

PhD Proposal: 3D Shape Modelling of the Human Head

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The proposed PhD project is concerned with the mathematical and computational modelling of human craniofacial 3D form and variation and its clinical application in craniofacial surgery. The work sits in the research areas of Computer Vision and Machine Learning.

We wish to accurately, reliably and automatically parameterise craniofacial surfaces in children and adults. This will allow us to compare two head surface scans (eg. pre- and post-operative), since current automatic labelling of various head parts is poor and manual annotation is difficult, inaccurate and time-consuming. We aim to develop state-of-the-art automatic landmarking algorithms and shape modelling processes using Machine Learning techniques. The models will allow us to morph the head shape of syndromic patients to unwind the dysmorphia and see what they should look like without the genetic condition (e.g. Apert syndrome), thus providing target shapes for operations.

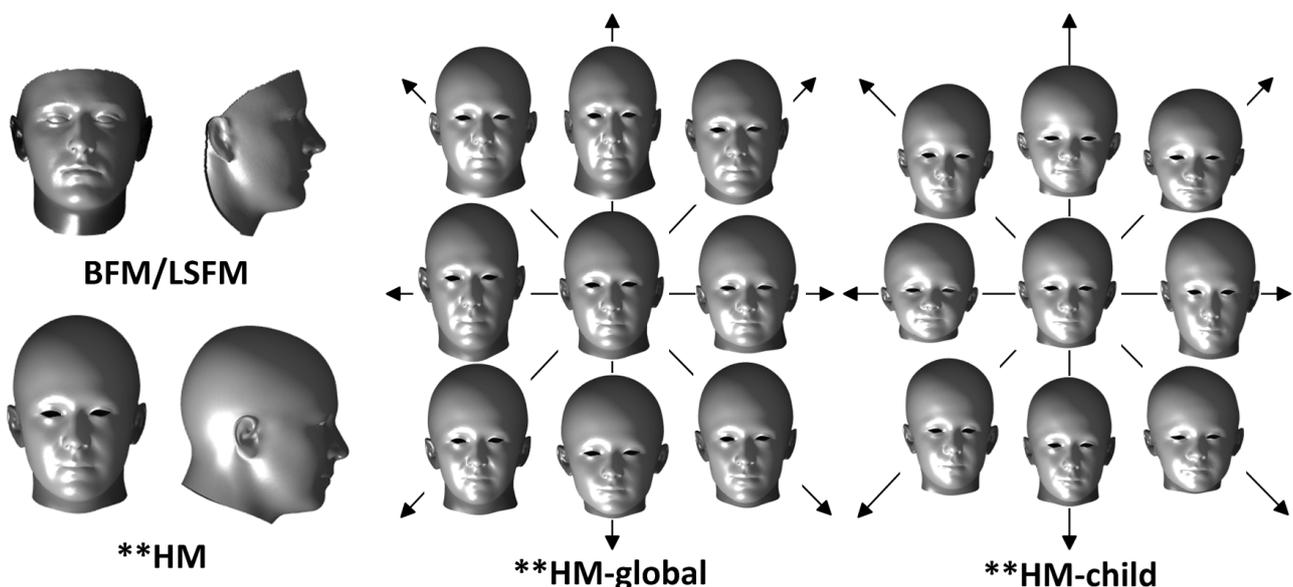


Figure 1: Human head models

1) **Health technologies priority area.** The proposed project matches to the EPSRC DTA strategic *Health Technologies* priority area. The work will be used to develop software tools to aid craniofacial clinicians plan, conduct and assess reconstructive craniofacial interventions.

2) **University and Department Research Strategy** This work aligns with three research themes identified as areas of research excellence by the University: (i) *Health and Wellbeing*, clearly successful work in this area will be of great benefit to craniofacial patients and their families in the UK, and more widely; (ii) *Risk, Evidence and Decision Making*, our software tools will allow craniofacial surgeons to support their planning and decision making with quantitative data around model-generated population norms and variances, this is currently completely lacking, and (iii) *Technologies for the Future*, our models will be developed using Machine Learning (ML) techniques, which have been identified by the Royal Society as a breakthrough technology that will transform our future. The CS Department is active in ML across at least three research groups (AI, CVPR, ACAG).

3) **Building on existing research.** There is currently one CS PhD student working in this area Hang Dai. He is working on the initial modelling of the Alder Hey *Headspace* 3D dataset of over 1500 3D images. This is the largest, wide demographic dataset of full head (including full cranium) and hence we have a unique opportunity to be first to develop statistical models of the full human head

surface. There is far more work to be done than a single PhD and a follow-on PhD will significantly strengthen our capability and impact in this area.

4) **Collaboration with other Departments.** In terms of 3D face and head modelling, we are collaborating with Prof Paul O'Higgins at the Hull-York Medical School and Dr Rob Jenkins in Psychology. We aim to submit research proposals to augment PhD work with RA-based development. We have a strong collaboration with the Craniofacial Department at Alder Hey Children's Hospital Liverpool.

5) **Related developments.** We have been approached by Google to develop an online tool that allows researchers to extract the populations statistics of any well-defined measurement on the human head. This led to us being awarded a Google Faculty Award for a project entitled *Headspace Online*. The proposed PhD project will directly relate to this work, as population statistics can be gathered automatically by automatic statistical model fitting.

6) **Capability to supervise the project.** There is a range of expertise in CS that relates to 3D Computer Vision and Machine Learning within Computer Vision and Pattern Recognition Group, Artificial Intelligence Group and Advanced Computer Architectures Group. There is a strong record of publications in 3D face analysis; for example, see the web pages of Nick Pears <https://www-users.cs.york.ac.uk/nep/> and Will Smith <https://www-users.cs.york.ac.uk/wsmith/>, who currently collaborate in this area.