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Finite Element Representation of Muscles

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Aims

- Create a generalised muscle model capable of being subject to compressive and tensile loads
- Implement the muscle model in to an elbow system and capture the interaction between the deformed muscle and the bone

Current Models

- Existing muscle models use complex material sub routines that are computationally expensive
- Some focus on the microscopic and mesoscopic scale of muscles such as the binding between actin and myosin proteins (Gielen et al., 2000)
- Some also utilise MRI and CT scans that render the models subject specific

Mesh & Geometry

- A mesh was created using tetrahedral elements, which were then converted to truss elements (Figure 1)
- This reduced the computational cost because truss elements have a single degree of freedom and hence can only deform axially, this is synonymous with the behaviour of a muscle

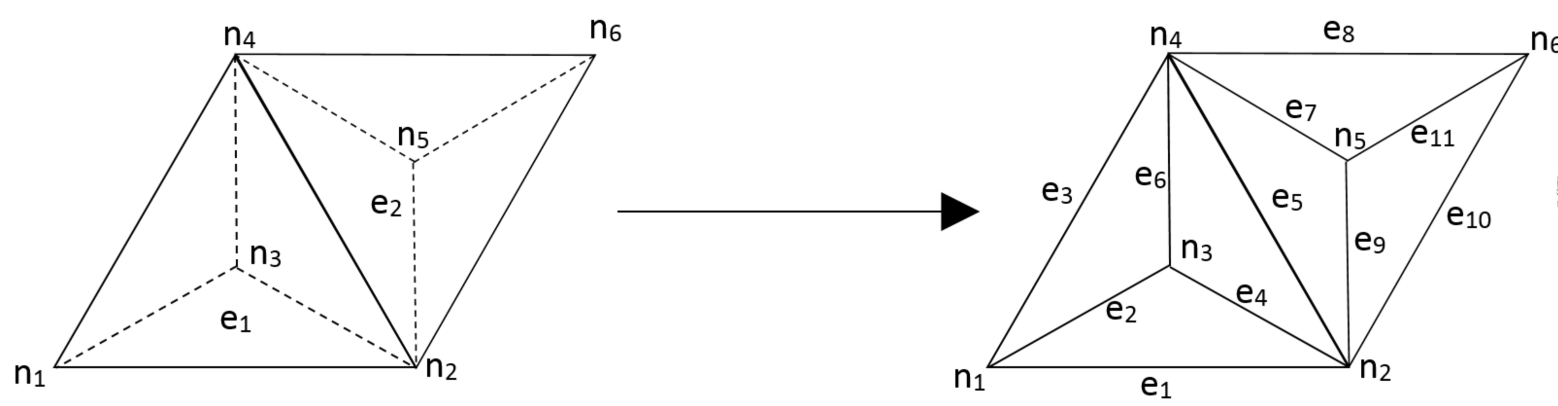

Figure 1: Conversion from tetrahedral to truss elements

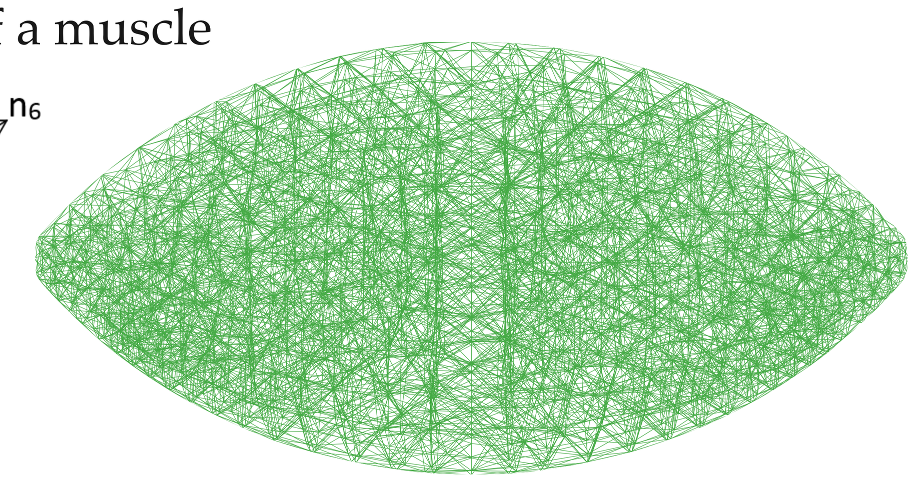

Figure 2: Mesh of the muscle

Final Muscle Model

- Utilised a hyper elastic material that accurately captured the passive response of the muscle (Figure 4)
- The model could be subject to both compressive and tensile forces (Figures 3 & 4)
- Eight connector elements around the exterior of the muscle induced the compressive force
- The wires that followed the geometry were similar to those found in the literature (Böl and Reese, 2008)

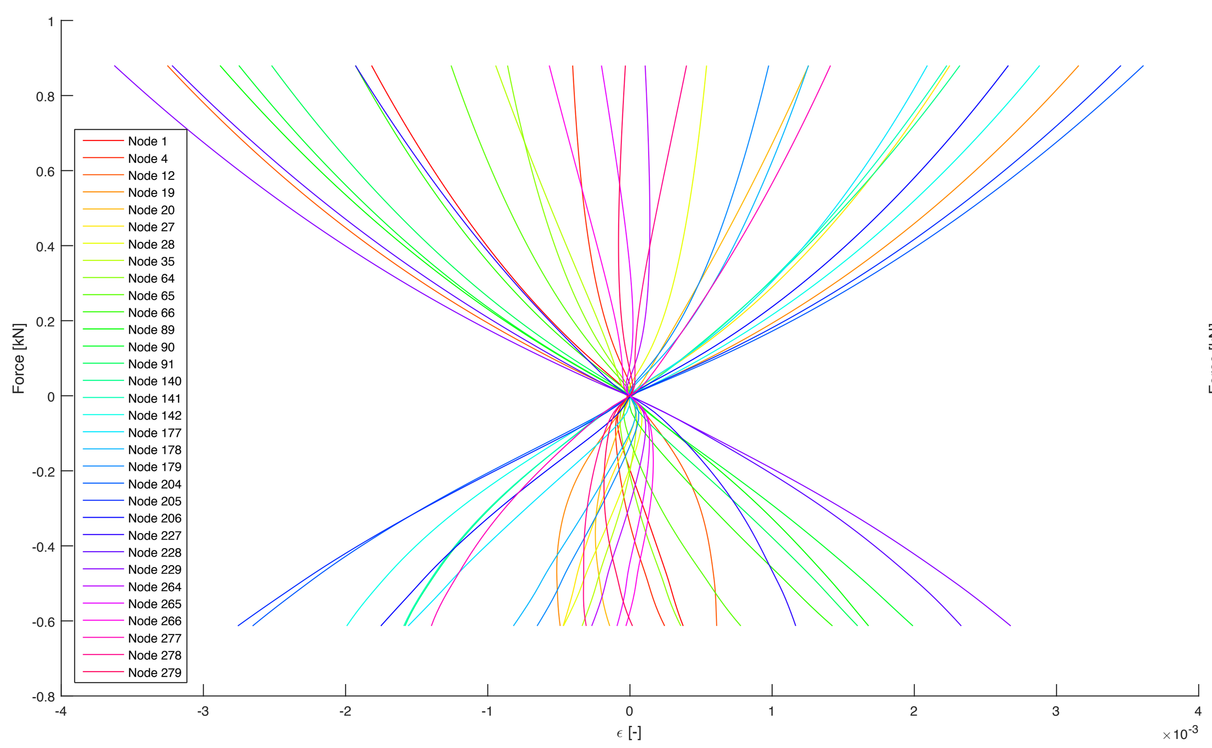

Figure 3: Force-strain graph in the X direction

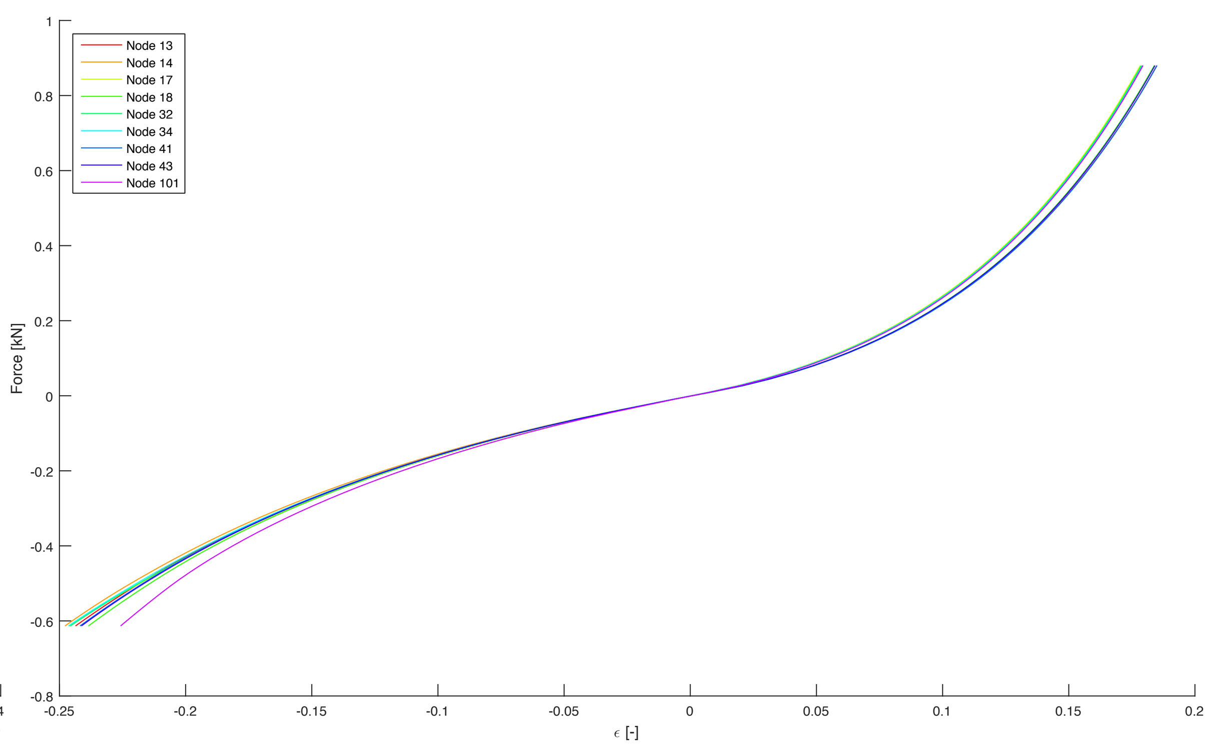

Figure 4: Force strain graph in the Y direction

Acknowledgements

I would like to thank Dr Phillips and his research team for their support and guidance throughout this project

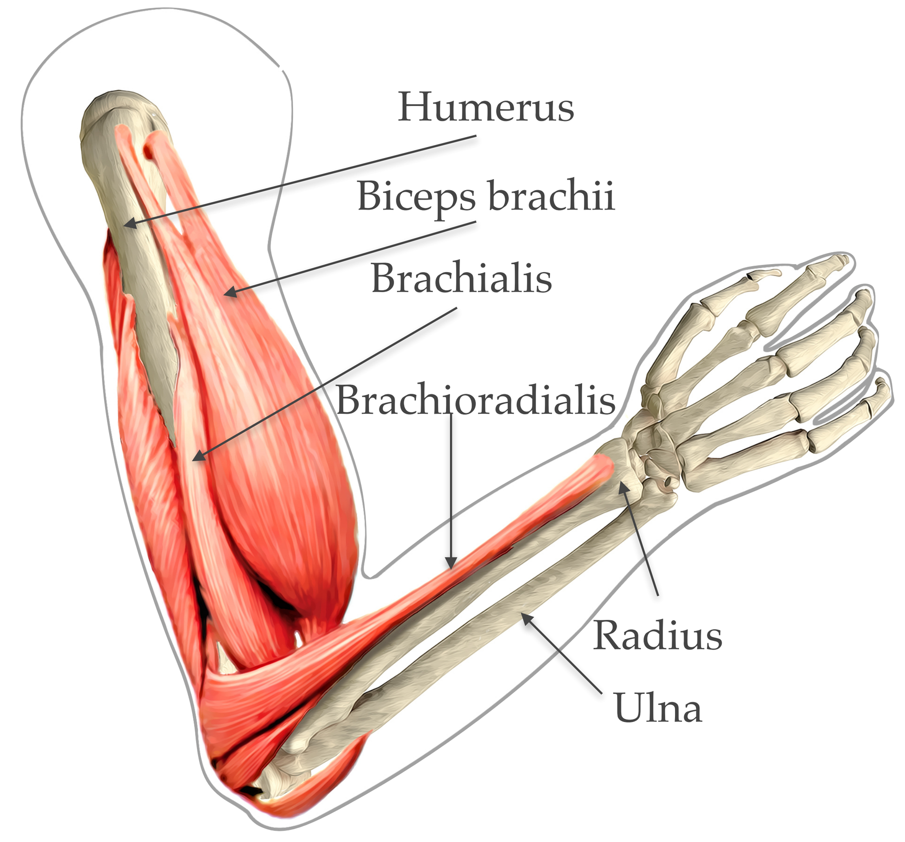

Figure 5: Anatomical model of the elbow system

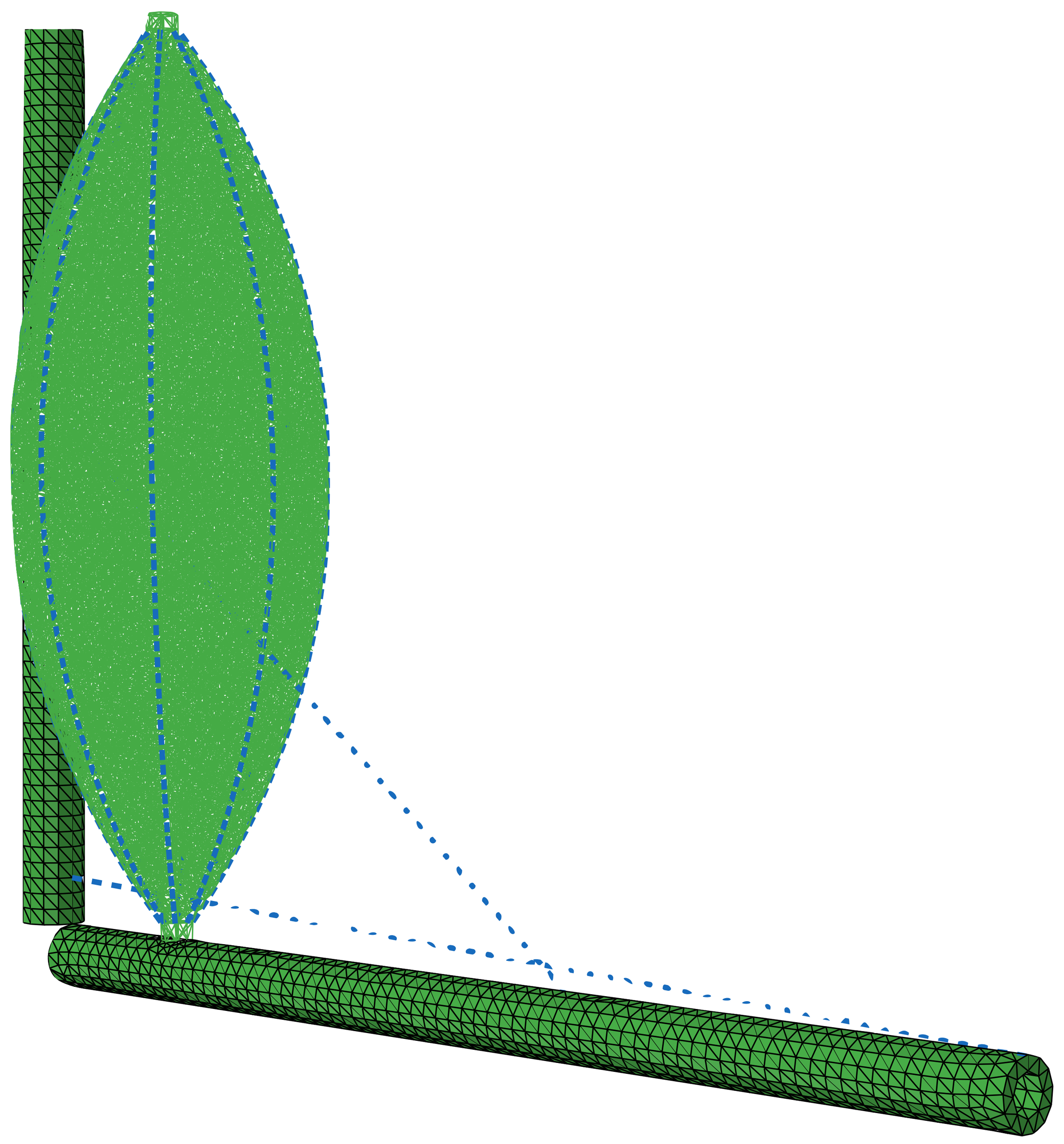

Figure 6: Elbow system in *Abaqus*

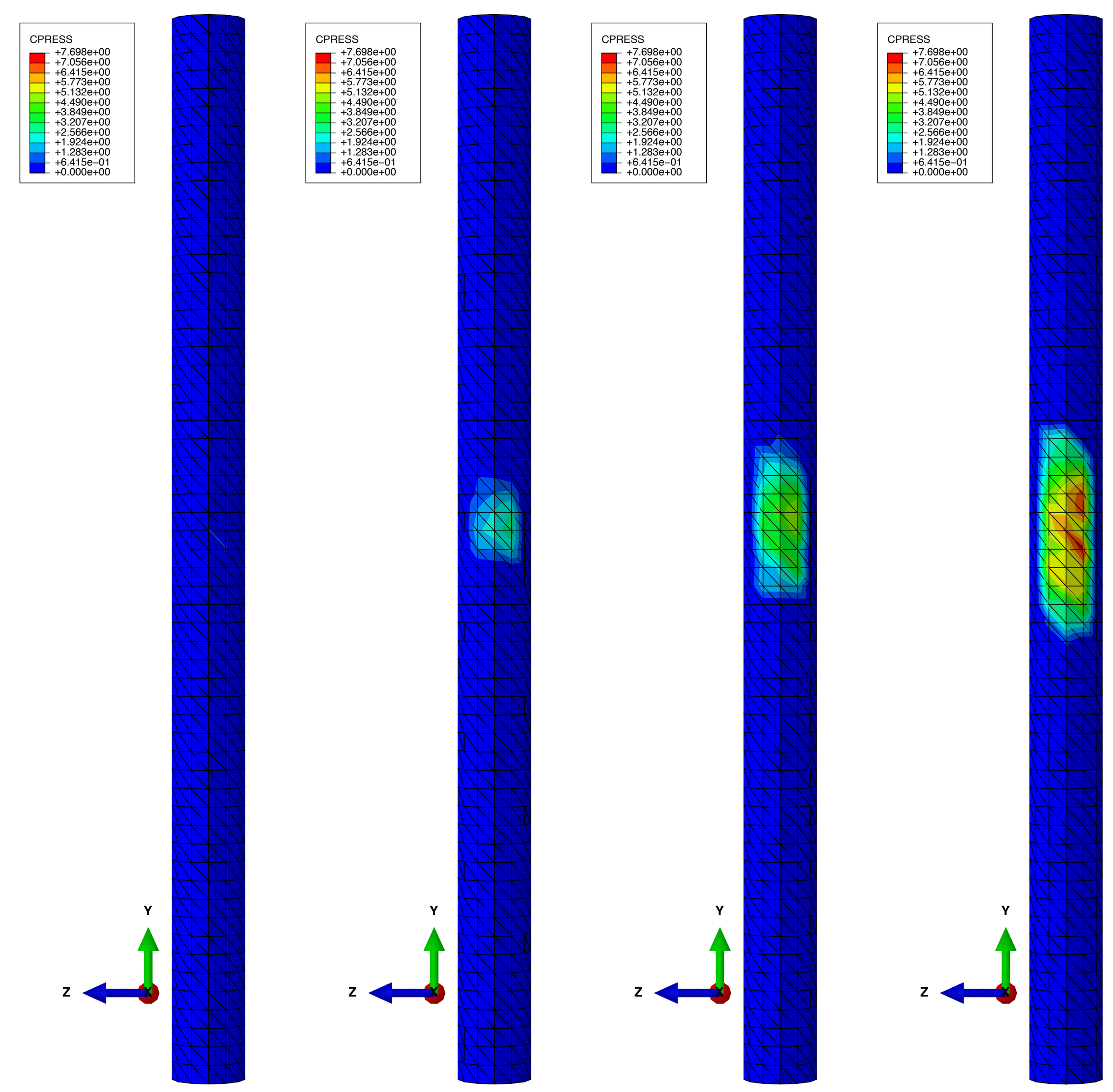

Figure 7: Contact pressure on the humerus

3D Elbow Mechanism

- The biceps brachii was chosen as the muscle to model in three dimensions because it makes contact with the humerus in the system that was adapted from the literature (Siemienski, 1992; Rasmussen et al., 2001)
- The brachialis and brachioradialas were modelled as wires
- The ulna and radius were combined to model the forearm (Figures 5 & 6)
- The contact between the biceps brachii and the humerus was modelled using a node to surface contact

Conclusions

- The muscle model correctly captured the passive behaviour of the muscle and leaves scope for further work to manipulate the active response of the muscle
- The elbow mechanism accurately modelled the contact pressure between the humerus and biceps brachii (Figure 7)
- A musculoskeletal model can be used to obtain muscle forces, implemented in to the elbow mechanism model and the resulting contact pressures can be applied to finite element models of bones

References

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