Prediction of Sea Ice Edge by Using Image Processing Techniques

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Outline

- Problem
- Approach
- Result & Discussion
- Future work

Antarctica

- The southern most icy continent of the world surrounding the south pole is called Antarctica.
- Antarctica is located between the latitudes of approximately 65^0 S and 90^0 S
- Antarctica is called pulsating continent because its ice pack grows from an area of 2.6×10^6 km^2 by March-end (end of southern summer) to about 18.8×10^6 km^2 by September-end (end of southern winter)

Salient Features of Antarctica

- Fifth largest continent about $14X10^6$ km^2
- Mean Surface elevation is over 2000m
- Lowest temperature recorded -89 ^0C
- Wind velocity up to 200 km/h
- About 10% of the cost is rocky
- The driest continent in the world
- The highest point in the continent is Vinson Massif with height of 5140 m
- Locked in the Antarctica land mass is 90% of the world's ice cover and 70% of the global fresh water
- The 10% of Antarctica is free of ice
- The thickness of ice on the remaining 90% of the continent is 0.6-4.5 km
- Antarctica started forming at least $50X10^6$ years ago

Problem

Prediction of pulsating nature of Sea Ice Edge over the Antarctica

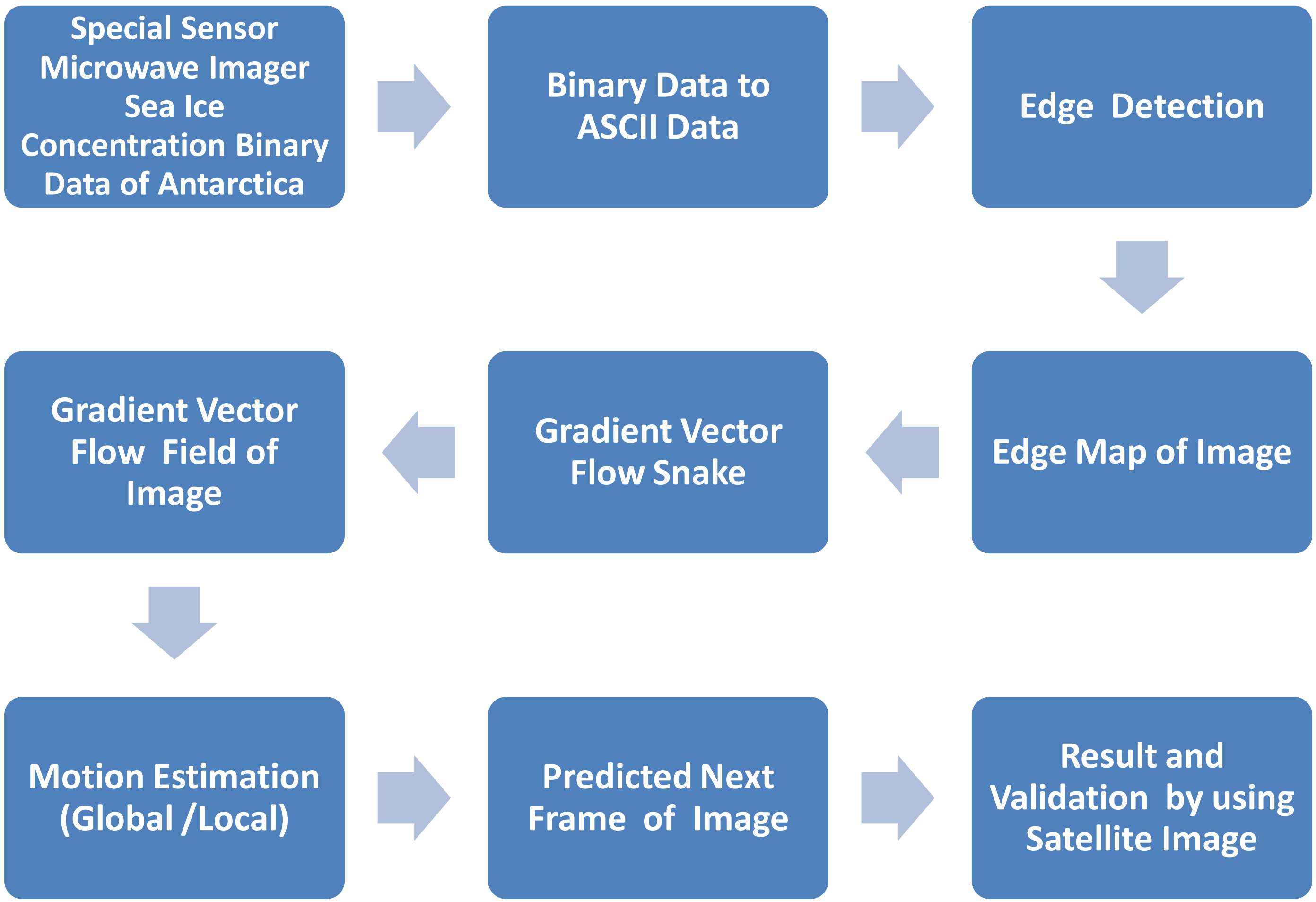
Pulsating continent : Antarctica

Pulsating Antarctica: Seasonal Variation of Antarctica Sea Ice Edge from 1st July 2002 to 1st July 2005

Why Antarctica Sea Ice Edge?

- Antarctic sea-ice cover plays an important role in the earth's climate, primarily by insulating the ocean from the atmosphere and increasing the surface albedo.
- Sea-ice formation and the accompanying convective processes are the main driving force for the global thermohaline circulation.
- Densification of sea water by brine rejection as a result of intensive freezing is strongest in open water areas and the bottom-water formation.
- Sea-ice edge is a potential indicator of climate change.
- Fishing and commercial shipping activities as well as military submarine operations need reliable ice edge information for safety purposes.

Approach

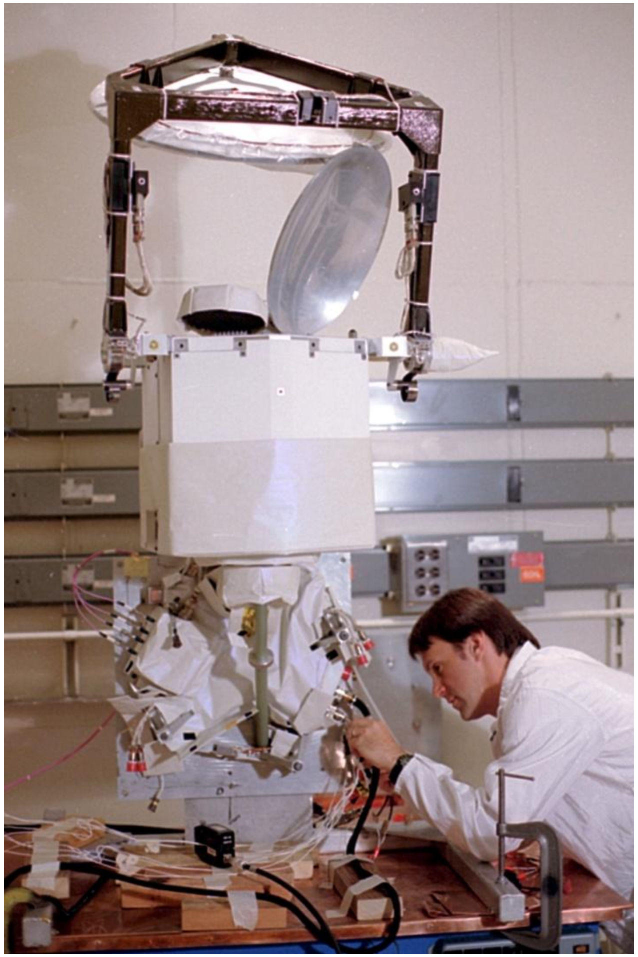


Special Sensor Microwave Imager Sea Ice Concentration Binary Data of Antarctica
Binary Data to ASCII Data
Edge Detection
Edge Map of Image
Gradient Vector Flow Snake
Gradient Vector Flow Field of Image
Motion Estimation (Global /Local)
Predicted Next Frame of Image
Result and Validation by using Satellite Image

Sea Ice Concentration Data

- The sea ice concentration derived from the Special Sensor Microwave/Imager (SSM/I) using Bootstrap Algorithm with daily varying tie-points.
- The sea ice concentration is gridded on polar stereographic projection with 25km x 25 km resolution
- It is provided in binary two-byte integer format.
- Temporal coverage: 1987 to till date, Daily and monthly

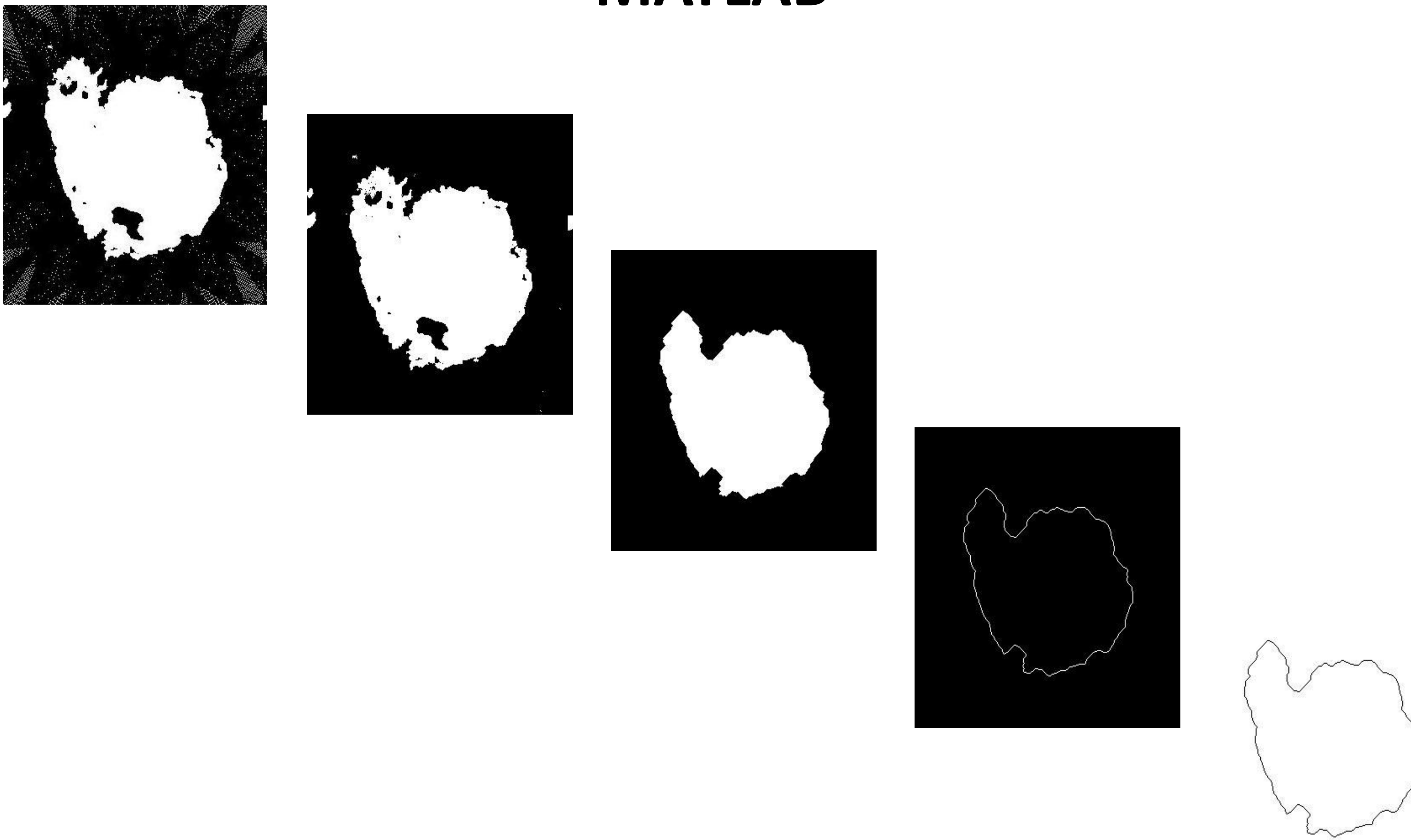
Special Sensor Microwave/Imager



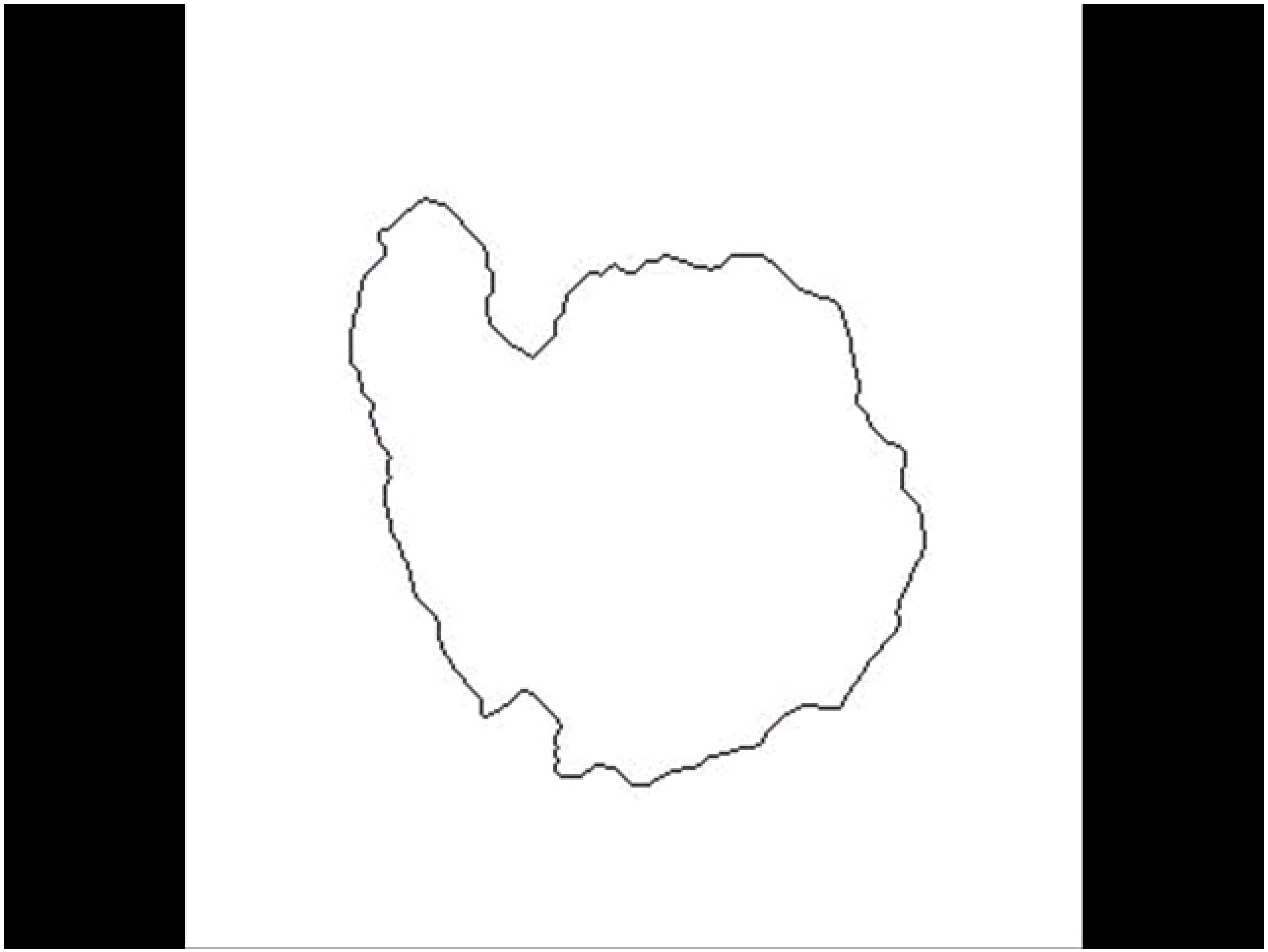
Bootstrap Algorithm: http://nsidc.org/data/docs/daac/bootstrap/index.html

Data Source :The National Snow and Ice Data Center (http://www.nsidc.org)

Different Steps to getting edge by using MATLAB



Variation in Sea Ice edge in Antarctica in 2006



Gradient Vector Flow Snake

- Snake (or Active Contour) are cures defined within an image domain that can move under the influence of the internal forces coming from within the cures itself and external forces computed form the image data
- An energy minimizing spline guided by external constraint forces and pulled by image forces toward features.
- Model is always minimizing its energy functional and therefore exhibits dynamic behavior : Active Contour Model.
- The way the contours slither in the model while minimizing their energy is know as Snake Model.
- The snake’s energy depends on its shape and location
- Snakes can be closed or open
- GVF snake is active contour which use the gradient vector field as a external force.

Applications of Snake

- Edge Detection
- Motion Tracking
- Shape Modeling
- Image Segmentation
- Pattern Recognition

Why Gradient Vector Flow Snake?

- Insensitivity to initialization
- Large capture range
- An ability to progress into boundary concavities
- Detects shapes with boundary concavities
- Does not need prior knowledge about whether to shrink, or expand towards boundary

GVF Snake Model

- A snake is a curve $X(s)=[x(s),y(s)], s \in [0,1]$ that moves through the spatial domain of an image to minimize the energy functional

$$E_{snake} = \int_0^1 [E_{internal}(X(s)) + E_{external}(X(s))]ds$$

where $E_{internal}$ is the internal energy and $E_{external}$ is the external energy of the snake, respectively

Internal Energy

- The internal energy for Snake can be written as

$$E_{Internal} = [\ \underbrace{(\alpha(s)|X'(s)|^2}_{\text{Elasticity}} + \underbrace{\beta(s)|X''(s)|^2)}_{\text{Rigidity}}\ ] / 2$$

Note : where X' and X'' are the 1^{st} and 2^{nd} derivatives of the snake with respect to s and α(s), β(s) specify the elasticity and rigidity of the snake, respectively and are often independent of s.

External Energy

- The external energy computed from the image data is a weighted combination of energies which attract the snake to lines or edges Image data
- For a Gray-level Image I(x, y)

$$E^1_{external} = -|\nabla I(x, y)|^2$$

$$E^2_{external} = -|\nabla[G_\sigma(x, y) * I(x, y)|^2$$

- For a line drawing (black on white) Image I(x, y)

$$E^3_{external} = I(x, y)$$

$$E^4_{external} = G_\sigma(x, y) * I(x, y)$$

where G_σ is the 2D Gaussian function with standard deviation σ and ∇ is the gradient operator

Implementation

The process of my implementation:

1 Import an image

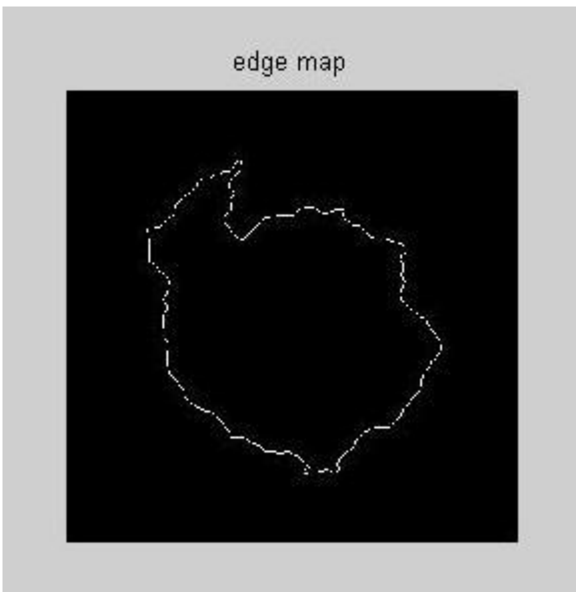
2. Initialize the snake for the image

3. Compute the edge map of the image

4. Input the edge map to the GVF solver

5. Deforms the snake

Edge Map



- Edge map f(x , y) derived from the image I(x , y) having the property that it is larger near the image edges

$$f(x , y) = -E^{(i)}_{external}(x , y)$$

i=1,2,3, or 4.

Gradient Vector of Edge Map

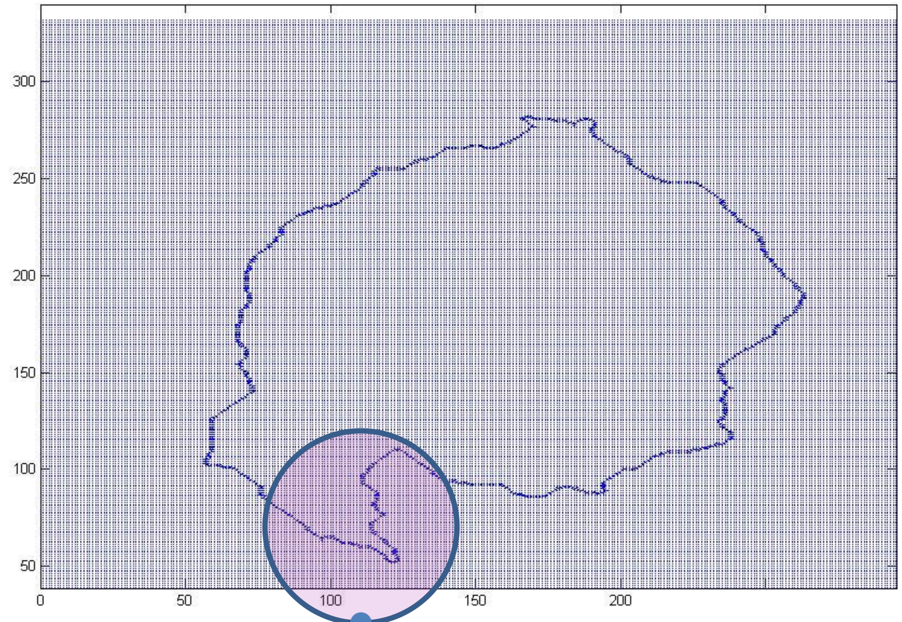
General Properties:

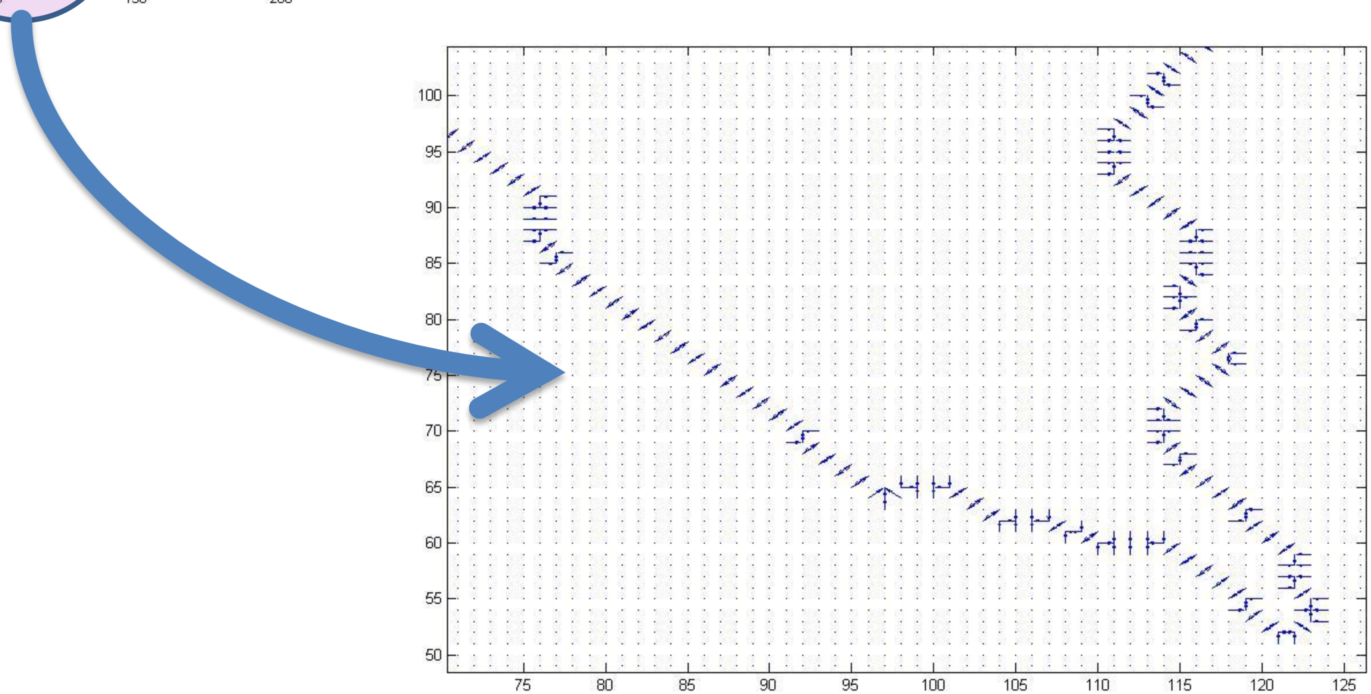
- These vectors pointing toward the edges, which are normal to the edges at the edges.
- These vectors generally have large magnitudes only in the immediate vicinity of the edges.
- In homogeneous regions, where $I(x, y) \approx$constant, $\Delta f \approx 0$.

Effects:

- A snake initialized close to the edge will converge to a stable configuration near the edge.
- The capture range will be very small, in general.
- In homogeneous regions will have no external forces whatsoever.

Gradient of the Edge map





Gradient Vector Flow

- The GVF field is defined to be a vector field

$$V(x , y) = [u(x , y), v(x , y)]$$

- V(x , y) is defined such that it minimizes the energy functional

$$\varepsilon=\iint \mu(u_x^2+u_y^2+v_x^2+v_y^2) +|\nabla f|^2|V - \nabla f|^2 dxdy$$

where f(x , y) is the edge map of the image and μ is noise parameter

- Using the calculus of variations, GVF field can be obtained by solving following Euler equations

$$\mu\nabla^2 u - (u - f_x)(f_x^2 + f_y^2)=0$$

$$\mu\nabla^2 v - (v - f_y)(f_x^2 + f_y^2)=0$$

where ∇^2 is the Laplacian operator and f_x and f_y are the partial derivative of the edge map

Numerical Implementation

- Equations can be solved by treating gradient vector flow u and v as functions of time and to set up the iterative solution, we can write

$u_{i,j}^{n+1} = (1- b_{i,j}\Delta t)u_{i,j}^{n} + r(u_{i+1,j}^{n} + u_{i,j+1}^{n} + u_{i-1,j}^{n} + u_{i,j-1}^{n} - 4u_{i,j}^{n}) + c_{i,j}^{1}\Delta t$

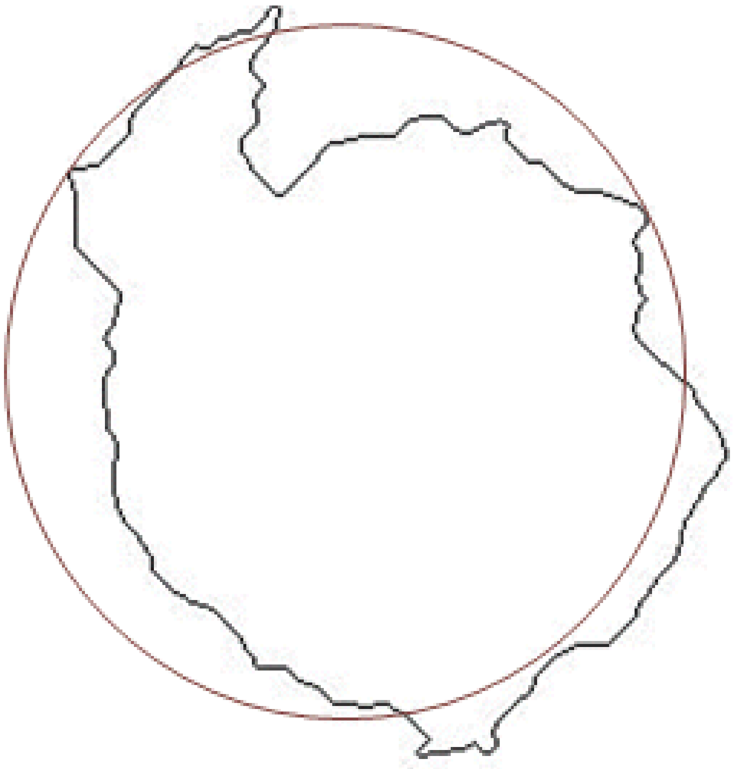
$v_{i,j}^{n+1} = (1- b_{i,j}\Delta t)v_{i,j}^{n} + r(v_{i+1,j}^{n} + v_{i,j+1}^{n} + v_{i-1,j}^{n} + v_{i,j-1}^{n} – 4v_{i,j}^{n}) + c_{i,j}^{2}1\Delta t$

where the indices i, j, and n correspond to x, y and t respectively,
$r = \{\mu\Delta t /\Delta x\Delta y\}\leq(1/4)$ and

$b(x, y) = f_x (x, y)^2 + f_y(x, y)^2$

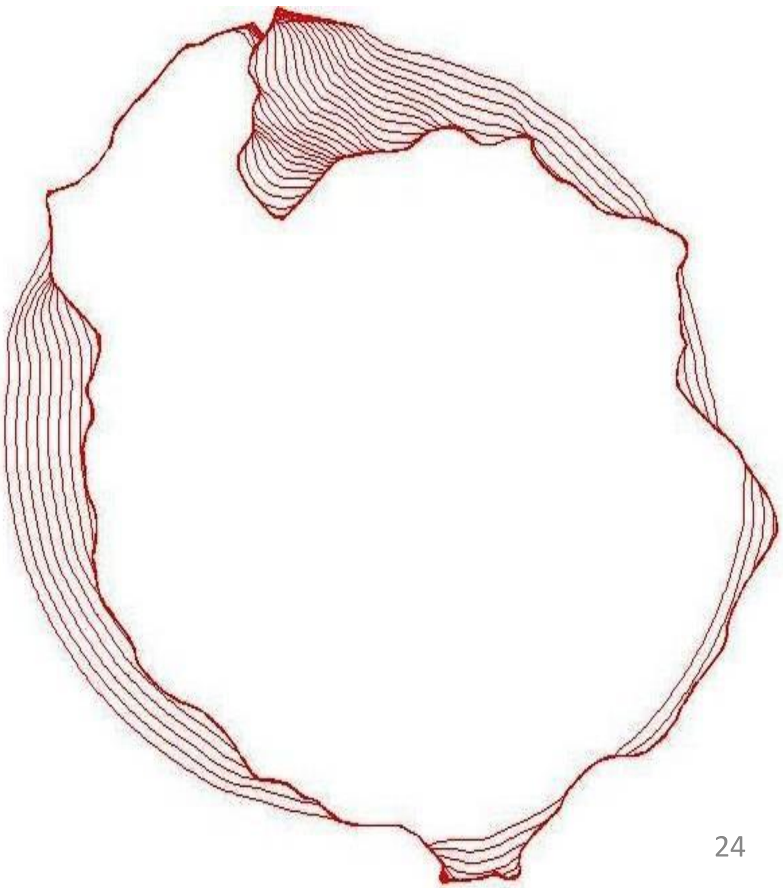
$c^1=b(x, y)*f_x(x, y)$

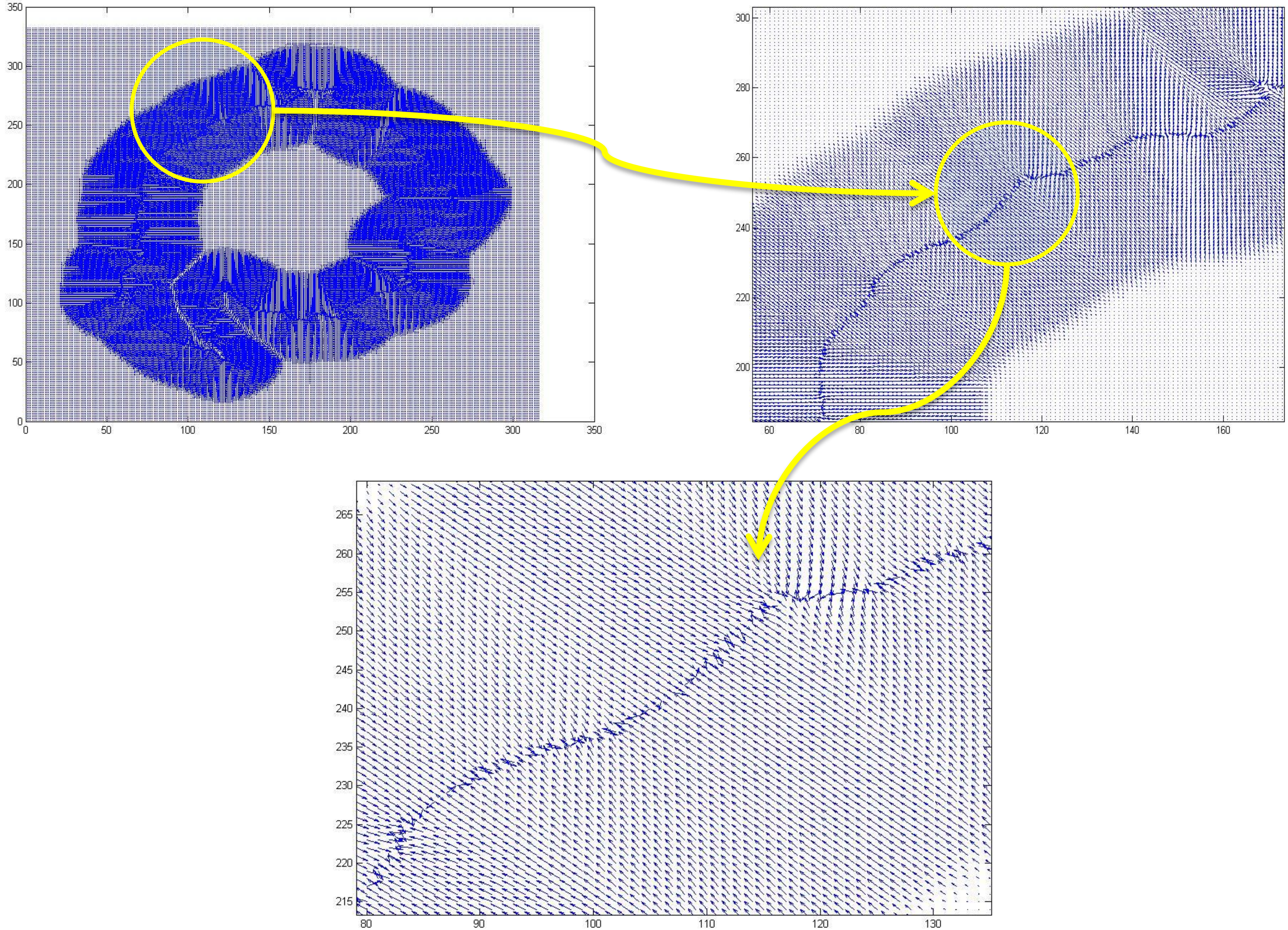
$c^2=b(x, y)*f_y(x, y)$



Initial Snake

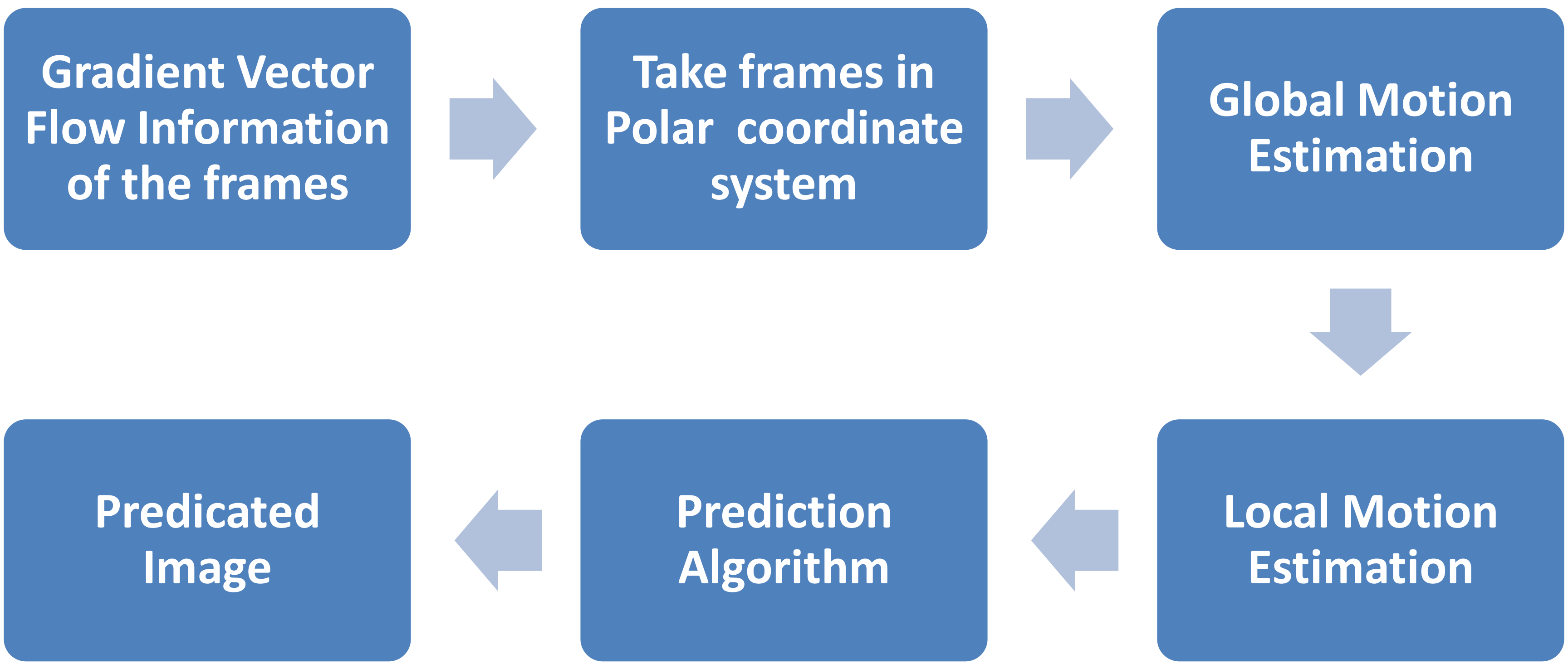
Convergence of a Snake using GVF external force towards edge





Normalized Gradient Vector Flow Field

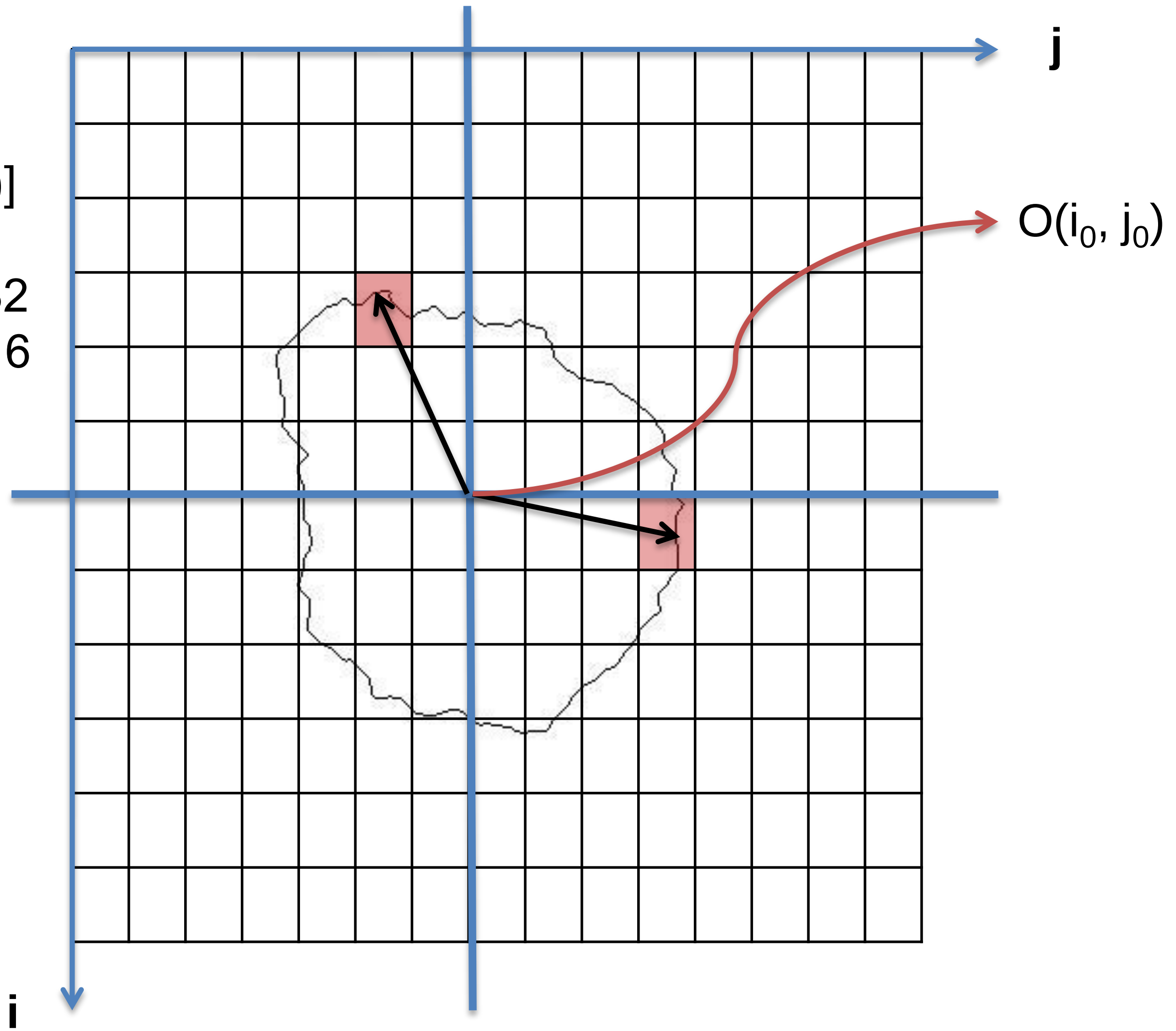
Motion Estimation



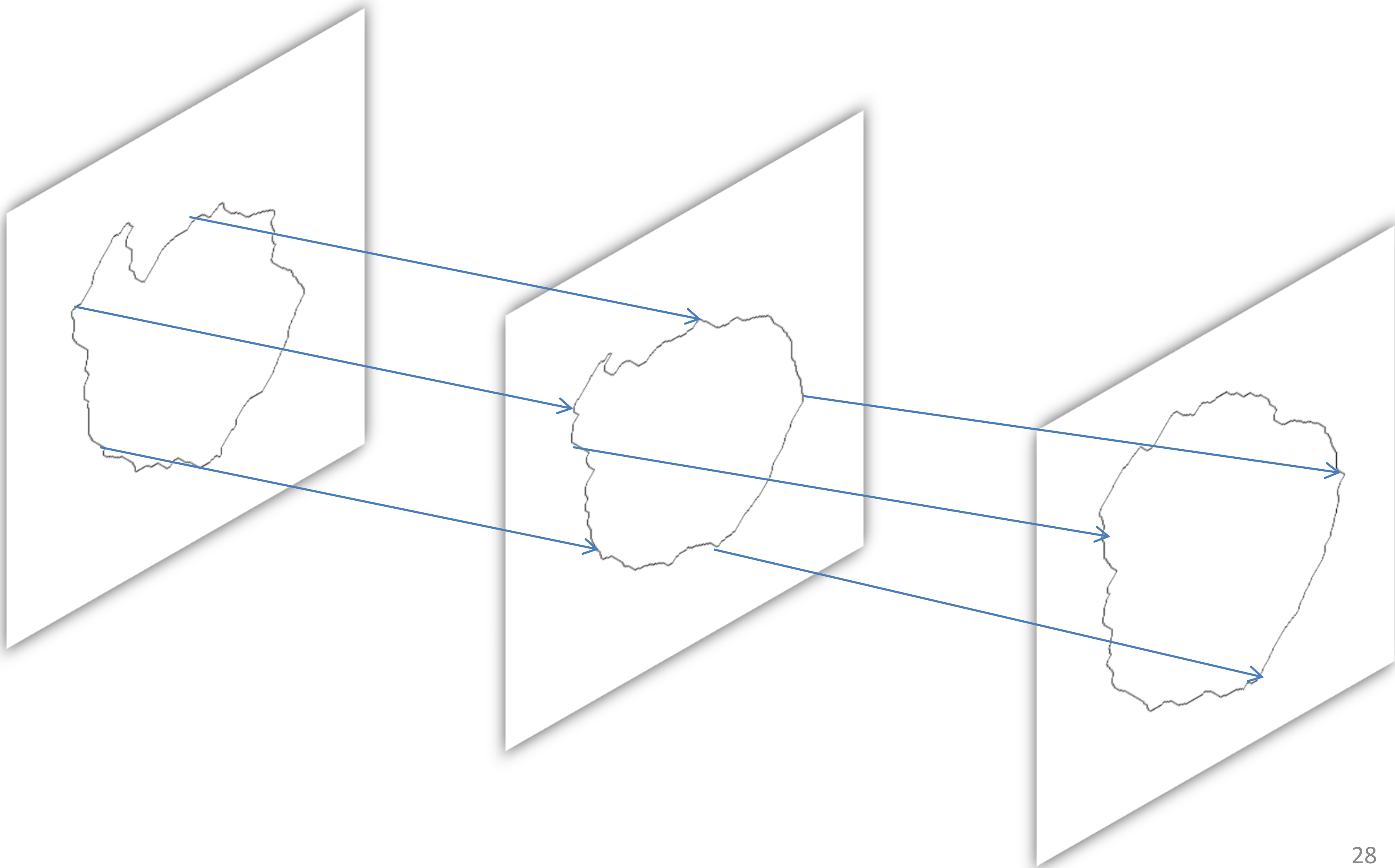
Global Motion Estimation

$\Phi = \tan^{-1} [(i_u - i_0)/(j_v - j_0)]$

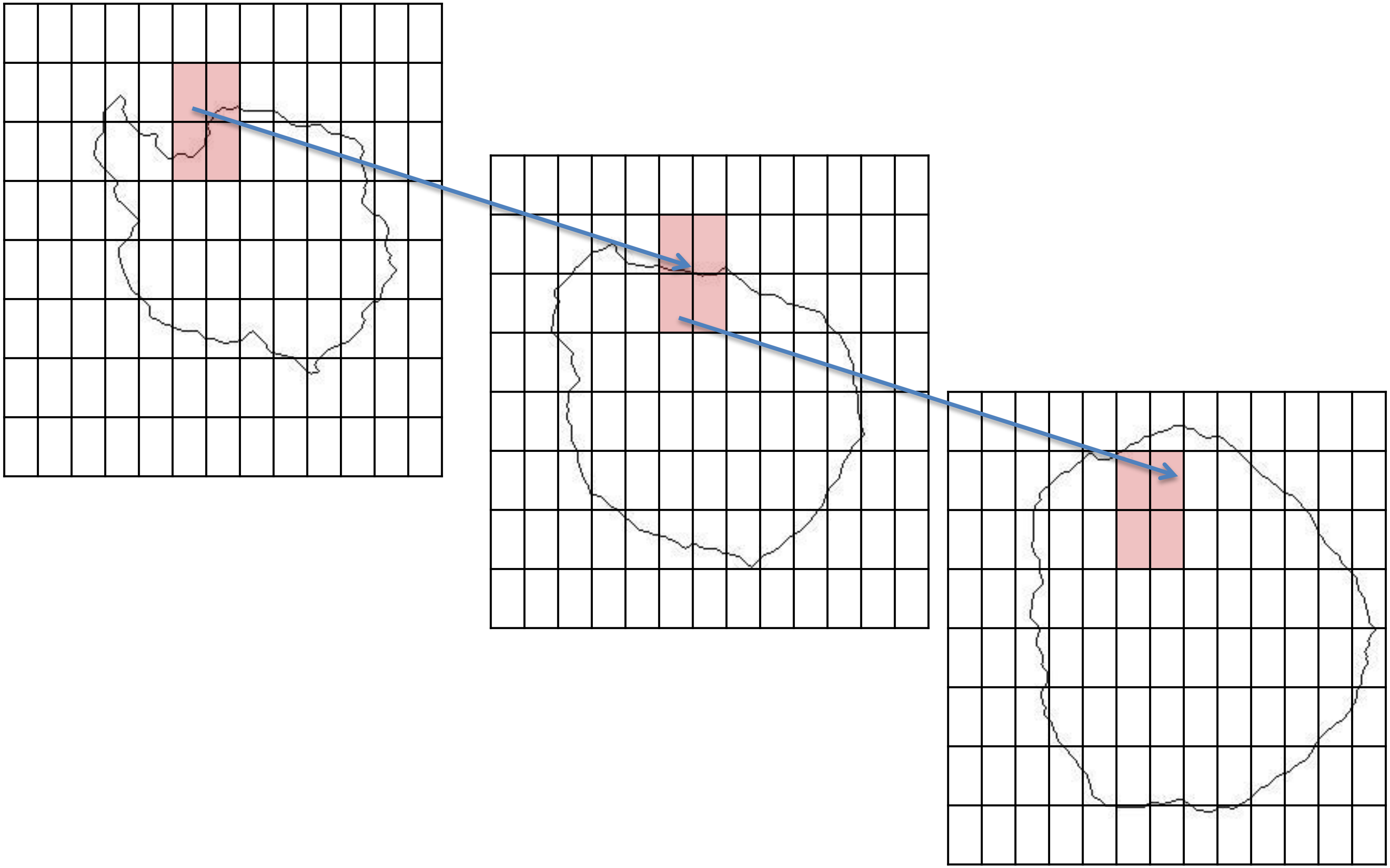
Where, $u=1,2,\ldots 332$
$v=1,2,\ldots 316$



Global Motion Estimation



Local Motion Estimation



Result and Discussion

- Awaited…

Future Work

- Improve reliability of **Sea Ice Edge Prediction**
- Prediction of **Random Deformation** in Shape
- Estimation and Tracking of **Ice Bergs Deformation**
- Prediction of **Biological Cell Growth and Decay**

Thank You

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