Slide 1

- Model for cell growth, cell division and packing
- Under soft constraints
- Phase field modeling (Diffuse inteface methods)
- Using one of many computational methods: Finite element framework
- Membrane: Zero level set

Slide 2

- Mathematical problem, packing of spheres
- Fixed volume. Optimal arrangement
- Inaccurate representation with right
- Shows embryo of starfish and cell evolution in a fixed volume.
- Challenge is to develop numerical methods to model alongside, incorporate the physics with it.

Slide 3

- Peruse though the motivation slide
- Previous literature studies based on it, Our numerical framework and
- Demonstrate certain examples

Slide 4

- Figure shows light microscopy embryonic diagram of a sea urchin
- Nucleus divides, as indicated by arrows.
- Division proceeds evenly and then due to the fixed volume confinement it starts packing
- it forms a morula after multiple anisotropic cell divisions. Motivation

Slide 5

- Another problem which serves as our motivation is tumor growth
- Dense stromal tissue prevents drug transport
- Interactions between fibronectins, calcinogens, cancerous fibrogens cause this. Investigate

Slide 6

- Previous literature analysed these issues (on lattice and off latice)and came up with cellular automata
- Collection of colored sets on structured grids which depend on rules set by neighbouring sets/cells
- Jagged boundaries, crude model
- Cannot capture cell interaction, cell division etc

Slide 7

- Off latice addressed this problem of jagged boundaries and came up with vertex models
- Though it represents collection of cells broadly
- Cell shapes are primitive, minimally represents the original smooth shapes

Slide 8

- Now we demonstrate our numerical framework to model these system
- illustrates cell division progressively.
- The cells are non overlapping and have anisotropy and smoothness
- The ellipse is an user defined boundary. Blue indicates cell exterior.
- Red indicates cell cytoplasm and the intermediate rainbow like transition from red to blue indicates cell membrane
- our frame work is based on volume compaction

Slide 9

- Two categories of equations
- Solves 2nd order and 4th order pdes
- Can model both conserved and non conserve fields

Slide 10

- free energy density function which depends on order parameter and its spatial derivative
- Scalar fields are considered as individual cells

- Bulk energy term, diffuse interface membrane, κ control thickness
- Penalty term enforces cellular repulsion or non overlapping of scalar fields

Slide 11

- we take a standard variation formulation
- Resulting chemical concentration is what we are interested in (scalar field, order parameter)
- Home grown code

Slide 12

- Show video. Explain division from 2 to 4
- Time scales are similar
- Anisotropic growth, reiterate the color legend
- Packing of soft deformable structures illustrated

Slide 13

- Refresh what we said so far
- Unlike other methods we do not have interface evolving mechanics