A presentation on…

Prediction of Antarctic Sea Ice Edge Using Active Contour Model

By
PRAVIN KUMAR RANA
(06CL6003)
Under the guidance of
Dr. A. ROUTRAY
Dr. MIHIR K. DASH

Centre for Ocean, Rivers, Atmosphere and Land Sciences
Indian Institute of Technology
Kharagpur-721302
India

Outline

- Problem
- Approach
- Prediction Model
- Result & Error Analysis
- Concluding Remarks

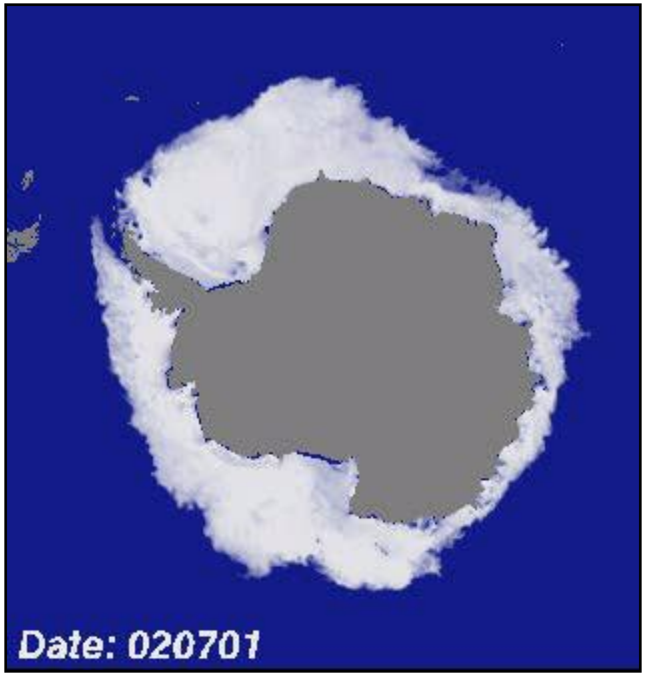
Antarctica: An Introduction

- **The southern most icy continent of the world surrounding the south pole**

- **Located between the latitudes of approximately 65^0 S and 90^0 S**

- **The Pulsating Continent**

Pulsating Continent : Antarctica



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

Why Antarctica Sea Ice Edge?

- Earth Climate System
  - Earth Radiation Budget
  - Global Ocean Circulation
- Marine Biota
- Climate Modeling
- Navigation
- Military Operations

Problem ?

Prediction of Pulsating Nature of Sea Ice Edge over the Antarctica

Present Sea Ice Edge Information Scenario

- A number of current microwave sensors make daily global observations of sea-ice cover, in particular, the SeaWinds and SSM/I. Based on these observations, sea-ice extent can be estimated directly using different detection techniques

- The United State's National Ice Center provides biweekly information about global sea-ice condition but this service depends on availability of good, quality controlled satellite data

- Due to the persisting severe weather condition over the Antarctic availability of good data is a very few

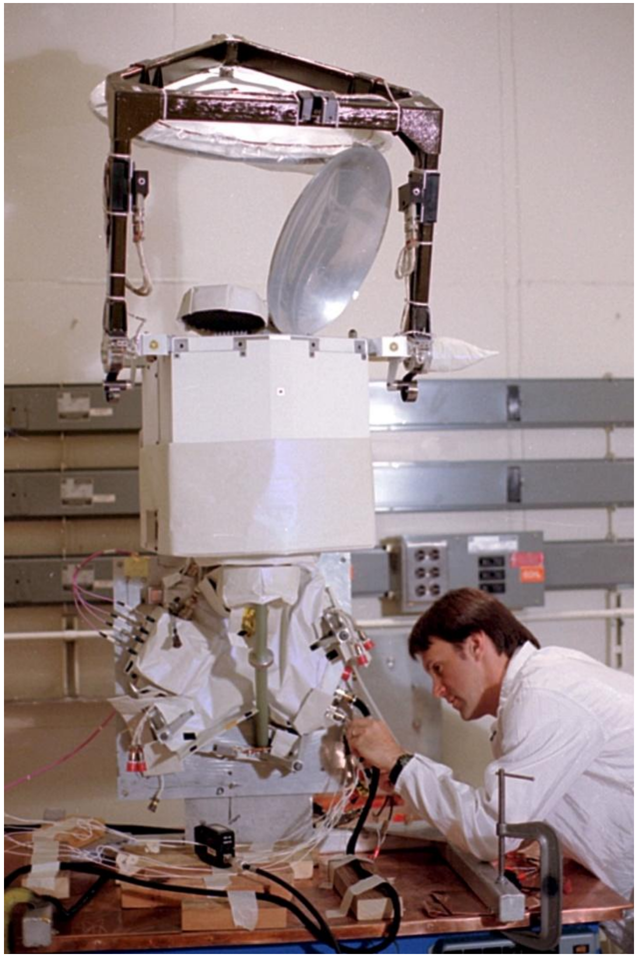
Approach

- **Active contour Model**

- **Polynomial Statistical Method**

Sea Ice Concentration Data

Special Sensor Microwave/Imager

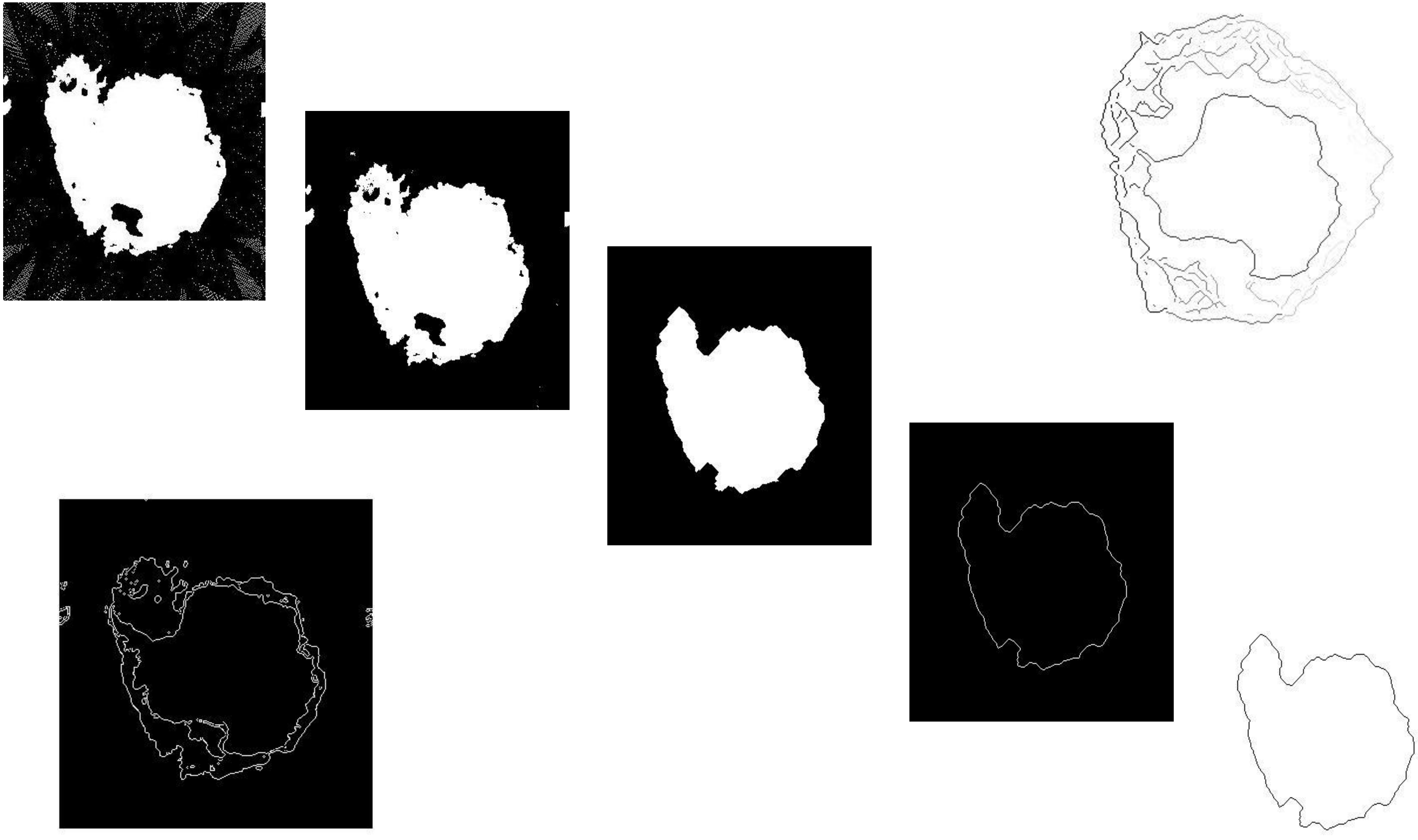


- **Source : SSM/I using Bootstrap Algorithm with daily varying tie-points**
- **Grid Resolution: 25km x 25 km**
- **Format :Binary two-byte integer**
- **Spatial Coverage: Whole Globe in 2 days**
- **Temporal Coverage: 1987 to till date, (Daily and monthly)**

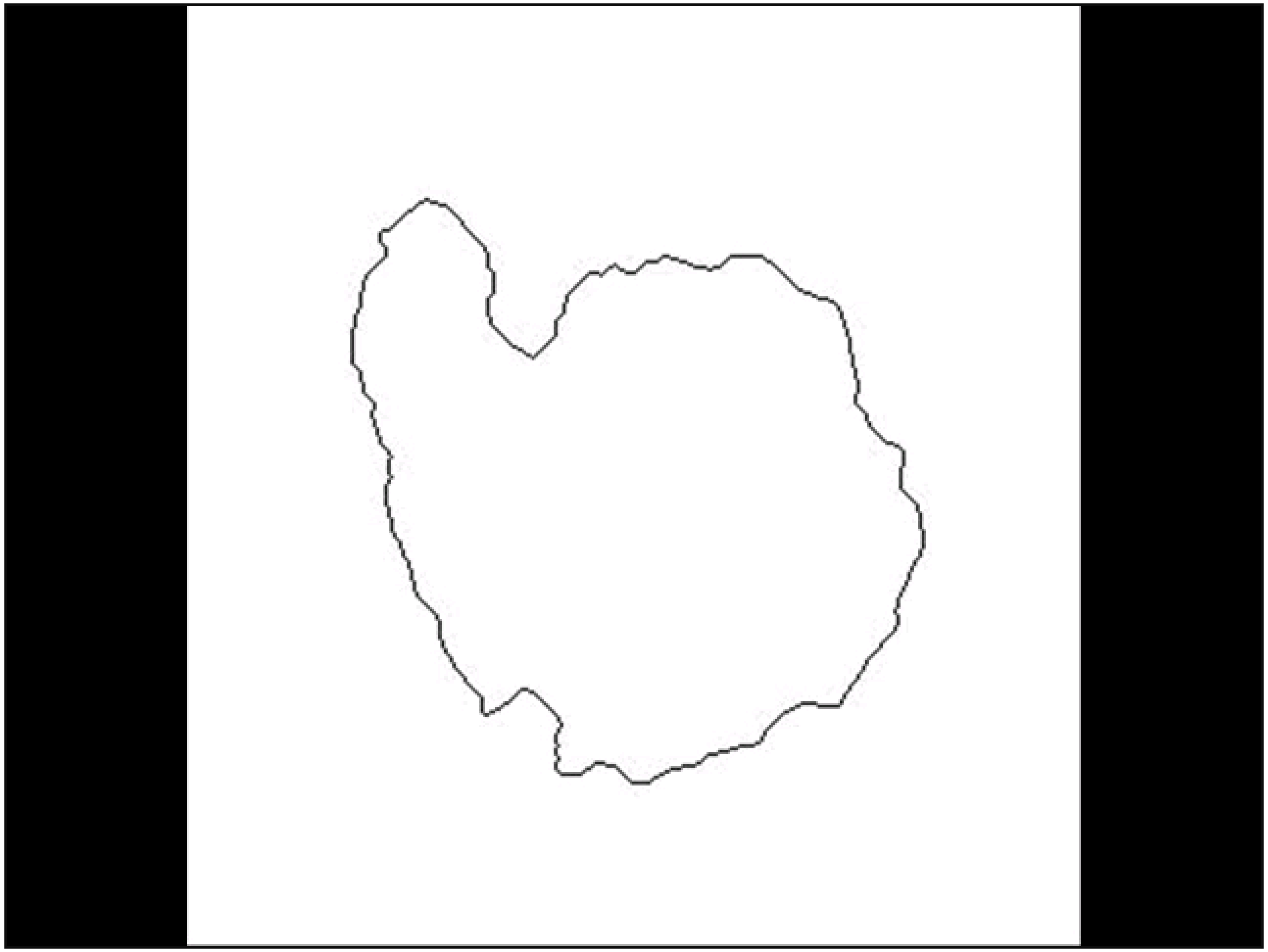
Bootstrap Algorithm: http://nsidc.org/data/docs/daac/bootstrap/index.html

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

Different Steps To Getting Edge



Variation of Antarctic Sea Ice Edge in 2004



Parameterization of Antarctic Sea Ice Edge

Active Contour Model (Or, Snake)

An energy minimizing spline guided by external constraint forces and pulled by image forces toward features

Source: Kass, M., A. Witkin, and D. Terzopoulos, 1987: Snakes: The Active contour models, International Journal of Computer Vision. 1, pp. 321-331

Overview of Active Contour Model

- **Active Contour are curves 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**
- **Model is always minimizing its energy functional and exhibits dynamic behavior : Active Contour**
- **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**

Active Contour 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

$$E_{Internal} = [\, \{\, (\alpha(s)|X'(s)|^2 \;+\; \beta(s)|X''(s)|^2)\} \,/2]$$

Elasticity **Rigidity**

where X′ and X′′ are the 1st and 2nd derivatives of the snake with respect to s and α(s) and β(s) specify the elasticity and rigidity of the snake, respectively

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 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

Methods for Snake

- **Multi-resolution**

  Advantage :Issue of range capture

  Limitation :Can’t specify how the snake moves across different resolution

- **Pressure Forces**

  Advantage :Can be push an snake into boundary concavities

  Limitation :Sensitive to initialization

- **Distance Potentials**

  Advantage :Can provide large capture range

  Limitation :Can't move a snake into concavities

- **Gradient Vector Flow**

Gradient Vector Flow Snake

Source: Chenyang Xu and J.L. Prince, 1998: Gradient Vector Flow: A New External Force for Snakes, Proc. IEEE Conf. on Comp. Vis. Patt. Recog. (CVPR), Los Alamitos: Comp. Soc. Press., 7, pp. 66-71

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**

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

Numerical Implementation

- Using the calculus of variations & by treating GVF u and v as functions of time. GVF field can be obtained by solving following

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

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

$r = \{\mu\Delta t / \Delta x\Delta y\} \leq (1/4)$

$b(x, y) = fx(x, y)^2 + fy(x, y)^2$

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

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

where, i ,j and n corresponds x , y, and t respectively and f_x and f_y are the partial derivative of the Edge Map

Implementation

The Process of Implementation:

1. Import an image

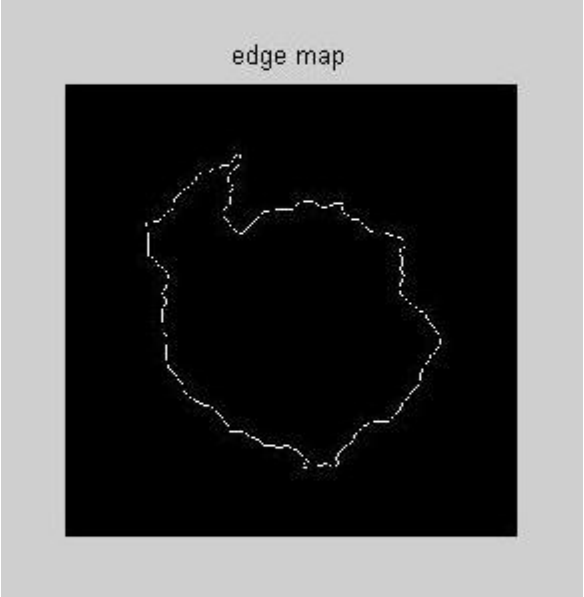
2. Initialize the snake for the image

3. Compute the Edge Map of the image

4. Input the Edge Map to the GVF Solver

5. Deforms the Snake

Edge Map

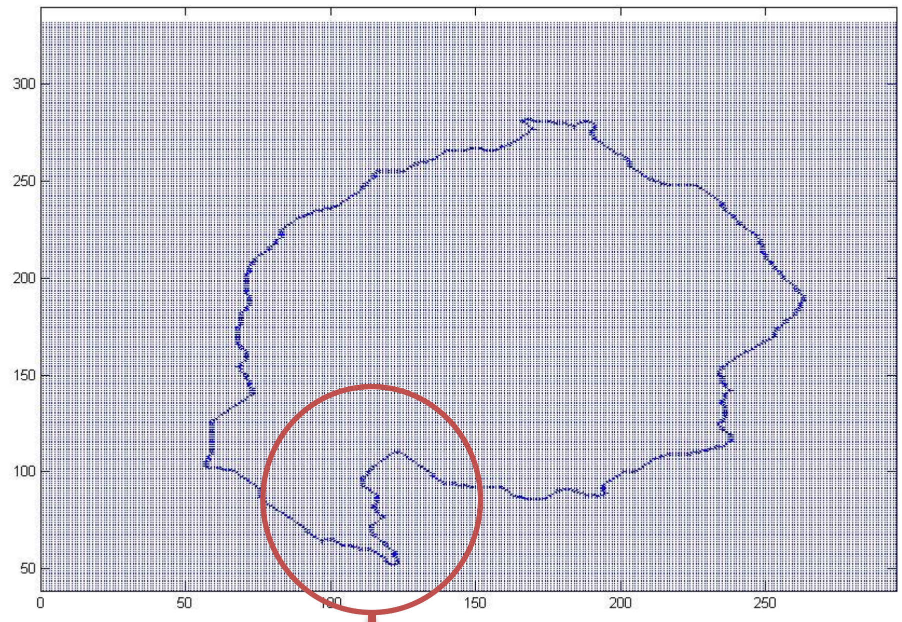


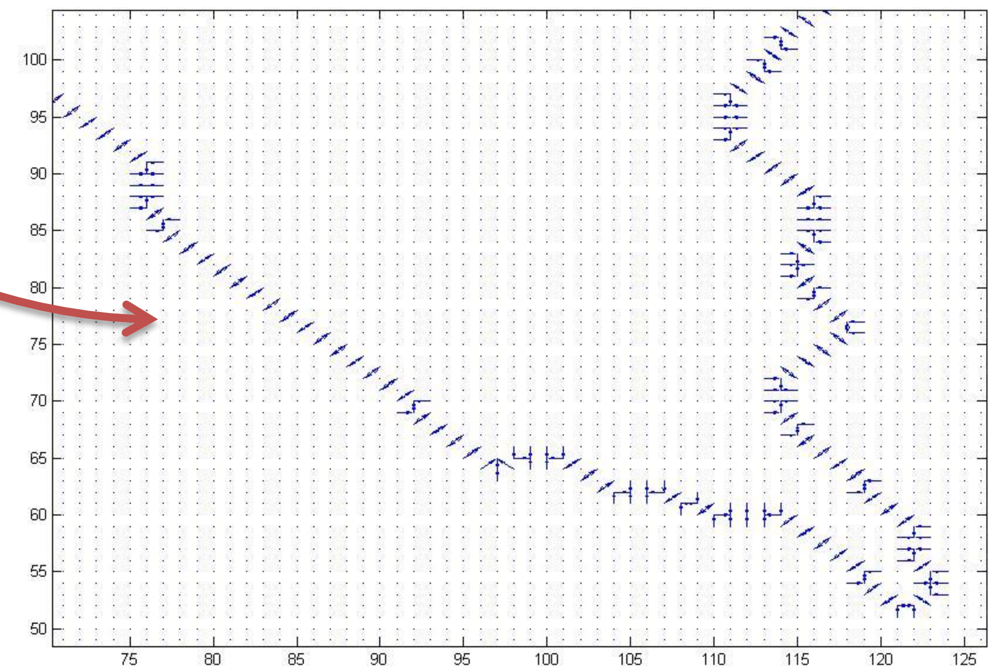
- **Edge map f(x , y) derived from the image intensity (I(x , y)) having the property that it is larger near the image edges**

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

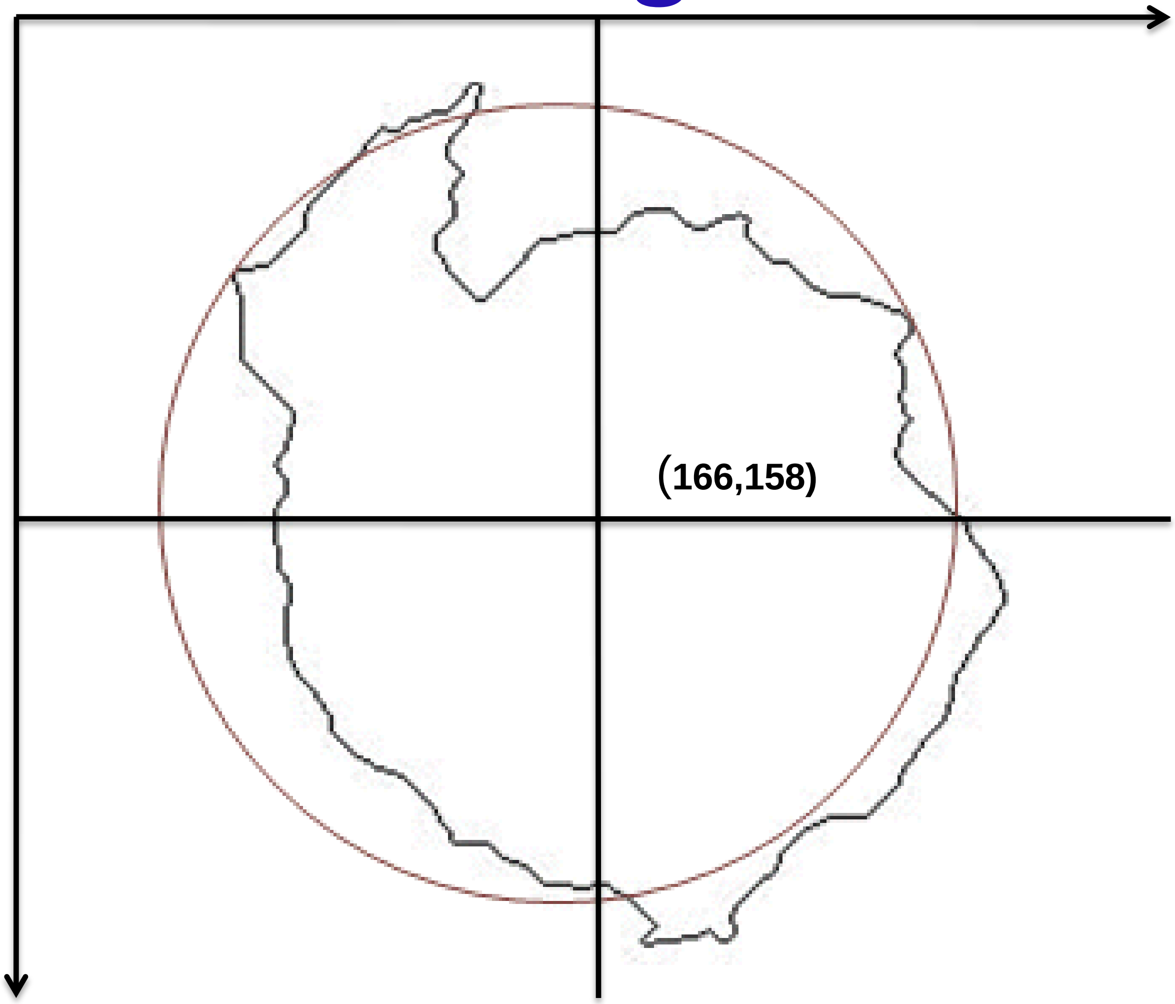
i=1,2,3, or 4.

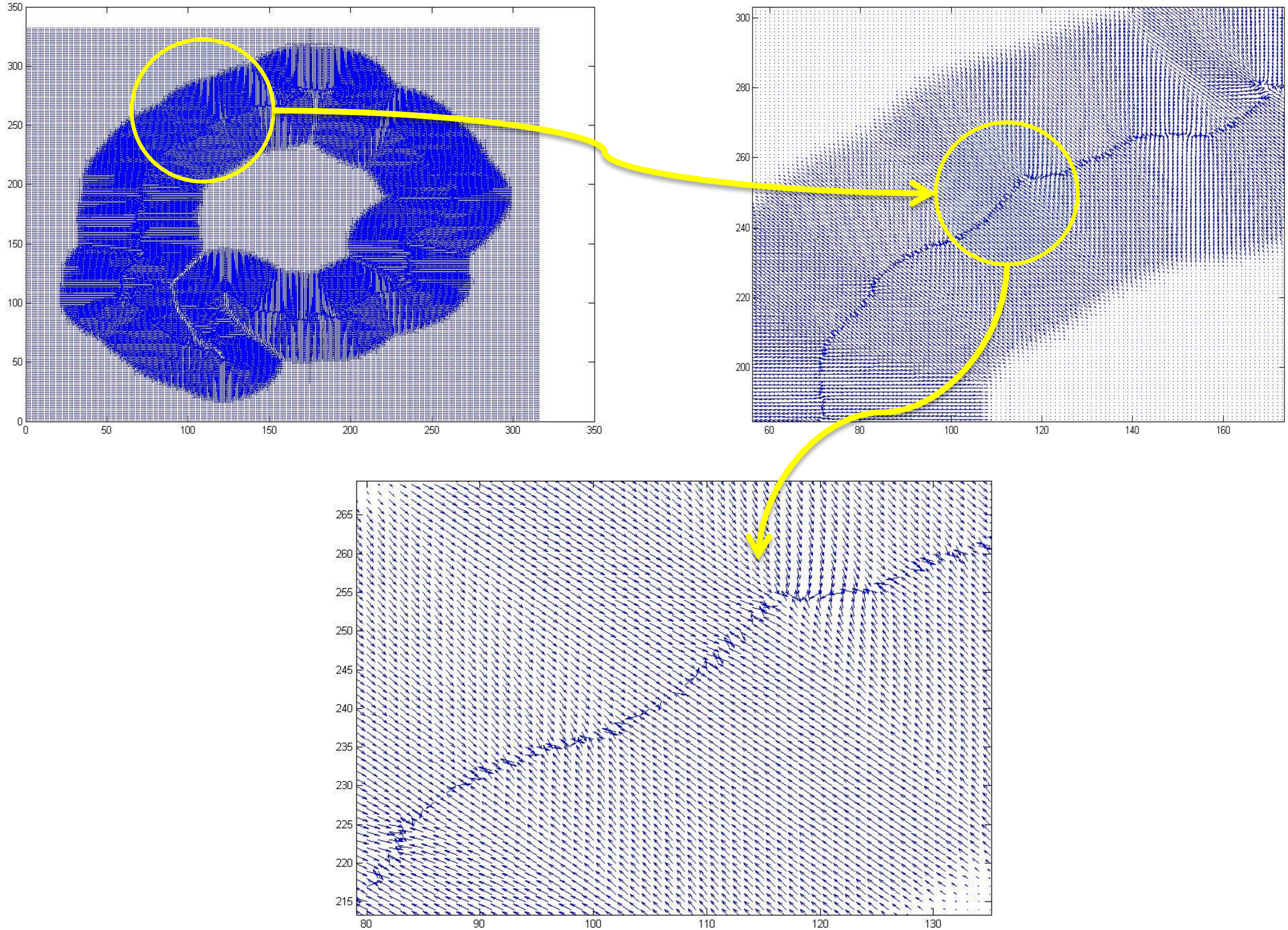
Gradient of Edge Map





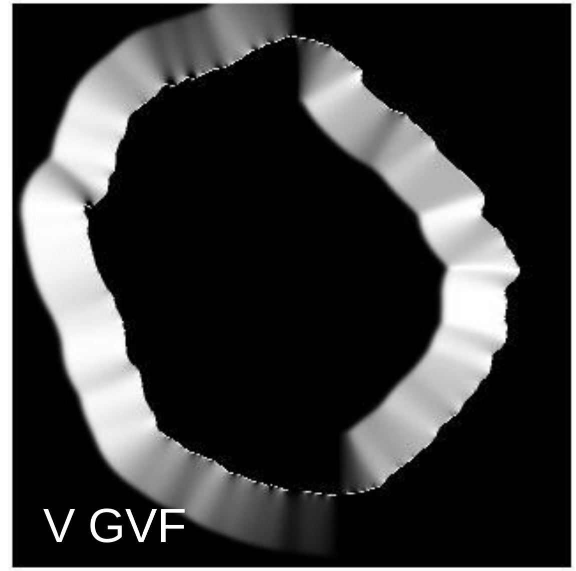
Initial Snake With Input Edge Image



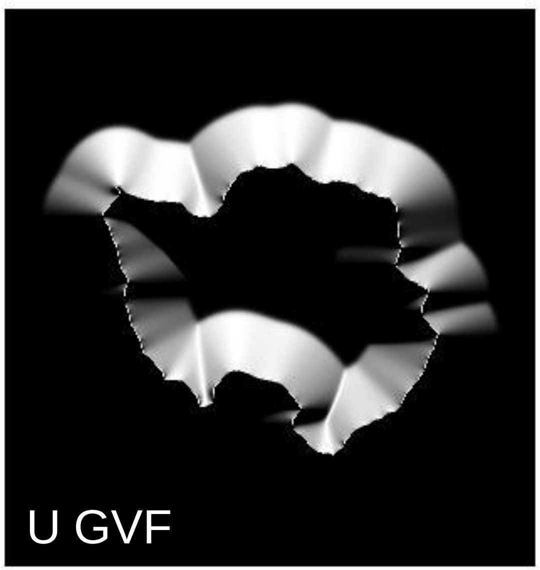


Normalized Gradient Vector Flow Field

September, 2006

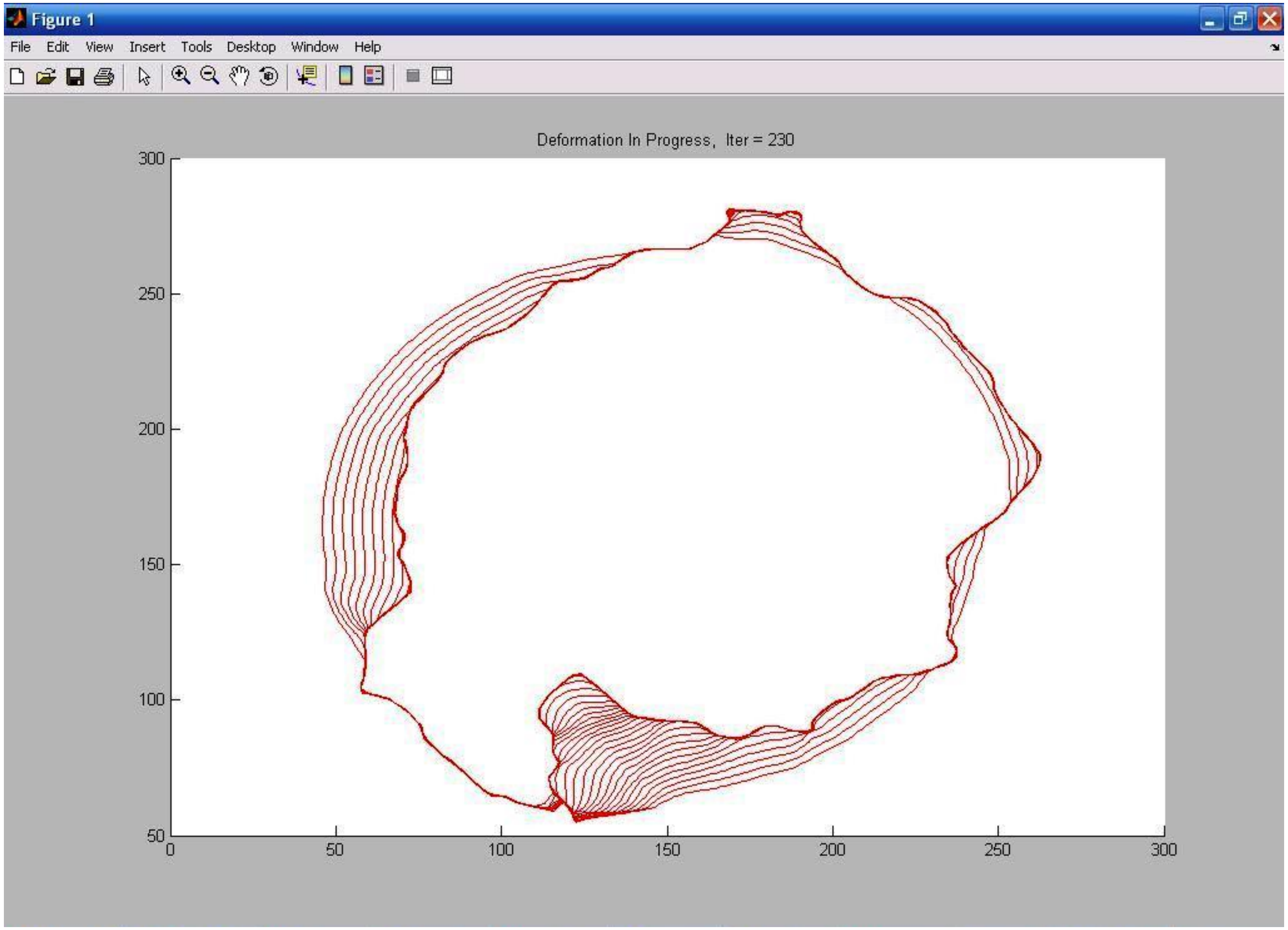


Normalized 3D View GVF U- And V- Component

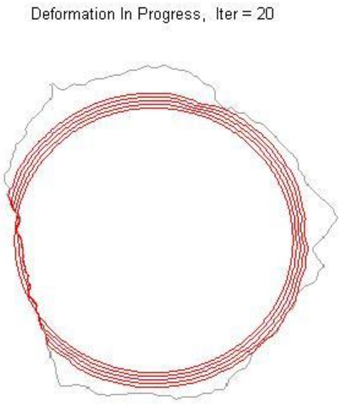


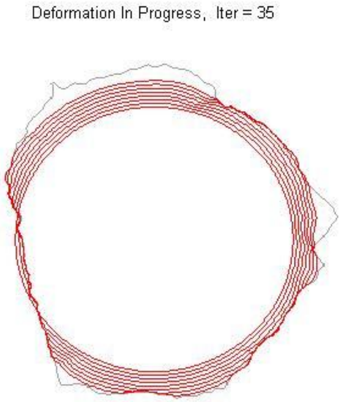
February, 2006

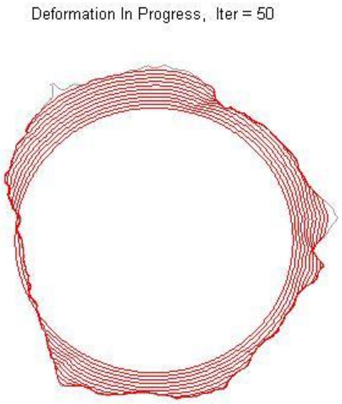
Convergence of A Snake Using GVF External Force Towards Edge



Deformation of GVF Snake

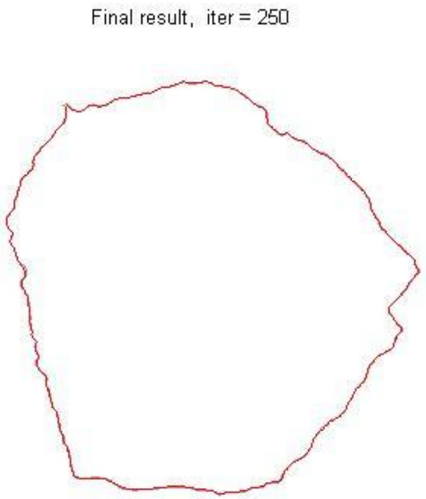




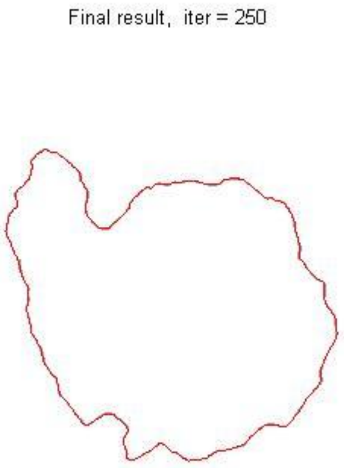


Parameterization Result

September, 2006



February, 2006



GVF Snake Model Parameter

- **Snake Initialization: (166,158)**
- **Elasticity(α) : 0.05**
- **Rigidity(β): 0**
- **Regularization (μ):0.02**
- **Damping coefficient (γ):1**

Prediction Model

Prediction Approach

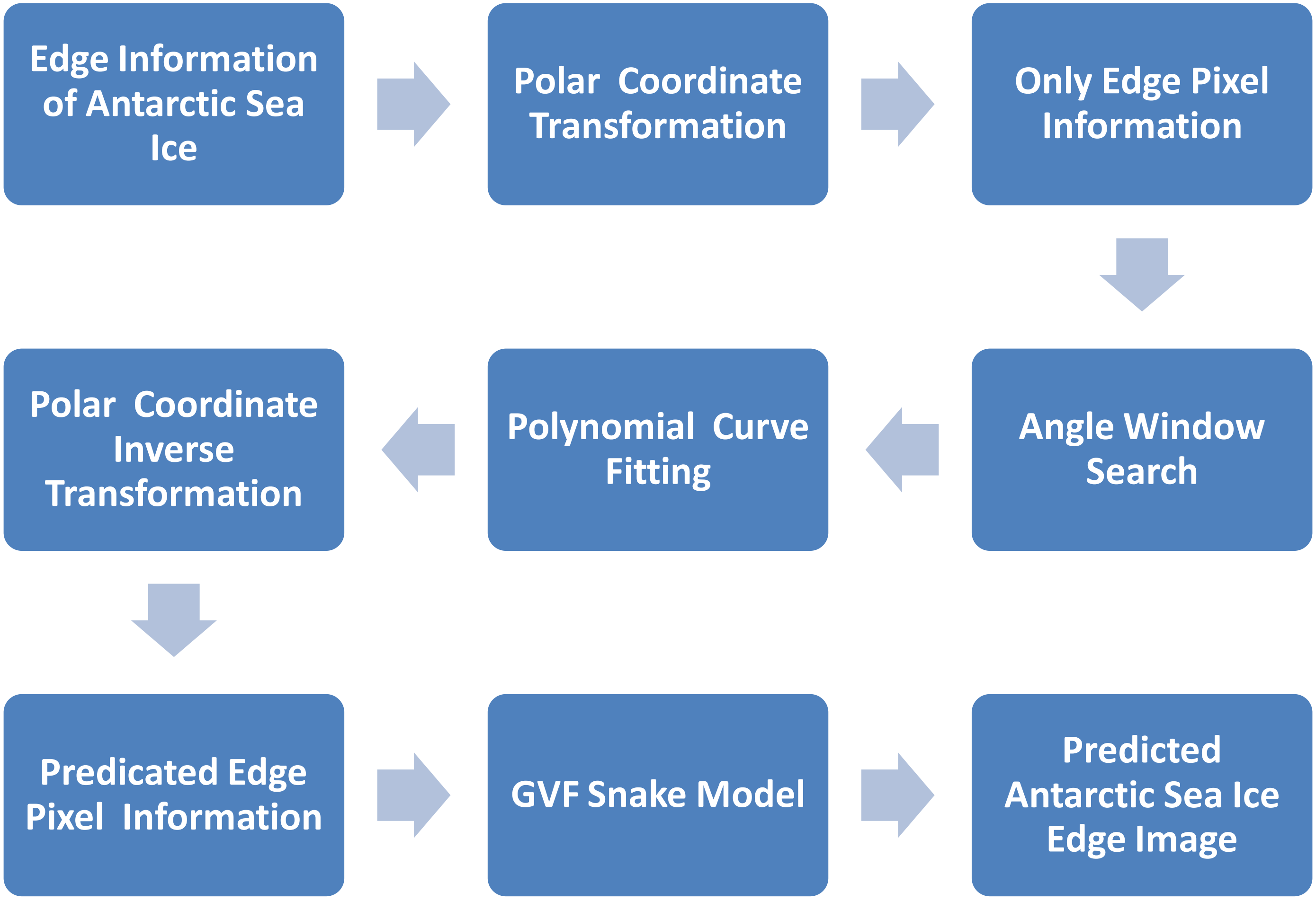
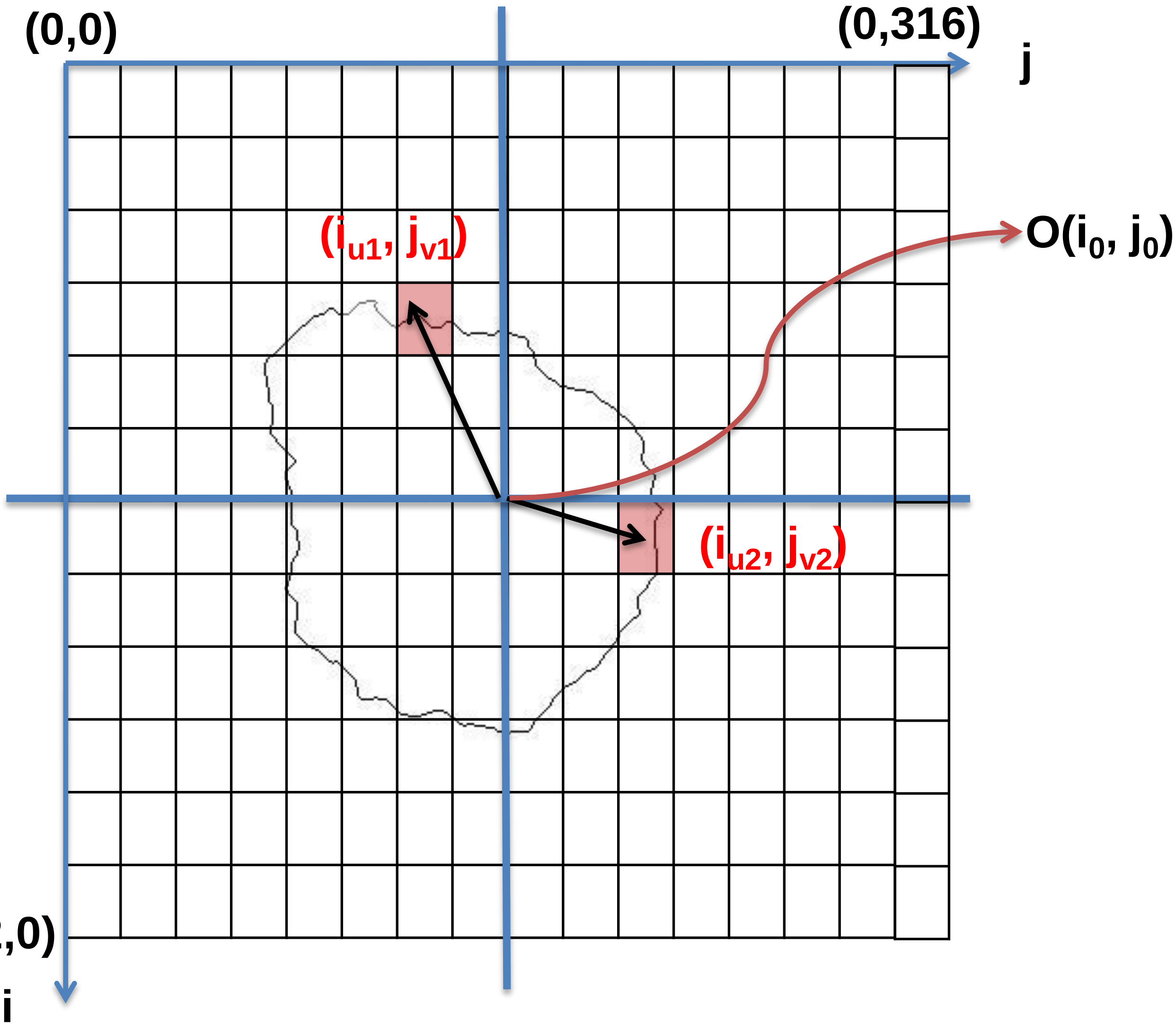


Image Polar Coordinate Parameter

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

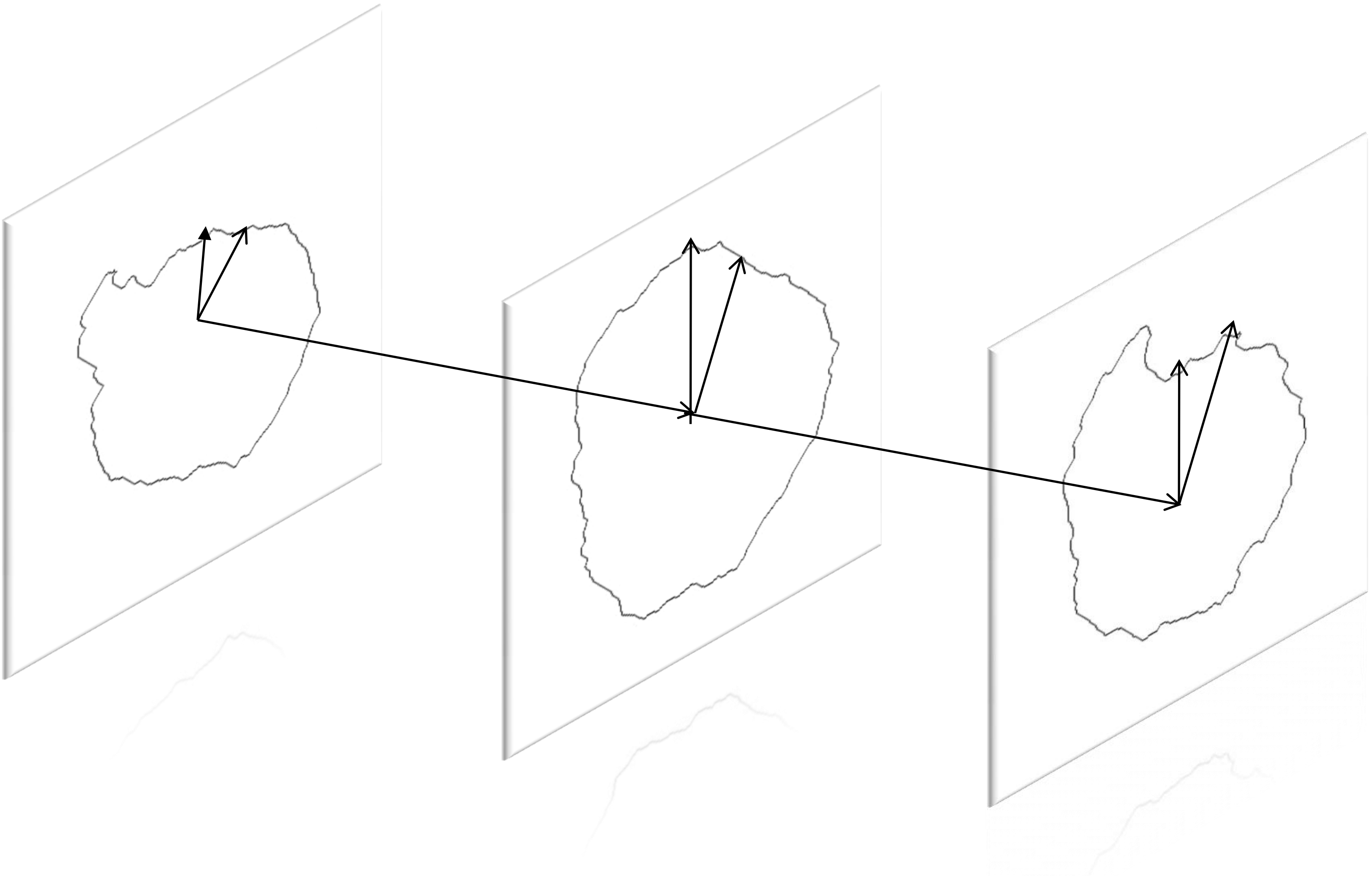
$r = \sqrt{((i_u - i_0)^2 + (j_v - j_0)^2)}$

Where,
u=1,2,…332
v=1,2,…316



Angle Window Search

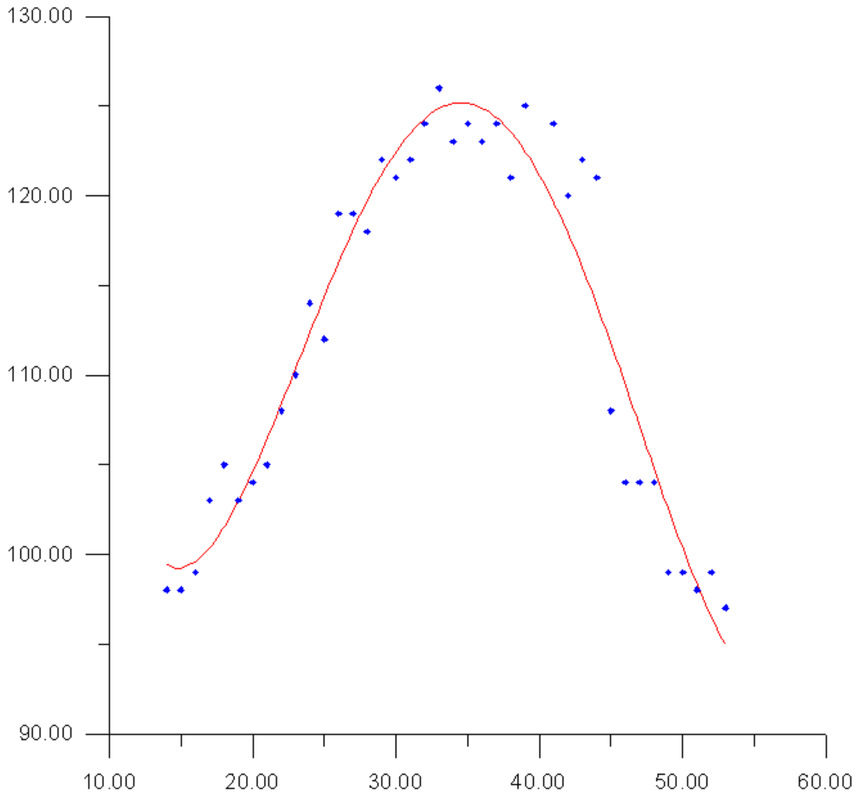
Angle Window $= \pm 0.2^0$



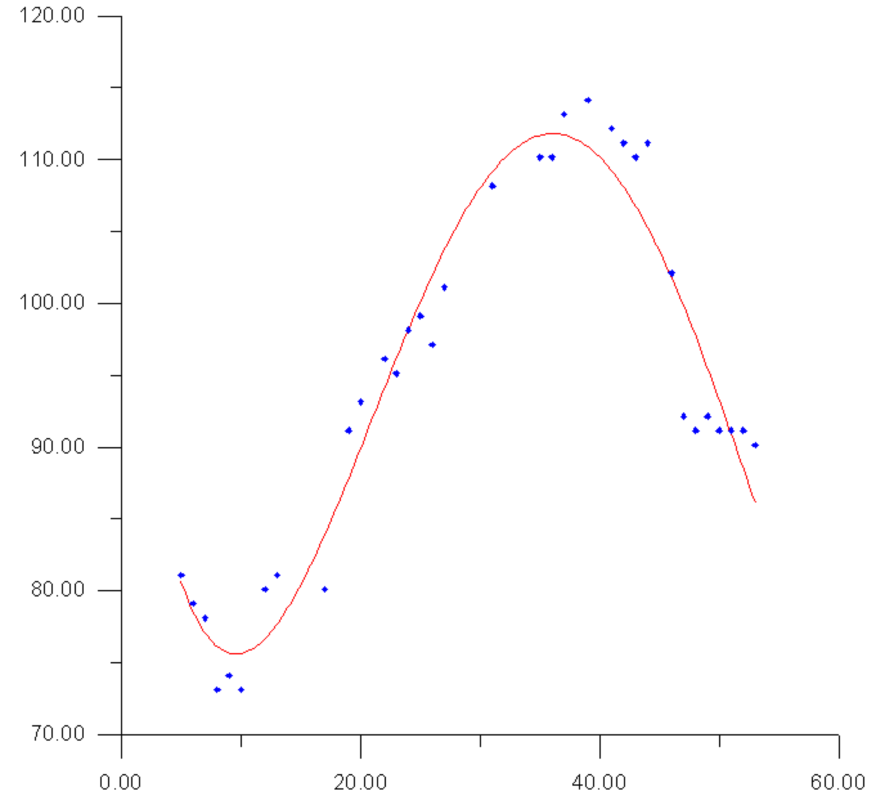
Polynomial Curve Fitting

r_1=206.556 - 18.4108(t)+ 1.05311(t^2)- 0.0225838(t^3) + 0.000160733(t^4)

r_{93} =133.542-15.7129(t)+1.18814(t^2)- 0.0288763(t^3) + 0.000227632(t^4)



1^0

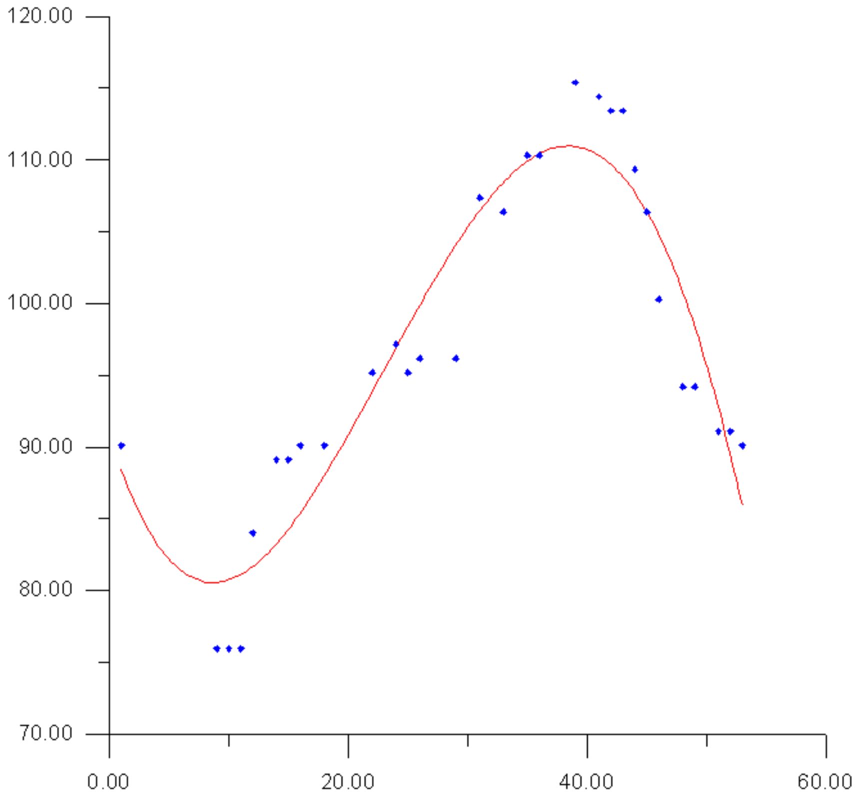


93^0

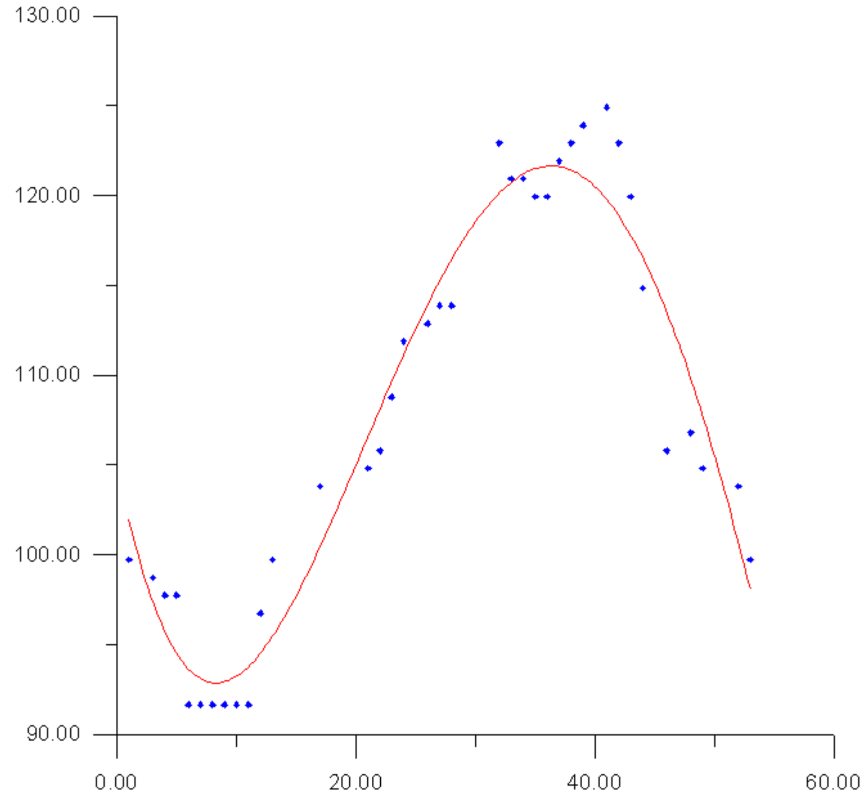
Polynomial Curve Fitting

r_{185}=95.3196-2.88371(t) + 0.197632(t^2)-0.00352258(t^3) + 1.44726 X 10 $^{-005}$ (t^4)

r_{153}=82.988-6.43698(t) + 0.649314(t^2)-0.016198(t^3) + 0.000119787(t^4)



185^0



153^0

Prediction Model Equation

$$\begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ \vdots \\ r_{360} \end{pmatrix} = \begin{pmatrix} A_1 & B_1 & C_1 & D_1 & E_1 \\ A_2 & B_2 & C_2 & D_2 & E_2 \\ A_3 & B_3 & C_3 & D_3 & E_3 \\ A_4 & B_4 & C_4 & D_4 & E_4 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_{360} & B_{360} & C_{360} & D_{360} & E_{360} \end{pmatrix} \begin{pmatrix} t^4 \\ t^3 \\ t^2 \\ t \\ 1 \end{pmatrix}$$

Or,

$$r = At^4 + Bt^3 + Ct^2 + Dt + E$$

where,

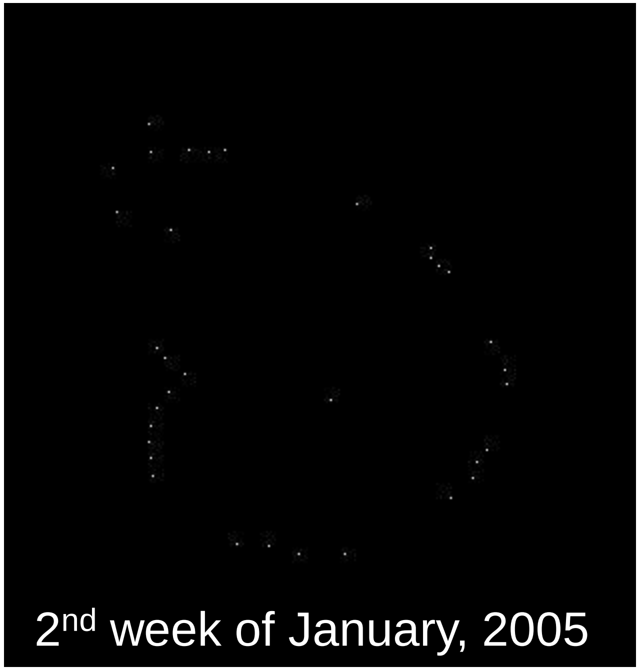
r_Θ = The radius of the each pixel locations, Θ=1,2,3,4…,360

t= Time, t=1, 2, 3, 4…

and

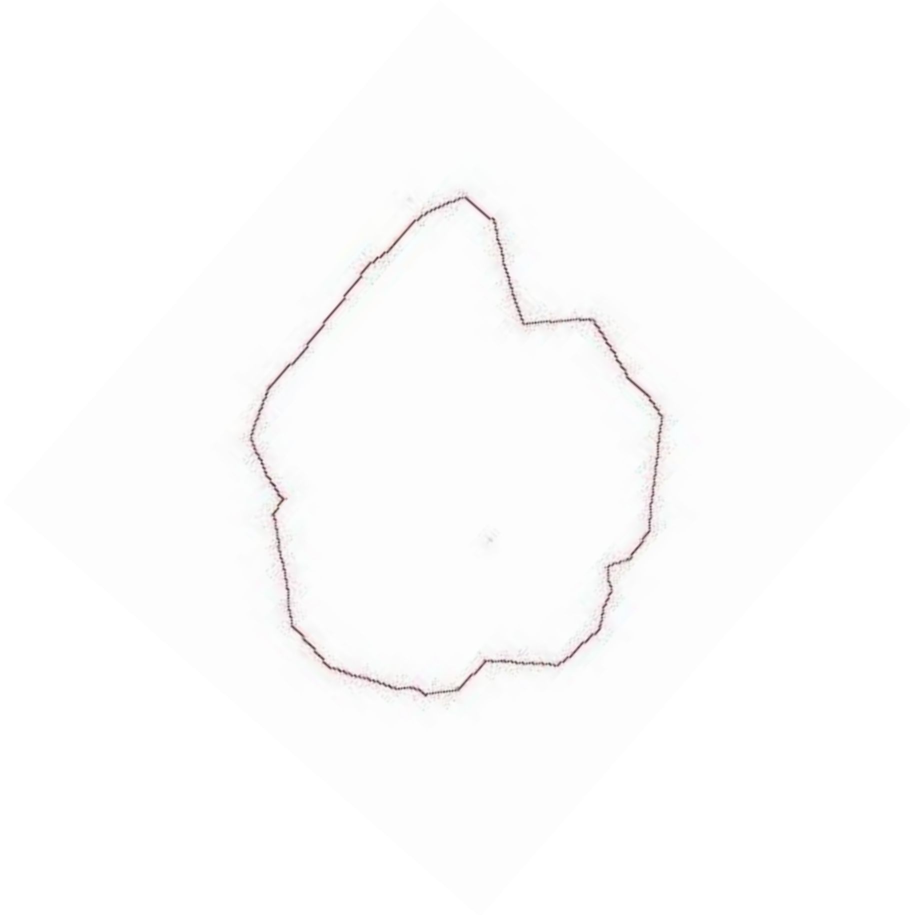
A, B, C, D,E = Polynomial Coefficients

Predicted Edge Pixel

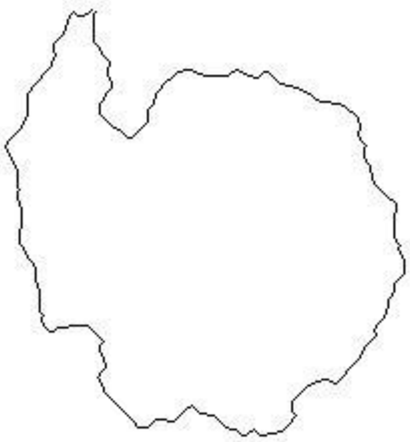


Result

Predicted Image : 1st week of January, 2005

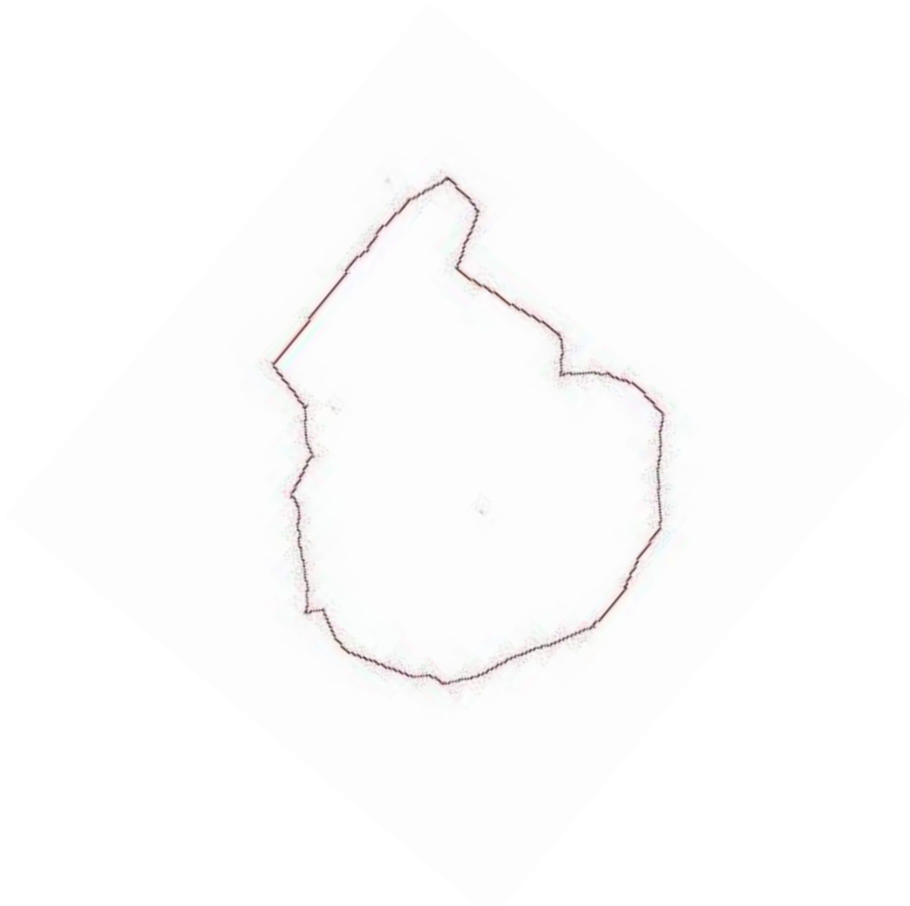


SSM/I Image: 1st week of January , 2005

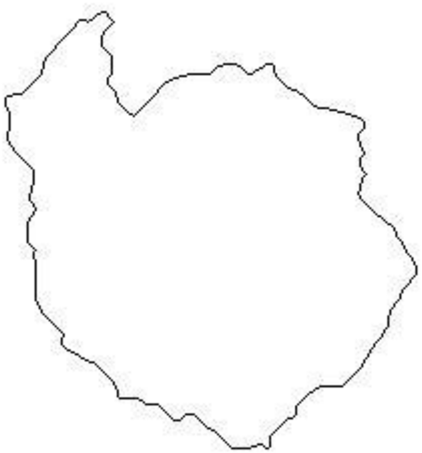


Result

Predicted Image : 2nd week of January, 2005



SSM/I Image : 2nd week of January, 2005



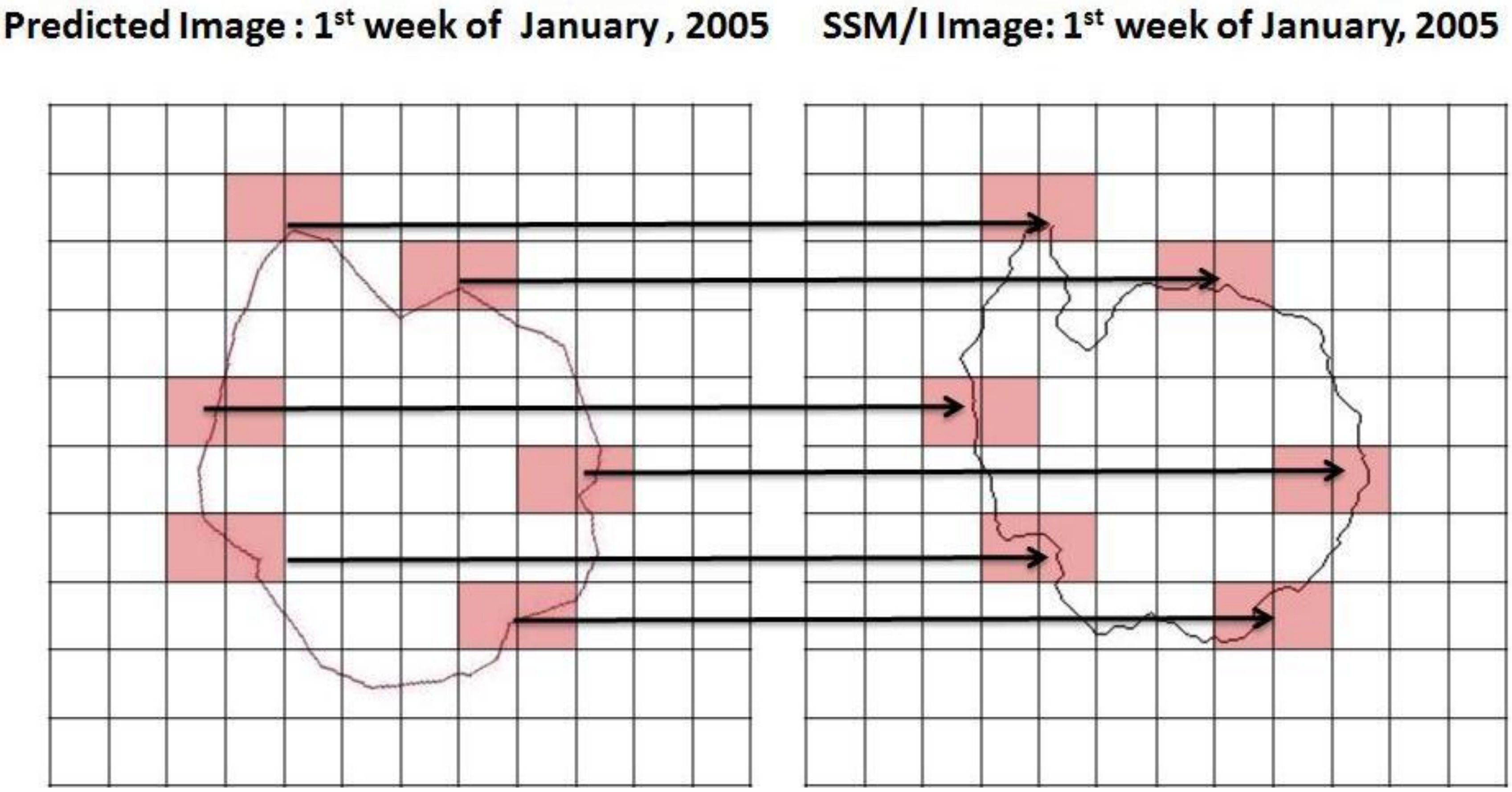
RMS Error Analysis

$$RMS = \sqrt{\frac{\sum_{n=1}^{n=360}\left(r_{reference} - r_{predicted}\right)^2}{n}}$$

Where, $r_{reference}$ = Reference Image Pixel Position
$r_{predicted}$ = Predicted Image Pixel Position

RMS Error Analysis

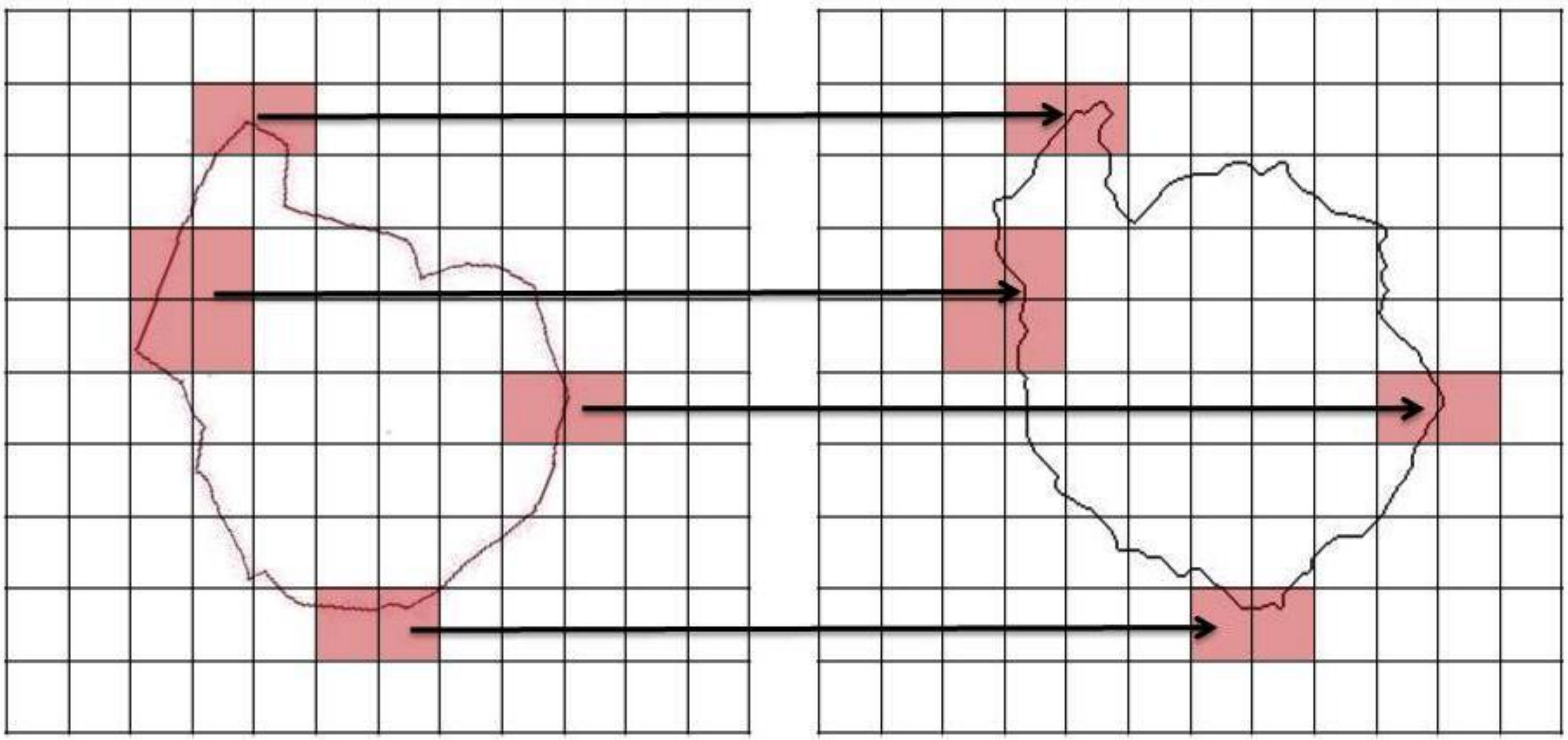
Average Error : 10 %



RMS Error Analysis

Average Error : 11 %

Predicted Image : 2nd week of January, 2005 SSM/I Image : 2nd week of January, 2005



Conclusion

- **The broad features of the predicted edge match well with that observed edge.**
- **Radial RMS Error is of the order of 10%**
- **The visual interpretation shows the GVF snake model has simulated the ice edge with 90 % accuracy**
- **Large deviation at the region around Antarctic peninsula due to use of the Averaging Technique to decide the ice edge when multiple edges are present at a particular angle**

Paper Accepted @ Conference

- **Pravin K. Rana**, A. Routray, Mihir K. Dash and P.C. Pandey (2008), abstract entitled "***Prediction of Antarctic sea ice edge using Artificial Intelligence***"***,*** is approved by the International Scientific Organizing Committee of the **SCAR/IASC IPY Open Science Conference 2008** for Oral Presentation at St. Petersburg, Russia from July 8 to July 11, 2008.

Future Work

- **Improve model reliability of Sea Ice Edge Prediction**
    - **Using more robust techniques**
    - **Using longer time series**
- **Used for the regional sea ice prediction**

Applications

- Used for deriving the sea ice extent before the satellite era
- Used in the climate model to give a better forecast
- Used for better study of the climate change signal
- Help in coast effective navigation and military plan in Polar Region.
- Used for prediction of the ice edge in the Arctic Edge Detection

Thank You