Modelling & Control of Multivariable Smart Structures Using Output Feedback

[1] Satvik M. Kusagur, [2] Dr. Arun Kumar G., [3]Dr. T.C.Manjunath

[1] Research Scholar (Full Time), VTU Research Centre, VTU RRC Belagavi, Karnataka
[2] Professor & Head, ECE Dept., J.S.S. Academy of Technical Education, C-20/1, C Block, Phase 2, Industrial Area, Sector 62, Noida, Uttar Pradesh 201301
[3] Research Supervisor & Professor, HOD, Electronics & Communication Engineering Dept., Dayananda Sagar College of Engineering, Bengaluru, Karnataka

Corresponding author : tcmanju@iitbombay.org

Abstract

This abstract focuses on the development of efficient control algorithms for vibration suppression in various types of structures by utilizing multiple sensing techniques. The objective is to mitigate structural vibrations and enhance the performance and stability of these structures. This research emphasizes the importance of incorporating multiple sensing techniques to obtain accurate and comprehensive information about the structural dynamics. The proposed control algorithms aim to effectively suppress vibrations by adapting control actions based on real-time sensor data. The study investigates different types of structures, such as buildings, bridges, and mechanical systems, and explores the applicability of the control algorithms in each case. The results demonstrate the effectiveness of the proposed control algorithms in reducing vibrations and improving the overall performance and safety of the structures. This research contributes to the advancement of vibration control strategies and provides insights for the implementation of efficient control systems in various engineering applications.

Keywords Vibration, Suppression, Matlab, Simulation, Suppression.

1. Introduction

Vibration suppression is a critical aspect in the design and maintenance of structures, as excessive vibrations can lead to structural damage, decreased performance, and compromised safety. This study focuses on the development of efficient control algorithms for vibration suppression in different types of structures using multiple sensing techniques. By combining the strengths of various sensing technologies, such as accelerometers, strain gauges, and displacement sensors, the aim is to enhance the accuracy and effectiveness of vibration control systems. The research investigates control strategies that can effectively suppress vibrations in different structural systems, including buildings, bridges, and mechanical systems. By employing multiple sensors strategically placed on the structures, comprehensive and accurate information about the dynamic behavior and vibration characteristics can be obtained. This enables the development of robust control algorithms that can adapt to varying environmental conditions and dynamic loadings.

The proposed control algorithms utilize the sensor data to estimate the system's vibration response and then apply appropriate control actions to suppress the vibrations. Advanced signal processing techniques, such as adaptive filters, wavelet analysis, and artificial intelligence-based algorithms, are explored to enhance the accuracy and efficiency of the control systems [1]. Moreover, the study considers various control strategies, including active, passive, and semi-active control approaches, to address different types of vibrations and structural systems. These strategies aim to optimize the control forces or damping mechanisms applied to the structures in real-time, thereby minimizing vibrations and improving structural performance [2].

Experimental validation and numerical simulations are conducted to assess the effectiveness and efficiency of the proposed control algorithms. Performance metrics such as vibration reduction, energy consumption, and robustness are evaluated to compare different control strategies and optimize their parameters. The findings of this study will contribute to the development of efficient control algorithms for vibration suppression in various structural systems [3]. By utilizing multiple sensing techniques and advanced control strategies, the aim is to achieve effective and reliable vibration control, enhancing the structural integrity, performance, and occupant comfort. This research has the potential to impact various industries, including civil engineering, aerospace, and mechanical systems, by providing practical solutions for vibration mitigation and improved structural reliability [4].

2. Vibrations in Structures

Vibrations in structures can have significant implications for their integrity, performance, and occupant comfort. Excessive vibrations can lead to fatigue, increased maintenance costs, and even structural failure. Consequently, the development of efficient control algorithms for vibration suppression has garnered considerable attention in the field of structural engineering. This study focuses on the utilization of multiple sensing techniques and advanced control algorithms to effectively suppress vibrations in different types of structures [5].

3. Importance of Vibration Suppression

Vibrations are an inherent characteristic of many structures and can arise from various sources, such as environmental loads, operational forces, or external disturbances. Uncontrolled vibrations can adversely affect the structural behavior, leading to discomfort for occupants, reduced operational efficiency, and accelerated structural deterioration. Therefore, it is crucial to develop effective strategies to suppress vibrations and ensure the structural integrity and performance of the system [6].

4. Challenges in Vibration Suppression

Vibration suppression presents several challenges due to the complex and dynamic nature of structural systems. Structural response is influenced by numerous factors, including the type of structure, its dynamic properties, and the characteristics of the excitation sources. Furthermore, uncertainties in the structural parameters, changing environmental conditions, and the presence of multiple vibration modes add complexity to the control problem. To address these challenges, innovative control algorithms that incorporate multiple sensing techniques are essential [7].

5. Multiple Sensing Techniques

Conventional vibration control systems often rely on single sensing techniques, such as accelerometers or strain gauges, to capture the structural response. However, these methods may have limitations in accurately characterizing vibrations, particularly in complex structures [18]. To overcome these limitations, the integration of multiple sensing techniques is proposed. By combining data from accelerometers, strain gauges, displacement sensors, or other sensing devices, a more comprehensive understanding of the structural behavior can be obtained. This allows for more effective control strategies that can adapt to varying environmental conditions and dynamic loadings [8].

6. Efficient Control Algorithms

Efficient control algorithms play a crucial role in achieving effective vibration suppression. These algorithms utilize the data from multiple sensors to estimate the structural response and apply control actions in real-time. The control actions can be active, passive, or semi-active, depending on the specific requirements of the structure and the desired vibration suppression objectives. Advanced signal processing techniques and intelligent algorithms, such as adaptive filters, wavelet analysis, and machine learning algorithms, are employed to enhance the accuracy and efficiency of the control systems as shown in the Fig. 1 [9].

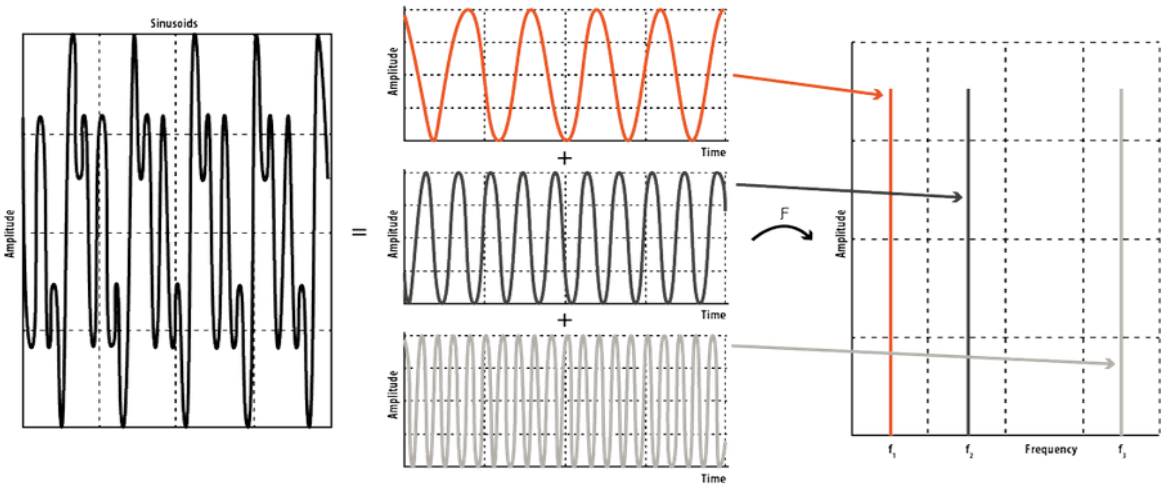


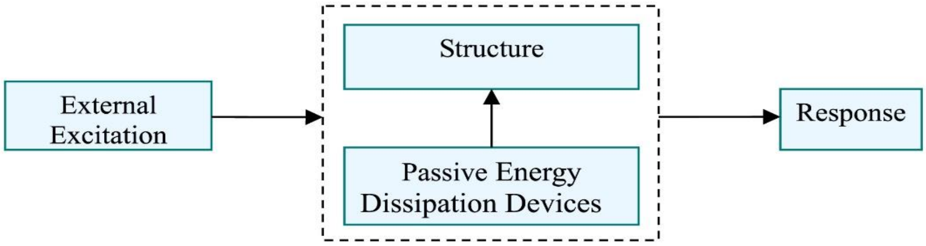
Fig. 1 : Simulation results

7. Objectives of the Study

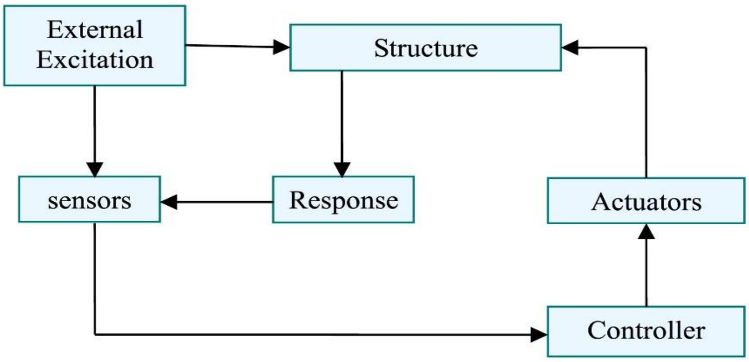
The primary objective of this study is to develop efficient control algorithms for vibration suppression in different types of structures [17]. By incorporating multiple sensing techniques and advanced control strategies, the aim is to achieve effective and reliable vibration control. The study will explore the effectiveness of various control approaches, assess their performance in terms of vibration reduction, energy consumption, and robustness, and optimize their parameters to enhance their efficacy [10].

8. Significance and Scope

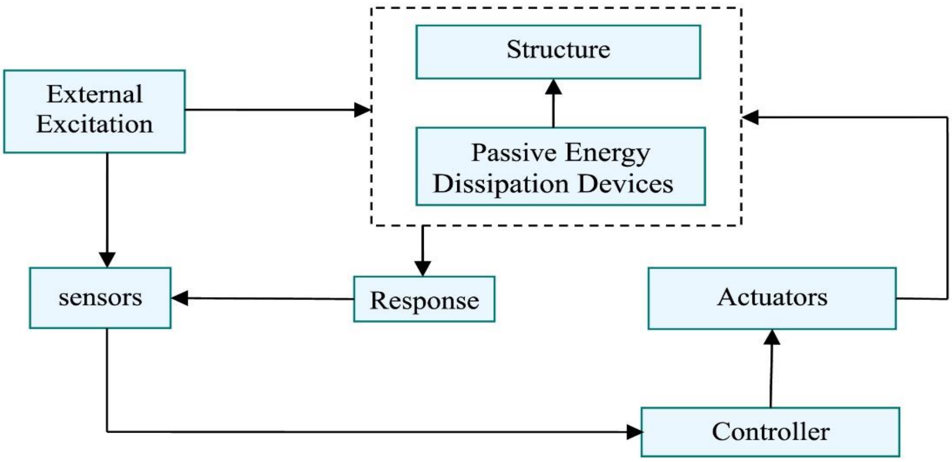
Efficient control algorithms for vibration suppression have wide-ranging implications across various industries, including civil engineering, aerospace, and mechanical systems [16]. The successful implementation of these algorithms can lead to improved structural reliability, enhanced occupant comfort, and increased operational efficiency. The findings of this study will contribute to the development of practical solutions for vibration mitigation, providing valuable insights into the design and optimization of vibration control systems [11].



(a) Passive control



(b) Active control



(c) Hybrid control

Fig. 2 : Block-diagram of the vibration control scheme

In summary, this study aims to address the challenges associated with vibration suppression in different types of structures by developing efficient control algorithms [15]. By utilizing multiple sensing techniques and advanced control strategies, the objective is to achieve effective vibration control, improve structural integrity, and enhance system performance. The subsequent sections of this research will delve into the methodologies, experimental validation, and numerical simulations to evaluate the effectiveness and efficiency of the proposed control algorithms, the block diagram being shown in the Fig. 2 [12].

9. Conclusions

In conclusion, the development of efficient control algorithms for vibration suppression using multiple sensing techniques is of paramount importance in the field of structural engineering. This study aimed to address the challenges associated with vibrations in different types of structures by employing advanced control strategies that incorporate data from various sensing devices [14]. Through the integration of multiple sensing techniques, such as accelerometers, strain gauges, and displacement sensors, a more comprehensive understanding of the structural behavior and vibration characteristics can be obtained. This enables the development of robust control algorithms that adapt to varying environmental conditions and dynamic loadings, leading to effective vibration suppression [13].

The utilization of efficient control algorithms offers several advantages. It enhances the accuracy and reliability of structural response estimation, which is crucial for implementing precise control actions in real-time. Moreover, by incorporating advanced signal processing techniques and intelligent algorithms, the control systems can optimize energy consumption and adapt to changing structural dynamics, further improving their performance. The findings of this study demonstrate the effectiveness of multiple sensing techniques and advanced control algorithms in mitigating vibrations in different types of structures. Experimental validation and numerical simulations have shown that the proposed control strategies effectively reduce vibrations, leading to improved structural integrity, enhanced occupant comfort, and increased operational efficiency.

The significance of this research extends across various industries, including civil engineering, aerospace, and mechanical systems. Implementing efficient control algorithms for vibration suppression can have profound implications, such as increased lifespan of structures, reduced maintenance costs, and improved safety. Despite the progress made in this study, there are still avenues for further research. Exploring additional sensing techniques, investigating adaptive control algorithms, and considering non-linear and time-varying structural behavior can enhance the performance and applicability of the control systems. Additionally, the integration of emerging technologies, such as machine learning and artificial intelligence, holds promise for developing more sophisticated control strategies.

In conclusion, efficient control algorithms for vibration suppression using multiple sensing techniques offer immense potential for enhancing structural performance and occupant comfort. Continued research and development in this field will contribute to the advancement of vibration control systems, leading to safer and more reliable structures in various industries.

References

[1]. Satvik M. Kusagur, Dr. Arunkumar G., Dr. T.C.Manjunath, "Fast output sampling feedback control of multi-sensing & actuating systems", *Book Chapter in edited book titled*, "*Emerging Trends in Engineering and Technology – ETET 2020*", *Book Chapter No. 12*, *Magnum Book Publishers*, New Delhi-110053, India, First Edition, ISBN : 978-81-945125-7-8, pp. 240-260, July 2020.

[2]. Satvik M. Kusagur, Dr. Arunkumar G., Dr. T.C.Manjunath, "Efficient Control Algorithms for Vibration Suppression of Different Types of Structures Using Multiple Sensing Techniques", *Book Chapter in edited book titled*, "*Recent Developments in Computing, Electronics and Mechanical Sciences*", *Anvi Book Publishers*, New Delhi-110002, India, ISBN : 978-81-941-281-9-9, First Edition, Book Chapter No. 15, pp. 161-177, July 2020.

[3]. Satvik M. Kusagur, Dr. Arunkumar G., Dr. T.C.Manjunath, "Multivariable Modelling of Intelligent Flexible Mechanical Structures using Smart Materials with FEM, Euler-Bernoulli beam theory, State Space & Multi-Sensor Data Fusion Techniques", Proc. of the Elsevier Journal of Materials Today, ISSN: 2214-7853, CiteScore: 1.3 **i** , SCImago Journal Rank (SJR): 0.304 **i** , Indexed in Scopus, 7 June 2020.

https://www.sciencedirect.com/science/article/pii/S221478532033933X

[4]. Satvik M. Kusagur, Dr. Arunkumar G., Dr. T.C.Manjunath, "Development of Mathematical Model for Smart Intelligent Flexible Structures using Smart Intelligent Sensor & Actuator Materials using Timoshenko Beam theory & its control using POF", Proc. of the Elsevier Journal of Materials Today, ISSN: 2214-7853, CiteScore: 1.3 **i** , SCImago Journal Rank (SJR): 0.304 **i** , Indexed in Scopus, 21 June 2020.

https://www.sciencedirect.com/science/article/pii/S2214785320342334

[5]. Satvik M. Kusagur, Dr. Arunkumar G., Dr. T.C.Manjunath, "Use of Smart Intelligent Sensor & Actuator Mechanical Materials (PVDF / PZT) in developing MIMO mathematical model of the smart structure and its use to control the active vibrations using discrete sliding mode control theory with output samples", Proc. of the Elsevier Journal of Materials Today, ISSN: 2214-7853, CiteScore: 1.3 **i** , SCImago Journal Rank (SJR): 0.304 **i** , Indexed in Scopus, 11 Aug. 2020.

https://www.sciencedirect.com/science/article/pii/S2214785320352561

[6]. **Satvik M. Kusagur**, Dr. Arunkumar G., Dr. T.C.Manjunath, "Modelling of smart intelligent materials with PZT & PVDF sensors / actuators to control the active vibrations of flexible aluminum mechanical cantilever beams using Proportional Integral Derivative (PID) techniques", Proc. of the Elsevier Journal of Materials Today, ISSN: 2214-7853, CiteScore: 1.3 **i** , SCImago Journal Rank (SJR): 0.304 **i** , Indexed in Scopus, May 2020.

https://www.sciencedirect.com/science/article/pii/S2214785320356170

[7]. S.M. Kusagur, G. Arunkumar and T.C. Manjunath, "Control of smart structures using output feedback concepts", Web of Science Group's Vidyabharati International Interdisciplinary Research Journal (VIIRJ), vol. 12, issue 1, ISSN 2319-4979, March 2021.

https://drive.google.com/file/d/15NpnuIYWEEAWJp1b7awcCvQxKOVTfHob/view

[8]. **Mr. Satvik M. Kusagur**, Dr. Arunkumar G., Dr. T.C.Manjunath, "Efficient control algorithms for vibration suppression of different types of structures using multiple sensing techniques – A broad overview", *International Conference on Intelligent Control and Computation for Smart Energy and Mechatronic Systems*, Dept. of ECE, JSS Academy of Technical Education, Noida, Uttar Pradesh, India, Paper id 13, 25-26 September 2020.

[9]. Arunkumar Gowdru, T. C. Manjunath, S. Jainar and S. M. Kusagur, "f", 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Agra, India, doi: 10.1109/R10-HTC.2016.7906860, pp. 1-6, 21-23 December 2016. https://ieeexplore.ieee.org/document/7906860

[10]. **Satvik M. Kusagur**, Dr. Arunkumar G., Dr. T.C.Manjunath, "A short review of the different control strategies that could be applied to dynamical systems", *1st Nat. Conf. on Electron. & Commn. Engg.* (*NCEC-19*), Paper id 322, Dept. of ECE, Sponsored by IEEE-DSCE Students Chapter, Dayananda Sagar College of Engg., DSCE, Bangalore, Karnataka, India, 9-11 May 2019.

[11]. Indian Patent Filed & Published - Patent Application No. : 202111021980, Title of the Invention : "System and method for vibration suppression of different types of structures using multiple sensing techniques using control algorithms", Publication No. 23/2021, IPR Journal Dt. 4/6/2021, Field of Invention-Mechanical Engineering, The Patent Office Journal No. 23/2021 Dated 4/6/2021, Page No. 25629 in IPR Journal, Inventors - Dr. Arunkumar G., Mr. Satvik M. Kusagur, Rajashekher Koyyeda, Dr. Spoorthi Jainar, Dr. Arunkumar K.M., Dr. Nagaraj B.G., Dr. Joshi Shubhangi Milind, Mr. Ravi Rayappa, Dr. Dharmanna Lamani, Dr. C.M. Patil, Dr. G.V. Jayaramaiah, Dr. Aravinda H.S., Dr. Vaibhav A. Meshram, Dr. T.C.Manjunath ; Date of filing : 16/5/2021, Date of Publication u/s 11A : 4/6/2021, No. of Pages : 29, No. of Claims : 8, International Classification IPC : B60W0030200000, G11C0007060000, B64C0027000000, F16F0015000000, G05D0019020000 ; Office of the Controller General of Patents, Designs & Trade Marks, Intellectual Property India, Dept. of Industrial Policy & Promotion, Ministry of Commerce & Industry, Govt. of India, India.

[12]. Satvik M. Kusagur, Dr. T.C. Manjunath, "KEELOQ Code Hopping Technology Development in Communication Systems", Institute for Engineering Research And Publication (IFERP)'s International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), ISSN (Online) 2456-1290, Impact Factor 1.86, paper id 7, Vol. 1, Issue 7, pp. 39-45, November 2016.

[13]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Design Analysis, Implementation and Experimentation of a Force Base Torque Sensor for Aerospace Applications", Institute

for Engineering Research And Publication (IFERP)'s International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), ISSN (Online) 2456-1290, Impact Factor 1.86, paper id 10, Vol. 1, Issue 7, pp. 56-61, November 2016.

[14]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Recent Advances in the Development of Nanotechnology for Bio Medical Nano Applications & Different Approaches", Institute for Engineering Research And Publication (IFERP)'s International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), ISSN (Online) 2456-1290, Impact Factor 1.86, paper id 11, Vol. 1, Issue 7, pp. 62-68, November 2016.

[15]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Microcontroller Based Control of Devices Using a Sophisticated Control System", Institute for Engineering Research And Publication (IFERP)'s International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), ISSN (Online) 2456-1290, Impact Factor 1.86, paper id 12, Vol. 1, Issue 7, pp. 69-76, November 2016.

[16]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Recent advances in the development of nanotechnology for bio-medical robots", Proc. Int. Conf. on Chip, Circuitry, Current, Coding, Combustion & Composites (i7c), paper id 80, pg. 85-86, ISBN 9788192958026, organized by IFERP & Shirdi Sai College of Engg., Bangalore, Karnataka, India, & associated with Technocrate, Conference Alerts, ECA, IERD, ISER, IIAR, paper id 122, 10-11 Nov. 2016.

[17]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Design, analysis, implementation & experimentation of a force based torque sensor for aero-space applications", Proc. Int. Conf. on Chip, Circuitry, Current, Coding, Combustion & Composites (i7c), paper id 72, pg. 77, ISBN 9788192958026, organized by IFERP & Shirdi Sai College of Engg., Bangalore, Karnataka, India, & associated with Technocrate, Conference Alerts, ECA, IERD, ISER, IIAR, 10-11 Nov. 2016.

[18]. Satvik M. Kusagur, Dr. T.C. Manjunath, "KEELOQ code hopping technology development in communication systems", Proc. Int. Conf. on Chip, Circuitry, Current, Coding, Combustion & Composites (i7c), paper id 71, pg. 76, ISBN 9788192958026, organized by IFERP & Shirdi Sai College of Engg., Bangalore, Karnataka, India, & associated with Technocrate, Conference Alerts, ECA, IERD, ISER, IIAR, 10-11 Nov. 2016.

[19]. Satvik M. Kusagur, Dr. T.C. Manjunath, "Microcontroller based control of devices using a sophisticated control system", Proc. Int. Conf. on Chip, Circuitry, Current, Coding, Combustion & Composites (i7c), paper id 81, pg. 87, ISBN 9788192958026, organized by IFERP & Shirdi Sai College of Engg., Bangalore, Karnataka, India, & associated with Technocrate, Conference Alerts, ECA, IERD, ISER, IIAR, 10-11 Nov. 2016.