Cellular systems on curved surfaces - from curvotaxis, coordinated motion and cell-dependent surface deformation

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Abstract

Cells sense and respond to local curvature, essentially by aligning the filaments with the principal curvature directions. This not only affects the shape of individual cells, but also plays an important role regarding cellular motion. For example, recent experiments on cylindrical epithelial tissues of MDCK cells suggest a strong connection between (extrinsic) curvature and collective cell rotation. To understand this interplay between cellular systems and curved surfaces, we will first focus on stationary surfaces.
Mathematically the influence of curvature in cellular systems has been modelled in the past by a coarse-grained continuous active polar gel model with ad hoc linear curvature terms, but not by an agent-based model. We therefore propose a multi phase field model to fill this gap. This model allows us to model each cell separately and thus to account for cellular properties and cell-cell interactions. The resulting system is solved using surface finite elements. To include extrinsic curvature contributions, we add a new part to the free energy of the system. This extrinsic curvature energy is inspired by the theory of surface liquid crystals, where extrinsic curvature effects are well understood. We consider cylindrical shapes and compare our results with experimental data for MDCK cells.

Finally, we give a brief insight into our current work on cellular systems on evolving surfaces, using the evolving surface finite element method. Here, we take a look at cell-dependent surface evolutions.

The talk is based on the following paper:
L. Happel and A. Voigt, *Coordinated Motion of Epithelial Layers on Curved Surfaces,* Physical Review Letters 132, 078401 (2024)

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