AI Summer School 2025

Medical Imaging Informatics

University of Pittsburgh

Introduction to Medical Image Annotations

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IEEE COMPUTER SOCIETY

Learning Objectives

After completing this lecture, you should be able to:

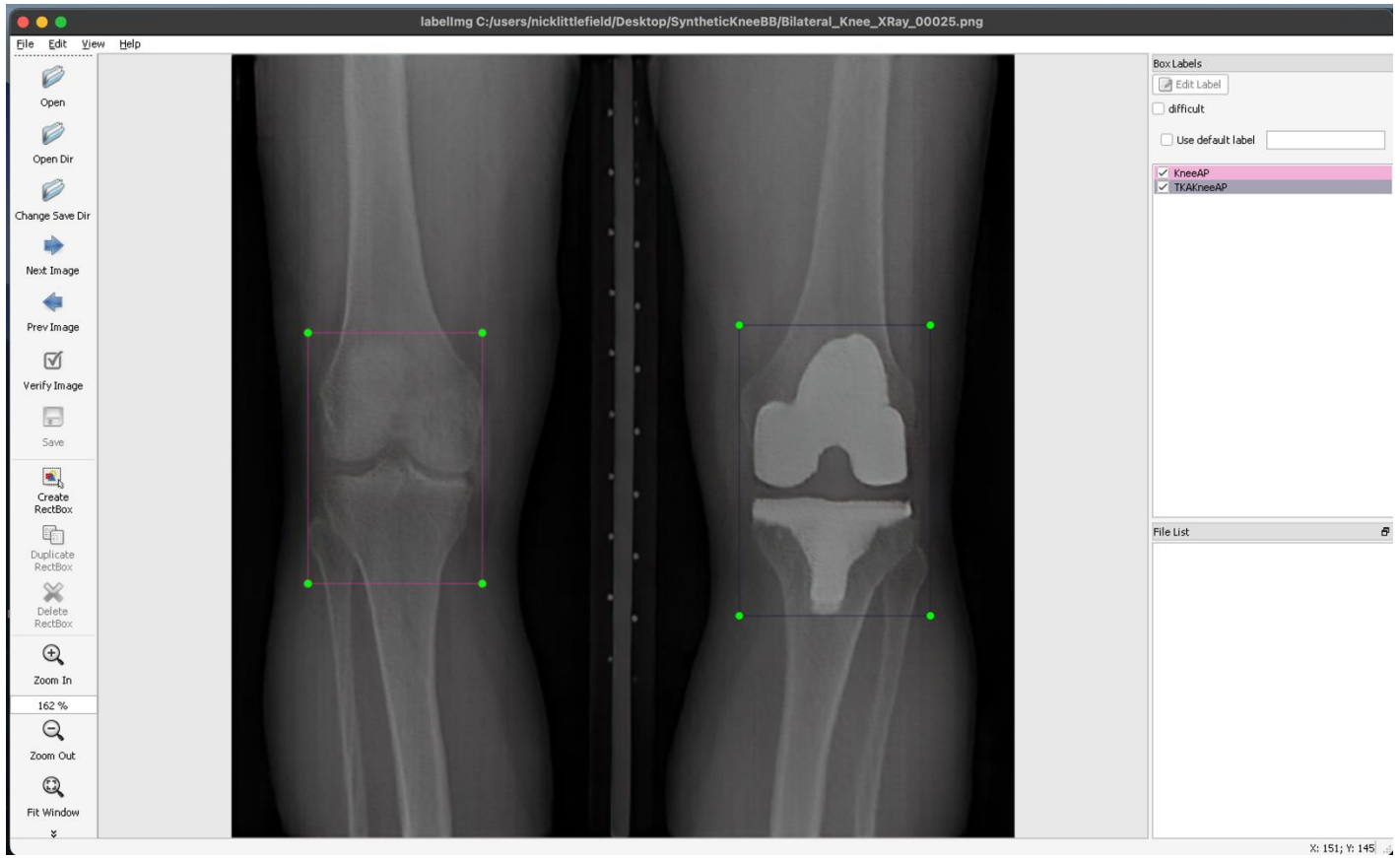
- Explain the overall process of medical image annotation
- Understand the different types of annotations
- Understand the primary steps in bounding box annotation for object detection
- Understand how to evaluate manual annotation
- Understand what tools are used for bounding box annotation
- Understand the common errors that occur in the annotation process

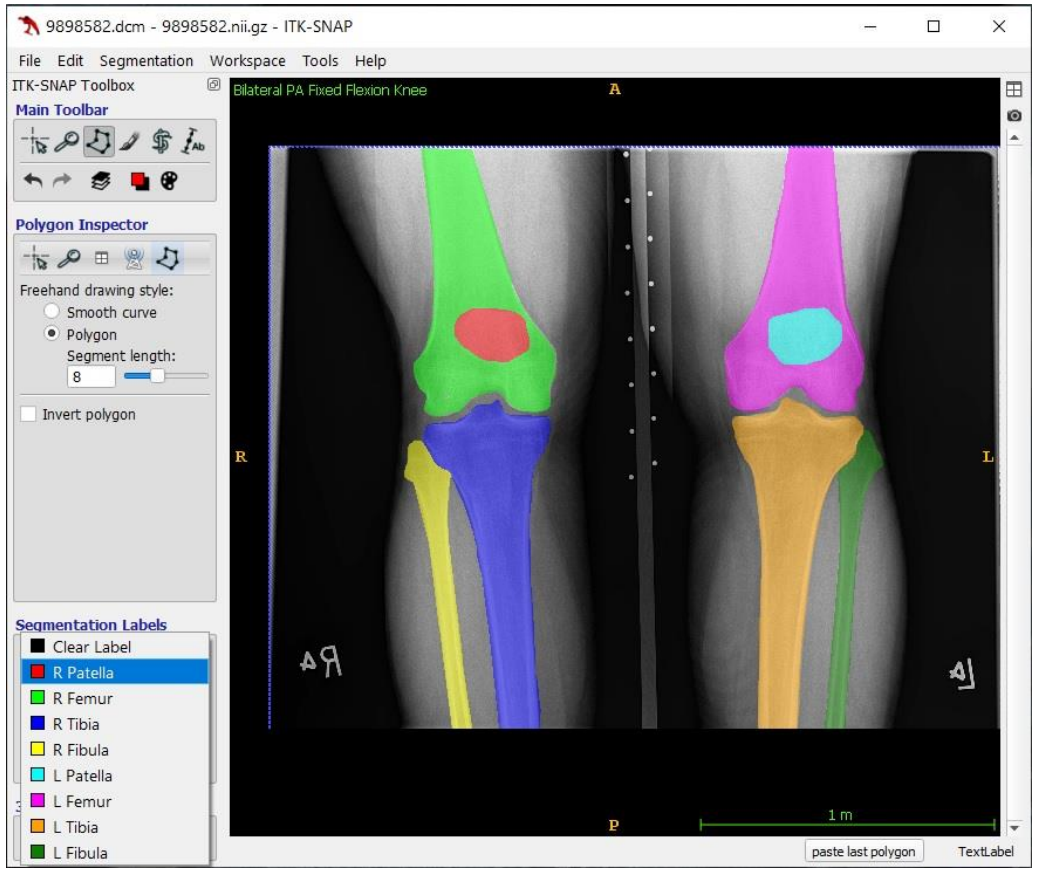
Outline

- Medical Image Annotation: What and Why?
- Types of Annotations in Medical Imaging
- Annotation Pipelines
- Challenges
- Evaluating Manual Annotations
- Annotation Tools
- Common Errors

Medical Image Annotation: What and Why?

- **Medical image annotation** is the process of labeling medical images to highlight specific features, structures, or abnormalities.
- Aids in training AI models, improving clinical decision support, research and development





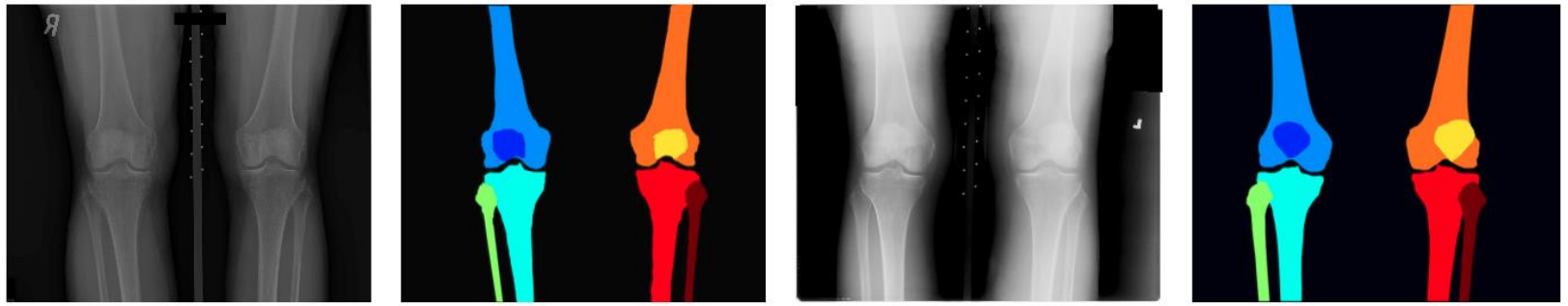
Types of Medical Image Annotation

- There are multiple types of medical image annotations:
  - Object Detection
  - Segmentation
  - Classification

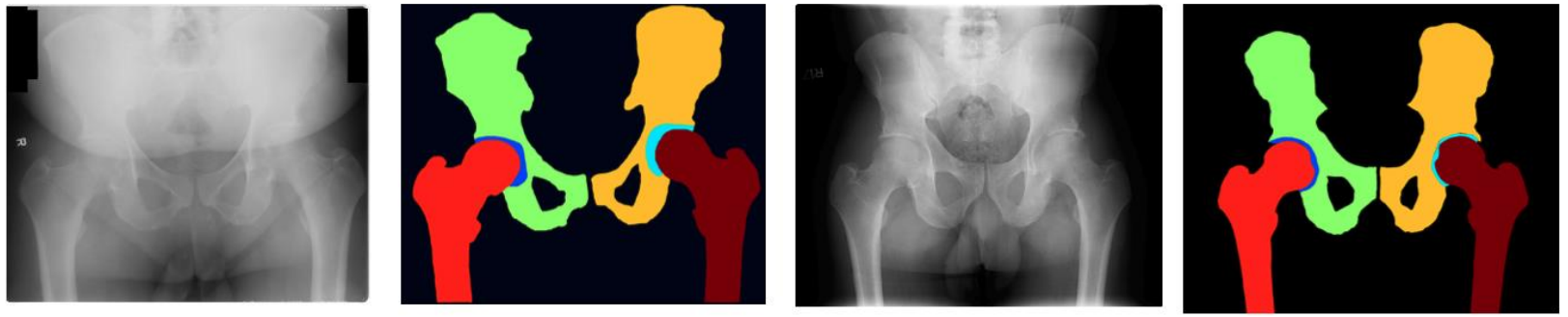
Student Activity: What are some example scenarios where you could use each type of annotation?

Types of Medical Image Annotation: Segmentation

- Outlines the boundaries of different structures (organs, tissue, bony anatomy)



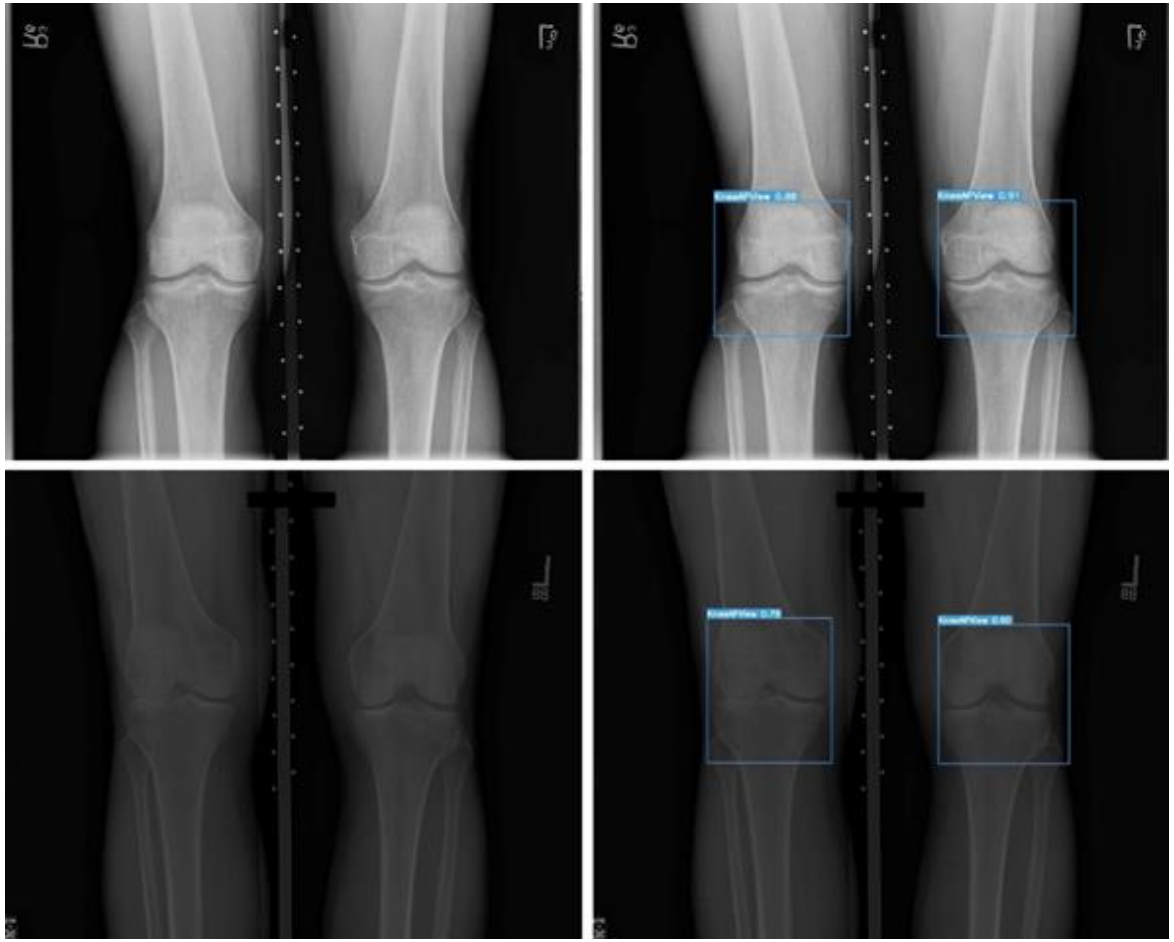
(a)



(b)

Types of Medical Image Annotation: Object Detection

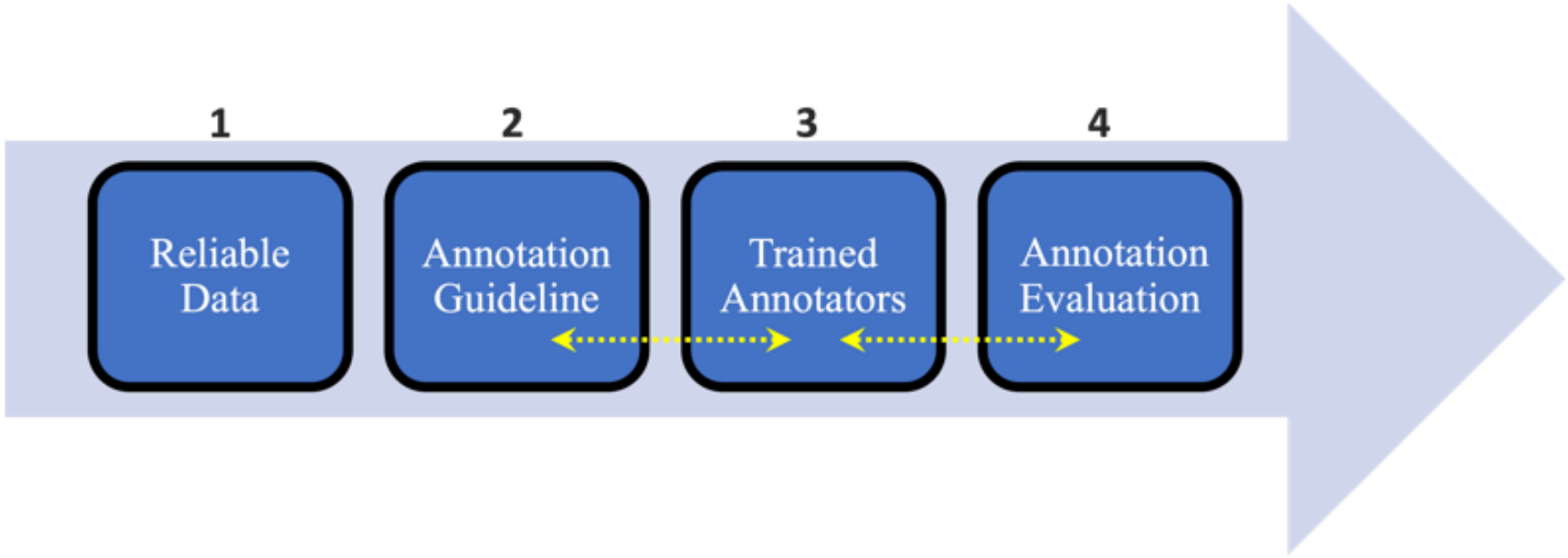
- Identifying and localizing regions of interest that contain specific objects
- Examples:
  - Cells in microscopic image
  - Knee joint area,
  - Brain tumors
  - Lung nodules



Types of Medical Image Annotation: Classification

- Assigning labels or categories to images based on the content of the image
- Examples:
  - benign vs. malignant brain tumors
  - lung cancer screening – benign, pre-cancerous, malignant,
  - fracture types – simple, compound, …

Typical Annotation Pipeline



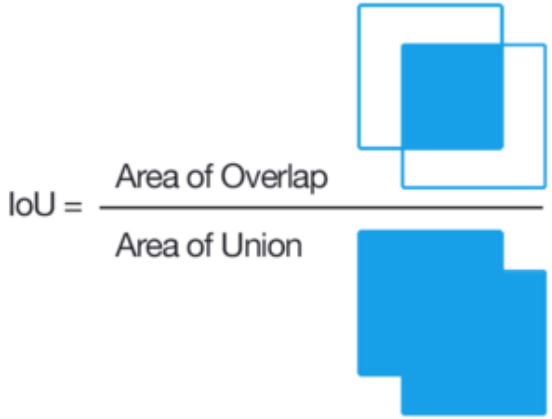
Challenges with Medical Image Annotations

- Accuracy and precisions of annotations: Annotations need to be precise and highly accurate to train AI models
- Consistency of the annotations: different annotators can have varying interpretation of the same image
- Time consuming and costly: Detailed annotations take extensive amount of time
- Complexity of medical images: images have different modalities, quality, and can contain artifacts

Student Activity: Accuracy and precision of annotations are important. How can we ensure precision across annotators and ensure annotators are annotating correctly?

Intersection over Union: What and Why?

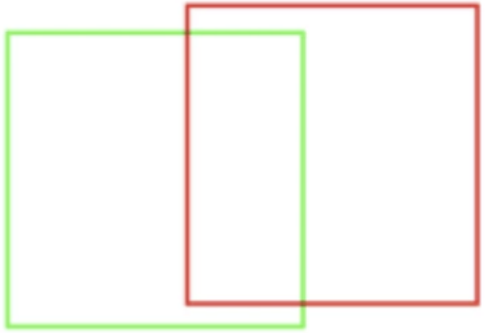
- When evaluating both **manual annotations** and **object detection** algorithms we need a metric to measure overall **quality** of the annotations or **performance** of the model
- **Intersection over Union (IoU)** measures the amount overlap between
  - Groups of annotators annotating medical images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

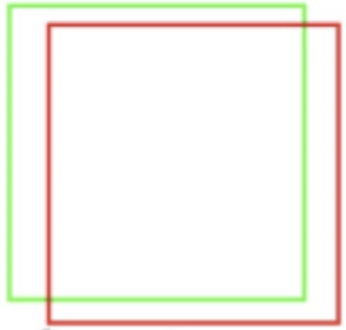
Different Ranges of IoU

IoU: 0.39



Poor

IoU: 0.71



Good

IoU: 0.92

Excellent

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:

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

  - 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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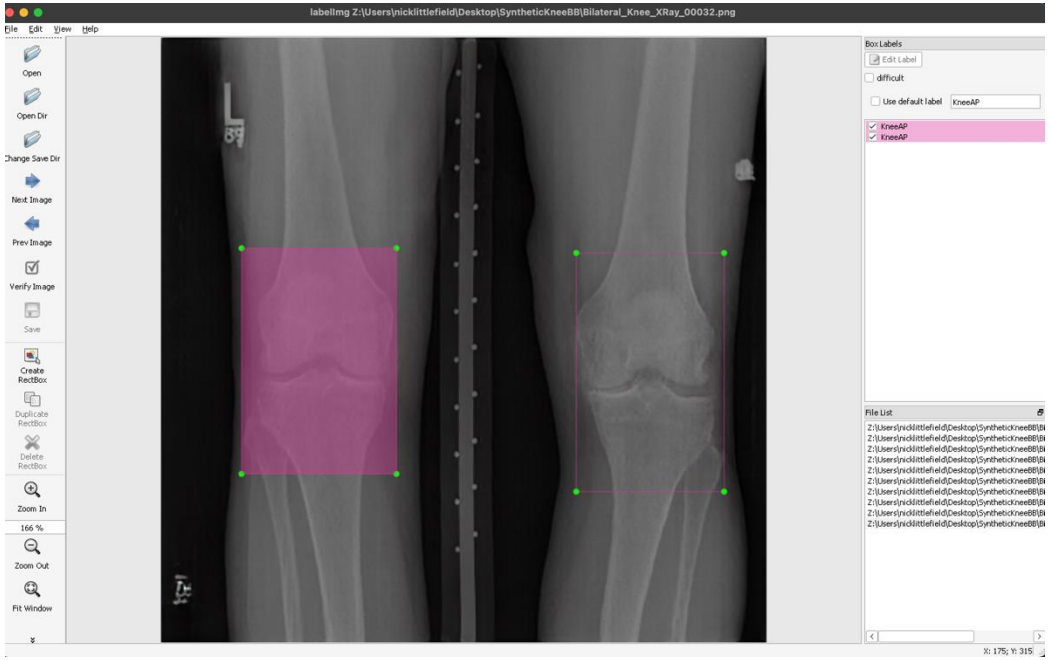
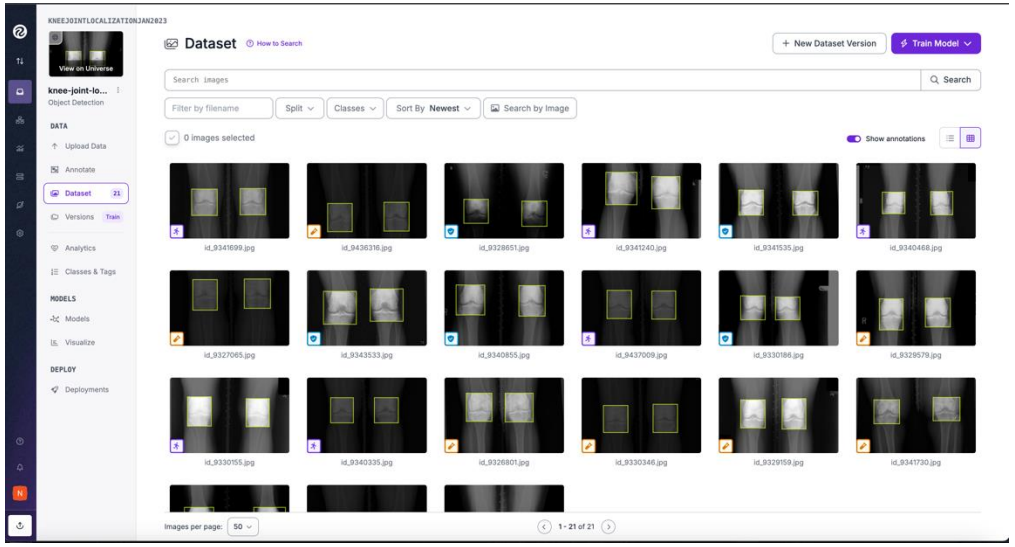
Tools for Object Detection Annotations: LabelImg

- Lightweight and easy-to-use image annotation tool for labeling bounding boxes for object detection in images
- Generates XML file containing the class of an object and the bounding box coordinates for the **upper left** and **lower right corners**



Tools for Object Detection Annotations: Roboflow

- Platform designed to help developers build, train, and deploy computer vision models—particularly for tasks like object detection, classification, and segmentation
- Allows for data management:
  - Upload and organize image datasets.
  - Annotate images directly in the browser or import annotations from other tools.
  - Automatically convert between bounding box formats (e.g., COCO, YOLO, Pascal VOC).



Common Mistakes in Image Annotation

- **Inaccurate bounding boxes:** boxes that are too loose or too tight can lead to poor model performance.
- **Inconsistent labeling:** different annotators may label the same structure differently (e.g., one calls it “tumor,” another “mass”).
- **Missing annotations:** forgetting to annotate an object entirely can introduce false negatives during training.
- **Incorrect class labels:** assigning the wrong category (e.g., labeling a benign tumor as malignant).
- **Overlapping or redundant boxes:** placing multiple boxes around the same object can confuse the model.
- **Ignoring image artifacts:** failing to distinguish between real features and noise/artifacts from poor imaging.
- **Non-standard formats:** saving annotations in incompatible formats (e.g., mixing YOLO and Pascal VOC without conversion).

Hand-On Practice: Manual Annotations in Roboflow

Thank you!

Questions!