Engineering and Innovation Research Studentship October 2020

Project title:	Design and validation of 3D printed aperiodic cellular structures
Discipline	**Engineering, Mathematics & Statistics**
Key words:	Aperiodic structures, 3D printing, additive manufacturing, engineering design
Supervisory team:	**Iestyn Jowers, Uwe Grimm, Richard Moat**
URL for lead supervisor's OU profile	**http://www.open.ac.uk/people/irj29**

Project Highlights:

- Explore cutting edge research into 3D printing of new geometries
- Validate mathematical theory through design and experimentation
- Develop programming and modelling skills desirable across many fields
- Present results at international conferences

Project Description:

This project will explore an exciting area of modern mathematics and its practical applications in design and engineering. The project is concerned with aperiodic crystallographic structures, which are ordered but are not symmetric under translation. They form a relatively new field of inquiry, and recent discoveries have fundamentally changed our understanding of the mathematics of crystallography and its applications in materials science.

Developments in additive manufacturing (aka 3D printing) have made it possible to manufacture forms that were previously not possible. Internal cellular structures are a common application, where high-value components, e.g. for aerospace industries, are designed from the inside out, so that material is only in place to carry necessary forces. Typically, such structures are based on regular grids, e.g. tetrahedral, and they improve the mechanical performance of a component while reducing its mass. We anticipate that cellular structures with aperiodic order will offer further improvements and will be of interest in areas such as aerospace, medical and structural engineering.

To date, research on aperiodic structures has mostly been at the macroscopic scale, e.g. into tilings of space like the famous Penrose tiles, or at the microscopic scale, e.g. into arrangements of atoms in quasicrystals. Quasicrystals are aperiodically ordered crystals which were first observed in 1982 in rapidly cooled aluminium manganese alloys, an unexpected discovery that was awarded the 2011 Nobel Prize in Chemistry. It has been found that quasicrystals exhibit remarkable properties as a result of their aperiodic structure. They are usually very hard, and their structure can be more isotropic than periodic crystals giving nearly uniform mechanical properties in all directions.

This project is an investigation of aperiodic structures at an intermediate mesoscopic scale, with the aim to incorporate these as internal cellular structures in high-value components for engineering applications. We anticipate that aperiodic structures at a mesoscopic scale will give rise to interesting mechanical behaviours, but to-date these have never been formally explored.

Research Methods:

The project will involve applying the mathematics of aperiodic order to design algorithms for generating aperiodic structures. Analytical models will be constructed based on existing models and will be applied to predict general behaviour of these structures. But, their complex geometry and the uncertainty about resulting material properties mean that the validity of these models will be validated via physical testing. Generated structures will be additively manufactured, and these will be tested to enable comparison of the mechanical properties of periodic and aperiodic structures.

Indication of project timeline:

Year 1: investigate algorithms for generating aperiodic frameworks, to create geometric data suitable for analysis and manufacturing
Year 2: development of analytical models for predicting mechanical properties of aperiodic structures
Year 3: validation of models through physical testing. Present findings to the scientific community and complete thesis write-up.

Background reading:

[1] Baake & Grimm. Chemical Society Reviews (2012) 41: 6821-6841
[2] Rosen Computer Aided Design & Applications (2007) 4(5): 585-594
[3] Torres-Sanchez & Corney. International Journal of Design Engineering (2011) 4(1): 5-22

Candidate Applications:

Applicants should have a strong background in mathematics and enthusiasm for manufacturing technology. Experience of programming is desirable. The student will join a well-established team researching engineering design and manufacturing at the Open University.

Applications should include:

- A 1000 word cover letter outlining why the project is of interest to you and how your skills match those required
- An academic CV containing contact details of three academic references
- Open University application form
- Applicants will need to demonstrate good competence in the English language. To be eligible for a full award, a student must have no restrictions on how long they can stay in the UK and have been ordinarily resident in the UK for at least 3 years prior to the start of the studentship.

Applications should be sent to
STEM-EI-PhD@open.ac.uk by 24.04.20