# Investigating a Suitable Mathematical Description of the Active Response of the Retina

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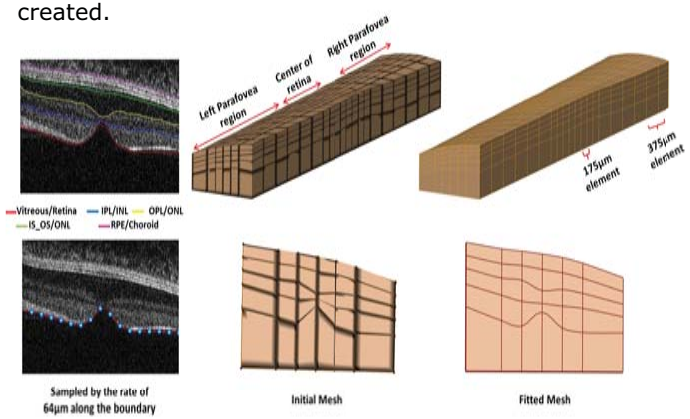
## Background

Retinal prosthetic devices aim to restore vision for blind by stimulating the intact ganglion cells. Dokos et al. [1] have developed a continuum bidomain model of the retinal tissue giving a microscopic approximation of retinal ganglion cell (RGC) activation in response to electrical stimulation. Here, we have applied their system of equations on an anatomically detailed mesh of the retina from optical coherence tomography (OCT) images and the pattern of the RGC activation is compared with the previous reported results in [1].

## Method

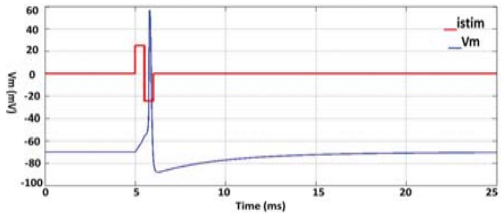
### 1. Generating a Large Anatomically Detailed Mesh of the Retina

256 SD_OCT images of a healthy male retina aged 30-40 years old using RS_3000 OCT scanning machine (software version 2.0) were provided and segmented. The segmented images were passed through a fitting process of [2] and 3D anatomically detailed mesh is created.




### 2. Simulating the Action Potential of a Single Ganglion Cell

The action potential of a single RGC was modeled in CellML using Fohlmeister et al.[3] formulation.

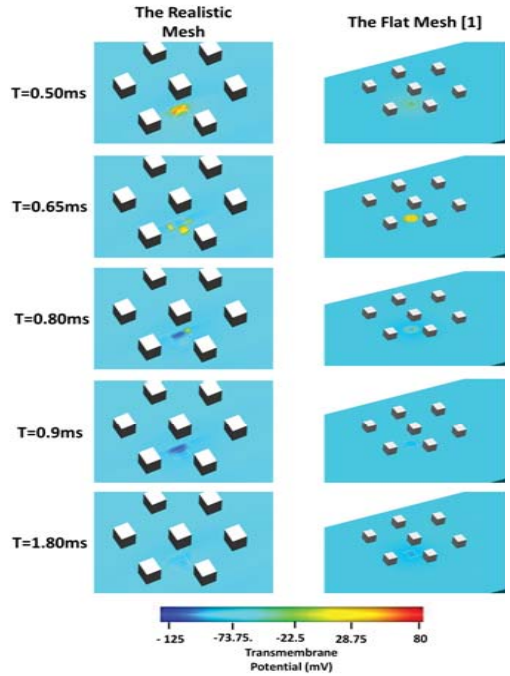



### 3. Applying Continuum Bidomain Equations

The classical bidomain equations couple the intracellular and extracellular domains through the membrane current. To model independent RGC activity the intracellular conductivity is set to zero along the active RGC layer:

$$
\begin{aligned}
-\nabla\sigma_{el}\nabla V_e &= J && \text{, within the injecting electrode}\\
\nabla\sigma_{el}\nabla V_e &= J && \text{, within the returning electrode}\\
\nabla\sigma_{e}\nabla V_e &= 0 && \text{, within the passive layers}\\
-\nabla\sigma_{e}\nabla V_e &= I_m && \text{, within the active layer}\\
\nabla\sigma_{i}\nabla V_i &= I_m && \text{, within the active layer}
\end{aligned}
$$

## Results




## Conclusion

- For the first time, RGC activation under electrical stimulation has been modelled in an anatomically detailed mesh of the retina. The active response of the retina was modelled by the classical bidomain equations [1].
- The gross anatomy of the retina in the realistic mesh resulted in charge leaking from the intracellular to the extracellular domain acting like a virtual electrode and causing an asymmetric activation of RGCs. This issue was not observed in the previous studies with simplified flat mesh of the retina.
- In the future study, the active response of the retina will be modeled by the system of equations introduced in [4]. In this formulation the intracellular potential is not free to change with extracellular potential, instead it is tied to a remote intracellular cellular region through a constant conductance. The finite element analysis of this formulation will be implemented in OpenCMISS.

## References

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4. Joarder, S.A., et al., *A continuum model of retinal electrical stimulation*. Journal of neural engineering, 2011. **8**(6): p. 066006.

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