

# Agent-Based Modeling of Ductal Structure in Pancreatic Precancer

Cameron Yeagle

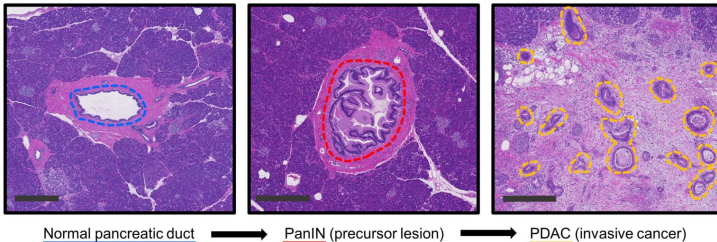
Advisors: Dr. Daniel Bergman and Dr. Elana Fertig

August 7, 2025



# Project Overview

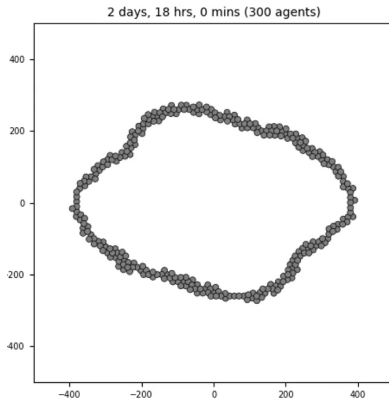
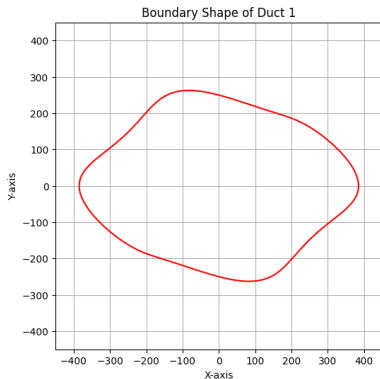
Goal: Develop framework for modeling dynamic ductal structures



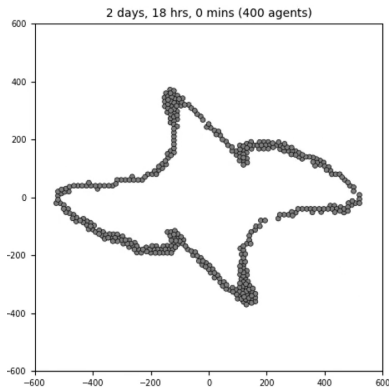
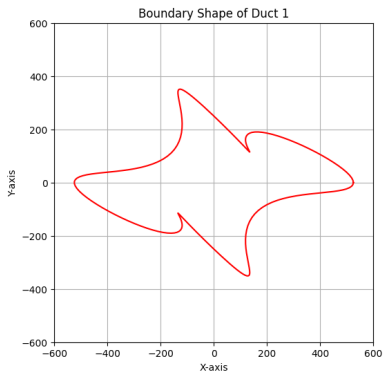
**Figure:** Kiemen, A. L., Wu, P.-H., Braxton, A. M., Cornish, T. C., Hruban, R. H., Wood, L., Wirtz, D., & Zwicker, D. (2023).



# Current Progress: Ex 1



## Current Progress: Ex 2



# Level Set Approach: Main Idea

- Main Idea

- ▶ The ductal region  $\Omega$  and basement membrane  $\Gamma = \partial\Omega$  are defined implicitly by a signed distance function  $\phi$ ,

$$\left\{ \begin{array}{ll} \phi(x) < 0, & x \in \Omega \\ \phi(x) = 0, & x \in \Gamma \\ \phi(x) > 0, & x \notin \Omega \\ |\nabla\phi(x)| = 1 \end{array} \right.$$



# Handling Deformations

$\forall$  point  $x(t)$  on  $\Gamma$ ,  $\phi(x(t), t) = 0$  must hold for all time, i.e.  $\frac{d\phi}{dt} = 0$ .

Hence, by multi-variable chain rule,

$$\frac{d\phi}{dt} = \frac{\partial\phi}{\partial t} + \nabla\phi \cdot \frac{dx}{dt} = \frac{\partial\phi}{\partial t} + \nabla\phi \cdot V$$

Let  $\tilde{V} = V \cdot n$ , where  $n$  is the unit normal vector  $\frac{\nabla\phi}{|\nabla\phi|}$ . Then

$$= \frac{\partial\phi}{\partial t} + \tilde{V}|\nabla\phi| = 0$$

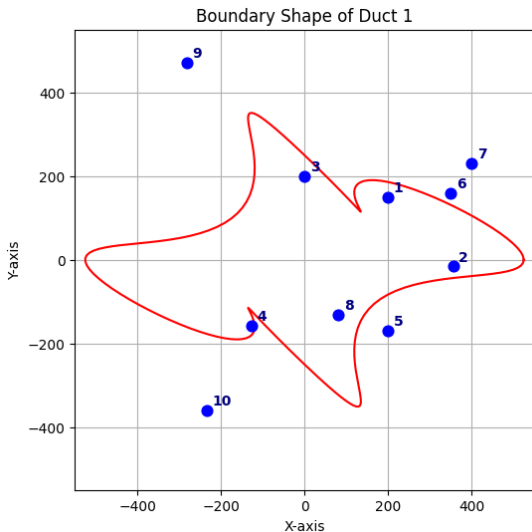


# Pros & Cons of the LSM

- Pros
  - ▶ Handles topological changes to the ductal structure implicitly
    - Typically,  $\phi$  is updated by solving a PDE
  - ▶ Easily adaptable to PhysiCell
- Cons
  - ▶ Difficult to initialize
  - ▶ Updating  $\phi$  via PDE introduces perturbations in SDF

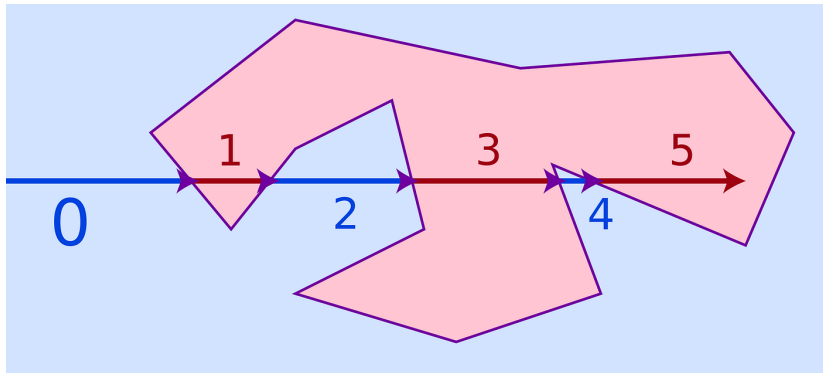


# Challenge: Initialization





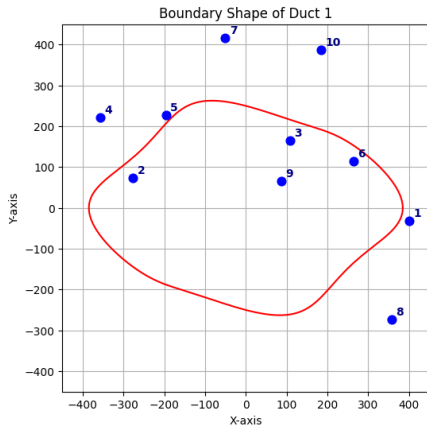
# Ray-Casting (Even-Odd Method)



**Figure:** Ajmera, G. (2024). Exploring algorithms to determine points inside or outside a polygon.



# Ray-Casting: Ex 1



Point 1: is OUTSIDE

Point 2: is INSIDE

Point 3: is INSIDE

Point 4: is OUTSIDE

Point 5: is OUTSIDE

Point 6: is INSIDE

Point 7: is OUTSIDE

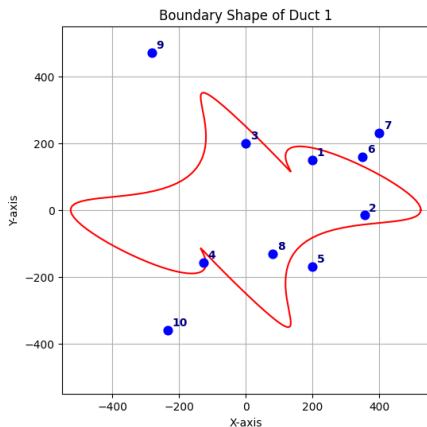
Point 8: is OUTSIDE

Point 9: is INSIDE

Point 10: is OUTSIDE



## Ray-Casting: Ex 2



Point 1: is INSIDE

Point 2: is INSIDE

Point 3: is INSIDE

Point 4: is INSIDE

Point 5: is OUTSIDE

Point 6: is OUTSIDE

Point 7: is OUTSIDE

Point 8: is INSIDE

Point 9: is OUTSIDE

Point 10: is OUTSIDE



# Future Work

- Implement Deformations
  - ▶ Have the boundary react to proliferation
  - ▶ Duct should collapse in
- Implement Visualization into Studio



Thank You!

Any Questions?

