Introduction to Medical Image Analysis

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Plenty of slides adapted from Thomas Moeslunds lectures
# Lecture 6 – BLOB analysis

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What can you do after today?

- Calculate the connected components of a binary image. Both using 4-connected and 8-connected neighbours.
- Compute BLOB features including area, bounding box ratio, perimeter, center of mass, and compactness.
- Describe blob feature distances in feature space.
- Classify binary objects based on their blob features.
Object detection and recognition

- Segmentation
- Isolate objects
- Feature extraction
- Classification
  - Pattern recognition
BLOB – what is it?

- BLOB = Binary Large Object
  - Group of connected pixels

- BLOB Analysis
  - Connected component analysis
  - Object labelling
Isolating a BLOB

- What we want:
  - For each object in the image, a list with its pixels

- How do we get that?
  - Connected component analysis

- Connectivity
  - Who are my neighbors?
  - 4-connected
  - 8-connected
Connected component analysis

- Binary image (0,1)
- Seed point: where do we start?
- Grassfire concept
  - Delete (burn) the pixels we visit
  - Visit all connected (4 or 8) neighbors
Opgave 10.12

Der laves en BLOB analyse på billedet, der ses i Figur 8. Hvor mange BLOBs er der i billedet når der bruge henholdsvis 4- og 8-connectivity.

1. 3 og 7
2. 9 og 5
3. 8 og 6
4. 7 og 5
5. 4 og 5
6. Ved ikke

Figur 8: Binært billede. Hvide pixels er forgrund (1) og sorte pixels er baggrund (0).
The result of connected component analysis

- An image where each BLOB (component) is labelled
- Each blob now has a unique ID = number
- What do we do with these blobs?
Features

- Feature
  - A prominent or distinctive aspect, quality, or characteristic
  - *This radio has many good features*

- Car (Ford-T) features
  - 4 wheels
  - 2 doors
  - 540 kg
  - 20 hp
Feature vector

- Feature vector
  - Vector with all the features for one object
- Ford-T features
  - 4 wheels
  - 2 doors
  - 540 kg
  - 20 hp
- Ford Fiesta features
  - 4 wheels
  - 3 doors
  - 1100 kg
  - 90 hp

\[ f = [4, 2, 540, 20] \]

\[ f = [4, 3, 1100, 90] \]
Feature extractions

- Compute features for each BLOB that can be used to identify it
  - Size
  - Shape
  - Position
- From image operations to mathematical operations
  - Input: a list of pixel positions
  - Output: Feature vector
- First step: remove invalid BLOBs
  - too small
  - too big
  - border BLOBs

Feature vector = [2,1,...,3]
Feature vector = [4,7,...,0]
BLOB Features

- Area
  - number of pixels in the BLOB
  - Can be used to remove noise (small BLOBS)
BLOB Features

- **Bounding box**
  - Minimum rectangle that contains the BLOB
  - Height: $y_{\text{max}} - y_{\text{min}}$
  - Width: $x_{\text{max}} - x_{\text{min}}$
  - Bounding box ratio:
    $$\frac{y_{\text{max}} - y_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}$$
  - tells if the BLOB is elongated
BLOB Features

- **Bounding box**
  - Bounding box area:
    $$ (y_{\text{max}} - y_{\text{min}}) \cdot (x_{\text{max}} - x_{\text{min}}) $$
  - Compactness of BLOB

Compactness = \frac{\text{BLOB Area}}{(y_{\text{max}} - y_{\text{min}}) \cdot (x_{\text{max}} - x_{\text{min}})}
BLOB Features

- Bounding box ratio
  - Bounding box height divided by the width
Compactness – which shape is most compact?

A) Shape 1:

B) Shape 2:

Compactness = \frac{\text{BLOB Area}}{(y_{\text{max}} - y_{\text{min}}) \cdot (x_{\text{max}} - x_{\text{min}})}
BLOB Features

- Center of mass \((x_c, y_c)\)

\[
x_c = \frac{1}{N} \sum_{i=1}^{N} x_i
\]

\[
y_c = \frac{1}{N} \sum_{i=1}^{N} y_i
\]
Center of mass

A) (12, 1.5)
B) (5, 8.5)
C) (6.5, 3.5)
D) (4.5, 0.5)
E) (7, 4.5)

Opgave 10.13

Ved at bruge 4-connectivity er den mindste BLOB fundet i billedet på Figur 8. Derefter er center of mass beregnet af denne blob. Origo af billedet er (0, 0) i øverste venstre hjørne og der benyttes et (x,y) koordinatsystem. Hvad er resultatet?

1. (12, 1.5)
2. (5, 8.5)
3. (6.5, 3.5)
4. (4.5, 0.5)
5. (7, 4.5)
6. Ved ikke

Figur 8: Binært billede. Hvide pixels er forgrund (1) og sorte pixels er baggrund (0).
BLOB Features

- **Perimeter**
  - Length of perimeter
  - How can we compute that?

\[
\sum ((f(x, y) \oplus SE) - f(x, y))
\]
Compactness II – which shape is most compact?

A) Shape 1:

B) Shape 2:

Compactness = \frac{\text{Perimeter}^2}{\text{BLOB Area}}
BLOB Features

- Circularity
  - How circle like

\[
\text{Circularity} = \frac{\text{Perimeter}}{2\sqrt{\pi} \cdot \text{Area}}
\]
After feature extraction

Area, compactness, circularity etc calculated for all BLOB

Feature vector = [2,1,…,3]

Feature vector = [4,7,…,0]

One feature vector per blob
Object detection and recognition

- Segmentation
- Isolate objects
- Feature extraction
  - Classification
    - Pattern recognition

(7,5)  (10,5)  (7,1)
(7,4)  ?
?
?
Why calculate features for a BLOB?

- When more objects are present after segmentation, how will you figure out which is the one of interest?
- **Solution:**
  - Make a model of the object you are looking for
  - Calculate its characteristics (features)
  - Calculate the characteristics (features) of each BLOB in the image
  - Compare the features of each BLOB with the features of the model
  - The best match defines the object

Where is the bird?
Model?

What is a model?
- Something you build before the “real thing”?  
- Something that looks really nice?  
- A mathematical description of something?

Mathematical model of an electromagnetic field
Classification

- To put things into classes
  - Determine if a BLOB is a bird, a car or a cloud
- The possible classes are normally already defined
  - Bird
  - Car
  - Cloud
Classification

- We have the model with some measured features
  - Area
  - Perimeter
- We have three BLOBs with measured features
- Which one is “closest” to the model

BLOB 1

BLOB 2

BLOB 3

Model

Class 1: Bird
Class 2: Car
Class 3: Cloud
Classification

- How to compare features?
- Measure the **distance** from each BLOB to the model and pick the BLOB with the shortest distance, i.e. the BLOB most similar to the model

- How do we define a distance?
Feature Matching

- Distance in *feature-space*
- Feature 1: Area
- Feature 2: Circularity
- 2 dimensional feature space
- Model: BLOBs:

```
Feature 1: Area
Feature 2: Circularity
MATCH!
```

![Graph showing feature matching]
Classification: Distance

- Euclidean distance
- “Straight line distance”

Distance from i’th BLOB to the Model:

\[ D(i) = \sqrt{(M_{f_1} - B_{i,f_1})^2 + (M_{f_2} - B_{i,f_2})^2} = \sqrt{\sum_{j=1}^{\text{# features}} (M_{f_j} - B_{i,f_j})^2} \]
How to generate the model

- Based on known samples
- Calculate class statistics for each class
The Fruit Machine
Each team should

- Estimate the following features from the model fruits
  - Projected 2D area (in square centimeters)
  - Bounding box ratio (rotate fruit until the ratio is smallest)
  - Perimeter (centimeters)

- Plot a feature-space using the area and the bounding box ratio

- Classify fruits using the learned features
  - Could be manual, implemented in Matlab or Excel
What fruits have?

- Area: 28 cm²
- Bounding box ratio: 0.78
- Perimeter: 20 cm

- Area: 69 cm²
- Bounding box ratio: 0.45
- Perimeter: 43 cm

- Area: 2 cm²
- Bounding box ratio: 0.85
- Perimeter: 6 cm
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Next week

- Pixel Classification
- Colour images
Exercises