MODELLING OF THE HUMAN TONGUE

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INTRODUCTION

The tongue has a complex histology consisting of multiple inter-weaving skeletal-muscle fibre groups, each with strongly directional properties. A good understanding of the functioning of the tongue is required to understand its role in Obstructive Sleep Apnoea (OSA) syndrome. OSA involves the collapse of the human upper airway, and has been linked to many medical and social ailments [1].

The development of a realistic computational model will assist in the research of this disorder, as well as linguistics and speech therapy. The aim of this work is to report on a constitutive model for the human tongue, and to demonstrate its use in computational studies.

METHODS

Anatomical data has been extracted from the female dataset of the Visible Human Project (VHP) [2]. All major muscle groups in the tongue and the surrounding region are incorporated into the model (Figure 1). The tongue and surrounding anatomy is modelled using a finite-element approach.

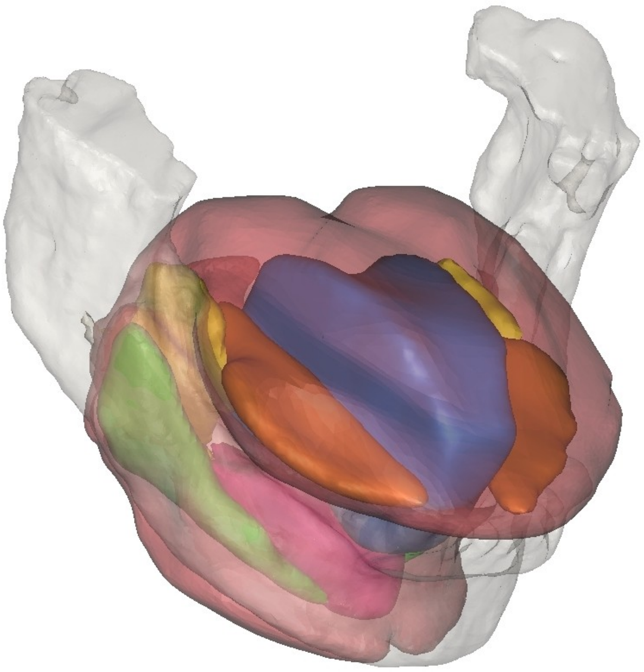

Figure 1: The mandible, tongue and its major constituent muscle groups captured from the VHP

Skeletal muscle is modelled using the Hill muscle model [3,4], where physical components of muscle fibres are represented by two non-linear elements arranged in series, both of which are in parallel with an additional non-linear element. Muscle fibres are embedded in an isotropic hyperelastic matrix. The work of Martins et al. [5] has been modified for the specific use in this work.

The effect of muscle activation is present in the model. The model is fully non-linear and is valid for large deformations. The inherent incompressibility of biological tissues is accounted for, and inertial forces are included. Provision has been made for the presence of multiple muscle fibre families in the matrix medium.

A Newton-Rhapson scheme is used to resolve the momentum equation, while continuous updates are made to the internal fibre-data by a hybrid Newton / Bisection method. This is used to provide a safe mechanism for root finding in discontinuous equations. Fibre (de)activation due to velocity or length constraints is accounted for.

RESULTS AND DISCUSSION

A realistic geometry of the tongue, epiglottis, hyoid bone, mandible and surrounding tissue have been extracted from the Human Visible Project. The geometry has been discretised into a structured mesh that is suitable for finite-element modelling (FEM). An open-source FEM library [6] has been used to simulate the behaviour of the tongue under different pressure conditions that will arise during breathing. This model is a precursor for the complete simulation of the human upper airway. The complete model will simulate air-flow using computational fluid-dynamics (CFD) and will include fluid-structure interaction.

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