AI Summer School 2024

Medical Imaging Informatics

University of Pittsburgh

Intersection Over Union (IoU)

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IEEE COMPUTER SOCIETY

Learning Objectives

After completing this lecture, you should be able to:

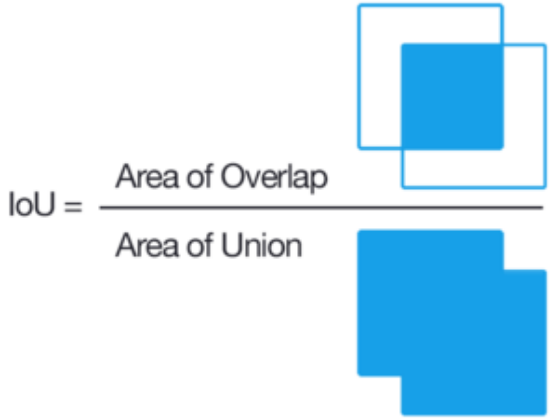
- Explain why Intersection over Union (IoU) is used for bounding boxes
- Understand what Intersection over Union (IoU) metric
- Interpret what the different ranges of IoU mean
- Be able to perform IoU calculations for different types of bounding boxes

Outline

- Intersection over Union: What and Why?
- IoU General Algorithm
- IoU Calculations
- Example Calculation

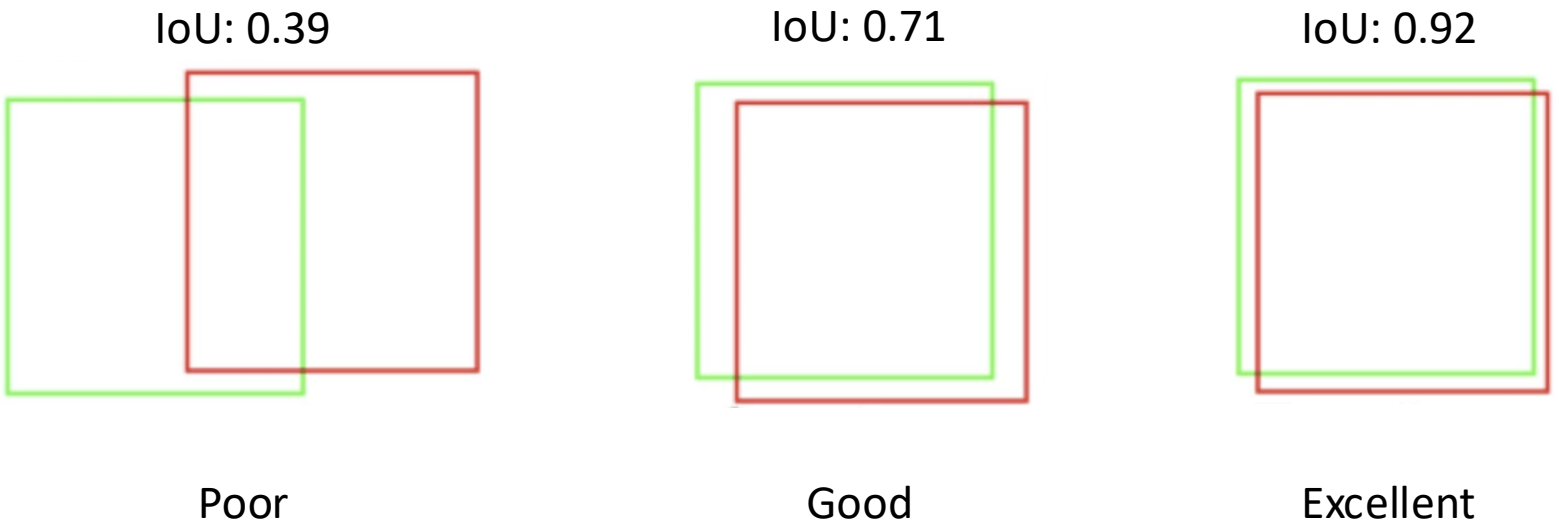
Intersection over Union: What and Why?

- When evaluating both **manual annotations** and **object detection** algorithms we need a metric to measure overall **quality** of the annotations or **performance** of the model
- **Intersection over Union (IoU)** measures the amount overlap between
  - Groups of annotators annotating medical images
  - The predicted bounding box and the ground truth bounding box



- The better the overlap between the groups of annotators or between the predicted bounding box and ground truth bounding box the better the inter-rater agreement between annotators and better the predictions

Different Ranges of IoU



IoU General Algorithm

- Calculating the IoU between two annotators:
  - Get the bounding box coordinates from both annotators
  - Compare the bounding boxes between the annotators
  - Calculate the area of overlap (intersection) and the area of the union
  - Divide the intersection by the union
  - Analyze the obtained results
  - Repeat for all annotated images
- The above algorithm can be done for object detection, but instead is done between the **predicted bounding box** and the **ground truth**.

Performing the IoU Calculation

- Suppose we have two annotators, A and B:
  - Extract the bounding box coordinates for A and B
  - Find the intersection coordinates of the bounding boxes:

$$x_{I_0} = \max(x_0^A, x_0^B)$$
$$y_{I_0} = \max(y_0^A, y_0^B)$$
$$x_{I_1} = \min(x_1^A, x_1^B)$$
$$y_{I_1} = \min(y_1^A, y_1^B)$$

  - Calculate the area of the intersection

$$A \cap B = (x_1^I - x_0^I) * (y_1^I - y_0^I)$$

Performing the IoU Calculation (Cont.)

- Suppose we have two annotators, A and B:
  - Calculate area of the union

$$Area\ A = \left(x_1^A - x_0^A\right) * (y_1^A - y_0^A)$$
$$Area\ B = (x_1^B - x_0^B) * (y_1^B - y_0^B)$$
$$A \cup B = AreaA + AreaB\ - A \cap B$$

  - Calculate the IoU

$$IoU = \frac{A \cap B}{A \cup B}$$

- The above steps can be done for object detection, but instead is done between the **predicted bounding box** and the **ground truth**.

Example: Calculating the IoU Between Two Annotations

- Suppose we have two annotators, A and B who have annotated the following knee x-ray:

A

X0: 105 X1: 556
Y0: 266 Y1: 845

B

X0: 144 X1: 562
Y0: 264 Y1: 683

Example: Calculating the IoU Between Two Annotations

- Suppose we have two annotators, A and B who have annotated the following knee x-ray:
  - Extract the bounding box coordinates for A and B

A		B	
X0: 105	X1: 556	X0: 144	X1: 562
Y0: 266	Y1: 845	Y0: 264	Y1: 683

  - Find the intersection coordinates of the bounding boxes:

$$x_{I_0} = \max\left(x_0^A, x_0^B\right) = \max(105, 144) = 144$$
$$y_{I_0} = \max\left(y_0^A, y_0^B\right) = \max(266, 264) = 266$$
$$x_{I_1} = \min\left(x_1^A, x_1^B\right) = \min(556, 562) = 556$$
$$y_{I_1} = \min\left(y_1^A, y_1^B\right) = \min(845, 683) = 683$$

  - Calculate the area of the intersection

$$A \cap B = (x_1^I - x_0^I) * (y_1^I - y_0^I) = (556 - 144) * (683 - 266)$$

$$= 410 * 417 = 171804$$

Performing the IoU Calculation (Cont.)

- Suppose we have two annotators, A and B:
  - Calculate area of the union

$$Area\ A = \left(x_1^A - x_0^A\right) * \left(y_1^A - y_0^A\right) = (556\ - 105) * (845 - 266) = (451\ * 579) = 261129$$
$$Area\ B = \ (x_1^B - x_0^B) * (y_1^B - y_0^B) = (562\ - 144) * (683\ - 264) = 418\ * 419 = 175142$$
$$A \cup B = AreaA + AreaB\ - A \cap B = 261129 + 175142\ - 171804 = 264467$$

  - Calculate the IoU

$$IoU = \frac{A \cap B}{A \cup B} = \frac{175142}{264467} = 0.662$$

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Thank you!

Questions!