PhD PROJECT PROPOSAL

PhD PROJECT TITLE

"The "Value" in Engineering Design: facilitating transdisciplinary design using topological methodology".

PhD SUPERVISORY TEAM

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PhD PROJECT DETAILS

Project abstract

Should be accessible to potential students and EPS academics outside the discipline. Might be shared publicly on CDT website. Max. 100 words.

The definition of "value" is highly dependent on perspective. The SARS-COV-2 pandemic, the environmental crisis and the developing perception of human equity, demonstrates the swiftly changing societal definition of value. Yet, in design, the foundation for the development and production of all engineering products, the definition of value is alarmingly narrow and predominately monetary.

This research will facilitate a step-change in how environmental and socioeconomic value are integrated into engineering design. By adopting a transdisciplinary approach, the project will utilise mathematical topological methodologies to translate the wider global definition of value (clinical, business, social, environmental) into a user-orientated design framework.

Application of Topology

The project will utilise topological data analysis methodology to analyse and integrate the implications of the biomedical device geometry, material, manufacturing and production design decisions on patient, clinical translation/commercial, national and global social dynamics, global healthcare and environmental factors.

- Network Graphs
- Classification Methods

DETAILED PROJECT DESCRIPTION

What does "value" mean? The widespread definition is in terms of economics. A business will prosper or fail, based on its' economic performance. Yet, the real-world, non-fiscal, impact of uninformed engineering design is creating increasingly more serious problems in our society. These limitations in design knowledge have been brought into stark relief this year: the cost of a ventilator valve in 2018 was less than £100. In 2020, the production of that valve could not fulfil the global requirements because of increased demand and travel disruption due to the SARS-COV-2 pandemic. What is the value of that valve now? The design of the ventilator failed to incorporate the non-fiscal value of globalisation vs localisation [1]. Indeed, there are many social impacts resulting from supply chain and production decisions, e.g. the impact of trade liberalization on the social determinants of health [2].

The importance of environmental and socioeconomic (ESE) factors - known as the triple bottom line - are becoming more widely acknowledged. Yet this knowledge is still far removed from the general remit of engineering. Whilst engineering is the bedrock of modern society, the interface between engineering and the requirements of our swiftly changing civilisation is indirect and suboptimal.

The UK is committed to sustainable energy generation and material use through the Clean Growth Strategy and the Circular Economy Package. Yet in these proposals, the means by which design engineering - the fundamental discipline underpinning the creation of all products - will achieve these targets is insubstantial. Concurrent design has been the paradigm of optimum-efficiency in engineering for the last 20 years [3]. It encompasses everything from supply chain, technical requirements, and manufacturing, through to recycling and disposal (Figure 1). This design process relies heavily on a product design specification - a co-creation of customer and engineer - to capture product requirements. But subjectivity is inherent; the specification is limited by the perspective of engineer and customer. Thus, the implementation of concurrent design has hitherto fallen short of concept.

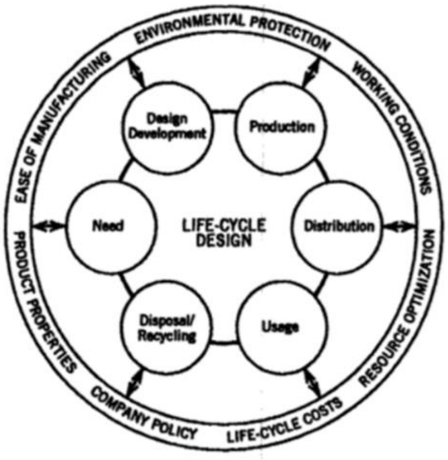

Figure 1: Traditional Concurrent Design Considerations, taken from [3]

Transdisciplinary design is an emerging concept, referring to the direct integration of other disciplines into traditional design engineering. To date, transdisciplinary design tends to be a skill held by a person, to integrating multidisciplinary knowledge into the design of a product. This approach is founded on combining knowledge bases, which may be subjective or incomplete, as opposed to drawing on one comprehensive source of knowledge. This research proposal aims to create a transdisciplinary process, facilitated by topological design techniques to translate quantitative and qualitative ESE information directly into the framework of design for a products' life-cycle (Figure 2).

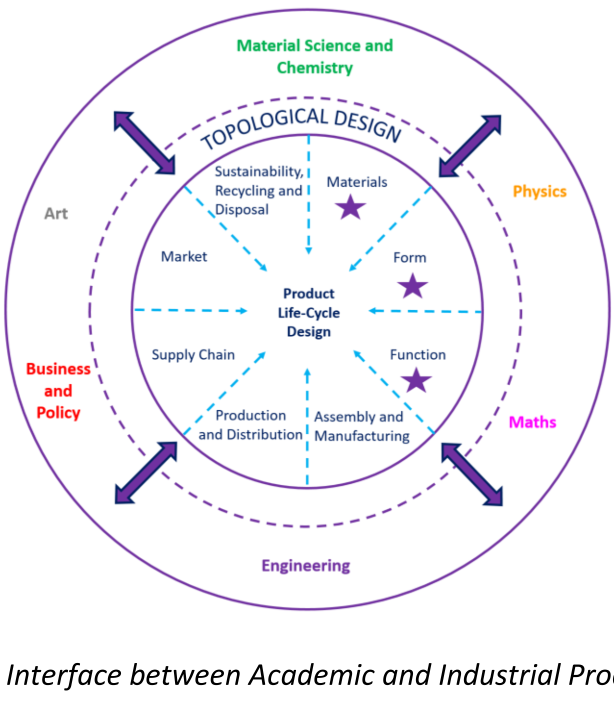

Figure 2: The Interface between Academic and Industrial Product Design.

The research project will develop topological data analysis techniques that draw information from across academia, translate and transform the information into a format, which can be integrated directly into the engineering design framework. To focus the scope of this transdisciplinary research project, validation analysis will be conducted on examples of biomedical engineering design methodology, both those clinically implemented and under research development.

The aim of the project will be achieved through the following series of overarching objectives:
O1) Investigate and evaluate the national and global ESE impact of design choices in the field of biomedical engineering
O2) Develop a topological design network graph from the information gathered in O1
O3) Analyse conceptual designs against expected qualitative outcomes

The research methodology shall build on knowledge gained during the 1st training year in the CDT. The skills to be developed and applied by the student will include but are not limited to; sourcing and framing information (Mindjet Manager) and interactions between engineering design parameters and ESE impacts; mapping relationships (vertices = parameters and edges = connections) using a network graph (Network X); developing a user-orientated network graph interface (Matlab); assessing the geometry and topology of the resulting conceptual designs using classification approaches. All topological design approaches shall be developed to interface with Autodesk software and approaches (Fusion 360/Netfabb/Generative Design), which represents a significantly streamlined trajectory to creating industrial impact.

This project, which utilises topological data analysis tools, to increase the scope of design analysis in engineering design, aligns with the fundamental strategy of the Topological Design CDT to create measurable industrial impact through topological design techniques. The project will run in collaboration with Autodesk and aligns with strategies of internal and external stakeholder organisations as follows:

UoB: Advanced Manufacturing Technology Centre
UoB: Birmingham Plastics Network
UoB: Healthcare Technologies Institute
EPSRC: Manufacturing the Future
UK Gov: Clean Growth Strategy

This project interfaces with several research trajectories currently underway in Dr Lauren Thomas-Seale's interdisciplinary research group. Current projects are focussed on either/both: developing design engineering approaches underpinned by mathematical theory and design for manufacturing of biomedical devices. The research team is well-established, with 7 PhD students and 1 research fellow, at the time of writing this proposal. The friendly team of researchers work closely with Dr Thomas Montenegro-Johnsons research group and the other named collaborating academics.

A student applying for this project will ideally have an undergraduate/postgraduate background in mathematics and/or engineering, with an interest in the other discipline. The student will require a naturally inquisitive mind complimented by well-rounded communication skills. Prospective students are encouraged to contact the Dr Thomas-Seale for further information and discussion.

[1] J. R. Bryson & V. Vanchan (2020) Tijdschr. Econ. Soc. Geogr. 111(3): 530-542
[2] C. McNamara (2017) Soc. Sci. Med. 176: 1-13
[3] A. Kusiak (1993) Concurrent Engineering: Automation, Tools and Techniques