Livewire and LiveVessel – Shortest Path approach to Image Segmentation

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Overview

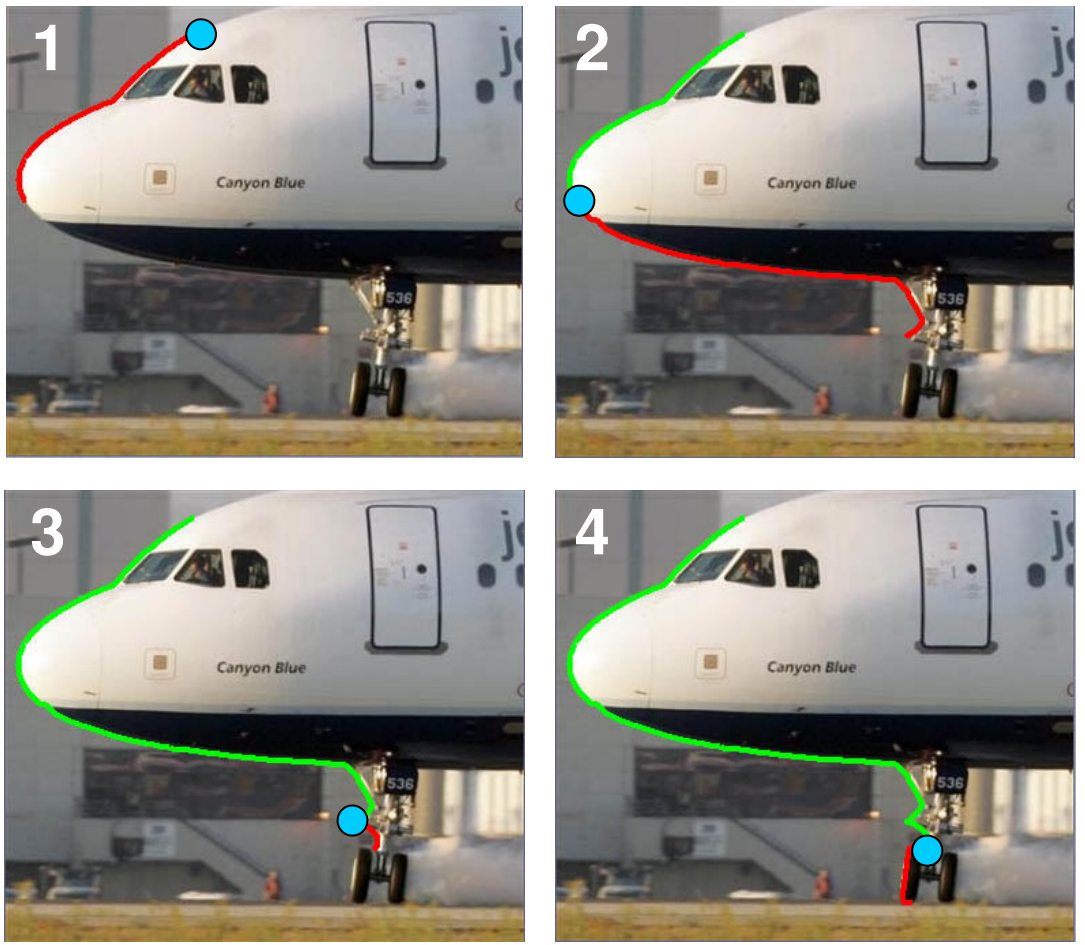
- Introduction to interactive segmentation techniques
- General 2D Livewire algorithm
- Extending of Livewire to vessel segmentation
- Livewire Demo

Segmentation Concepts

- General segmentation tool
  - Separating structures from background based on user input
- Semi-automatic segmentation
  - Fully automatic segmentation / modeling is sensitive to parameters
  - Manual segmentation is tedious and time-consuming
  - Livewire – User input gives accuracy, computer provides segmentation speed
- Other methods
  - Graph cuts, random walker, active contours/snakes (Fast marching method, level set implementations)
  - Many methods involve optimization of cost or energy function

Livewire Screenshots

Seed points locations magnified in blue for effect



Livewire Contour. Green = set contour, red = active contour

2D Livewire Algorithm

- Perform segmentation in a piece-wise fashion
- User can place seed points along a structure's edge quickly and efficiently
  - Computer will determine the optimal path between 2 points
- Show optimum contour wherever mouse is
  - Real-time feedback – computation speed critical
  - Data storage must be efficient
- Objective
  - As before, we are finding the optimal policy
    - This **basic** approach is a deterministic shortest path problem
    - Finding optimal contour from seed to ALL other points
  - Path corresponds to the segmentation contour

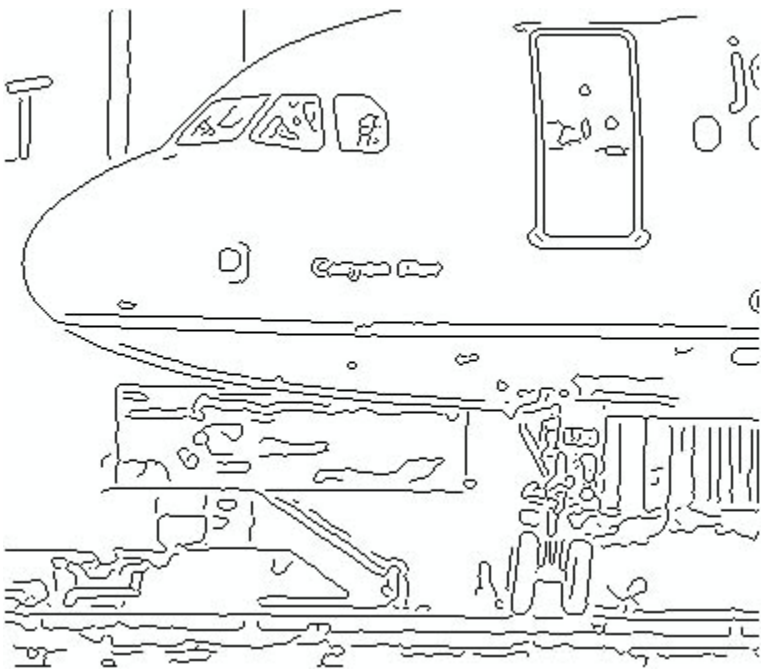
Algorithm

- Method
  - Migrating from pixel to pixel
  - Graph search manner
- States
  - $s \in S$, S = all pixels on image
- Actions
  - $a \in A_n$, A_n = set of all neighboring pixels – 7 possible pixels
- Rewards (cost)
  - Local (immediate) Reward - C
    - Local cost based on edge detection and other global operators
  - Euclidean distance away from previous state – D
- Optimality Equation
  - $v(s) = \min\{C + D(s) + v_{t-1}(s,a)\}$
- Optimal Decision Policy
  - Constitutes the contour that we want

Local Cost Determination

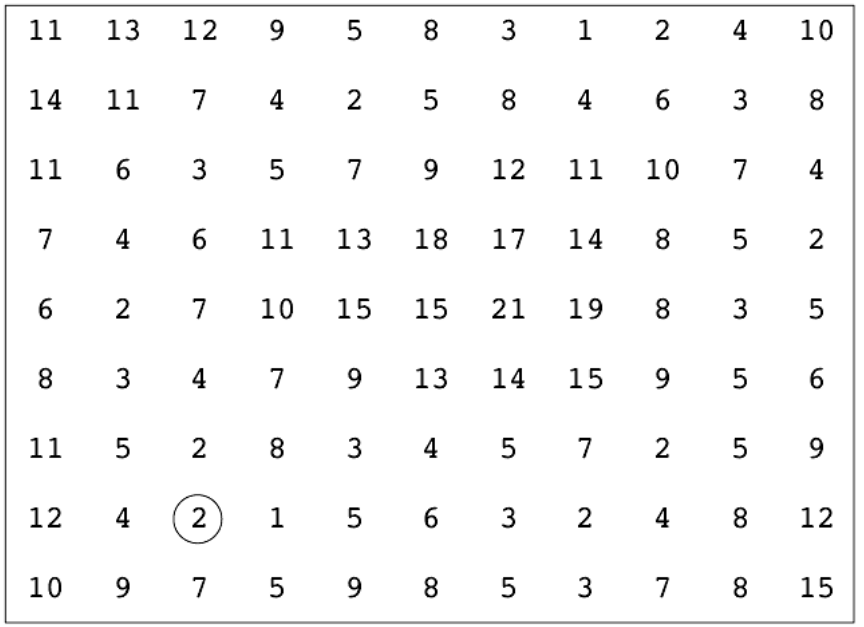
- External Costs
  - Edge detectors: Canny, Gradient magnitude, Laplacian of Gaussian
- Internal Costs
  - Gradient angle, contour length
- All factors are incorporated into a weighted sum

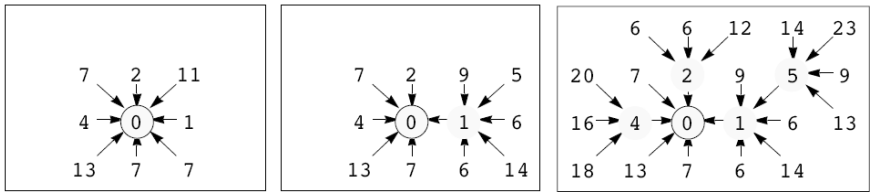
Original Image

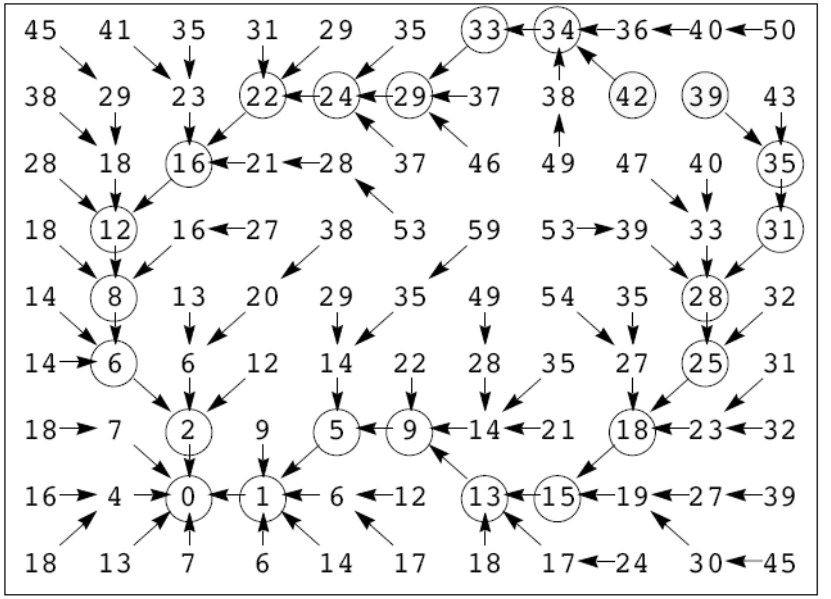


Canny Edge Detection

Graph Search



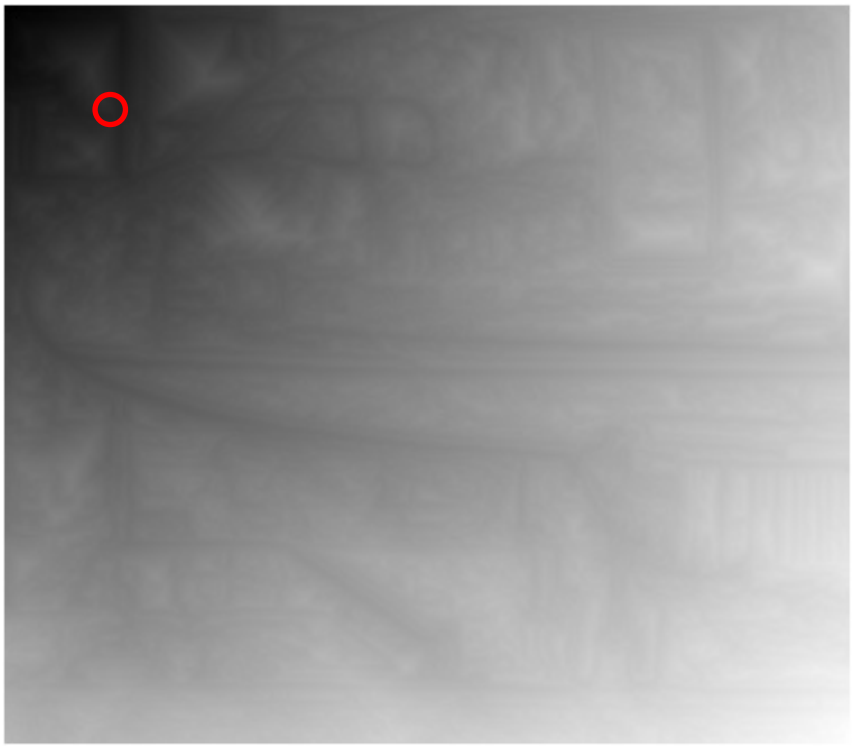




Graph search to find v(s) for all pixels

W. Barrett, E. Mortenson, *Interactive Live-wire Boundary Extraction,* Medical Image Analysis, 1997.

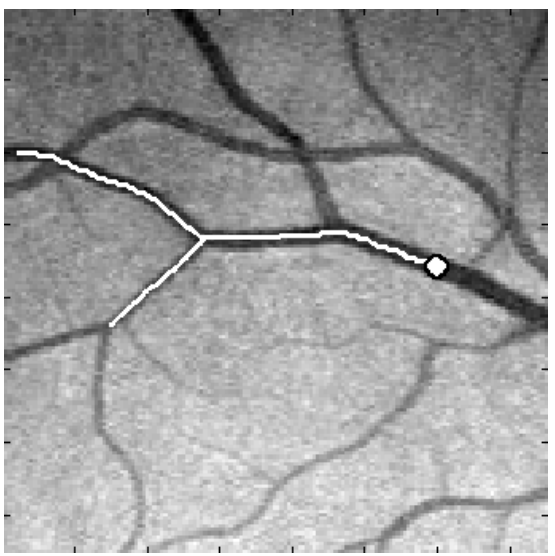
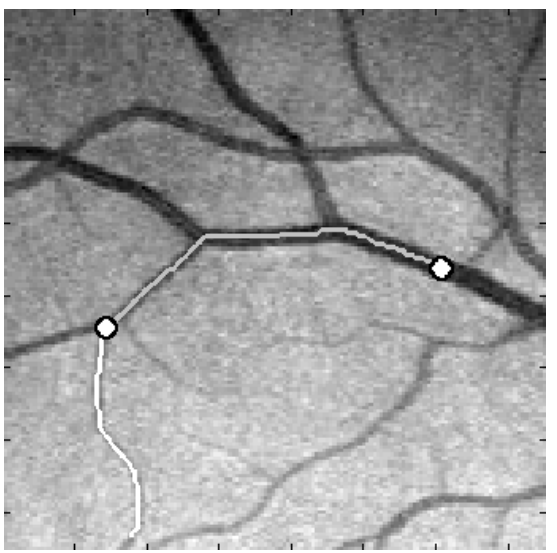
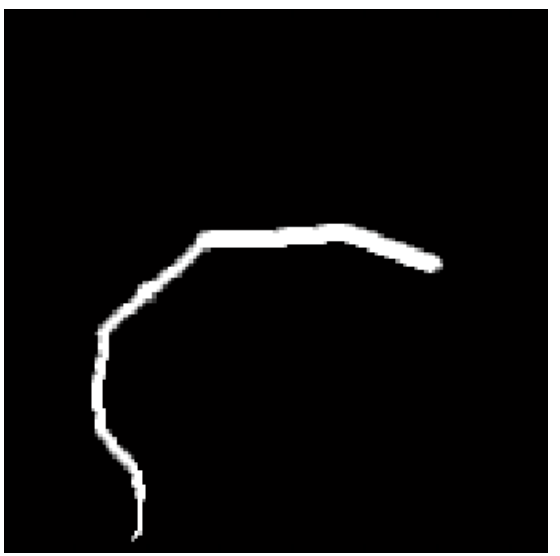
Cost Map



Cost map resulting from
graph search

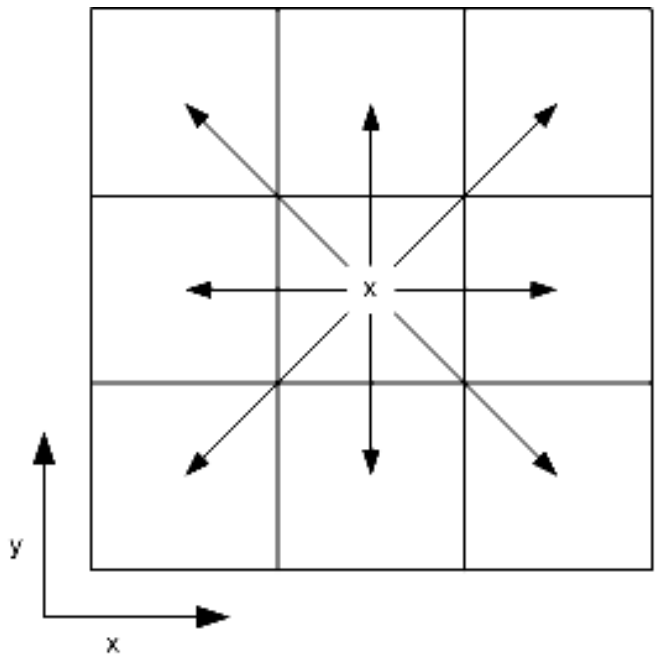
Live Vessel

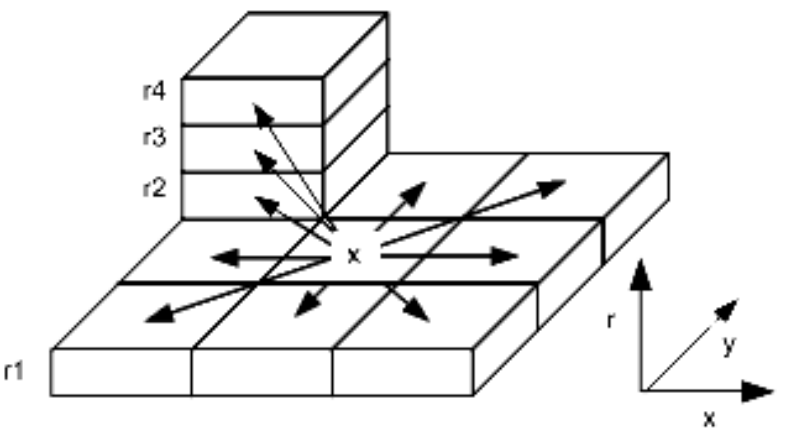
- Livewire for segmentation of vessels
- Goal is to segment vessel via median contour
- Optimize over spatial location and vessel radius at each location
- Extension of Livewire to semi-3D space {x, y, r}

Live Vessel

- Graph search extended to semi-3D space {x, y, r}
- Constrained graph search
  - No movement directly above or below {x,y} node
  - Radius takes 4 possible values
- 21 possible actions from a node
  - Cannot return to different radius values of previous state



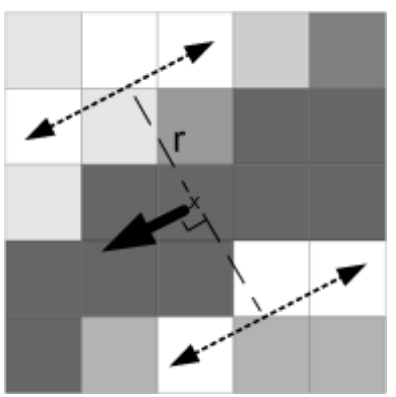


Local Costs

- External Costs:
  - Measure of 'vesselness' at each node (using eigenvectors of Hessian)
  - Edge evidence along median
    - Canny, Laplacian of Gaussian, gradient edge detectors

- Internal Costs
  - Changes in vessel direction
  - Changes in vessel radius
  - Median contour length

$$Cost(q,p) = w_1 C_V(p) + w_2 C_{Ev}(q,p) + w_3 C_{Ie}(p) + w_4 C_R(q,p) + w_5 C_S(q,p)$$



Pros/Cons of Livewire

- Advantages of Livewire over other user-interactive methods
  - More general; reduced initialization
  - Real-time: User immediately sees whether desired contour was obtained or not and can adjust contour otherwise
    - Direct control of contour
- Disadvantages
  - Sub-pixel accuracy not possible
  - Contour depends on weighting between internal and external costs
    - May ignore jagged edges or snap to wrong edges
  - Slower for 3D graph search

References

- W. Barrett, E. Mortenson, ***Interactive Live-wire Boundary Extraction***, Medical Image Analysis, 1997.

- K. Poon, R. Aburgharbieh, G. Hamarneh, ***Live-Vessel: Extending Livewire for Simultaneous Extraction of Optimal Median and Boundary Paths in Vascular Images***, MICCAI, 2007

Questions?