FACULTY OF APPLIED SCIENCES
UNIVERSITY
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DEPARTMENT
OF COMPUTER SCIENCE
AND ENGINEERING

An RBF Muscle Model

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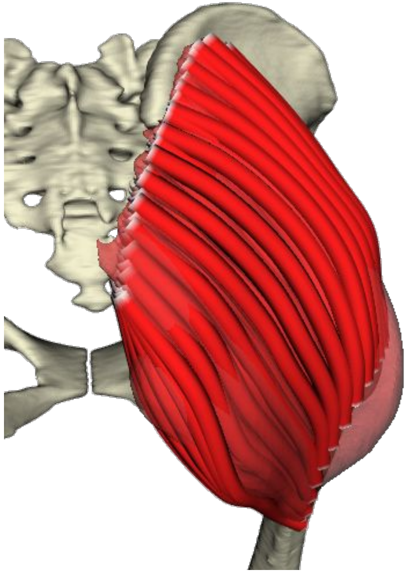
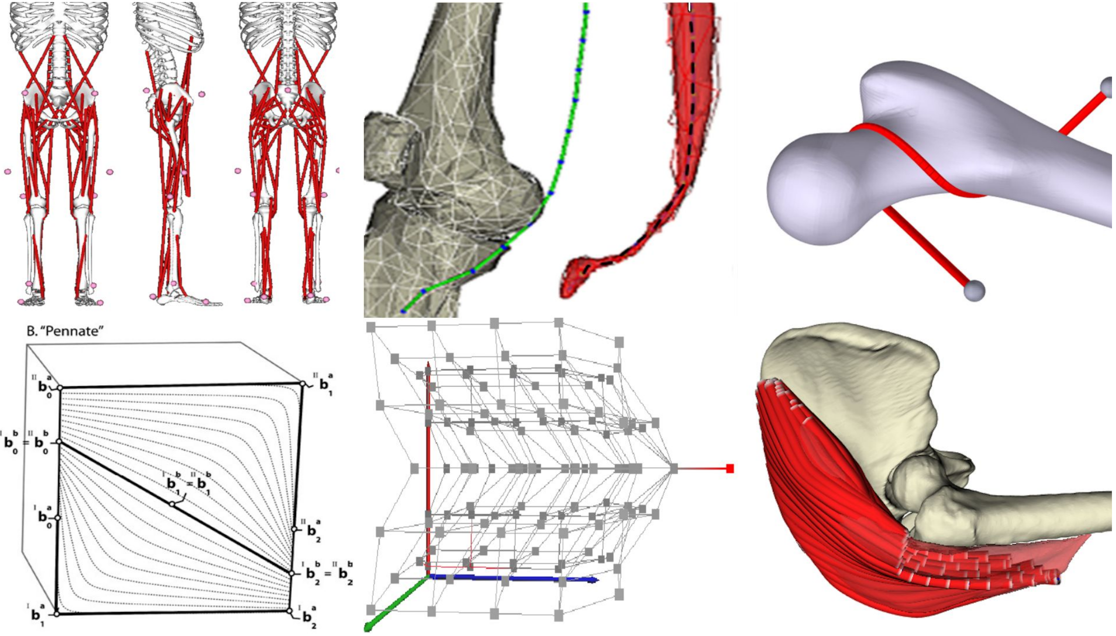
Introduction

- Problem definition
  - Position and shape of the muscle during the movement unknown, bones are defined
  - Muscle shape is approximated between the bones, to which the muscle is attached
  - Each model may be represented differently:
    - triangular surface mesh
    - models of fibres
  - Major behavioural requirements:
    - allow to calculate muscle force (for medical purposes)
    - preserve initial local shape (as much as possible)
    - preserve initial volume (...)
    - avoid collisions between entities (...)



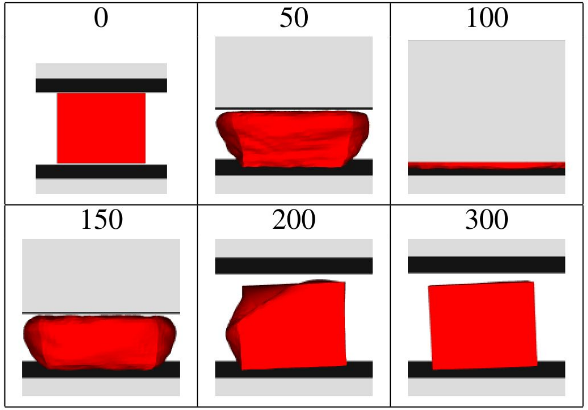
Existing approaches

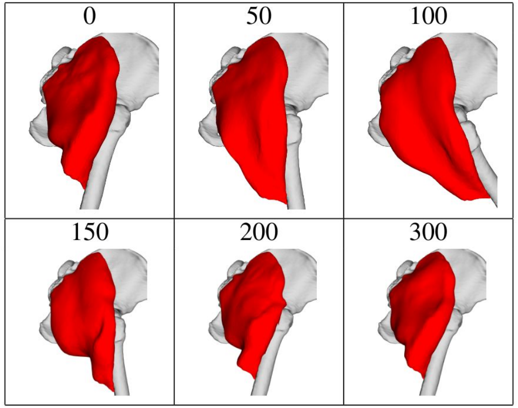


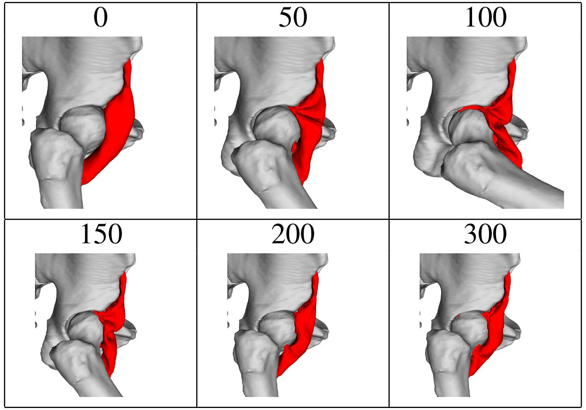
- Lines of action
- Via-points
- Wrapping obstacles
- Finite element methods
- Mass-spring systems
- Position-based dynamics

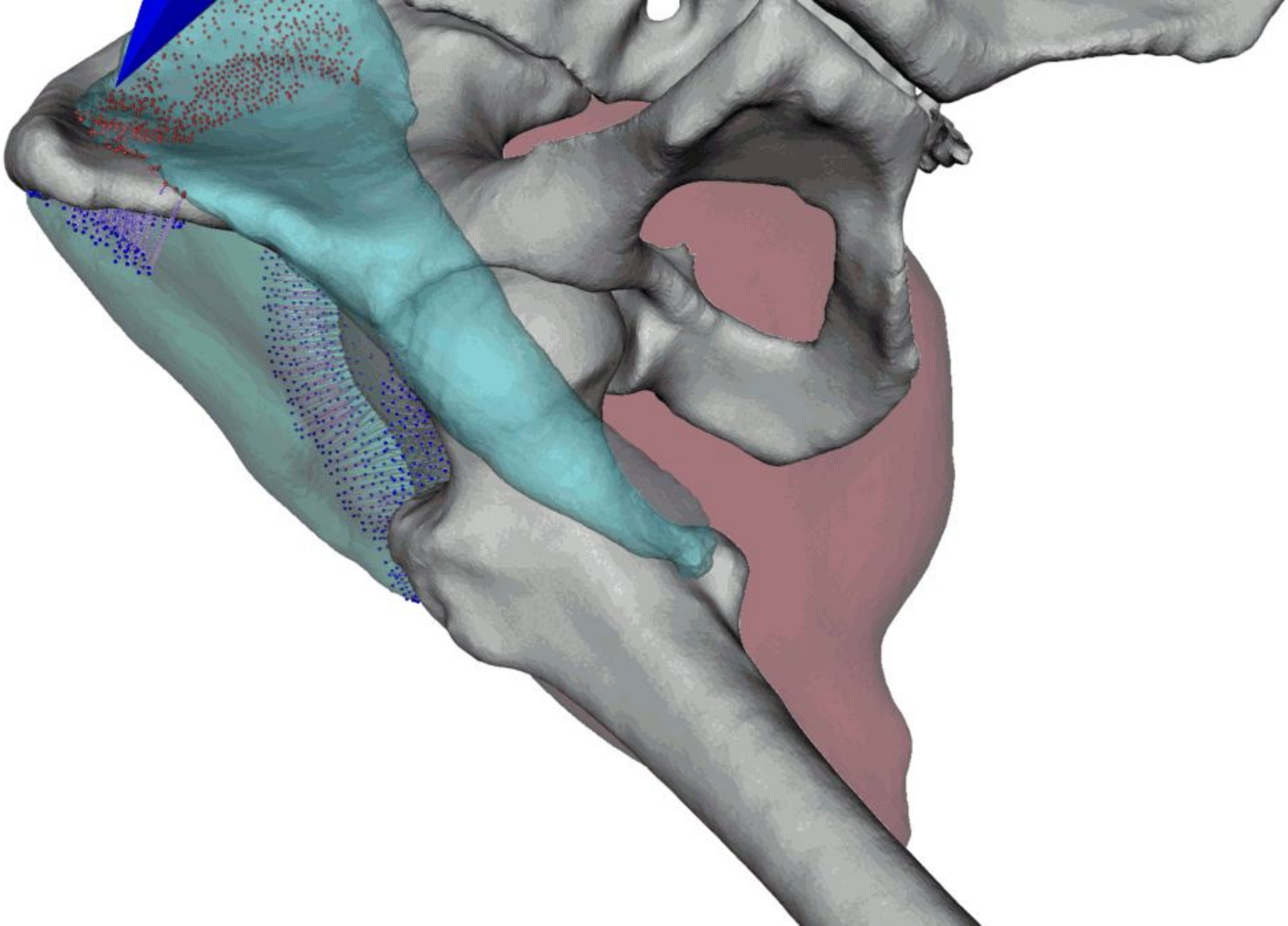
PBD: Position-based dynamics

- We work at this topic concurrently
- Produces deformed triangular mesh, preserving volume, shape, vertex distances and respects collisions
- Necessity of calculating and modifying all of the vertices









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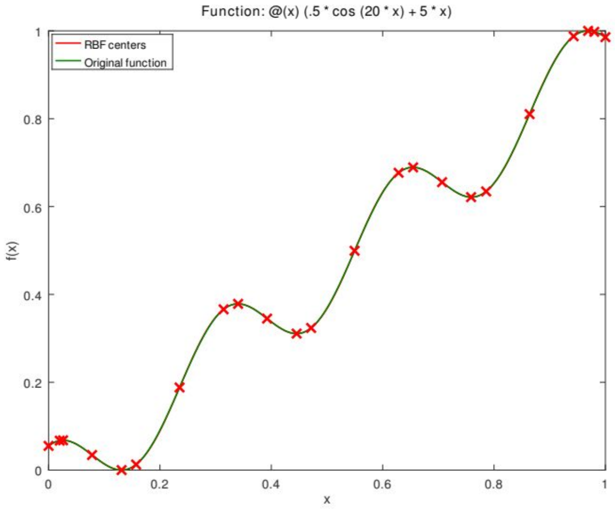
Radial basis functions

- The muscle may be represented differently
  - implicit surface approximation
- Radial basis functions - RBFs
  - weighted sum of individual RBFs
  - weights can be calculated
  - produces smooth approximation
  - if well selected (Gaussian), then infinitely differentiable

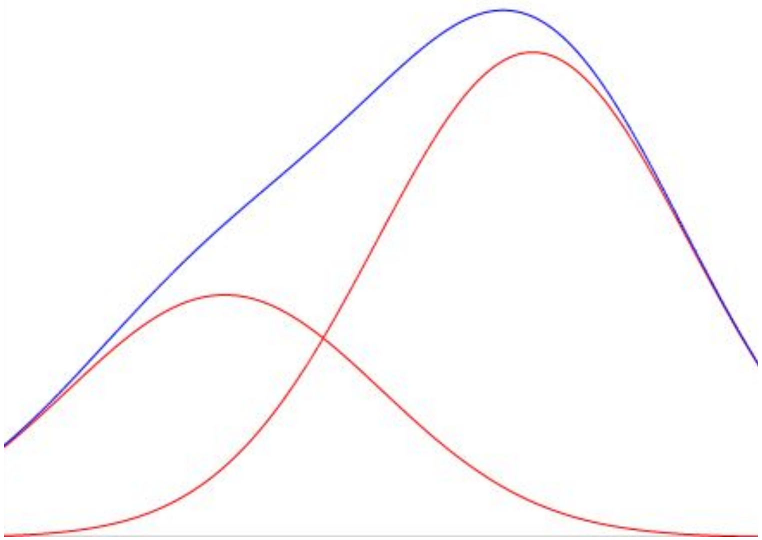


Gaussian radial basis functions

- find suitable
  - number of RBFs (depends on desired precision)
  - shape parameter
  - centre points

$$f\left(\mathbf{x}\right) = \sum_{i=1}^{N} \lambda_i e^{-\alpha||\mathbf{x}-\xi_i||_2^2}$$

α - shape parameter (global)
λ_i - weight of the individual RBF
ξ_i - centre of the individual RBF



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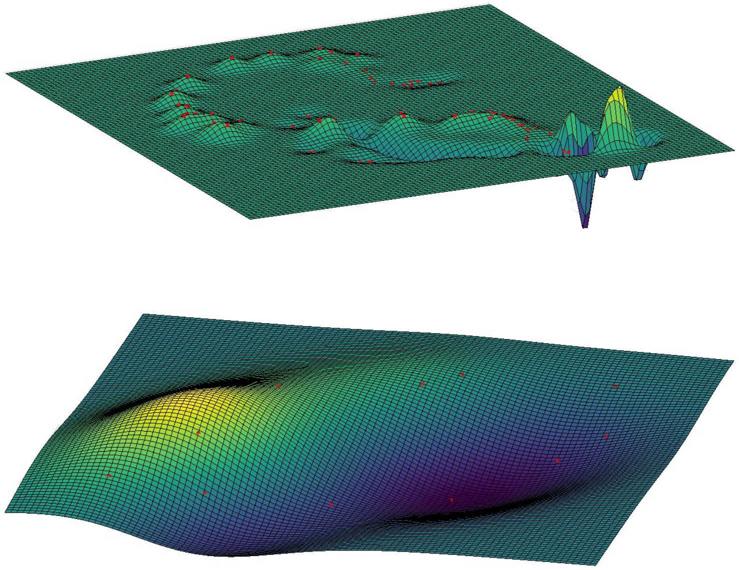
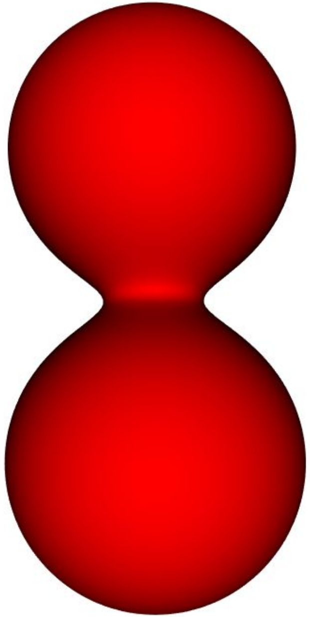
Radial basis functions

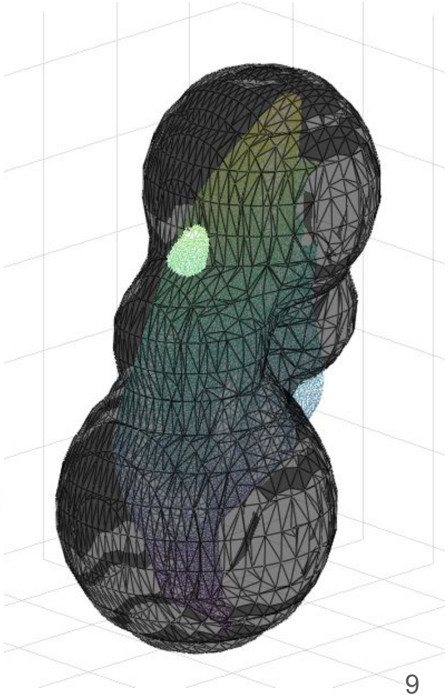
- Already used for the attachment estimation
  - The attachment is defined by a set of points on the boundary
  - The centre points = the boundary points
  - Task: find suitable shape parameters



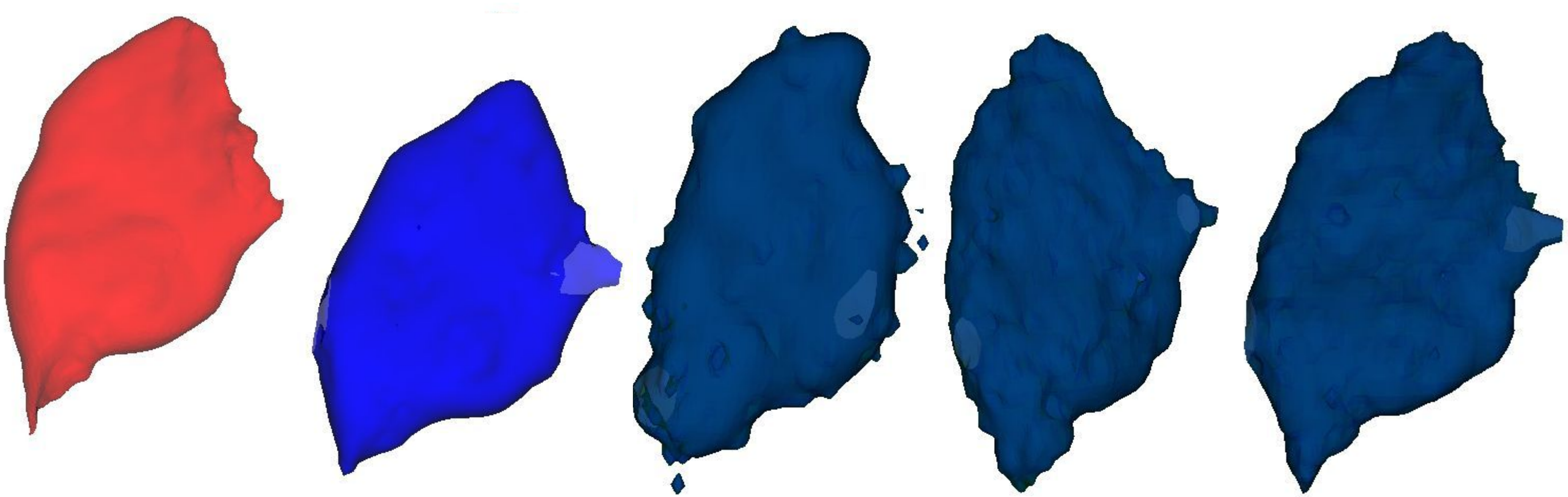
Radial basis functions in 3D

- Same idea as in 1D and 2D
- First step: select an isovalue
- 1 Gaussian RBF can be imagined as a "sphere"
- Multiple RBFs can merge those spheres together creating a "blob"
- Goal: create a muscle shape using just those "blobs"





The static muscle model



Compression ratios

- RBF approximation of the Triangular meshes, MSE < 5%

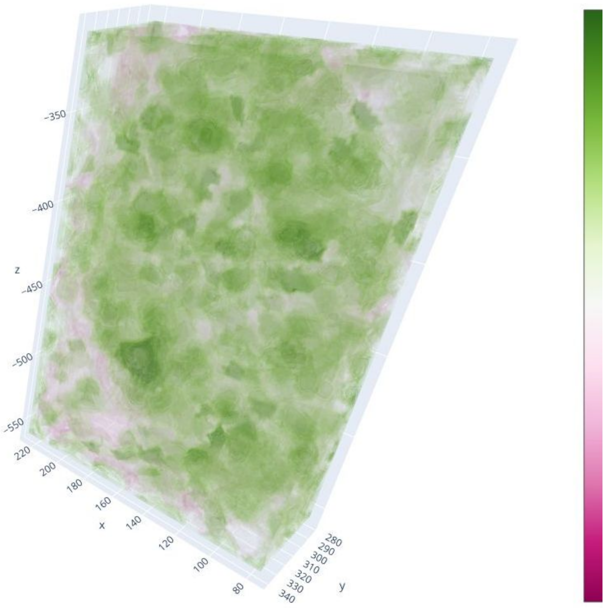
Muscle	Triangular meshes			RBF approximation		Ratio
	Vertices	Triangles	Memory	Centres	Memory	
Gluteus maximus	9878	19752	355560 B	184	7288 B	1:48
Gluteus medius	5313	10622	191220 B	50	2008 B	1:95
Iliacus	6931	13858	249468 B	167	6688 B	1:37
Adductor brevis	8564	17124	308256 B	25	1008 B	1:305

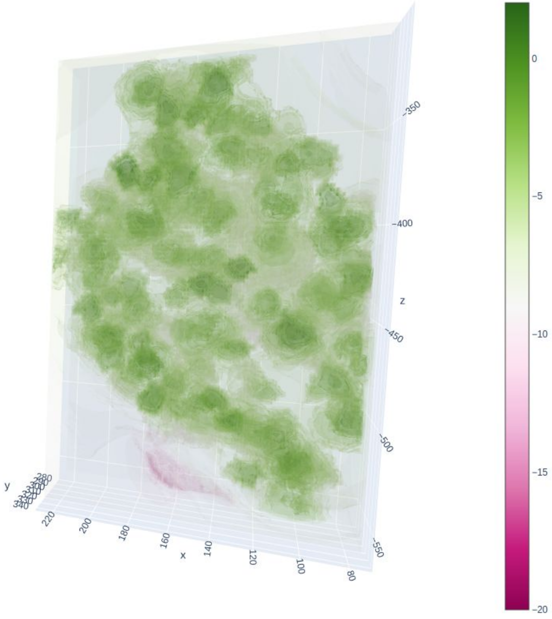
Dynamical model

- Preservation of the shape is done by curvature preservation
    a. move the attached part of the muscle
    b. to obtain the rest of the muscle:
        - recalculate the static model
        - do gradient descent to restore the curvature throughout the whole space
    c. repeat
- For the gradient descent is required to:
    a. find the Hessian matrix of the sum of all RBFs, representing the muscle
    b. obtain its eigenvalues
    c. get its mean => mean curvature
    d. evaluate the gradient of the difference between the original and just calculated mean curvature

Regularisation

- Force the RBF centres to be only inside/outside of the muscle
- Leading to "smoother" scalar field
  - reduce the amount of local extrema





Conclusion

- The theoretical model of finding the centre points is as follows:

$$\nabla C_{fj} = \frac{8\alpha^2}{d} \int_{\mathbb{R}^d} (\kappa_f - \kappa_{f_{\text{init}}}) \sum_{i=1}^{N} g_i(\mathbf{x}) (x_j - \xi_{ij}) (2\alpha||\mathbf{x} - \xi_{\mathbf{i}}||_2^2 - 2 - d) d\mathbf{x}$$

- The work in progress is to implement the theoretical model into the muscle modelling framework (static model already finished, dynamic is in progress)

Thank you for your attention