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Smart Structural Control and Health Monitoring

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Abstract

Civil infrastructures are exposed to various natural hazardous loads such as earthquakes and strong winds; these structures are also subjected to daily continuously repeated loading such as vehicles and other ambient loads. Therefore, structural damage due to these various loads is inevitable. In order to prevent structural damage due to natural hazardous loads, I have developed various smart structural control algorithms and systems in terms of passive, active, semi-active, and hybrid methods. Passive viscous dampers, base isolation systems, actuators, and magnetorheological dampers were used to configure these various control systems. Furthermore, to maximize control efficiency and minimize control cost, various multi-objective optimization methods were developed, including performance-based seismic design methods. Extensive numerical simulations and experimental tests were conducted to validate the developed methods and control devices.

Although these natural hazardous loads and daily repeated loads are well controlled using advanced and smart control systems, structural materials still gradually deteriorate due to weather and chemical reactions. Structural health monitoring (SHM) has received extensive worldwide interest from academia and industry. However, traditional structural damage detection methods suffer from unreliability due to poor damage detection performance because it is extremely difficult to extract damage-sensitive features to address various uncertainties coming from environmental effects and sensing noise. To overcome these fundamental problems, I introduced deep-learning-based damage detection methods using advanced deep convolutional neural networks. These methods received numerous follow-up studies and were applied to data-driven, physics-model-based, and computer-vision-based approaches. I also firstly developed an autonomous flight method of unmanned aerial systems for SHM to realize a fully automated SHM system. All these achievements will be presented.

Biography of Presenting Author

Young-Jin Cha received his Ph.D. (2008) from Texas A&M University in the Department of Civil and Environmental Engineering, M.S. (2004) from Yonsei University, and B. E. (2002) from Kumoh National Institute of Technology. He started as a post-doctoral fellow (2009) in the City College of New York, then he became post-doctoral associate at the Massachusetts Institute of Technology (MIT) (2012). He then joined the Department of Civil Engineering at the University of Manitoba in 2014.

He received 17 research grant totaling $1.2M from external granting agencies and industry partners such as CFI, NSERC, City of Winnipeg, and Research Manitoba. His extensive research activities in the structural health monitoring (SHM) and structural control for seismic damage reduction have led to the publication of 41 peer-reviewed, high-impact papers (average IF: 5.347) in top journals including one editorial, including *Computer-Aided Civil Infrastructure Engineering (CACIE) (impact factor (IF): 11.775, top rank 1 in Civil Engineering), IEEE Transactions on Industrial Electronics (IF: 8.236), Automation in Construction (IF: 7.7, top rank 2 in Civil Engineering), and Structural Health Monitoring (IF: 5.929)*. He has accepted/published 39 peer-reviewed, internationally recognized conference papers and delivered 73 conference presentations including five plenary speeches, 13 invited keynote speeches and one welcome speech. He also authored a book chapter that was published in the *United Nations Educational, Scientific, and Cultural Organization Encyclopedia of Life Support Systems (UNESCO)*.

His key scientific contribution is deep learning-based automated SHM with autonomous unmanned aerial vehicles (UAVs). He brought this topic to light with paper publications in top-ranking journals. Researchers, professors including scientists, students, and industry professionals from many different countries have been showing strong interest in this innovative topic since 2016. According to Google Scholar, he has received 4,775 citations, 1377 of which were received during the last year 2021 (retrieved on March 19, 2022). He was reported as top 0.45% and 0.65% cited scientist within Civil Engineering field and top 2% cited scientist in all areas for single year impact in the world in 2020 and 2021 from the Mendeley metadata of citations analyzed by Elsevier and coordinated by Stanford University. He has been reported more than serval hundred times as the most read author, most read research items, and citations in the Civil Engineering Dept. at U of M, with more than 97,000 readings since his account on www.researchgate.net was opened (retrieved on March 19, 2022).

He was named to 2005 Who's Who in America,' organized many symposiums in the MIT and Caltech through *Engineering Mechanics Institute* Conferences with the topics of Deep Learning and Autonomous UAVs for SHM. He is serving as an Associate Editor in *Engineering Report*, *Wiley* and *International Conference on Patten Recognition*, *Editorial Board Members*, and *core peer-reviewers* and in many top engineering journals associated with *ASCE, Elsevier, IEEE, and Wiley*. He is also serving and was severed as Co-Chairs and Technical/Organizing Committee members in many internal conferences in his research discipline such as AI and SHM.

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