

Paul Andrew Gardner - Curriculum Vitae

Dynamics Research Group
Department of Mechanical Engineering
University of Sheffield
Mappin Street, Sheffield
S1 3JD
United Kingdom

Summary

- Research Associate in the Department of Mechanical Engineering, University of Sheffield.
- PhD in Mechanical Engineering awarded 2019, MEng Mechanical Engineering (1st Class (Hons)) awarded 2015.
- Research interests include the application of statistical methods and machine learning for the improvement of physic-based modelling, verification and validation, uncertainty quantification and surrogate modelling.
- Published articles: 8 journal papers, 20 conference papers (3 peer reviewed).
- Publications pending: 9 journal papers (under review), and contribution to one book chapter (under review).

1. Personal Details

Email paulandrewgardner@gmail.com

2. Education

2015-2019	PhD, Department of Mechanical Engineering PhD studentship sponsored by EPSRC	University of Sheffield
	Topic: On Novel Approaches to Model-Based Structural Health Monitoring. Supervised by Dr. Robert J. Barthorpe	
2010-2015	MEng in Mechanical Engineering (1st Class (Hons)) With a year in industry	University of Sheffield
	Thesis Topic: Dynamic Characterisation of a Helicopter Fuselage. Supervised by Dr. Elizabeth J. Cross	

3. Employment History

2019-Present	Research Associate Dynamics Research Group, University of Sheffield 36 month research associate post as part of the DigiTwin (digital twins for improved dynamic design) EPSRC programme grant in collaboration with six universities and ten industrial partners. This role involved the development of advanced machine learning technologies and statistical techniques in generating robust verification and validation processes for digital twins.
2013-2014	Application Engineer/Software Test Engineer HBM nCode A year placement where roles included leading consultancy projects and customer training courses using DesignLife (CAE FE based fatigue software) for large aerospace and automotive OEMs in the UK and abroad, as well as delivering successful software demonstrations to a variety of engineering companies.

4. Prizes / Awards

IMechE Conference Grant

Awarded a £1000 conference grant from the IMechE to attend an international conference.

University of Sheffield Learned Society Fund

Awarded €300 to attend an international conference.

Sheffield Undergraduate Research Experience (SURE) project

Awarded £1250 to fund a research student for a six-week project.

5. Research

Research Interests

The digital revolution has seen a drive from industry and government funding bodies to develop effective tools that combine state-of-the-art data science and machine learning with advanced computer modelling techniques. The fusion of these disciplines within an engineering context provides a variety of economic and safety benefits, allowing more virtual-based analysis and predictive capabilities. My current research interests and expertise lie within these aims. I am particularly interested in integrating and improving engineering modelling techniques with statistical and machine learning methods. The technologies I have developed are broadly applicable, and I am excited to pursue applications within a rail context, which provides clear novel application areas for my expertise.

In pursuit of these research goals, I have a keen interest in a variety of cross-disciplinary research fields such as uncertainty quantification, verification and validation and machine learning. This breadth of research has allowed me to develop and adapt technologies from these fields whilst utilising engineering knowledge and modelling capabilities. As an example of this philosophy, I have developed a statistical approach - Bayesian history matching - that accounts for model-form errors and model discrepancies during calibration. Within this novel

method I have combined state-of-the-art machine learning techniques allowing the identification of the functional form of the missing model discrepancy from limited data, aiding improvements to engineering models. A further example of research approach is in the development of a transfer learning strategy for monitoring populations of engineering structures. As part of this technique I have utilised engineering modelling to enhance the effectiveness of these machine learning tools when large datasets are challenging to obtain.

My current research has demonstrated my flexibility in understanding and applying methodologies from a variety of research areas. I believe that this strength is important in developing a successful research career. I continue to improve existing methods I have developed, but am eager to expand my research to new application areas and techniques both independently and in a collaborative setting.

Relevant Research Experience

Reviewer for International Journals: I am a reviewer for Engineering Structures, Mechanical Systems and Signal Processing and the International Journal of Uncertainty Quantification.

Conference Session Chair: ASME 2018 Verification and Validation Symposium, IMAC XXXVIII 2020.

Consultancy projects: Experimental analysis in characterising dynamic properties for Metlase.

Programming Languages: MatLab, Python.

Engineering Software: ANSYS, Siemens LMS Testlab, Solidworks.

6. Teaching

Teaching Experience

Mechanical Engineering personal tutor: I am currently a first, third, and fourth year personal tutor for students on the Mechanical Engineering course at the University of Sheffield, where my role includes technical tuition as well as pastoral responsibilities.

BEng/MEng project student supervision: Assisted in the supervision of a number of final year projects on a variety of topics, including the experimental investigation and characterisation of fatigue damage, and the application of advanced machine learning techniques in overcoming singularities in finite element analysis.

Sheffield Undergraduate Research Experience (SURE) project supervision: Awarded £1250 for a six-week student research project entitled "Utilising state-of-the-art machine learning methods in analysing operational onshore wind turbine data in order to create health and financial diagnostics across populations".

Module Instructor: Designed and delivered course material for a Masters level online finite element course. I assumed sole responsibility for the teaching, assessment and feedback for the module. The role involved delivering content via face-to-face computer tutorials and dealing with individual student's queries both in person and online.

PhD level teaching: Produced and delivered material as part of a summer school programme on Verification and Validation; presented a lecture entitled: “Verification and Validation methods”.

Assisting third year course: Delivered a guest lecture on continuous systems for a module entitled ‘Structural Vibration’.

Industrial workshops: Led two industrial workshops. The first was a two-day workshop as part of my role at HBM nCode, where I delivered course material on fatigue theory and specific applications of DesignLife. The second was an industrial workshop on behalf of the Laboratory for Verification and Validation (LVV), where I generated and delivered lectures as well as laboratory activities on the topic of vibration testing.

Graduate Teaching Assistant: Performed a wide range of teaching activities including group tutorials, group project facilitation, supervision of workshop-based projects, as well as laboratory and computer-based tutorials as a demonstrator. These roles involved organising and running sessions, developing student’s knowledge through various teaching activities, providing guidance and feedback on tasks and answering technical questions on the given topics.

7. Professional Registrations

Associate Fellow of the Higher Education Academy

8. Other Relevant Experience

Responsibilities within the department

Dynamics Research Group Seminar Series: I organise a successful and well-attended seminar series with a balance of international, national and research group speakers. Seminars are arranged at least fortnightly and have improved and established a variety of academic links.

Dynamics Research Group Showcases: Instigated and organised two very successful research showcases (2017 and 2018). These events, involving talks and poster presentations, have consistently been attended by around fifty people from different departments across the university and from industry. The events have helped foster collaboration opportunities and disseminate current research from the group.

Open Days: I have been involved in various open day events on behalf of the Mechanical Engineering department. These events were to both prospective students and parents with my key responsibilities being to provide tours and establish good relationships between attendees and the department.

Invited Presentations

- “On learning for digital twins”, Digital Twin Research Workshop, AMRC Factory 2050, Sheffield, December 2019
- “Towards digital twins”, University of Cambridge, November 2019
- “Model validation and overcoming model discrepancy”, 2nd Dynamics Workshop, University of Sheffield, November 2019

- “Heterogeneous populations: mapping and transfer”, 2nd Dynamics Workshop, University of Sheffield, November 2019
- “Transfer learning for structural health monitoring”, Politecnico di Torino, October 2019
- “Model validation and overcoming model discrepancy”, Politecnico di Milano, October 2019
- “The use of Bayesian calibration in the prediction of damage in structures”, Mathematics Department, University of Sheffield, February 2017

9. Publications

Journal Papers

Under Review	P. Gardner , T.J. Rogers, C. Lord, R.J. Barthorpe, 2020, “Learning model discrepancy: a Gaussian process and sampling-based approach” <i>Submitted to Mechanical Systems and Signal Processing</i>
Under Review	K. Worden, L.A Bull, P. Gardner , J. Gosliga, T.J. Rogers, E.J. Cross, E. Papatheou, W. Lin, N. Dervilis, 2020, “An overview of recent developments in population-based structural health monitoring” <i>Submitted to Frontiers in Built Environment</i>
Under Review	K. Worden, R. Fuentes, N. Dervilis, C. Mineo, S.G. Pierce, E.J. Cross, P. Gardner , 2020, “Machine learning at the interface of SHM and NDE”, <i>Submitted to Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences</i>
Under Review	Y. Zhu, P. Gardner , D.J. Wagg, R.J. Barthorpe, E.J. Cross, R. Fuentes, 2020, “Robust equation discovery considering model discrepancy: a sparse Bayesian and Gaussian Process approach”, <i>Submitted to Mechanical Systems and Signal Processing</i>
Under Review	R. Fuentes, P. Gardner , N. Dervilis, T.J. Rogers, K. Worden, E.J. Cross, 2020, “Equation discovery for nonlinear dynamical systems: a Bayesian viewpoint”, <i>Submitted to Mechanical Systems and Signal Processing</i>
Under Review	L. A. Bull, P. Gardner , J. Gosliga, T. J. Rogers, N. Dervilis, E. J. Cross, E. Papatheou, A. E. Maguire, C. Campos and K. Worden, 2020, “Foundations of population-based SHM, Part I: Homogeneous populations and forms”, <i>Submitted to Mechanical Systems and Signal Processing</i>
Under Review	J. Gosliga, P. Gardner , L. A. Bull, N. Dervilis and K. Worden, 2020, “Foundations of population-based SHM, Part II: Heterogeneous populations - graphs, networks, and communities”, <i>Submitted to Mechanical Systems and Signal Processing</i>
Under Review	P. Gardner , L. A. Bull, J. Gosliga, N. Dervilis and K. Worden, 2020, “Foundations of population-based SHM, Part III: Heterogeneous

populations - mapping and transfer", *Submitted to Mechanical Systems and Signal Processing*

- 2020 R. Fuentes, **P. Gardner**, C. Mineo, T. J. Rogers, S. G. Pierce, K. Worden, N. Dervilis and E. J. Cross, 2020, "Autonomous ultrasonic inspection using Bayesian optimisation and robust outlier analysis", *Mechanical Systems and Signal Processing*
- 2020 **P. Gardner**, C. Lord and R. J. Barthorpe, 2020, "Bayesian history matching for structural dynamics applications", *Mechanical Systems and Signal Processing*, <https://doi.org/10.1016/j.ymssp.2020.106828>
- 2020 K. Worden, E. J. Cross, R. J. Barthorpe, D. J. Wagg and **P. Gardner**, 2020, "On digital twins, mirrors and virtualisations: Frameworks for model verification and validation", *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems Part B: Mechanical Engineering*, <https://doi.org/10.1115/1.4046740>
- 2020 D. J. Wagg, K. Worden, R. J. Barthorpe, and **P. Gardner**, 2020, "Digital twins: State-of-the-art and future directions for modelling and simulation in engineering dynamics applications", *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems Part B: Mechanical Engineering*, <https://doi.org/10.1115/1.4046739>
- 2020 **P. Gardner**, X. Liu and K. Worden, 2020, "On the application of domain adaptation in structural health monitoring", *Mechanical Systems and Signal Processing*, <https://doi.org/10.1016/j.ymssp.2019.106550>
- 2020 T. J. Rogers, **P. Gardner**, N. Dervilis, K. Worden, A. E. Maguire, E. Papatheou and E. J. Cross, 2020, "Probabilistic modelling of wind turbine power curves with application of heteroscedastic Gaussian Process regression", *Renewable Energy*, <https://doi.org/10.1016/j.renene.2019.09.145>
- 2019 **P. Gardner**, C. Lord and R. J. Barthorpe, 2019, "A unifying framework for probabilistic validation metrics", *ASME Journal of Verification, Validation and Uncertainty Quantification*, <https://doi.org/10.1115/1.4045296>
- 2018 **P. Gardner**, T. J. Rogers, C. Lord and R. J. Barthorpe, 2018, "Sparse Gaussian Process emulators for surrogate design modelling", *Applied Mechanics and Materials*, <https://doi.org/10.4028/www.scientific.net/AMM.885.18>

Book Chapters

- Under Review R. Fuentes, L. A. Bull, E. J. Cross, N. Dervilis, **P. Gardner**, T. J. Rogers, K. Worden, 2020, "Structural health monitoring and damage identification". To appear in SEM Experimental Structural Dynamics Handbook

Reviewed Conference Papers

- 2019 **P. Gardner**, C. Lord and R. J. Barthorpe, 2019, “Sequential Bayesian history matching for model calibration”, *Proceedings of the ASME 2019 Verification and Validation Symposium, Las Vegas, USA*
- 2019 **P. Gardner**, C. Lord and R. J. Barthorpe, 2019, “Learning of model discrepancy for dynamics applications using Bayesian history matching”, *Proceedings of the 13th International Conference on Recent Advances in Structural Dynamics, Leon, France*
- 2018 **P. Gardner**, C. Lord and R. J. Barthorpe, 2018, “An evaluation of validation metrics for probabilistic model outputs”, *Proceedings of the ASME 2018 Verification and Validation Symposium, Minneapolis, USA*

Conference Papers

- 2020 **P. Gardner**, M. Dal Borgo, V. Ruffini, Y. Zhu, A. Hughes, 2020, “Towards the development of a digital twin for structural dynamics applications”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 L. A. Bull, **P. Gardner**, J. Gosliga, N. Dervilis, E. Papatheou, A. E. Maguire, T J. Rogers, E. J. Cross and K. Worden, 2020, “Towards population-based structural health monitoring, Part I: Homogeneous populations and forms”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 J. Gosliga, **P. Gardner**, L. A. Bull, N. Dervilis and K. Worden, 2020, “Towards population-based structural health monitoring, Part II: Heterogeneous populations and structures as graphs”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 J. Gosliga, **P. Gardner**, L. A. Bull, N. Dervilis and K. Worden, 2020, “Towards population-based structural health monitoring, Part III: Graphs, networks and communities”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 **P. Gardner**, L. A. Bull, J. Gosliga, N. Dervilis and K. Worden, 2020, “Towards population-based structural health monitoring, Part IV: Heterogeneous populations, transfer and mapping”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 G. Tsialiamanis, D. J. Wagg, **P. Gardner**, N. Dervilis and K. Worden, 2020, “On partitioning of an SHM problem and parallels with transfer learning”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*
- 2020 **P. Gardner**, L. A. Bull, N. Dervilis, K. Worden, 2020, “Kernelised Bayesian transfer learning for population-based structural health monitoring”, *Proceedings of IMAC XXXVIII International Conference on Modal Analysis, Texas, USA*

- 2019 **P. Gardner** and K. Worden, 2019, "On the application of domain adaptation for aiding supervised SHM methods", *Proceedings of the 12th International Workshop on Structural Health Monitoring, Stanford, USA*
- 2019 **P. Gardner** and R. J. Barthorpe, 2019, "On current trends in forward model-driven SHM", *Proceedings of the 12th International Workshop on Structural Health Monitoring, Stanford, USA*
- 2019 K. Worden, E. J. Cross, **P. Gardner**, R. J. Barthorpe and D. J. Wagg, 2019, "On digital twins, mirrors and visualisations", *Proceedings of IMAC XXXVII International Conference on Modal Analysis, Florida, USA*
- 2019 D. Wagg, **P. Gardner**, R. J. Barthorpe and K. Worden, 2019, "On key technologies for realising digital twins for structural dynamics applications", *Proceedings of IMAC XXXVII International Conference on Modal Analysis, Florida, USA*
- 2018 **P. Gardner**, C. Lord and R. J. Barthorpe, 2018, "A multi-level uncertainty integration strategy for forward model-driven SHM", *Proceedings of ISMA2018 International Conference on Noise and Vibration Engineering, Leuven, Belgium*
- 2018 **P. Gardner**, C. Lord and R. J. Barthorpe, 2018, "A probabilistic framework for forward model-driven SHM", *Proceedings of the 9th European Workshop on Structural Health Monitoring, Manchester, UK*
- 2018 **P. Gardner**, C. Lord and R. J. Barthorpe, 2018, "Bayesian history matching for forward model-driven structural health monitoring", *Proceedings of IMAC XXXVI International Conference on Modal Analysis, Florida, USA*
- 2017 **P. Gardner**, R. J. Barthorpe and C. Lord, 2017, "Bayesian calibration and bias correction for forward model-driven SHM", *Proceedings of the 11th International Workshop on Structural Health Monitoring, Stanford, USA*
- 2016 **P. Gardner**, R. J. Barthorpe and C. Lord, 2016, "The development of a damage model for the use in machine learning driven SHM and comparison with conventional SHM methods", *Proceedings of ISMA2016 International Conference on Noise and Vibration Engineering, Leuven, Belgium*
- 2016 **P. Gardner**, R. J. Barthorpe and C. Lord, 2016, "Quantification of uncertainty for experimentally obtained modal parameters in the creation of a robust damage model", *Proceedings of the 6th European Conference on Structural Control, Sheffield, UK*

Appendix

Course Attendance

- Introduction to Sequential Monte Carlo Methods, VUB Belgium, 2017

Conference and Workshop Attendance

- IMAC XXXVIII, Houston, USA, February 2020 (Presented 3 papers and chaired a session)

- The 12th International Workshop on Structural Health Monitoring (IWSHM), Stanford, USA, September 2017 (Presented 2 papers)
- The ASME 2019 Verification and Validation Symposium, Las Vegas, USA, May 2018 (Presented 1 paper)
- The 8th International Conference on Recent Advances in Structural Dynamics, Lyon, France, April 2019 (Presented 1 paper)
- The 3rd Workshop on Nonlinear System Identification Benchmarks, Eindhoven, Netherlands, April 2019 (Presented 1 presentation)
- The 28th International Conference on Noise and Vibration Engineering (ISMA), Leuven, Belgium, September 2018 (Presented 1 paper)
- The 9th European Workshop on Structural Health Monitoring (EWSHM), Manchester, UK, July 2018 (Presented 1 paper)
- The ASME 2018 Verification and Validation Symposium, Minneapolis, USA, May 2018 (Presented 1 paper and chaired a session)
- The 2nd Workshop on Nonlinear System Identification Benchmarks, Liège, Belgium, April 2018
- IMAC XXXVI, Orlando, USA, January 2018 (Presented 1 paper)
- The 11th International Workshop on Structural Health Monitoring (IWSHM), Stanford, USA, September 2017 (Presented 1 paper)
- The 27th International Conference on Noise and Vibration Engineering (ISMA), Leuven, Belgium, September 2016 (Presented 1 poster)
- The 6th European Conference on the Control of Structures (EACS), Sheffield, UK, July 2016 (Presented 1 paper)