UNIVERSITY OF BIRMINGHAM

CENTRE FOR DOCTORAL TRAINING IN TOPOLOGICAL DESIGN

SUBMISSION OF RESEARCH PROJECTS FOR CDT PhD STUDENTS

RESEARCH PROPOSAL FORM AND INFORMATION PACK

PhD PROJECT PROPOSAL

PhD PROJECT TITLE
Simulation-Driven Topology Design of Pneumatic Shape-Changing Objects

1. PhD SUPERVISORY TEAM

Principal Supervisor
Please provide, name, email, School and Research Group

Dr Hyunyoung Kim
h.kim.4@bham.ac.uk
School of Computer Science
Human-Centred Computing Group

Co-Supervisor
Please provide, name, email, School and Research Group

Dr Lauren E. J. Thomas-Seale
l.e.j.thomas-seale@bham.ac.uk
School of Engineering
Biomedical Engineering Research Group and the Manufacturing Research Group

Associated Academics
Please provide, name, email, School and Research Group. May be outside UoB.

Dr Anne Roudaut
Anne.Roudaut@bristol.ac.uk
Department of Computer Science
Bristol Interaction Group

2. 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.

Imagine a world where a mother builds robot arms that can hand objects to her disabled husband, and a father builds a toy that has the shape of the children's favourite character and wiggles its tail when touched. Towards this vision, we aim to provide software that lay users can design soft robots and interactive objects. The software will be able to predict the behaviour of pneumatically powered objects based on their designs. It further should find the best designs based on the target shape-change provided by lay users.

How does the project utilise topology or topological design?

Max. 100 words.

Topological design is the centre of this project. The shape-change behaviour of pneumatic widgets not only depends on their material shore but also on their topology. Figure 1 shows how the design of topology can control the shape-change of pneumatic widgets. Depending on their initial shape and parameters such as the width of the widgets and thickness of the wall, we can control the widgets' shape-change.

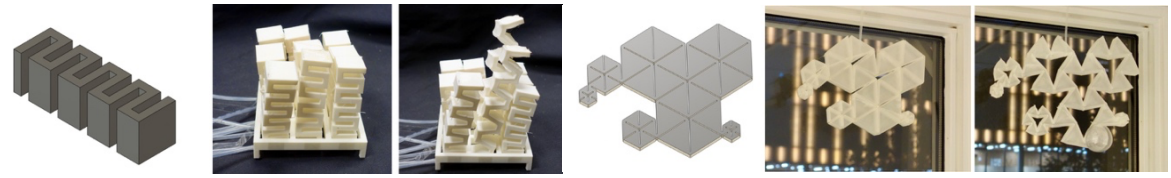

Figure 1. Examples of how topology affects the shape-change of pneumatic widgets. Left: the folded widgets mainly show length change. Right: the auxetic widget expands on a plane and show area change [3].

3. DETAILED PROJECT DESCRIPTION

Please submit the details of the proposed project here. Information on the details required in this section can be found in the guidance below in point 3. Max. 1000 words including figures, diagrams and references.

Currently, research in soft robotics [1] and HCI [2,3] provided software tools to design shape-changing objects based on elastic materials. However, the research focuses on simple robotic applications such as grippers or does not provide a shape-change simulation of the objects in the design process. This limits the exploration of novel designs of pneumatic soft robots and interactive objects. The software developed in this project should be able to design and predict the behaviour of pneumatically powered soft robots and shape-changing objects. Our final goal is to allow lay users to input the shape-change of a target object and the software finds the best design for them.

Aims:

1. **To computationally simulate the behaviour of pneumatic widgets before fabricating them (WP1)**
2. **To enable movement and shape-change driven design (WP2)**

WP1: The first goal of this project is to understand how the topology of elastic polymer widgets affect the objects' shape-change when they are pneumatically inflated. Our recent paper shows that different initial shapes and design parameters result in varied types and scales of shape changes [3] (Figure 2). We want to investigate the shape-changes systemically and embed the data in our software so that users can see the simulated shape-change on the software before fabricating pneumatic objects. To evaluate the software's accuracy and improve it, the work package will involve fabricating shape-changing widgets and comparing their behaviour with simulation results.

WP2: Our second goal is to build software that can suggest widget designs to users based on the shape-change they want. It will be based on the software above. One of the main contributions of this work package will be developing an easy-to-use interface for users to input desired shape-changes and see simulation results to minimize their design iteration. This work package will also involve user studies to evaluate if the software is usable and can support users' creativity.

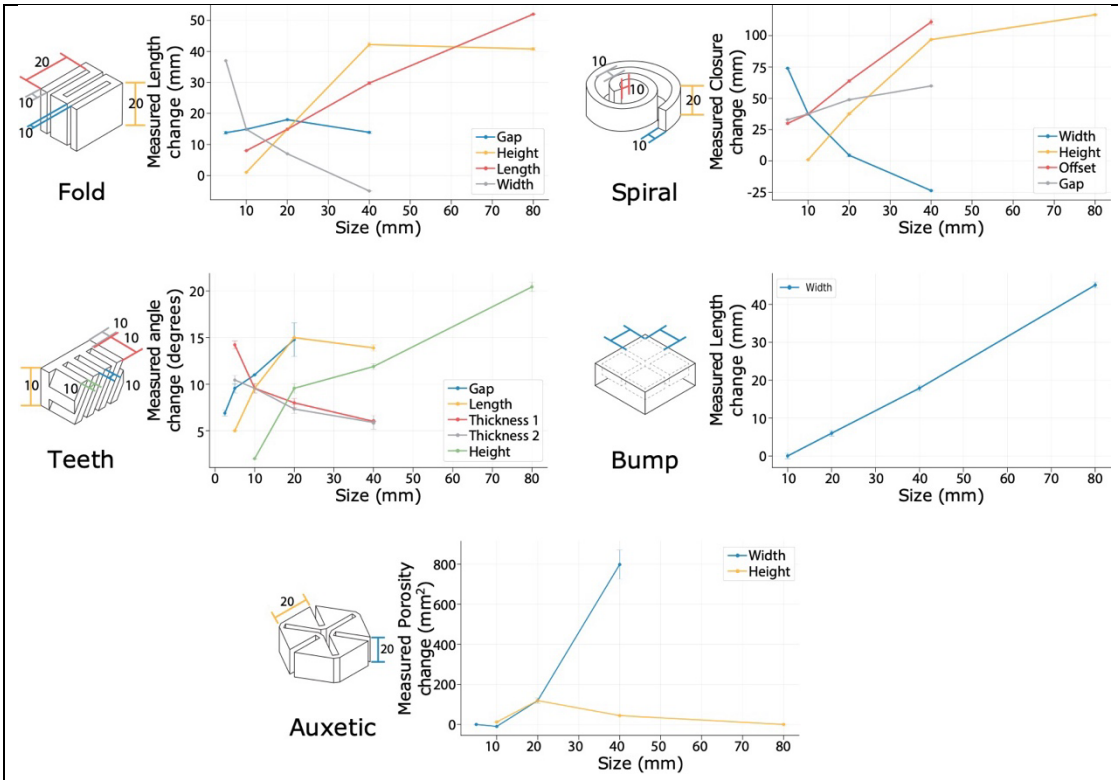

Figure 2. Results of the characterization of pneumatic shape-changing widgets [3]. These plots show the magnitude of the modified features versus the change of shape the widgets expressed. The numbers on the widgets show the baseline size of the features. For example, the Fold widget had baseline parameters of gap 10 mm, length 20 mm, height 20 mm, and width 10 mm. We then changed each parameter one by one, e.g., changed length from 10 mm to 80 mm (red line in the plot).

(1) https://softroboticstoolkit.com/sofa

(2) Sarah Sahabi, SoRoCAD 2.0: Extending a CAD Tool for Soft Robotics, Bachelor's Thesis

(3) Hyunyoung Kim, Aluna Everitt, Carlos Tejada, Mengyu Zhong, and Daniel Ashbrook. "MorpheesPlug: A Toolkit for Prototyping Shape-Changing Interfaces." In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, pp. 1-13. 2021.

4. YEAR 1 PROJECT DETAILS

a. Semester 1:

M-Level module selection:

Please read to Information Summary regarding this section. Please suggest at least 20 credits worth of M-Level EPS modules in each of semesters 1 and 2 suitable for a student on this project, including the module title and code.

Mechanical Engineering	***LM Advanced Manufacturing, 33330 (semester 1)***
Computer Science	***Research Skills, Eval Methods and Stats, 34239 (semester 1)***
Computer Science (semester 1)	***Human-Computer Interaction Theory and Practice, 30512***

Mini-project 1 abstract:

Supervisor name and email: Dr Hyunyoung Kim, h.kim.4@bham.ac.uk

Description: *Please summarise what the student will do in this project. Max. 200 words.*

Aim: The aim of the MP1 is to give the student foundation knowledge across the disciplines involved in the project. The objectives of the MP1 follows:

MP1-O1) Conduct a literature study of computational design for digital fabrication in Human-Computer Interaction and soft robotics.
MP1-O2) Learn related tools such as Fusion 360, finite element analysis, and 3D printers to be able to fabricate pneumatic shape-changing objects and use them.
MP1-O3) Learn Human-Computer Interaction theories and evaluation methods to be able to design a user interface for the final design software and conduct user studies in the later part of the PhD.

The MP1 will be focused on enhancing the student's knowledge of CAD and digital fabrication tools. The MP1 will run alongside "LM Advanced Manufacturing" and "Research Skills, Eval Methods and Stats".

Covid-19 adjustments:

Please describe how the effects of potential lockdown and social distancing will be mitigated in this project. Max. 100 words.

If needed, the MP1 can be completed through remote working when there is proper support such as online streaming from the modules.

b. Semester 2:

M-Level module selection:
Please read to Information Summary regarding this section. Please suggest at least 20 credits of M-Level EPS modules suitable for a student on this project, including the module title and code.

Mechanical Engineering Synoptic Mechanical Engineering, 23778 (semester 2)

Mini-project 2 abstract:
Supervisor name and email: Dr Hyunyoung Kim, h.kim.4@bham.ac.uk
Description: *Please summarise what the student will do in this project. Max. 200 words.*

Aim: The aim of the MP2 is for the student to customize an existing finite element analysis tool for the project and evaluate the tool

MP2-O1) Conduct a literature review of finite element analysis and evaluation methods in Human-Computer Interaction.
MP2-O3) Develop finite element analysis tool based on open source and evaluate the tool using a visual tracker such as Opti track.
Mp2-O2) Submit the initial results of the analysis to a related conference.

The MP2 will be focused on customizing an existing software tool, developing research skills, and learning to write an academic article. The "Synoptic Mechanical Engineering" help the student to understand how to simulate the physical properties of an object in software. The supervisors will teach the student how to write an academic paper.

Covid-19 adjustments:
Please describe how the effects of potential lockdown and social distancing will be mitigated in this project. Max. 100 words.

If needed, the MP1 can be completed through remote working when there is proper support such as online streaming from the modules.

5. INTERNSHIP/PLACEMENT SUMMARY

Max. 100 words

Autodesk are not able to offer a locally agreed internship with the CDT, however the supervisors will support the student to apply for the formal Autodesk internship scheme. https://www.autodesk.com/careers/students