A Model for Bleb Expansion Using the Level Set Method

S.H. Dinuka S de Silva[1], Emmanuel Asante-Asamani[1]

Department of Mathematics, Clarkson University[1]

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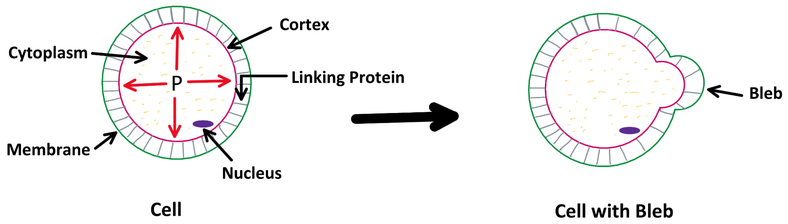
Background

- A bleb is a hemispherical protrusion of the cell membrane caused by localized decoupling of the cytoskeleton from the plasma membrane.

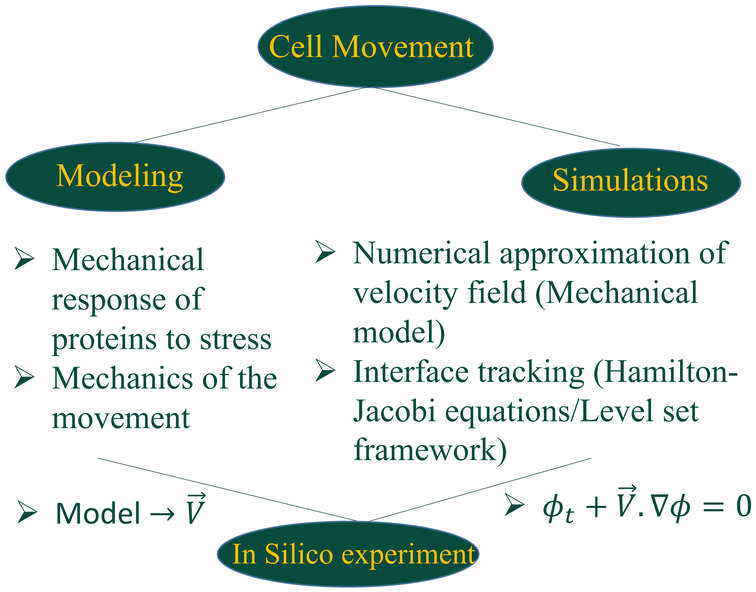


- How do cells coordinate their movement using blebs?
- How do blebbing cells adjust their movement in response to stress in their environment?
- How does cell shape effect bleb size?
- Which proteins regulate blebbing?

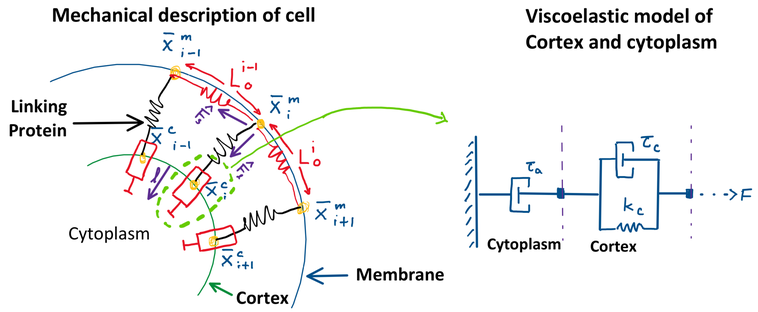
Research Objective

- The current focus of our research is to investigate the role of cell shape and membrane-cortex adhesion strength on bleb size

Methodology



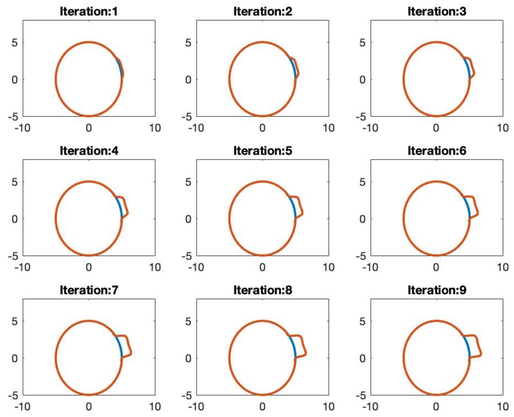
Mechanical Model



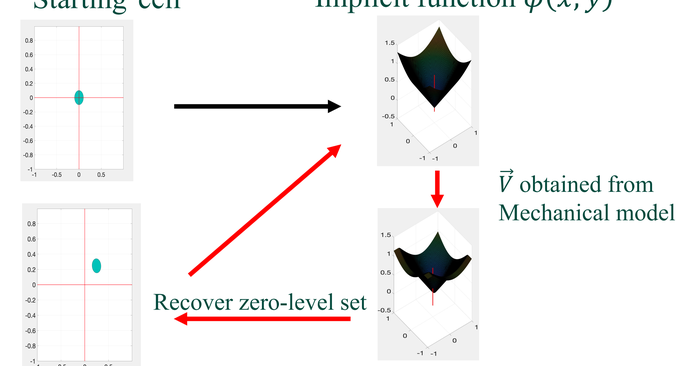
- In Voigt model τ_a, τ_c are viscous elements and k_c is the elastic element
- The velocity field can obtain by using following equations
- $\dot{x}^m = -\left(\frac{k_c}{\tau_c}\right) l + \left(\frac{1}{\tau_a} + \frac{1}{\tau_c}\right) F_T$
- $\frac{dl}{dt} = -\frac{\kappa_c}{\tau_c} l + \frac{1}{\tau_c} F_T$
- Here, $F_T = P_{eq} - (F_s + F_B + F_l)$
- $P_{eq} = 2\gamma^c_{ten}\kappa_c(x)\vec{n}$, $F_s = \left(\hat{F}_S.\vec{n}\right)\vec{n}$, $F_B = B\kappa(\mathrm{x})\vec{n}$, and $F_l = \left(\hat{F}_l.\vec{n}\right)\vec{n}$

Algorithm and Result

- Compute force at each membrane point, F_T^n
- Update viscoelastic strain, $l_i^n = \frac{\left\|(F_T^n)_i\right\|}{\kappa_c}\left(1 - e^{(-k_c/\tau_c)(n\Delta t)}\right)$
- Calculate velocity, $(\dot{x}_i^m)^n = -\left(\frac{k_c}{\tau_c}\right) l_i^n + \left(\frac{1}{\tau_a} + \frac{1}{\tau_c}\right) F_T^n$
- Update membrane position, $(\bar{x}_i^m)^n = (\bar{x}_i^m)^n + \Delta t\ (\dot{x}_i^m)^n$

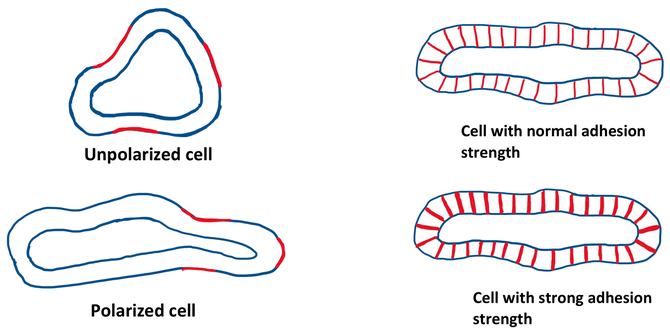


Ongoing1: Interface Tracking



Ongoing 2

- Effect of cell shape & curvature on bleb size
- Effect of adhesion strength on bleb size



Reference

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