George Tsialiamanis

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Summary

Research

The aim of my research is to build robust and reliable digital twins of mechanical systems. I am interested in developing methods that shall provide useful information and predictions about real-life systems. As a result, I have explored various approaches in physics-based, data-driven and hybrid modelling, with a particular emphasis on utilising machine learning.

My research for the past years has mainly been about the various challenges in the definition of digital twins of structures. Such challenges arise from the complexity of large-scale structures and the need to model them. Therefore, my research is focussed on the definition of accurate models for various functionalities of real-life structures: on the assessment of the health-state of the physical twin, the management of the various data and knowledge about the structure and about decision making. As a result, as part of the wider research for digital twins, my interests are aimed at the fields of structural dynamics, nonlinear dynamics, structural health monitoring and definition of knowledge graphs and knowledge-bases. To tackle problems in the aforementioned field, my research is extensively focussed on various machine-learning techniques. Such interest is straightforward, because a digital twin is indissolubly connected to data science and because of the potential of these methods to deal with problems which have been so far quite challenging for analytical solutions. Some examples of my research using such algorithms are, the use of generative adversarial networks for nonlinear modal analysis, for the definition of a generative digital twin of a structure and for remaining useful life prediction, and the use of graph neural networks for definition of healthy-state conditions in a population. Furthermore, I am interested in the adjacent and recently-emerging field of population-based structural health monitoring, which aims at exploiting information from a population of structures to create more accurate models about the health state of every member of the population. As a consequence, my research interests have also turned into transfer learning, multi-task learning and meta-learning, fields with a fundamentally population-based treatment to solving problems.

Motivated by the population-based approach to structural health monitoring, my research interests have also turned towards more general population-based approaches to digital twins. One of the fields that I am interested in is that of healthcare and biomechanical engineering. More specifically, I am working on dealing with the problem of definition of digital twins of spines of patients with cancer. The problem requires use of deep learning for the purposes of image processing and image resolution enhancing, which shall subsequently be used to create a more accurate digital twin of each spine.

Another aspect of my research on digital twins of systems is the modelling of the behaviour of nonlinear structures. Part of my research is focussed on using state-of-the-art machine learning techniques to deal with the identification and predictive modelling of nonlinear real-life structures. Part of this research is also aimed at the nonlinear modal analysis of structures, a problem for which I have used machine learning techniques with quite promising results.

Definition of digital twins of more general systems is also part of my interests. A field that my research includes in is that of knowledge graphs, which might be essential for the definition of a digital twin. Knowledge graphs could be used for many different fields of digital twins and may enable transfer of knowledge between different domains. A cross-domain approach to digital twins encourages exchange of data, methods, algorithms and ideas, and could solve big problems, such as data scarcity, or the automated transfer of knowledge between various fields.

Although my research is mainly about data-driven approaches, I have worked on physics-based approaches. During my work time as a simulation engineer at Beta CAE Systems S.A., a company whose main objective

is the development of simulation software and tools for structures, I was involved in developing finite element software for quite nonlinear phenomena, such as car crashes. As in my master's thesis, I worked on creating intrusive physics-based surrogate models of large finite element models. Of course, I used in parallel machine learning approaches to accelerate the simulations that were of interest of the stakeholders.

Teaching

My experience at teaching and guidance has mainly been in the form of assistance to Ph.D. and masters students. I have participated in discussions and have provided guidance to several of my colleagues during my time as a Ph.D. student and as a research associate. Moreover, I have provided code for Ph.D. students to help them advance with their work. The code was both for algorithms which I have developed and for existing algorithms of the literature, with which I am familiar. Another contribution to the work of my colleagues was to give seminars about meta-learning and about diffusion models during the machine-learning journal clubs of the Dynamics Research Group. I have also served as co-supervisor in various final year projects of M.Eng. students of the mechanical engineering department of the university of Sheffield. The projects were focussed on the use of machine learning or knowledge graphs for mechanical engineering applications. Another instance of acquiring teaching experience was my participation as an assistant in the UK Acoustics Network Summer School 2019, which was about machine learning and my role was to assist participants with the use of python to code machine learning algorithms.

Administration

As the main organiser of seminars on digital twins for the Digital Twins for High Value Engineering Application (DTHIVE) project at the University of Sheffield, I was responsible for inviting speakers, coordinating seminar topics, promoting the seminars to interested individuals, and moderating the events. Additionally, I served as an assistant organiser for the 3rd Dynamics Research Group workshop held in December 2020. In my capacity as a member of the Dynamics Research Group, I also arranged travel logistics for our attendance at the UNCECOMP conference in Athens in June 2023. Furthermore, I initiated regular meetings for research associates within the Dynamics Research Group with the goal of fostering discussion and sharing of research ideas, as well as providing an opportunity for members to present on topics outside of their primary research area, which may be beneficial to the group. In addition, I have participated in seminars as part of my Ph.D. early career training, which were about collaboration, management of teams, and resolving conflict in a work environment.

Professional Standing

I have been invited to give talks and presentations at esteemed institutions such as the Alan Turing Institute, Los Alamos National Laboratory, and Sheffield Workshop on Structural Dynamics. These opportunities have allowed me to share my expertise on topics such as creating digital twins of structures and utilising machine learning techniques for this purpose. Moreover, I have independently acquired funding from the Los Alamos National Laboratory, as a result of my invited presentation, in order to collaborate with the Non-Destructive Testing & Evaluation (E-6) group for the use of diffusion models on enhancing CT scans for the purpose of non-destructive evaluation (NDE) of structures. I have been awarded the best paper award at the International Modal Analysis conference for my paper about the use of graph neural networks for structural health monitoring. This research was conducted during my secondment at ETH Zurich. Moreover, I have been active in providing reviews for high-quality journals, for example the journal of Mechanical Systems and Signal Processing (MSSP). I am also a chartered member of the Institution of Civil Engineers in Greece, which was achieved after being interviewed by members of the institution, based on my master's thesis.

Education

University of Sheffield — Sheffield, United Kingdom
Ph.D. in data-driven methods for mechanical engineering — 2018–2022

- Early stage Researcher (ESR) under Marie Sklodowska-Curie Actions 2020 Innovative Training Network (ITN): "Dynamic Virtualisation: Decision Support for Virtualisation" DyVirt, focussed on the developemnt of digital twins of structures.
- Research position focussed on the development of machine learning methods for digital twins of structures, as well as their Verification and Validation (VnV).
- Participation in training weeks and workshops regarding presentation skills, networking, collaboration and managing of teams, and resolving conflict in a work environment.

National Technical University of Athens — Athens, Greece
Master in Civil Engineering, GPA: 8.22/10 — 2012–2017

- Five-year studies program focussed on a wide range of civil engineering topics, such as structural engineering, fluid mechanics, soil mechanics, earthquake engineering, dynamics etc.
- Master thesis: "High performance surrogate models" (http://dx.doi.org/10.26240/heal.ntua.14740), including the development of techniques for speeding up model simulations using neural networks, intrusive and non intrusive methods.

Experience

University of Sheffield — Sheffield, United Kingdom
Lecturer — 2023 –Present

University of Sheffield — Sheffield, United Kingdom
Postdoc Researcher — 2021 –2023

- Postdoc researcher in the Dynamics Research Group (DRG) of the University of Sheffield, funded by the Digital Twins for High Value Engineering Applications (DTHIVE) and by the DigiTwin program, aiming at developing machine-learning methods for actual digital twins.
- Collaboration with the medical school of the University of Sheffield aimed at using diffusion models to enhance the quality of CT scans, with the later goal of developing digital twins of human spines.
- Participation in experiments doing ground vibration tests on a Hawk aircraft in the Laboratory of Verification and Validation (LVV) of the Dynamics Research Group (DRG) of the University of Sheffield.
- Collaboration with IOTICS, an external collaborator of the program, with a view to developing an ontology corresponding to the digital twin of the Hawk aircraft.

Los Alamos National Laboratory — Los Alamos, New Mexico, USA
Visiting researcher — June 2022, Sep.-Oct. 2023

- Acquired funding independently as a guest researcher aimed at applying diffusion model techniques for resolution enhancement and denoising of CT scans.
- Collaboration focussed on machine-learning approaches for the development of accurate structural dynamics models of aerospace, civil and mechanical engineering systems.
- Development of technology based on the concept of a digital twin and attempts to build tools for higher-fidelity modelling of structures and the use of such digital twins in the context of structural health monitoring, or more broadly, asset management.

ETH Zurich — Zurich, Switzerland
Research assistant — Oct. 2019 –Jan. 2020

- Secondment position under the DyVirt funding project.
- Collaboration with a view to developing machine learning models of structures.

– Studied the recently-emerged graph neural network method, which was of interest to the hosting group, and proposed it as a solution to the problem, of interest of the Sheffield Dynamics Research Group, of modelling heterogeneous populations of structures.

– Journal publication regarding the use of graph neural networks for the purposes of population-based structural health monitoring and conference publication about the use of generative adversarial networks for structural health monitoring.

Beta-CAE systems S.A. Thessaloniki, Greece

Intern as a simulation engineer in the Crash Division. 2017 –2018

– Beta-CAE systems S.A. is active in the field of development of scientific software (finite element models) for the purposes of modelling structures.

– Surrogate modelling for large nonlinear dynamic simulations of car finite element models.

– Training in the use of several commercial finite element software packages.

– Development of machine learning for crash test regression purposes and crash modes classification.

– Development of a tool for classification of large databases of car crash simulations.

Research

Research areas

- **Digital twins:** Definition of digital twins as an augmented digital copy of a system. Considering the inseparable relationship of such models to the acquisition and use of data, my research is focussed on the use of such methods to provide accurate models of structures, taking into account potential uncertainties [1], to perform functionalities using machine learning [19] that are difficult using traditional approaches [2, 14, 17], the use of a common terminology to define the accuracy of digital twin models as mirror models [1], and the organising of the content of such digital entities using methods such as knowledge graphs [9].

- **Structural health monitoring (SHM):** As a field tightly connected to the acquisition from data in order to assess the health state of a structure, my work focusses on the use of machine-learning techniques to perform several functionalities of SHM. I am interested in exploiting machine-learning models to explain the behaviour of structures and to make inference about their health state [16]. I have used state-of-the art machine learning models for the purposes of SHM, such as generative adversarial networks for generation of data of missing states for structures [8], to perform unsupervised inference with an available dataset [7], and to estimate the remaining useful life of structures [10]. I have also utilised graph neural networks for the purposes of using abstract graph representations of structures to define their normal conditions within a population [3] and to perform crack localisation in a structure [13]. Moreover, I have recently been interested in the use of meta-learning as a tool to perform population-based SHM [5, 16].

- **Nonlinear dynamics:** I am interested in using powerful machine learning algorithms in the domain of structural identification and modelling of nonlinear phenomena. I have attempted to improve previous approaches to nonlinear modal analysis using a variation of the deep-learning algorithm of generative adversarial networks [2], I have worked on the identification of nonlinearity in real-life structures [18], and I am recently interested in creating population informed models for nonlinear phenomena [5, 16] as an attempt for a better-validated model for structural dynamics. Moreover, I have worked in the field of damage prognosis, an extensively nonlinear phenomenon, applying machine learning approaches to deal with the problem [10, 16].

- **Biomechanics:** As an SHM-adjacent field, I have been recently interested and been involved in applications of machine learning approaches to biomechanics. I am currently working in a project to create digital twin models of patients' spines. Part of the research is focussed on the auxiliary task of using the novel deep-learning technique of diffusion models to enhance the image resolution of clinical CT scans, in order

to create more accurate models of the spines in the future without the need to subject patients to high levels of radiation. The goal of the project is to make more accurate inference about the health state of patients with cancer and the more efficient decision making regarding a potential operation. This involvement led to being offered a secondment to LANL about the use of similar methods for non-destructive evaluation of structures.

- **Surrogate modelling:** A great deal of research is performed in this field with a view to reducing the computation of physical models. For digital twins this is of great importance to make proper studies of "what-if" scenarios, online predictions, and decisions. My work in the field was mainly during my internship, where my employer needed solutions to making large nonlinear finite element models to provide results in a shorter time, so that the stakeholders could study many different scenarios in less time. As a result, I worked in machine learning approaches to classification and regression regarding crash-test simulations, as well as intrusive finite element approaches.

Future research plans

- **Population-based digital twins:** Motivated by the recently-emerged field of population-based structural health monitoring, I am interested in applying similar technologies to create digital twins of systems. My intention is to continue my research on digital twins, allowing their application in various fields. I believe that such an interdisciplinary approach to digital twins could allow exchange of ideas, information and data that could further assist in creating digital copies of objects of interests, whether these are structures or some other system.

- **Healthcare:** A field that could be largely benefited from the application of existing methods of structural dynamics and structural health monitoring could be that of healthcare. The field is traditionally approached via the use of statistics, leaving room for more accurate modelling using high-dimensional and multi-source data. Moreover, with the recent increase in use of smart devices (e.g. smart watches and smart phones), machine learning could be exploited to perform more accurately the various functionalities needed for the field. Such approaches could aim at solving problems in various stages of dealing with diseases, for example in the diagnosis stage, the prognosis stage and the decision making regarding the quality of life of the patients. The framework could be potentially connected with a long-shot goal of creating digital twins of humans aimed at performing personalised healthcare and improving public health in general.

- **Non-destructive evaluation:** I have recently worked in the field of evaluating the properties of spines using CT scans. I have also acquired funding to conduct research in the field of non-destructive evaluation for structures at the Los Alamos National Laboratory. Both applications include the use of powerful machine-learning image-processing algorithms. The use of such algorithms has not been widely used in the field of structural health monitoring and health monitoring in general, as a result it is a field that I would be keen to discover and attempt the use of such deep-learning models, such as diffusion models.

Publications

Journal publications

1. G. Tsialiamanis, D.J. Wagg, N. Dervilis and K. Worden, "On generative models as the basis for digital twins", *Data-Centric Engineering*, vol. 2, 2021.

2. G. Tsialiamanis, M.D. Champneys, N. Dervilis, D.J. Wagg and K. Worden, "On the application of generative adversarial networks for nonlinear modal analysis", *Mechanical Systems and Signal Processing*, vol. 166, p. 108 473, 2022.

3. G. Tsialiamanis, C. Mylonas, E. Chatzi, N. Dervilis, D.J. Wagg and K. Worden, "Foundations of population-based SHM, Part IV: The geometry of spaces of structures and their feature spaces", *Mechanical Systems and Signal Processing*, vol. 157, p. 107 692, 2021.

4. M.D. Champneys, G. Tsialiamanis, T. Rogers, N. Dervilis and K. Worden, "On the dynamic properties of statistically-independent nonlinear normal modes", *Mechanical Systems and Signal Processing*, vol. 181, p. 109 510, 2022.

Journal publications under review

5. G. Tsialiamanis, N. Dervilis, D.J. Wagg and K. Worden, "Towards a population-informed approach to the definition of data-driven models for structural dynamics", under review at *Mechanical Systems and Signal Processing*, 2023.

Published peer-reviewed conference publications

6. G. Tsialiamanis, D.J. Wagg, P. Gardner, N. Dervilis and K. Worden, "On partitioning of an SHM problem and parallels with transfer learning", *Topics in Modal Analysis & Testing, Volume 8: Proceedings of the 38th IMAC, A Conference and Exposition on Structural Dynamics 2020*, Springer International Publishing, 2021.

7. G. Tsialiamanis, E. Chatzi, N. Dervilis, D.J. Wagg and K. Worden, "An application of generative adversarial networks in structural health monitoring", *EURODYN 2020: Proceedings of the XI International Conference on Structural Dynamics*, Vol. 2, European Association for Structural Dynamics (EASD), 2020.

8. G. Tsialiamanis, D.J. Wagg, N. Dervilis and K. Worden, "On generating parametrised structural data using conditional generative adversarial networks", *Data Science in Engineering, Volume 9: Proceedings of the 39th IMAC, A Conference and Exposition on Structural Dynamics 2021*, Springer International Publishing, 2022.

9. G. Tsialiamanis, D.J. Wagg, I. Antoniadou and K. Worden, "An ontological approach to structural health monitoring", *Topics in Modal Analysis & Testing, Volume 8: Proceedings of the 38th IMAC, A Conference and Exposition on Structural Dynamics 2020*, Springer International Publishing, 2021.

10. G. Tsialiamanis, N. Dervilis, D.J. Wagg and K. Worden, "On an application of generative adversarial networks on remaining lifetime estimation", *Proceedings of the Thirteenth International Workshop on Structural Health Monitoring (IWSHM), March 15-17, 2022, (formerly December 7-9. 2021)*, DEStech Publications, Inc., 2023.

11. G. Tsialiamanis, D.J. Wagg, N. Dervilis and K. Worden, "A neat approach to structural health monitoring", *EURODYN 2020: Proceedings of the XI International Conference on Structural Dynamics*, European Association for Structural Dynamics (EASD), 2020.

12. G. Tsialiamanis, M.D. Champneys, D.J. Wagg, N. Dervilis and K. Worden, "On the use of cycle-consistent generative adversarial networks for monlinear modal analysis", *Topics in Modal Analysis & Parameter Identification, Volume 8: Proceedings of the 40th IMAC, A Conference and Exposition on Structural Dynamics 2022*, Springer International Publishing, 2022.

13. C. Mylonas, G. Tsialiamanis, K. Worden and E. Chatzi, "Bayesian graph neural networks for strain-based crack localization", *Data Science in Engineering, Volume 9: Proceedings of the 39th IMAC, A Conference and Exposition on Structural Dynamics 2021*, Springer International Publishing, 2022.

14. T. Simpson, G. Tsialiamanis, N. Dervilis, K. Worden and E. Chatzi, "On the use of variational autoencoders for nonlinear modal analysis", *Nonlinear Structures & Systems, Volume 1: Proceedings of the 40th IMAC, A Conference and Exposition on Structural Dynamics 2022*, Springer International Publishing, 2022.

15. M.D. Champneys, G. Tsialiamanis, T.J. Rogers, N. Dervilis and K. Worden, "On modelling statistically independent nonlinear normal modes with Gaussian process NARX models", *Nonlinear Structures & Systems, Volume 1: Proceedings of the 40th IMAC, A Conference and Exposition on Structural Dynamics 2022*, Springer International Publishing, 2022.

Arxiv conference publications

16. G. Tsialiamanis, C. Sbarufatti, N. Dervilis and K. Worden, "On the use of meta-learning for population-based remaining useful life prediction", presented at *1st Conference on Durability, Repair and Maintenance of Structures (DRMS), Porto, Portugal 2023*, 2023.

17. G. Tsialiamanis, N. Dervilis, D.J. Wagg and K. Worden, "A meta-learning approach to population-based modelling of structures", *presented at the 41st IMAC, A Conference and Exposition on Structural Dynamics 2020*, Springer International Publishing, 2023.

18. G. Tsialiamanis and C.R. Farrar, "On the detection and quantification of nonlinearity via statistics of the gradients of a black-box model", *presented at the 41st IMAC, A Conference and Exposition on Structural Dynamics 2020*, Springer International Publishing, 2023.

Book chapters in press

19. K. Worden, G. Tsialiamanis, E.J Cross and T.J. Rogers, "Artificial neural networks", *Machine Learning in Modeling and Simulation - Methods and Applications, T. Rabczuk, K.-J. Bathe (Eds)*, Springer Nature.

Administration

- **Organiser of Digital Twin seminars**. Coordination of seminars for the DTHIVE project about digital twins, invitation of speakers, advertisement and chairing the seminar. Sep. 2021 - May 2022
  University of Sheffield
- **Assistant organiser** for the 3rd Dynamics Research Group workshop. December 2020
  University of Sheffield
- **Travelling organiser** for the participants of the Dynamics Research Group at the UNCECOMP conference in Athens. June 2023
  University of Sheffield
- **Research session organiser**. Organised meeting sessions between research associates to share everyone's recent research and to share any interesting research someone has come across. Sep. 2022 - Jan. 2023
  University of Sheffield

Professional Standing

Invited seminars and presentations

Cardiac Digital Twin Workshop, Alan Turing Institute London, United Kingdom
Invited speaker March 2023

- Invited speaker regarding the development of structural digital twins and structural health monitoring models.
- Interdisciplinary event aimed at bringing people from different digital twin fields together to exchange ideas.

Deblurring of CT scans using diffusion models, LANL Los Alamos, New Mexico, USA
Invited speaker February 2023

- Invited to make a presentation about the use of diffusion models for the purposes of deblurring CT scans.
- Participation of people from various groups of LANL, including the Engineering Institute and the Non-Destructive Testing & Evaluation group.
- The talk resulted in offering of funding to visit LANL in the future for an extended period of time and conduct research on the use of diffusion models in collaboration with the Non-Destructive Testing & Evaluation group.

3rd Sheffield Workshop on Structural Dynamics Sheffield, United Kingdom
Presenter December 2020

- Invited presentation about the use of graph neural networks for population-based structural health monitoring.
- Part of the wider theme of presentations about machine learning and the Foundations of Population-Based Structural Health Monitoring.

Acquired funding

Los Alamos National Laboratory Los Alamos, New Mexico, USA
Guest researcher Sep. - Oct. 2023

– Acquired funding independently as a guest researcher aimed at applying diffusion model techniques for resolution enhancement and denoising of CT scans.
– Funding offered for three months with flexible visiting dates from the Non-Destructive Testing & Evaluation (E-6) group.

Awards

Best paper award Orlando, Florida, USA (virtually)
Conference paper presenter Feb. 2021

– Best Paper in Data Science for Engineering award at the International Modal Analysis Conference (IMAC) 2021.
– Award sponsored by Los Alamos Dynamics, LLC.

Reviewer

- **Mechanical Systems and Signal Processing (MSSP)**, Elsevier, (16 assignments)
- **Data-centric Engineering (DCE)**, Cambridge University Press (2 assignments)
- **Journal of Engineering Applications of Artificial Intelligence**, Elsevier (2 assignments)
- **Journal of Engineering Mechanics**, American Society of Civil Engineers (1 assignment)
- **Scientific reports**, Nature (1 assignment)

Professional body member

Technical Chamber of Greece (TEE) Greece
Chartered engineer Feb. 2018 - Present

– Chartered member of the institution of civil engineers in Greece.
– Passed the interview process for the chartership.

Teaching

- **Applications assistant** The UK acoustics network summer school 2019 (UKANSS19). Provided assistance to participants of the summer school regarding the use of python for handling data, coding machine-learning methods, and using those to make predictions about unseen data. August 2019
  Machine Learning for Acoustics Summer School, Wales
- **Final year project co-supervisor** Co-supervision of final year projects of students of Prof. Nikolaos Dervilis and Prof. David Wagg in the fields of machine learning for structural engineering and knowledge-graph construction for digital twins. 2019 - 2023
  University of Sheffield
- **Machine-learning journal club seminars** I gave seminars about meta-learning and diffusion models for my colleagues at the Dynamics Research Group. The seminars were about presenting and explaining state-of-the-art machine-learning methods for Ph.D. students and postdocs. 2022 - 2023
  University of Sheffield
- Participation in discussions about Ph.D. students' projects and offer of help in the form of advice for research adjacent to mine and in the form of code implementations of methods, which I had developed or had implemented.
  University of Sheffield

Skills

- **Programming languages:** Python, MATLAB, C++, Fortran, Maple.
- **Computer Applications:** Tensorflow, Keras, Pytorch, Linux, LaTeX, NASTRAN, LS-DYNA, Abaqus, Microsoft Excel.

Languages

- **English** Full professional proficiency
  - **EXAM:** Michigan English language proficiency C2 certificate
- **Greek** Native speaker
- **Spanish** Limited working proficiency
  - **EXAM:** Instituto Cervantes nivel intermedio (B2 certificate)
- **French** Elementary proficiency
  - **EXAM:** Greek national language exams (A2 certificate)
- **German** Elementary proficiency

Extracurricular Activities

- Participation in the Hellenic Mathematics Society student competition 2009–2011
  Participated in math competition organised every year by the Hellenic Mathematics Society and passed 1st (Thales) and 2nd (Euclides) stages of the competition.