Today’s Agenda

Final project presentation & report
Edge-based segmentation – thresholding
Region-based segmentation
Morphological image processing techniques
Final Exam Schedule

Final exam has been scheduled:
4:00 p.m. – 6:30 p.m., Tuesday, Dec. 6

Requirement:
- Closed book and closed notes
- One page double-sided cheat sheet is allowed
- A calculator is allowed for +,-,*/

It will cover all the topics discussed in class
Final-Project Presentation (Section 001)

For students in Section 001:

- **Team project – a single presentation**: Each team has 18 minutes (15 minutes for presentation and 3 minute for questions) to present your project.
  - Both members should take part in the presentation.
  - You will present in class even if one member is in Sect. J60.

- **Single person project**: Each student has 13 minutes (10 minutes for presentation and 3 minute for questions) to present your project.
Final-Project Presentation (Section 001)

Presentation days:
  • Tuesday, Nov. 22
  • Tuesday, Nov. 29
  • Thursday, Dec. 1

Send me an email (tongy@cec.sc.edu) by 11:59pm, Nov. 18 including preference of these three days in a decreasing order. Earlier email has higher priority in choosing the day.
Final-Project Presentation (Section J60)

For students in Section J60 (except those have a team project with students in Section 001):

Each student has 10 minutes to present your project

Submit a link to your prerecorded video to Blackboard by 11:59pm, Nov. 29

Uploading a video to Blackboard – YouTube
What Should Be Included In the Final-Project Presentation

For a research/hands-on project
• An introduction of the background
• A brief literature review
• Methodology of your proposed method
• Experiment setup: dataset, evaluation metrics, etc.
• Experimental results if any
• Conclusion

For a survey project
• An introduction of the background
• A discussion on the papers you reviewed
• Comparison of the methods/groups you reviewed
• Conclusion

Note: You don’t need to complete the survey project by presentation date. You can cover part of the papers in your full list.
# Final Presentation Criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Worth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Problem</td>
<td>Did you make clear the nature of the problem you were trying to solve?</td>
<td>15</td>
</tr>
<tr>
<td>Description of Methodology</td>
<td>Did you present the methodology clearly? Did you provide sufficient (key) information to the audience?</td>
<td>25</td>
</tr>
<tr>
<td>Description of Experiment (Research project)</td>
<td>Could your experiment design – dataset, evaluation metrics, baseline approaches effectively demonstrate your proposed method?</td>
<td>25</td>
</tr>
<tr>
<td>Discussion and Comparison (Survey project)</td>
<td>Did your discussion clearly show your understanding of the methods? Did you make critical comments on the methods?</td>
<td>25</td>
</tr>
<tr>
<td>Visual Aids</td>
<td>Were visual aids used effectively? Were slides clear and easy to read by the audience?</td>
<td>10</td>
</tr>
<tr>
<td>Clarity &amp; Organization</td>
<td>Was the presentation easy to understand; did it have a logical flow and organization?</td>
<td>15</td>
</tr>
<tr>
<td>Timing</td>
<td>Was the presentation well-paced? Did it fit within the time allotted?</td>
<td>10</td>
</tr>
</tbody>
</table>
On the Final Project Report

Written report due time: 11:59pm. Dec 5th

• Report format: the same as a conference paper
  – For example, you can use a template for ICIP 2023
    Information for Authors – 2023 IEEE International Conference on
    Image Processing (iee eicip.org)
  Length: around 4 pages (+ 1 page reference) double-column
• Code must be submitted with clear comments (Research project only)

Academic integrity (avoiding plagiarism)

• don’t copy other person’s work
• describe using your own words
• complete citation and acknowledgement whenever you use
  any other work (either published or online)
Requirement for Final Project

In form of a complete research project
- Introduction (problem formulation/definition)
- A brief literature review
- The proposed method and analysis
- Experiment
- Conclusion
- Reference

A survey research
- A well-defined problem or topic
- A complete list of previous (typical) work on this problem – you need to include >=15 references
- Analyze/discuss these methods and compare them, preferred in groups
- Conclusion
- Reference
# Final Project Report Grading Criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Worth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Problem</td>
<td>Did you make clear the nature of the problem you were trying to solve?</td>
<td>10</td>
</tr>
<tr>
<td>Description of Methodology</td>
<td>Did you present the methodology clearly?</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Did you provide sufficient (key) information to the readers?</td>
<td></td>
</tr>
<tr>
<td>Description of Experiment (Research project)</td>
<td>Could your experiments effectively demonstrate your proposed method?</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Was the problem comprehensively reviewed?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Did your discussion clearly show your understanding of the methods?</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Did you make critical comments on the methods you reviewed?</td>
<td></td>
</tr>
<tr>
<td>Writing Clarity</td>
<td>Does the report read well? Is it easy to understand?</td>
<td>10</td>
</tr>
<tr>
<td>Organization &amp; Length</td>
<td>Is the report well-organized?</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Does it have a logical flow?</td>
<td></td>
</tr>
<tr>
<td>Reference</td>
<td>Is the reference section complete and in consistent format; are the citations in the text in consistent format?</td>
<td>5</td>
</tr>
</tbody>
</table>
Edge-based Segmentation -- Intensity Thresholding

Object/background segmentation:

\[ g(x, y) = \begin{cases} 
1 & \text{if } f(x, y) > T \\ 
0 & \text{if } f(x, y) \leq T 
\end{cases} \]

- A constant \( T \) - global thresholding
- A variable \( T \) - local/regional thresholding; adaptive thresholding
- Multiple \( T \) - multiple thresholding
Key Factors Affect Thresholding

- Separation between peaks
- Noise level
- Relative sizes of objects and background
- Uniformity of the illumination source
- Uniformity of the reflectance of the image
The Role of Noise in Image Thresholding

**FIGURE 10.36** (a) Noiseless 8-bit image. (b) Image with additive Gaussian noise of mean 0 and standard deviation of 10 intensity levels. (c) Image with additive Gaussian noise of mean 0 and standard deviation of 50 intensity levels. (d)–(f) Corresponding histograms.
The Role of Illumination in Thresholding

**FIGURE 10.37** (a) Noisy image. (b) Intensity ramp in the range \([0.2, 0.6]\). (c) Product of (a) and (b). (d)–(f) Corresponding histograms.
How to Pick the Threshold

1. Select an initial estimate for the global threshold, $T$.

2. Segment the image using $T$ by producing two groups of pixels.

3. Compute the mean of these two groups of pixels, say $m_1$ and $m_2$.

4. Update the threshold $T = (m_1 + m_2)/2$.

5. Repeat Steps 2 through 4 until convergence.
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An Example

FIGURE 10.38  (a) Noisy fingerprint. (b) Histogram. (c) Segmented result using a global threshold (the border was added for clarity). (Original courtesy of the National Institute of Standards and Technology.)
Image Segmentation

Two categories based on intensity properties:

1. Discontinuity – edge-based algorithms
2. Similarity – region-based algorithms

Mathematical expressions:

(a) \( \bigcup_{i=1}^{n} R_i = R \)

(b) \( R_i \) is a connected set, \( i = 1, ..., n \)

(c) \( R_i \cap R_j = \phi, \forall i \neq j \)

(d) \( Q(R_i) = TRUE \)

(e) \( Q(R_i \cup R_j) = FALSE \) for adjacent regions \( R_i \) and \( R_j \)
Region-Based Segmentation

- Region growing
- Region splitting and merging
Region Growing Algorithm

-A procedure that groups pixels or subregions into larger regions based on predefined criteria for growth

-Start with a set of “seed” points and grow regions by appending neighboring pixels that satisfy the given criteria
  - Connectivity
  - Stopping rules
    - Local criteria: intensity values, textures, color
    - Prior knowledge: size and shape of the object
An Example

\[ Q = \begin{cases} 
    \text{True} & \text{if } |I_{\text{seed}} - I(x,y)| \leq T \\
    \text{False} & \text{otherwise} 
\end{cases} \]

**FIGURE 10.51** (a) X-ray image of a defective weld. (b) Histogram. (c) Initial seed image. (d) Final seed image (the points were enlarged for clarity). (e) Absolute value of the difference between (a) and (c). (f) Histogram of (e). (g) Difference image thresholded using dual thresholds. (h) Difference image thresholded with the smallest of the dual thresholds. (i) Segmentation result obtained by region growing. (Original image courtesy of X-TEK Systems, Ltd.)
Region-Splitting and Merging Algorithm

Step 1: Keep splitting the region while $Q(R_i) = FALSE$ and $R_i > \min\ Size$

Step 2: Merge the subregions while $Q(R_i \cup R_j) = TRUE$

**FIGURE 10.52**
(a) Partitioned image.
(b) Corresponding quadtree. $R$ represents the entire image region.
An Example

FIGURE 10.53
(a) Image of the Cygnus Loop supernova, taken in the X-ray band by NASA’s Hubble Telescope. (b)-(d) Results of limiting the smallest allowed quadregion to sizes of 32 × 32, 16 × 16, and 8 × 8 pixels, respectively. (Original image courtesy of NASA.)

\[
Q = \begin{cases} 
  \text{TRUE} & \text{if } \sigma > a \& 0 < m < b \\
  \text{FALSE} & \text{otherwise}
\end{cases}
\]
Advanced Approaches for Image Segmentation

General-purpose image segmentation is far from well solved

It is still a research problem that is being investigated by many researchers

Image segmentation by K-means clustering

Image segmentation with Graphic Models (MRF, CRF, etc.)

Semantic Segmentation with Deep Learning

http://blog.qure.ai/notes/semantic-segmentation-deep-learning-review
Morphological Image Processing – Techniques to Improve Image Segmentation

Objective: Extract image components for representation and description of region shape including

- Boundaries
- Skeletons
- Convex hull

Applications:
- Edge detection
- Blob/connected component detection

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.
**Basic Concepts**

- **2D Integer space** $Z^2$
- **Union, intersection, complement, difference**
- **Set reflection** $\hat{B} = \{w \mid w = -b, b \in B\}$  
  B is a set of 2D points $(x, y)$
- **Set translation** $(B)_z = \{c \mid c = b + z, b \in B\}$  
  -- move the center/origin of B by z pixels
- **Structure elements (SEs):** small sets/subimages used in morphology
  - Black dots are centers/origins of SE
  - SEs for images
An Example of Morphology

Create a new set by running B over A so that the origin of B visits every element of A.

An example of erosion: If B is completely contained in A for each operation, the new element is a member of the new set.

The shaded cell belongs to A/B

Erosion result
Common Morphological Operations

Two basic operations

• Erosion
• Dilation

Other operations

• Opening/closing
• Hit-or-Miss transform
• Thinning/thickening
• Hole filling
Erosion

Set translation

$$(B)_z = \{c \mid c = b + z, b \in B\}$$

$A \ominus B = \{z \mid (B)_z \subseteq A\}$

or

$A \ominus B = \{z \mid (B)_z \cap A^c = \emptyset\}$

Shrink or thin objects and remove the details smaller than the SE
Erosion

A \Theta B = \{ z \mid (B)_z \subseteq A \} \text{ or } A \Theta B = \{ z \mid (B)_z \cap A^c = \emptyset \}

Shrink or thin objects and remove the details smaller than the SE
**Dilation**

**FIGURE 9.6**
(a) Set $A$.
(b) Square structuring element (the dot denotes the origin).
(c) Dilation of $A$ by $B$, shown shaded.
(d) Elongated structuring element.
(e) Dilation of $A$ using this element. The dotted border in (c) and (e) is the boundary of set $A$, shown only for reference.

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

Set reflection about its origin: \( \hat{B} = \{ w | w = -b, b \in B \} \)

\[
A \oplus B = \{ z | (\hat{B})_z \cap A \neq 0 \} \quad \text{or} \quad A \oplus B = \{ z | (\hat{B})_z \cap A \subseteq A \}
\]

Grows or thickens objects and remove the gaps smaller than the SE.
Properties of Dilation

- Dilation is commutative \( A \oplus B = B \oplus A \)

- Dilation is associative \( A \oplus B \oplus C = A \oplus (B \oplus C) \)

- Dilation is distributive over the union operation

\[ A \oplus (B \cup C) = (A \oplus B) \cup (A \oplus C) \]
Properties of Erosion and Dilation

• Erosion: $A \ominus B \ominus C = A \ominus (B \oplus C)$

• Erosion and dilation are duals of each other
  \[ A \oplus B = (A^c \ominus \hat{B})^c \]

• $A \subseteq (C \ominus B)$ if and only if \((A \oplus B) \subseteq C\)

• If $A \subseteq C$, $A \oplus B \subseteq C \oplus B$ and $A \ominus B \subseteq C \ominus B$
Opening

• Smooth the contour of an object
• Break narrow bridges
• Eliminate thin protrusions

\[ A \circ B = \bigcup \{(B)_z \mid (B)_z \subseteq A\} \]

\[ A \circ B = (A \ominus B) \oplus B \]

\[ (A \circ B) \circ B = A \circ B \]

\[ (A \circ B) \subseteq A \]

if \( A \subseteq C, A \circ B \subseteq C \circ B \)

The SE rolls within the boundary of \( A \).

**FIGURE 9.8** (a) Structuring element \( B \) “rolling” along the inner boundary of \( A \) (the dot indicates the origin of \( B \)). (b) Structuring element. (c) The heavy line is the outer boundary of the opening. (d) Complete opening (shaded). We did not shade \( A \) in (a) for clarity.
Opening (Cont’d)

Thin isthmus

Isthmus removed

Smoothened outer corners

\[ A \odot B = (A \ominus B) \oplus B \]
Opening and closing are duals of each other \[ A \cdot B = (A^c \circ \hat{B})^c \]

The SE rolls outside the boundary of \( A \).
Closing (Cont’d)

Eliminated thin gulf

Smoothed inner corners

$A \oplus B$

$A \cdot B = (A \oplus B) \ominus B$
Opening & Closing

\[ A \ominus B \subseteq A \circ B = (A \ominus B) \oplus B \]

\[ A \odot B = (A \oplus B) \ominus B \]

\[ A \ominus B \subseteq A \circ B \subseteq A \subseteq A \odot B \subseteq A \oplus B \]
An Example of Opening & Closing

- An opening removes all noise
  - removing the white noise by erosion
  - removing the black noise by dilation
- An additional closing fills the gaps

**FIGURE 9.11**
(a) Noisy image.
(b) Structuring element.
(c) Eroded image.
(d) Opening of \( A \).
(e) Dilation of the opening.
(f) Closing of the opening.
(Original image courtesy of the National Institute of Standards and Technology.)