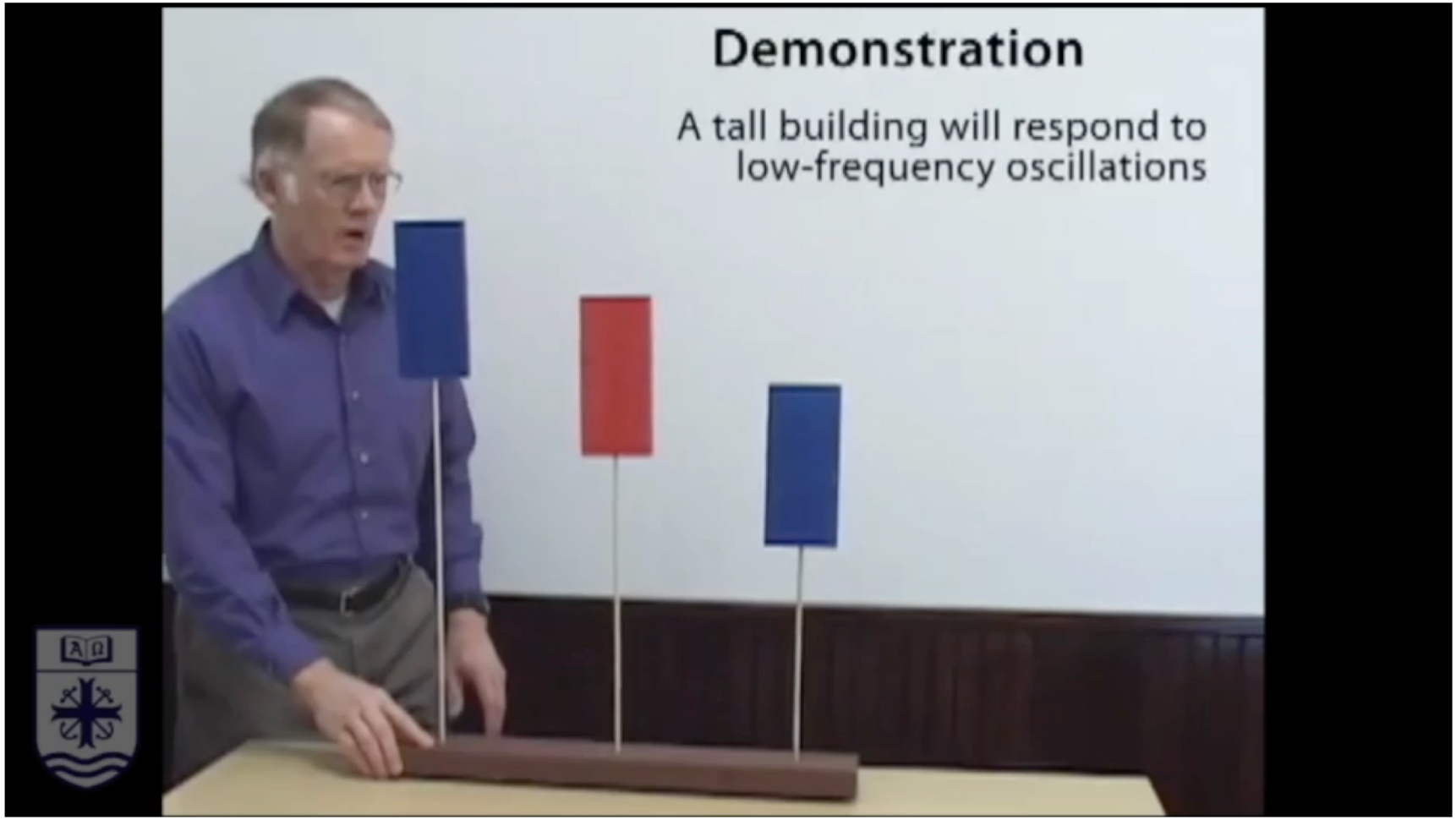
Introduction | Design & Simulation | Result & Validation | Conclusion

Background(Motivation)

Windmill Collapse

Earthquake

Background(Frequency response)



[1]: Building Resonance: Structural stability during earthquakes

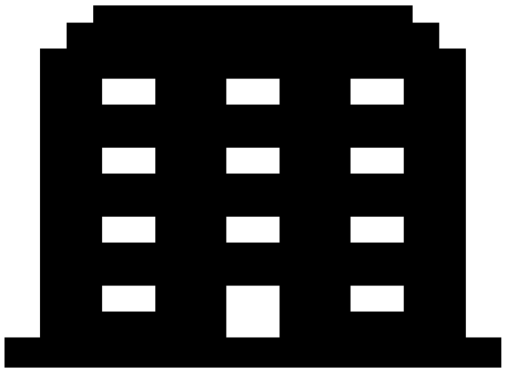
Background(Earthquake wave)

Date	Time (UT)	Location	Magnitude (USGS)	$(\delta z)_{max}$ (mm)	$(\delta f)_{max}$ (Hz)	Altitude (km) for 3.849 MHz	Altitude (km) for 4.624 Mhz
08/17/99	00:01:39	Turkey (Izmit)	$7.8 M_s$	5.5	0.5	235	240
08/20/99	10:02:21	Costa Rica	$6.9 M_s$	0.3	0.4	150	170
09/20/99	17:47:18	Taiwan (Chi-Chi)	$7.7 M_s$	1.6	0.3	168	186
09/30/99	16:31:15	Oaxaca	$7.5 M_s$	1.0	0.15	unknown	170
10/16/99	09:46:44	California	$7.4 M_s$	1.1	0.7	154	183
11/12/99	16:57:19	Turkey	$7.5 M_s$	2.8	0.4	216	221
01/28/00	14:21:07	Kuril Islands	$6.8\ M_w$	0.4	0.15	unknown	unknown
03/28/00	11:00:22	Bonin Island	$7.6\ M_s$	1.8	0.8	137	162
05/04/00	04:21:16	Sulawesi	$7.6\ M_w$	0.3	0.3	226	280
06/04/00	16:28:25	Southern Sumatera	$8.3\ M_e$	1.0	0.4	142	168
06/18/00	14:44:13	South Indian Ocean	$8.0\ M_e$	3.4	1.1	143	169
11/16/00	07:42:16	New Ireland	$7.8\ M_s$	0.9	0.5	189	N/A

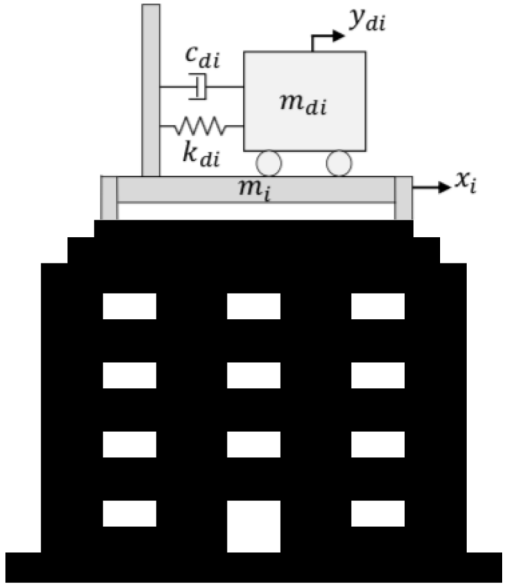
The dominant frequencies extend in surface waves from about 1 to 0.1 hertz.

[2] Artru, J., Farges, T. and Lognonné, P., 2004.

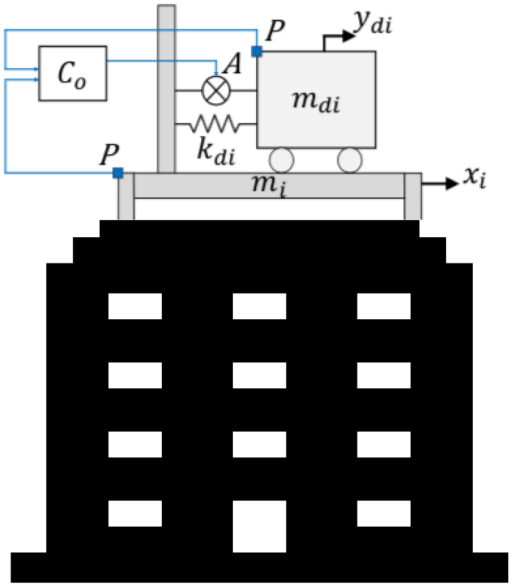
Objective



No Controller



Passive Controller

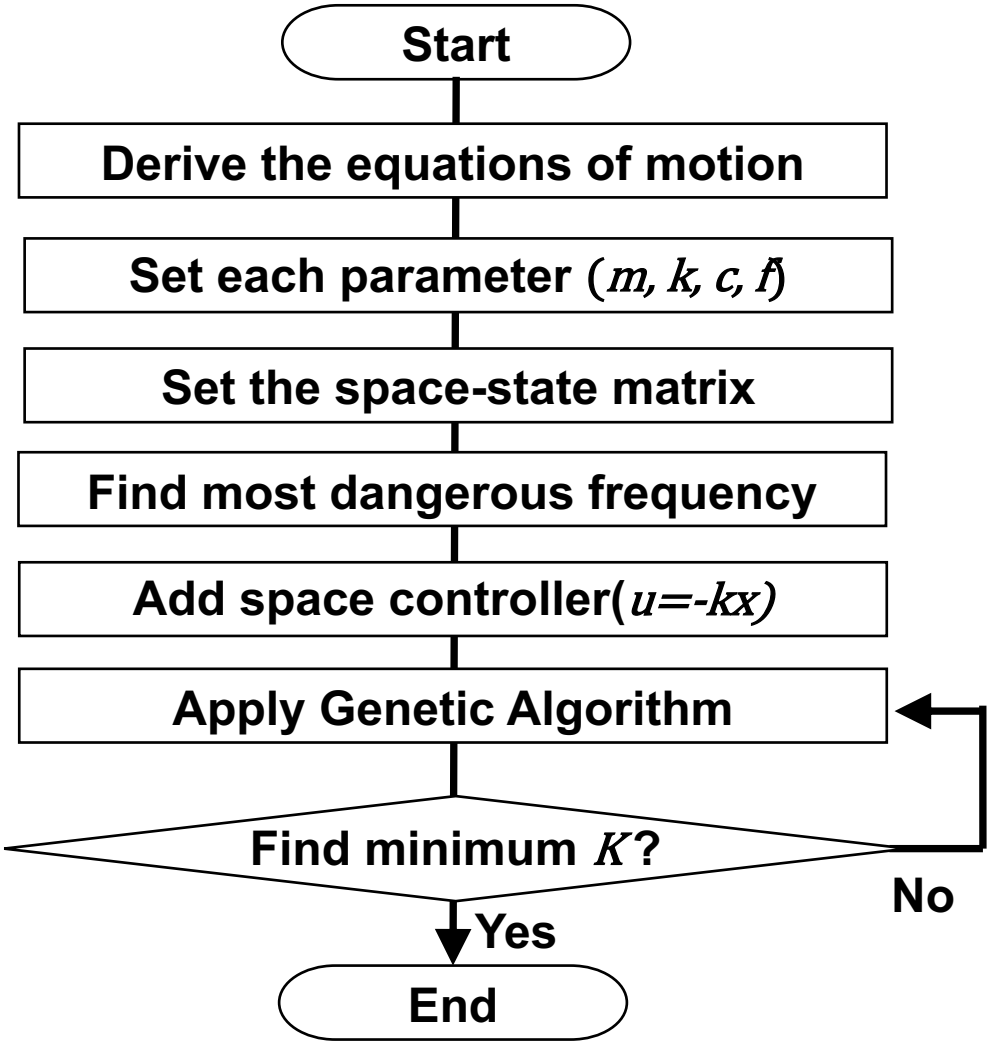


Active Controller

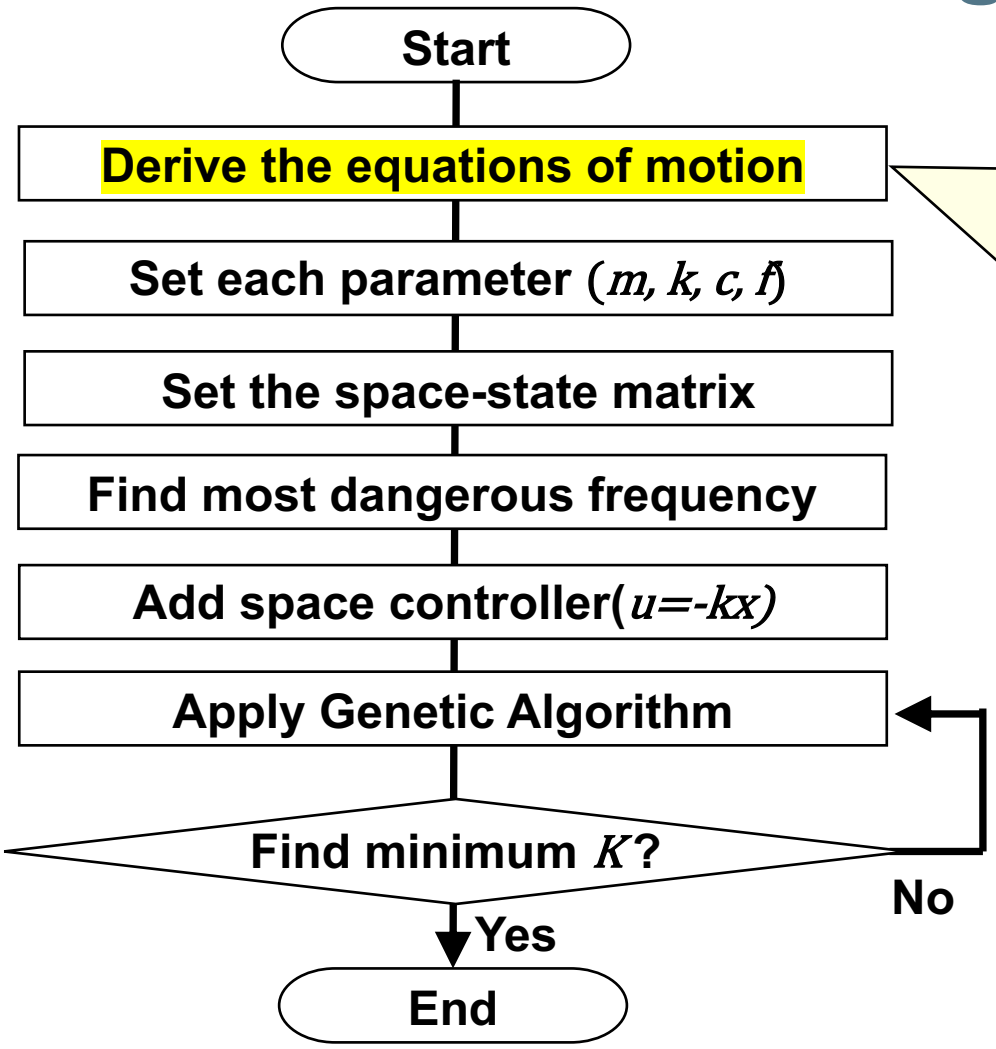
Project Flow

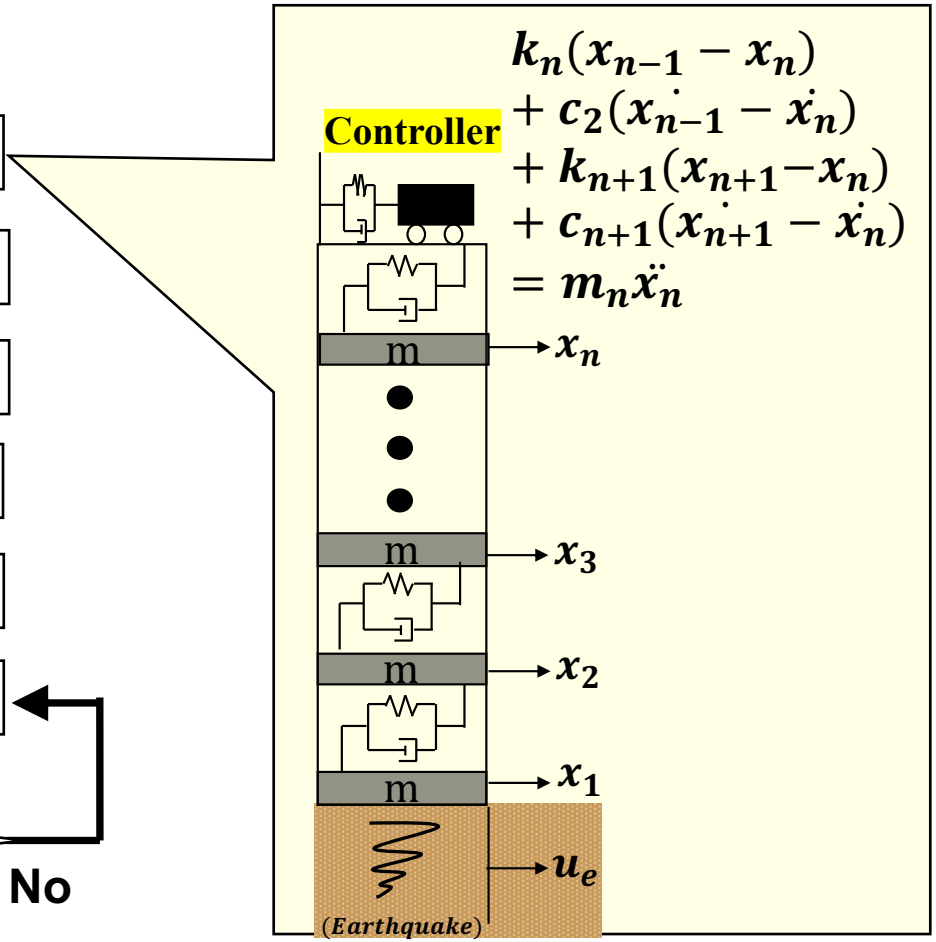
Introduction → **Design & Simulation** → Result & Validation → Conclusion

Flowchart for Design and Simulation

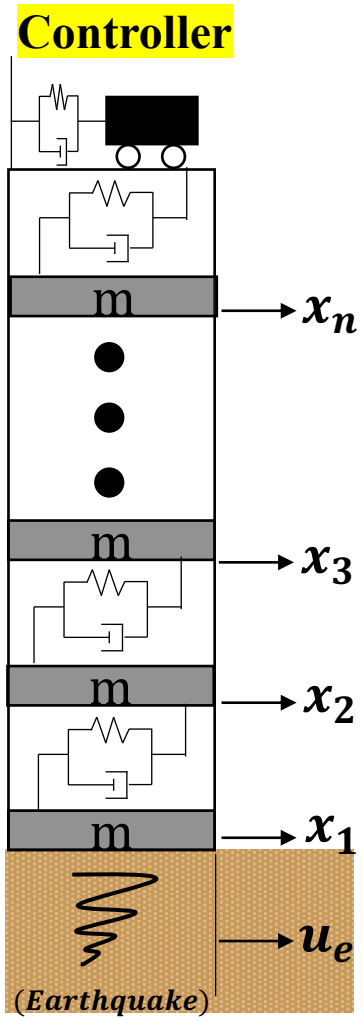


Flowchart for Design and Simulation





Dynamic Equations

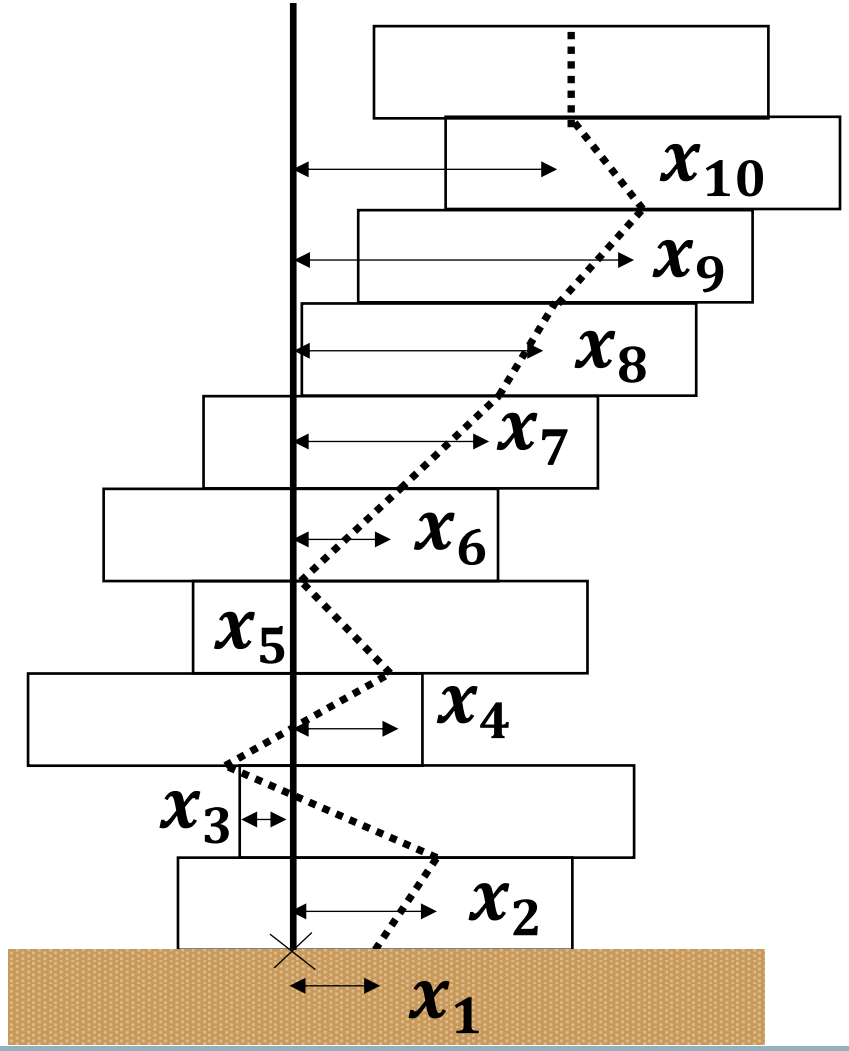


$$k_n(x_{n-1} - x_n) + c_2(\dot{x}_{n-1} - \dot{x}_n) - k_{n+1}(x_{n+1} - x_n) + c_{n+1}(\dot{x}_{n+1} - \dot{x}_n) = m_n\ddot{x}_n$$

$$k_2(x_1 - x_2) + c_2(\dot{x}_1 - \dot{x}_2) - k_3(x_2 - x_3) + c_2(\dot{x}_2 - \dot{x}_3) = m_2\ddot{x}_2$$

$$k_1(u_e - x_1) + c_1(\dot{u}_e - \dot{x}_1) - k_2(u_1 - x_2) + c_2(\dot{u}_1 - \dot{x}_2) = m_1\ddot{x}_1$$

Modelling Goal



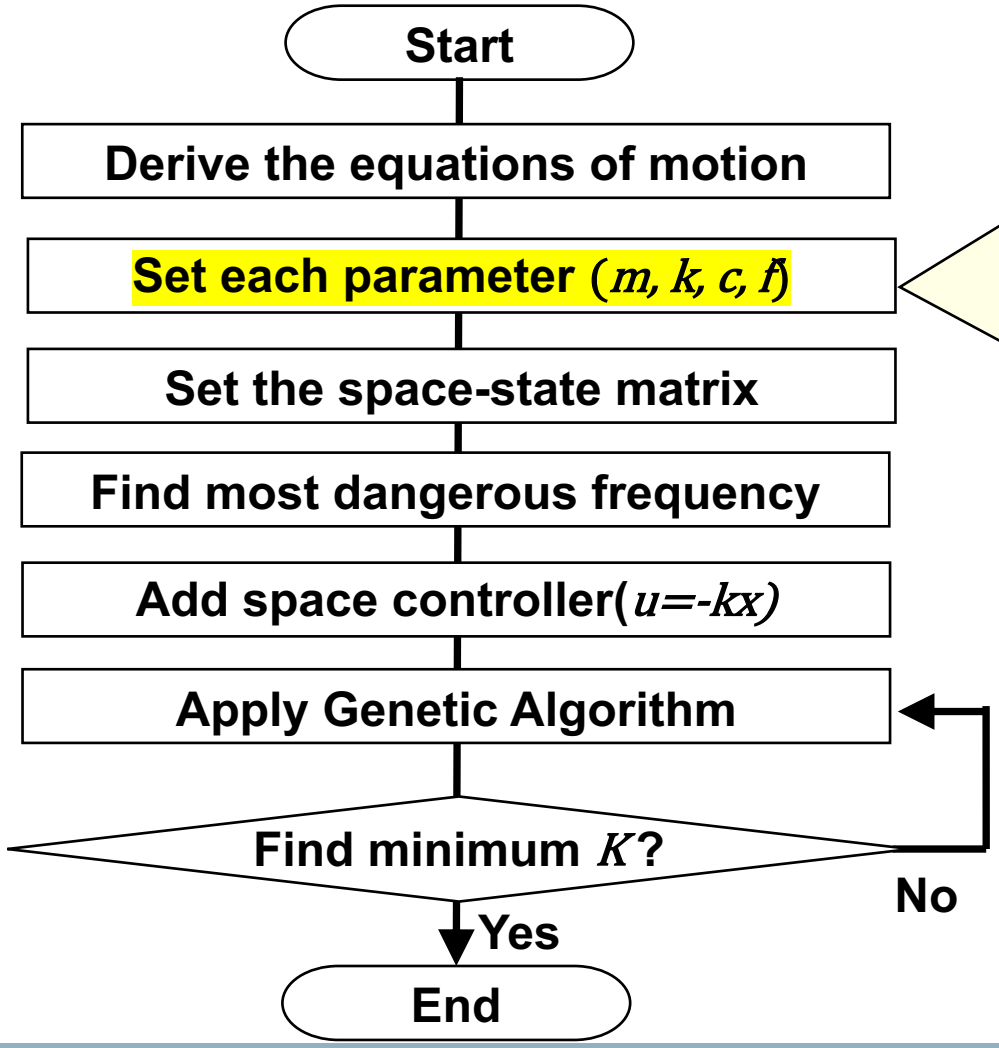
(1) Minimize

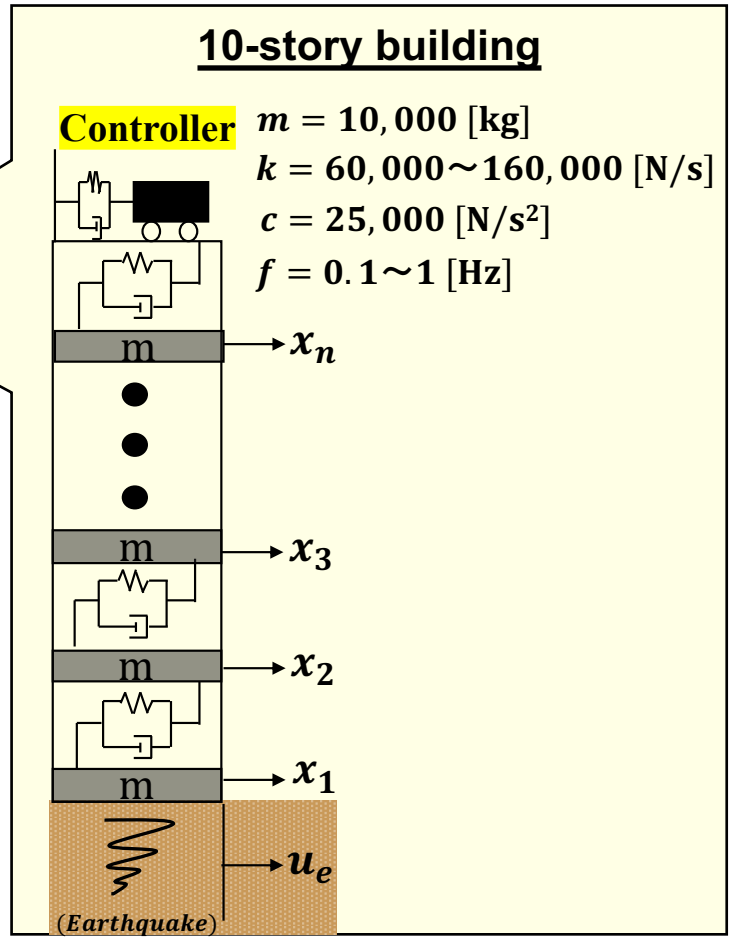
$$x_{10} - x_1$$

(2) Minimize

$$|x_2 - x_1| +$$
$$|x_3 - x_2| +$$
$$\cdots |x_{10} - x_9|$$

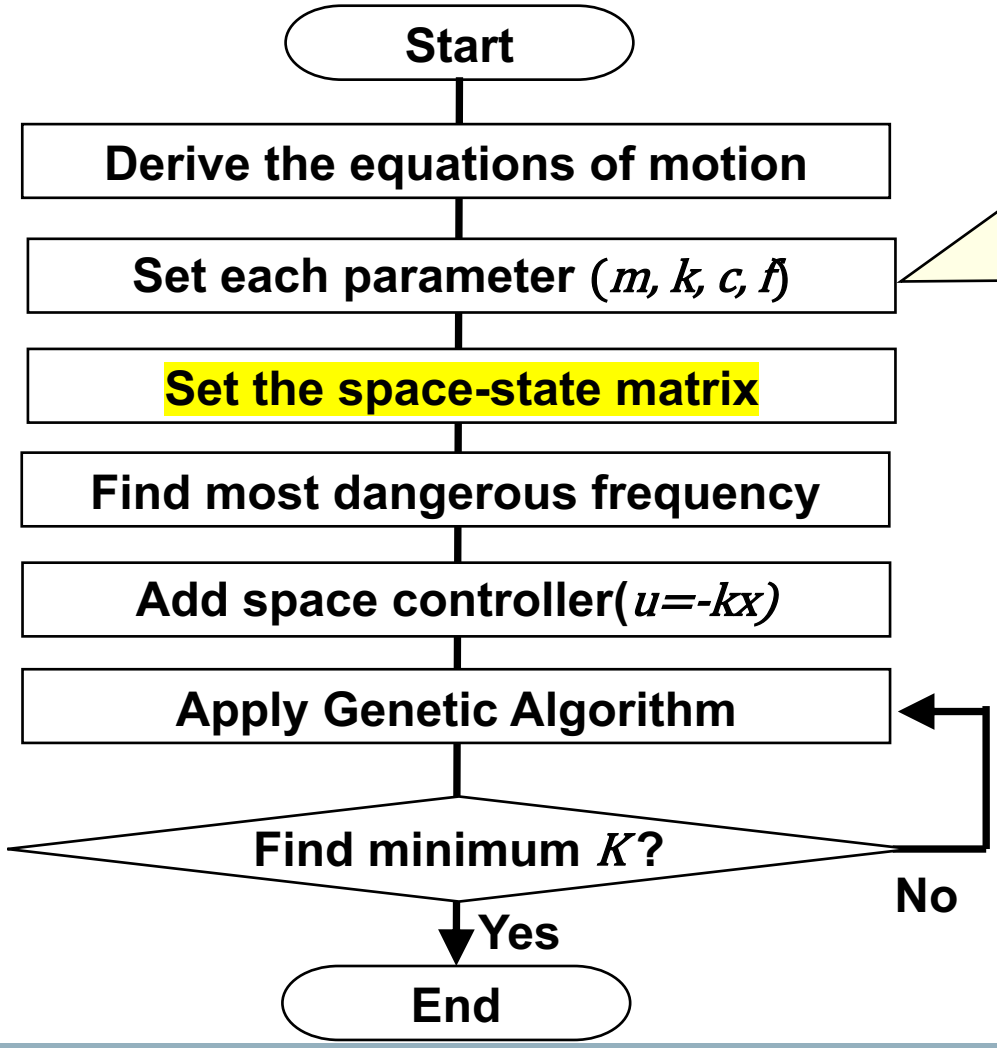
Flowchart for Design and Simulation





[3] Earthquake shaking of multistory building

Flowchart for Design and Simulation



$$\dot{x} = Ax + Bu + B_e d_e$$

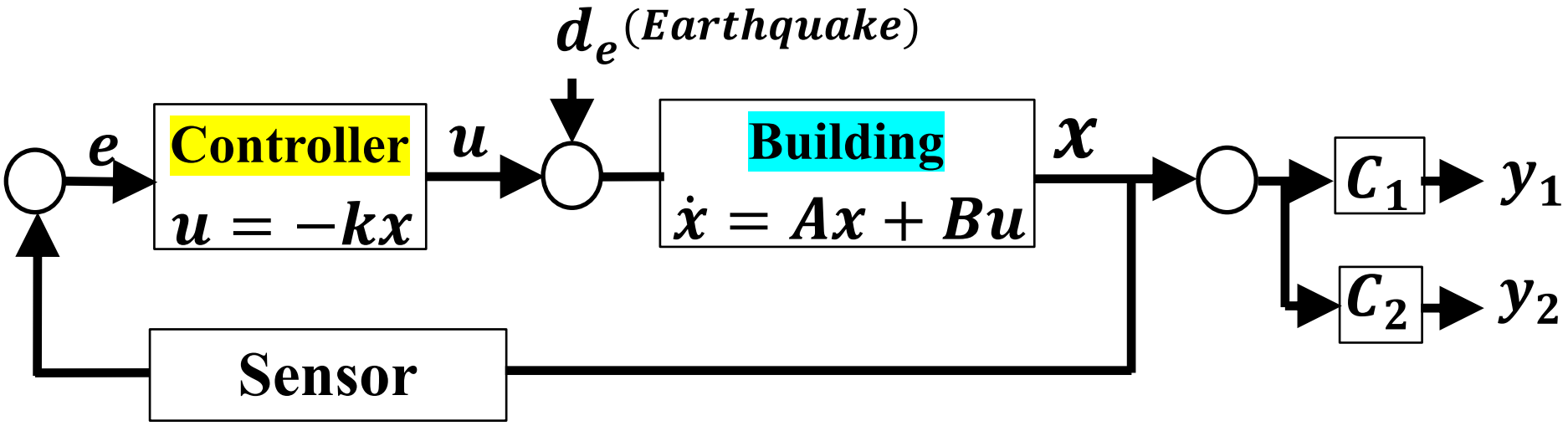
$$y_1 = C_1 x$$

$$y_2 = C_2 x$$

$$A2 = A - BK$$

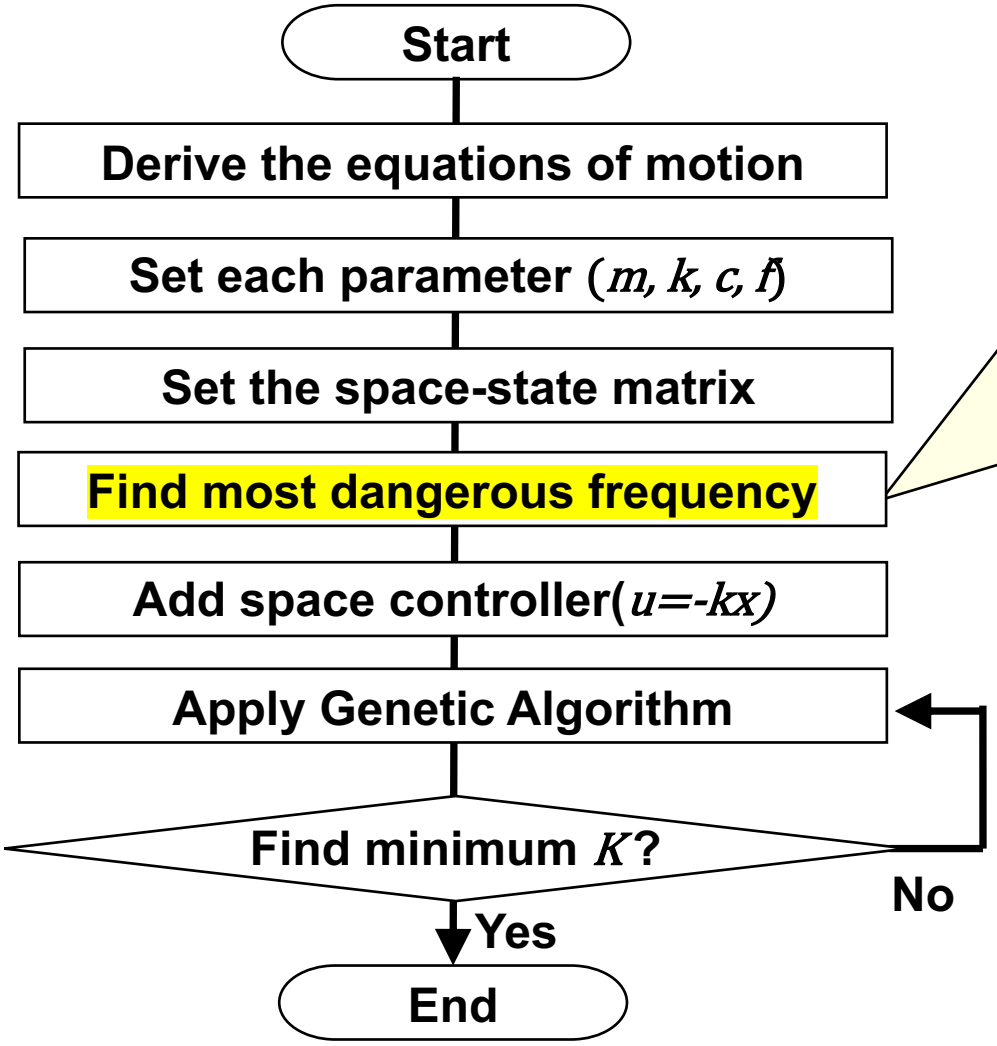
$$\dot{x} = A2x + B_e d_e$$

State Feedback Controller



$$\dot{x} = Ax + Bu + B_e d_e$$
$$y_1 = C_1 x$$
$$y_2 = C_2 x$$

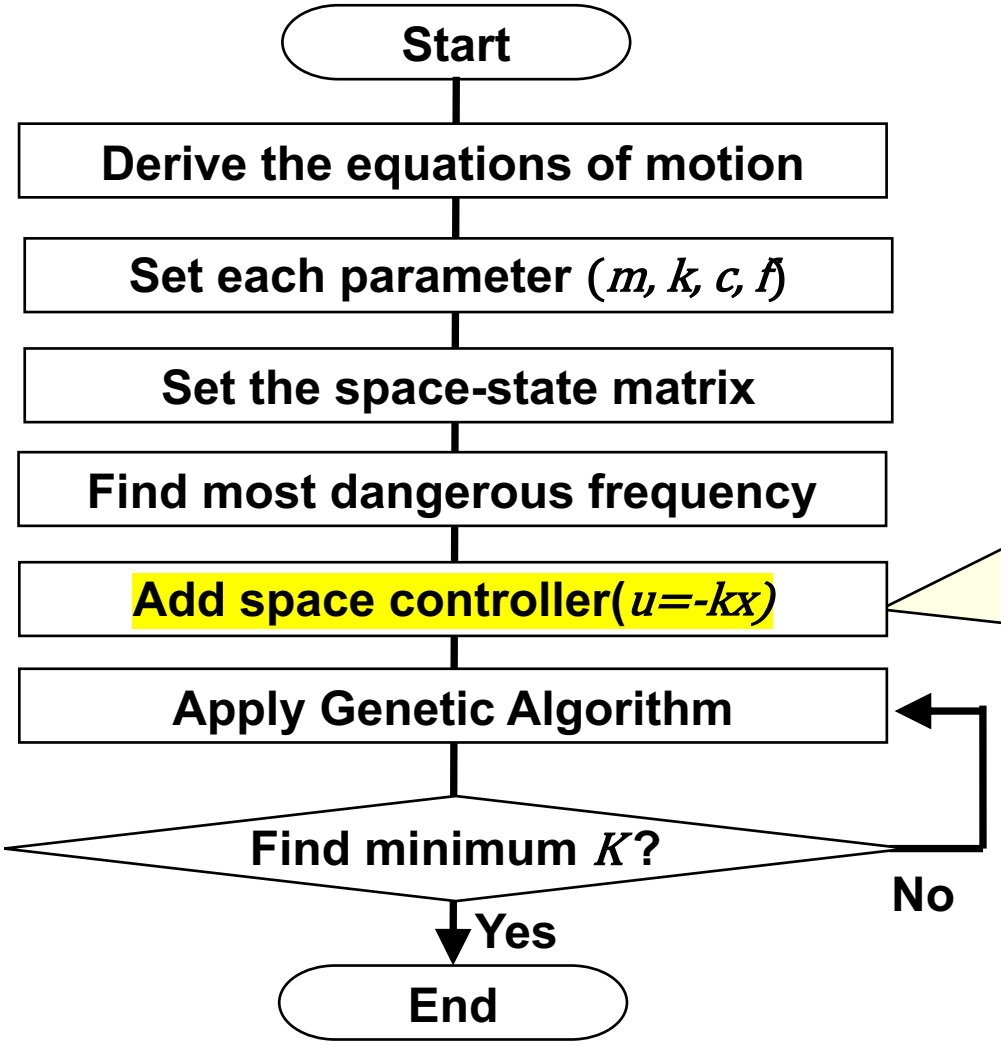
Flowchart for Design and Simulation



1. Find the range of the frequency with large amplitudes.

2. Use Genetical Algorithm to find the most dangerous frequency of two evaluation standards

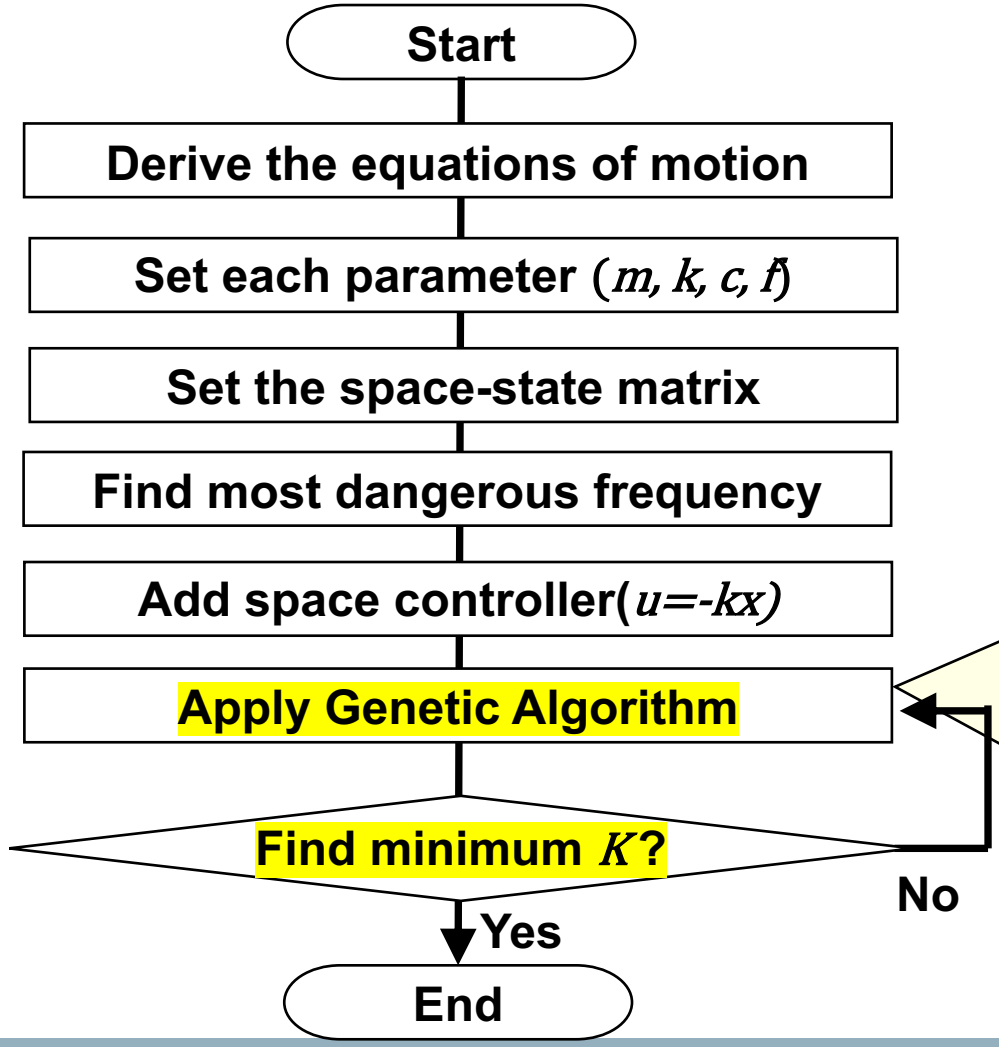
Flowchart for Design and Simulation

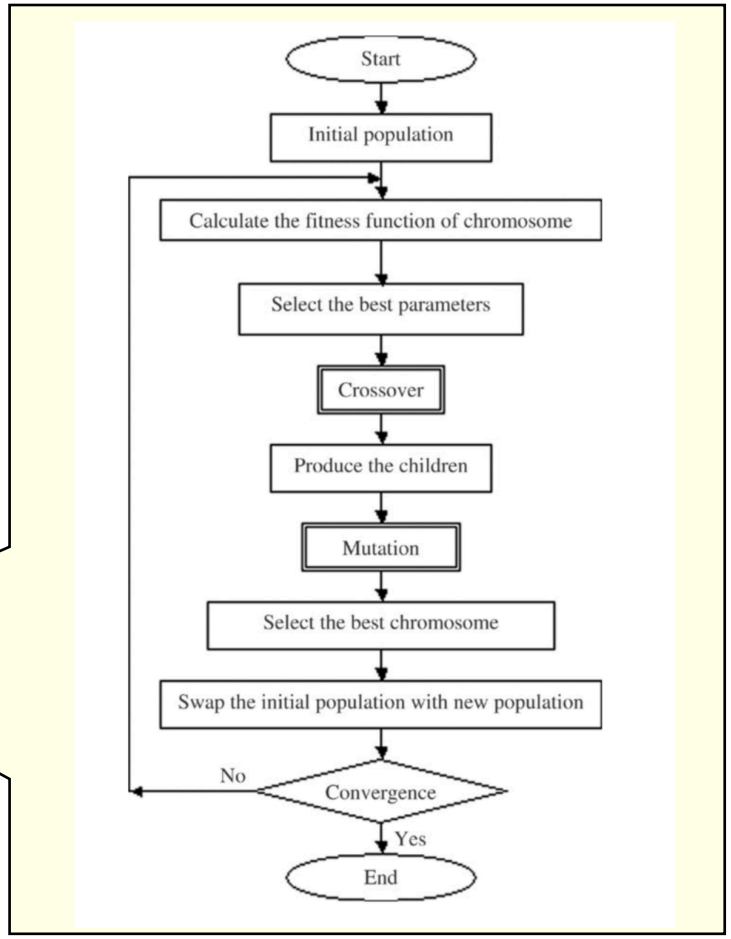


The k matrix is zero in column 1 to 16

A(20,17:20)=[K(10)/M(10),C(10)/M(10),-(K(10)+K(11))/M(10),-(C(10)+C(11))/M(10)];

Flowchart for Design and Simulation





Project Flow

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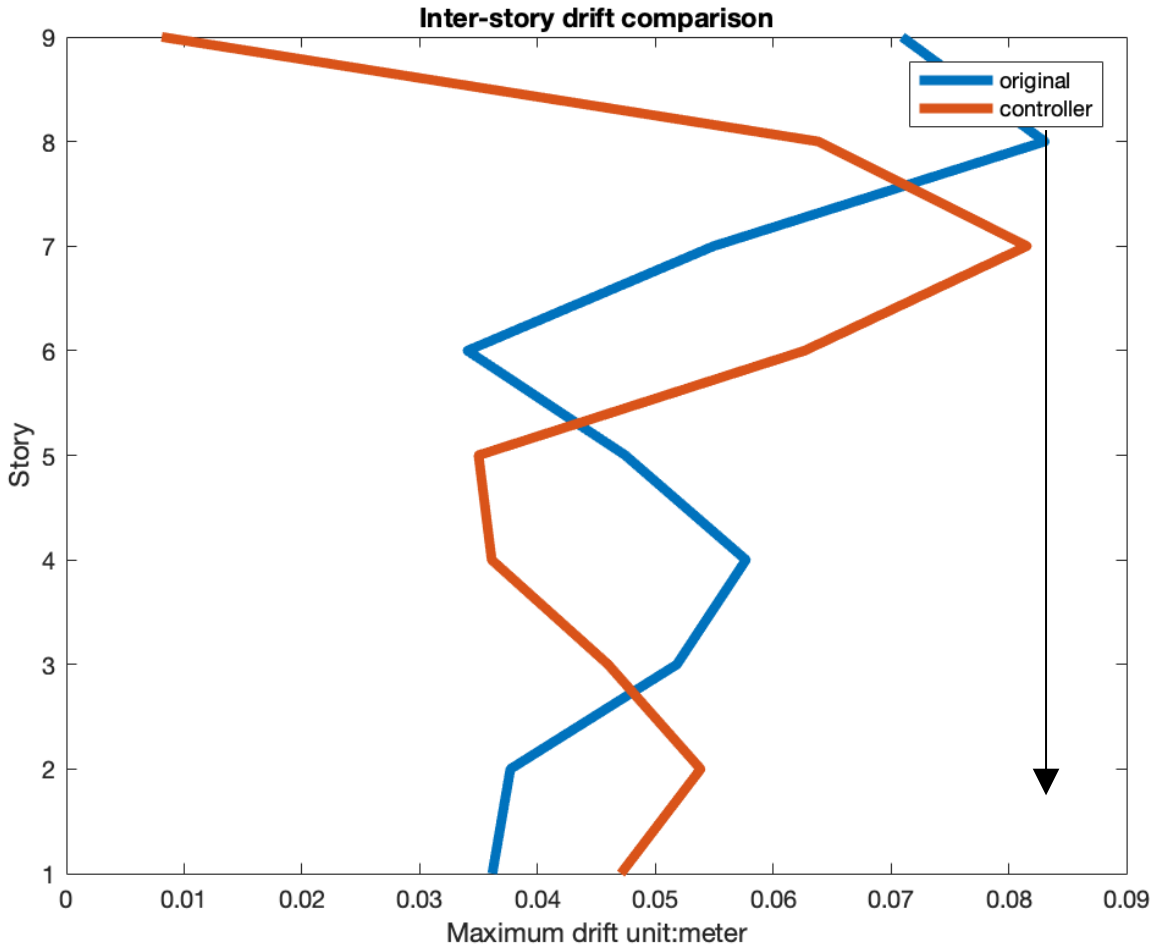
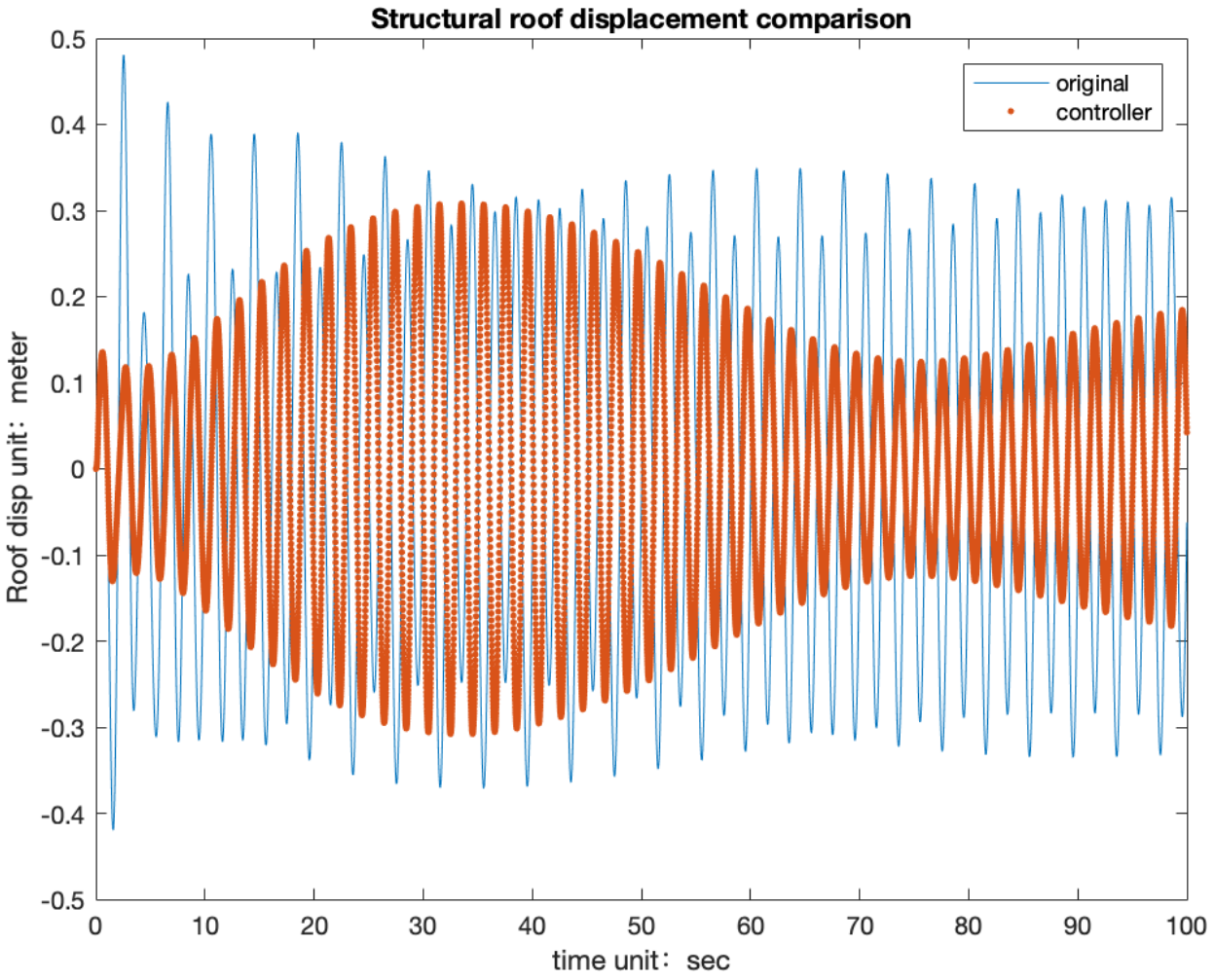
Result: Drift comparison



The total sum of drift decreases 27%

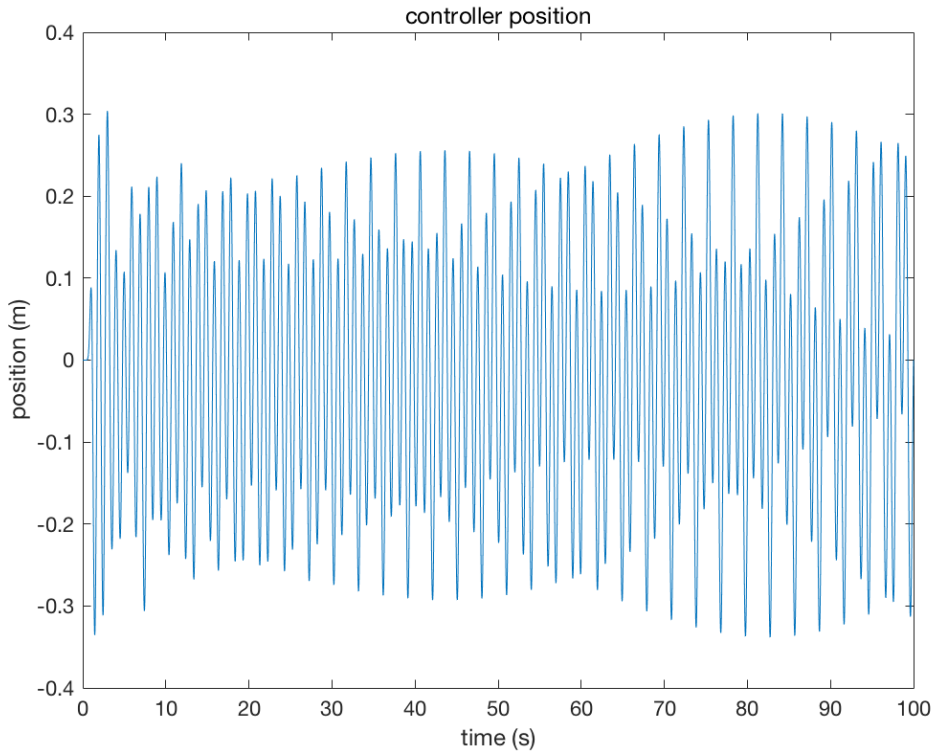
Less drift ⟷ **More drift**

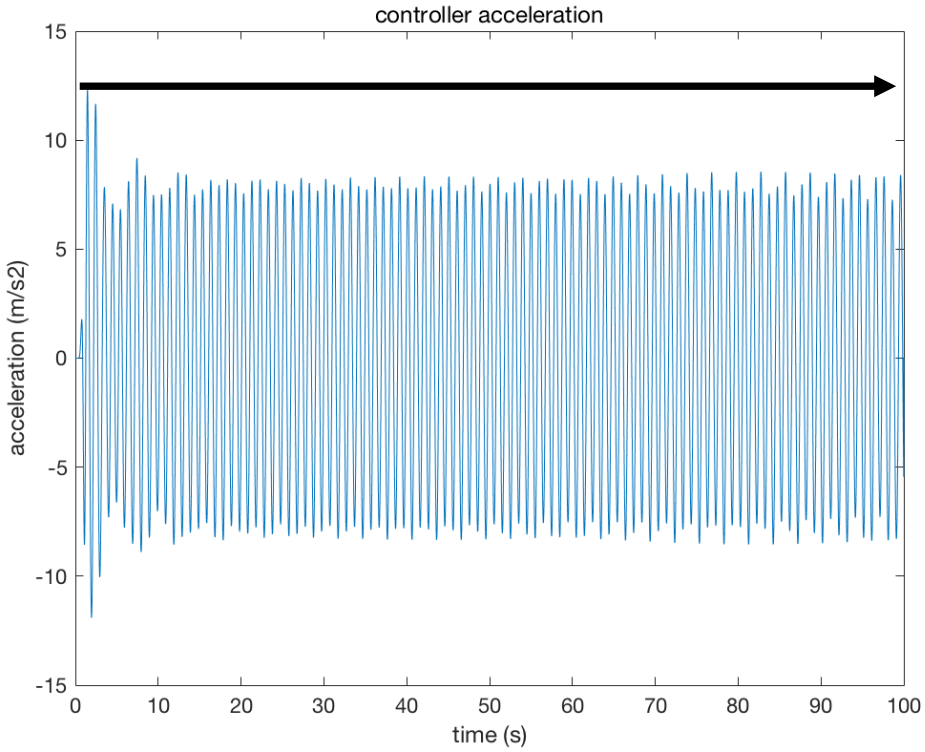
Result: Displacement(Roof)



The displacement of roof decreases 60%

Validation: Displacement for each drift

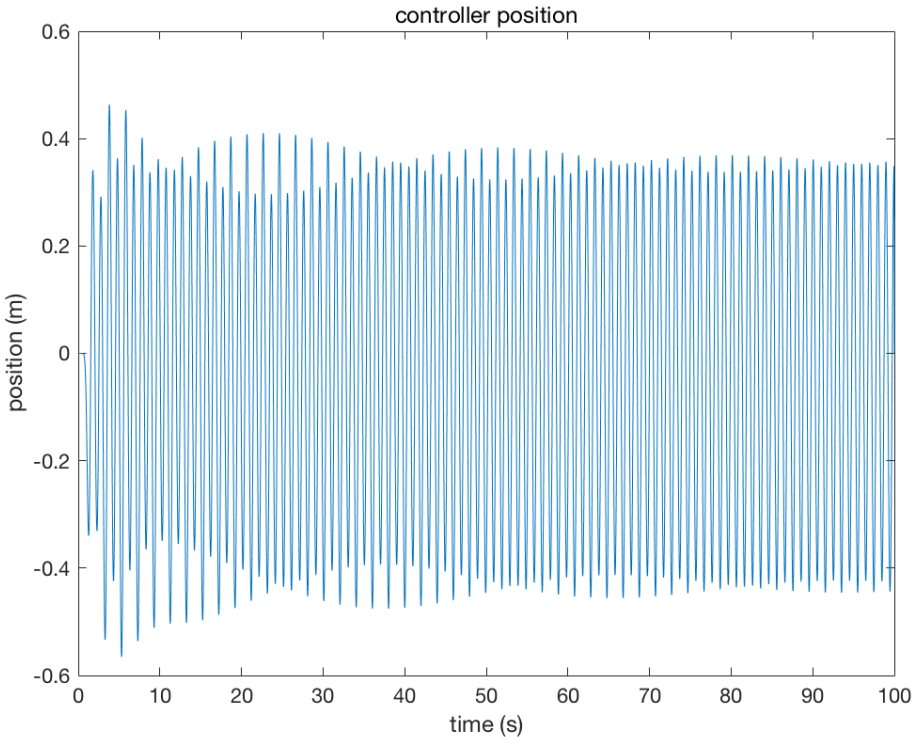


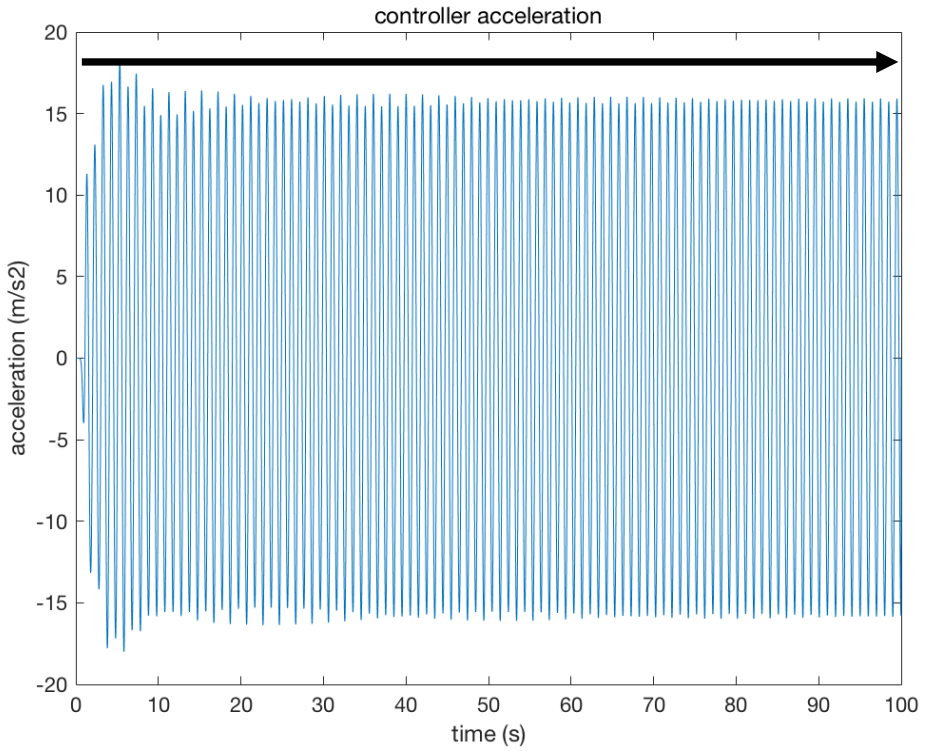


Position

Acceleration

Validation: Displacement for roof





Position

Acceleration

Project Flow

Introduction → Design & Simulation → Result & Validation → **Conclusion**

Conclusion

- **Our controller is successful, it can reduce the the oscillation of tall building effectively.**
- **Our model can respond to any frequencies while changing K gain value.**

Future work

- **Increase the robustness of the system.**
- **Try to reduce the noise from the sensors.**
- **Do cost function for application.**

References

[1] Building Resonance: Structural stability during earthquakes https://www.iris.edu/hq/inclass/animation/building_resonance_the_resonant_frequency_of_different_seismic_waves

[2] Artru, J., Farges, T. and Lognonné, P., 2004. Acoustic waves generated from seismic surface waves: Propagation properties determined from Doppler sounding observations and normal-mode modelling. *Geophysical Journal International*, *158*(3), pp.1067-1077.

[3] Earthquake shaking of multistory building https://www.cengage.com/math/book_content/0495108243_zill/projects_archive/de7e/ProjectModule3.pdf

[4] Pourzeynali, S., Lavasani, H.H. and Modarayi, A.H., 2007. Active control of high rise building structures using fuzzy logic and genetic algorithms. *Engineering Structures*, *29*(3), pp.346-357.

Any questions?