Segmentation quality estimation

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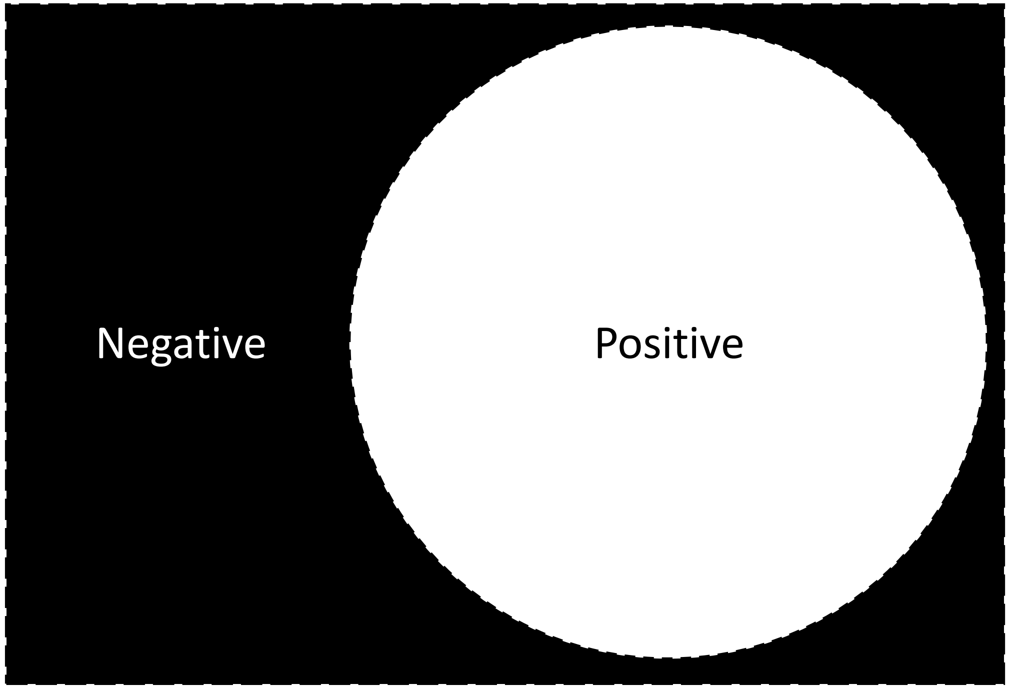
Algorithm evaluation

- In general
  - Define what's positive and what's negative.



Algorithm evaluation

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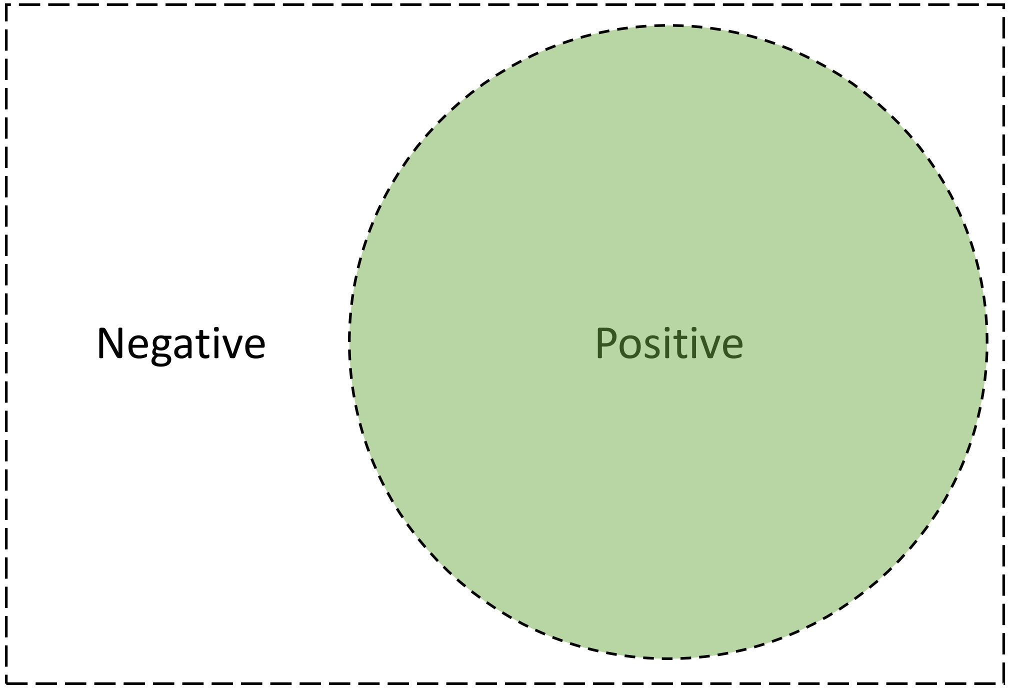

Algorithm evaluation

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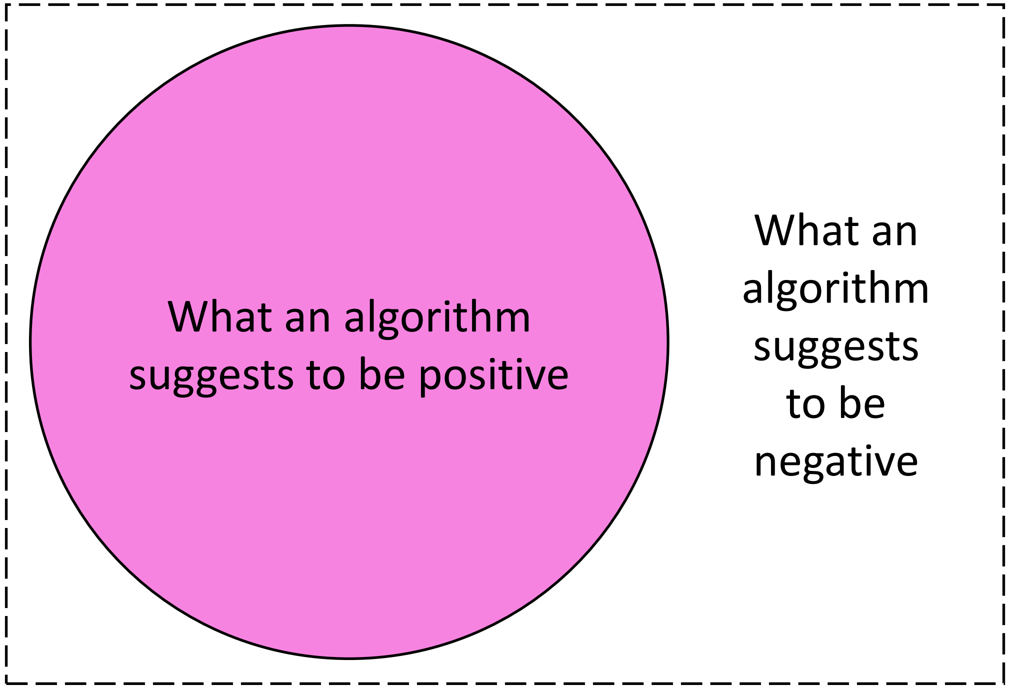
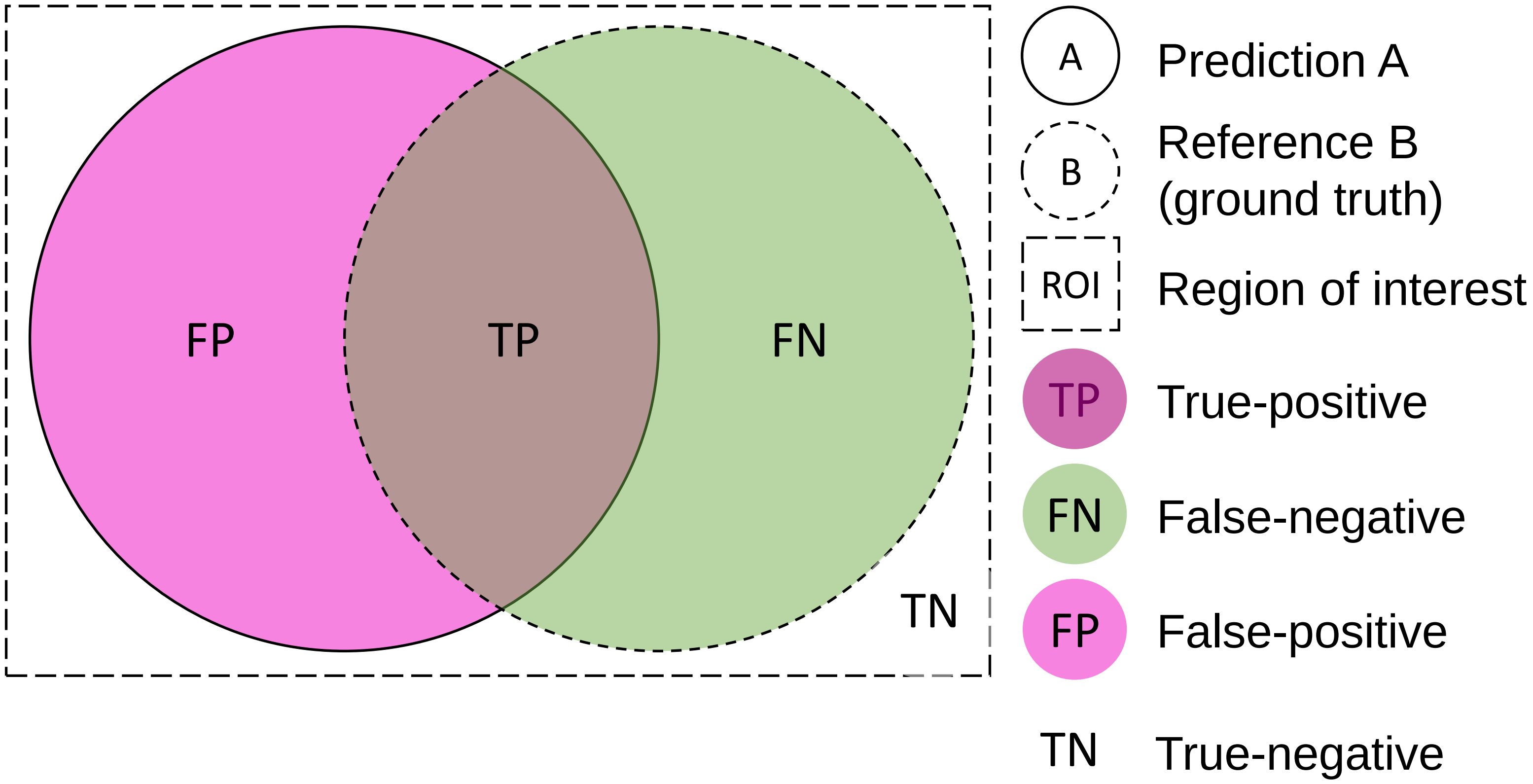


Algorithm evaluation

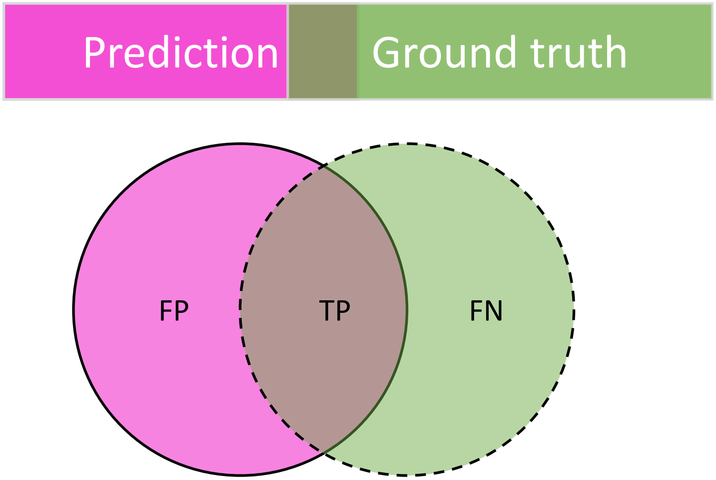
- In general
  - Define what's positive and what's negative.
  - Compare with a reference to figure out what was true and false

  - Welcome to the Theory of Sets

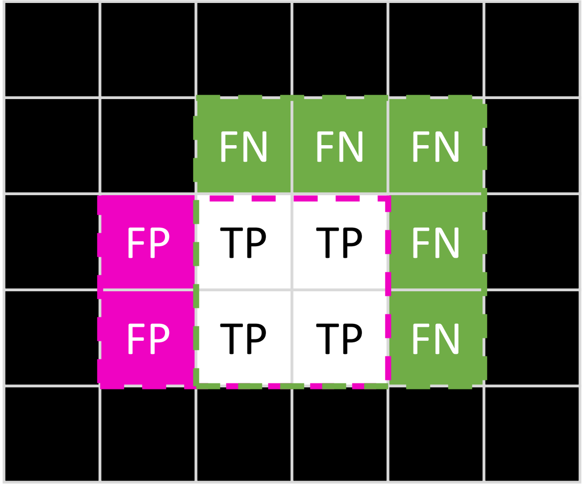


Precision	$\frac{TP}{TP+FP}$	What fraction of points that were predicted as positives were really positive?
Recall (a.k.a. sensitivity)	$\frac{TP}{TP+FN}$	What fraction of positives points were predicted as positives?

Pixel-wise versus Object-wise evaluation



- Pixel wise: Segmentation quality



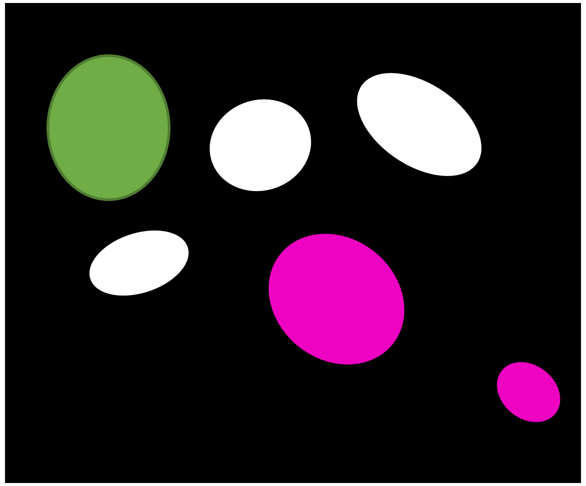
True-positive: 4

False-negative: 5

False-positive: 2

Precision: 4/6 = 66%
Recall: 4/9 = 44%

- Object wise: Detection quality



True-positive: 3

False-negative: 1

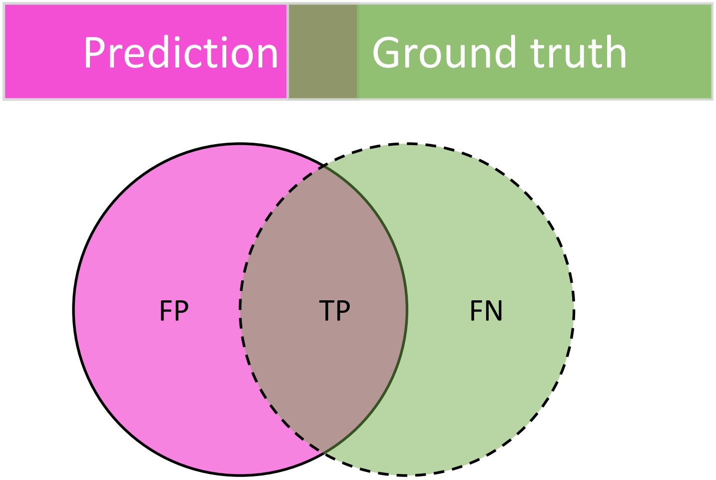
False-positive: 2

Precision: 3/4 = 75%
Recall: 3/5 = 60%

Precision $$\frac{TP}{TP + FP}$$

Recall (a.k.a. sensitivity) $$\frac{TP}{TP + FN}$$

Pixel-wise versus Object-wise evaluation

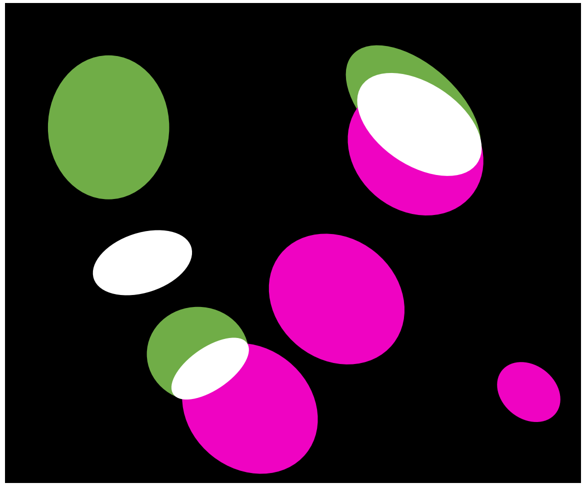


Intersection-over-union (a.k.a. Jaccard index) $$\frac{TP}{TP+FN+FP}$$

Precision $$\frac{TP}{TP+FP}$$

Recall (a.k.a. sensitivity) $$\frac{TP}{TP+FN}$$

- In practice: Mixed



Objects with at least 50% *pixel-wise overlap* between P and GT

True positive: 2
False positives: 3
False negatives: 2

Precision: 2/5 = 40%
Recall: 2/4 = 50%

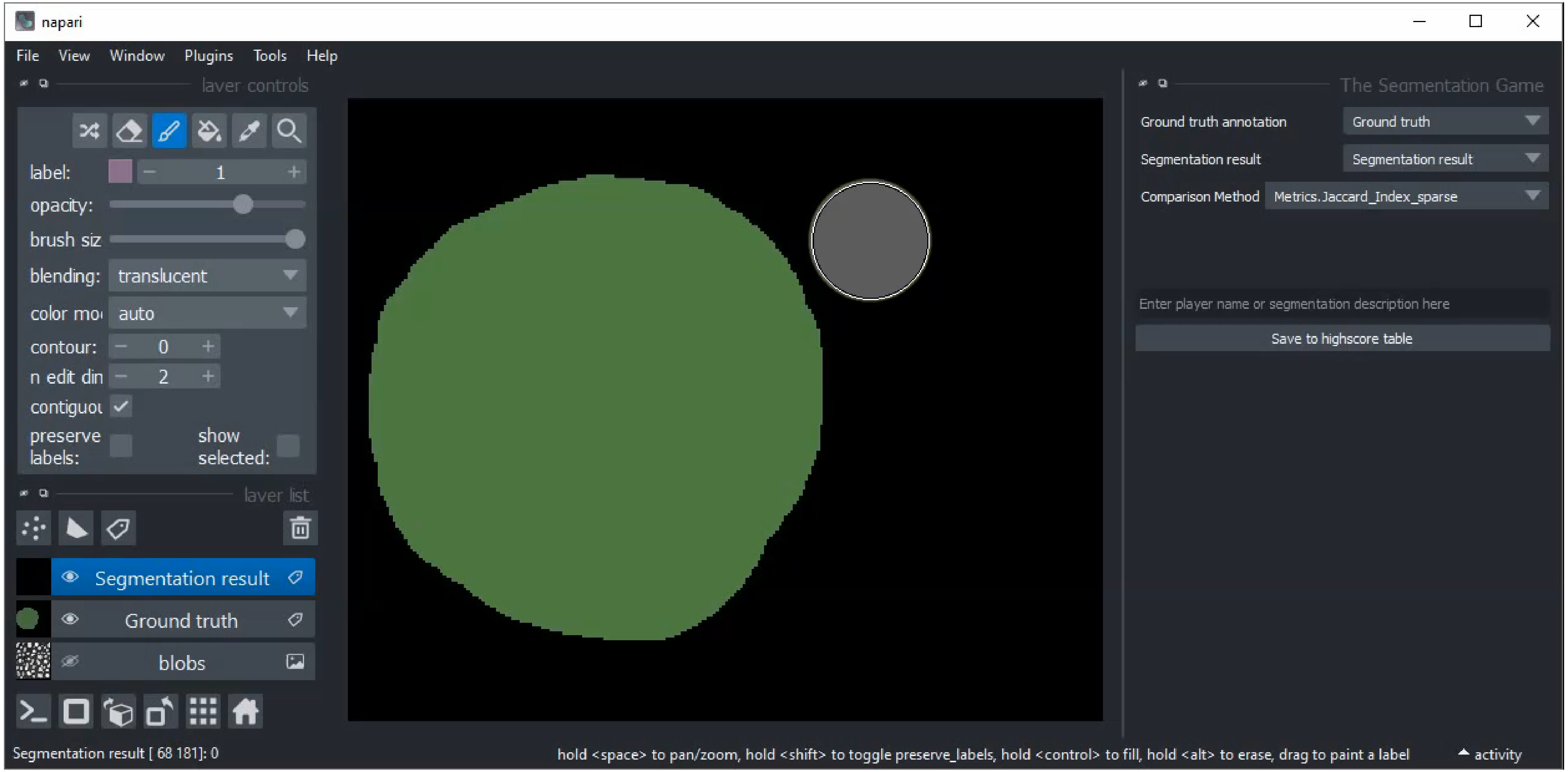
Average Overlap for all ground-truth objects:

(0 + 1 + 0.5 + 0.2) / 4

≈ 43%

Pixel-wise versus Object-wise evaluation

- Average Overlap for all ground-truth objects
- https://github.com/haesleinhuepf/the-segmentation-game



Algorithm evaluation

- Voxel-wise Youden-Index

$$YI = p_{TP} + p_{TN} - 1$$

- Volume error

$$\Delta_V = V_A - V_B$$

$$\delta_V = \frac{\Delta_V}{V_B}$$

- Dice Index

$$DI(A,B) = \frac{2\,|A \cap B|}{|A| + |B|}$$

- Jaccard Index

$$JI(A,B) = \frac{|A \cap B|}{|A \cup B|} = \frac{DI}{2 - DI}$$

- Contour distance

$$d_{e,min}(a,B) = \min(d_e(a,b)|b \in B)$$

$$\bar{d}_c(A,B) = \frac{\sum_{\forall a \in C(A)} d_{e,min}(a, C(B))}{|C(A)|}$$

$$\bar{d}_{bil,c}(A,B) = \frac{\bar{d}_c(A,B) + \bar{d}_c(B,A)}{2}$$

- Hausdorff distance

$$d_H(A,B) = \max(d_{e,min}(a,B)|a \in A)$$

$$d_{bil,H}(A,B) = \max(d_H(A,B), d_H(B,A))$$

- Simplified Hausdorff distance

$$d_H(A,B) = \max(d_{e,min}(a, C(B))|a \in C(A))$$

- Volume standard deviation

$$\delta_{\bar{V}} = 2\frac{|V_A - V_B|}{|V_A + V_B|}$$

- Classification error

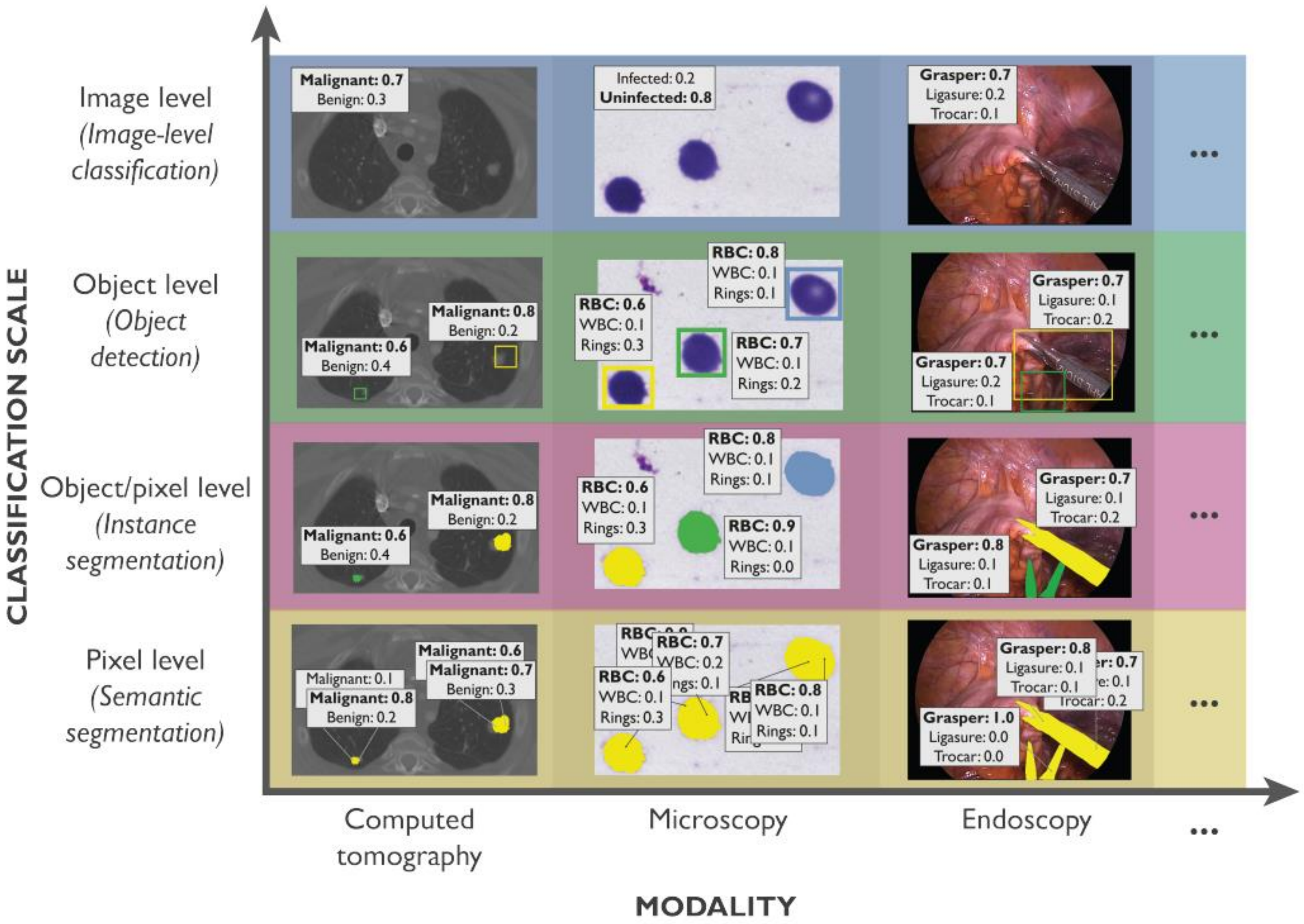
$$e_{Class} = \frac{H}{|TP| + |FN|}$$

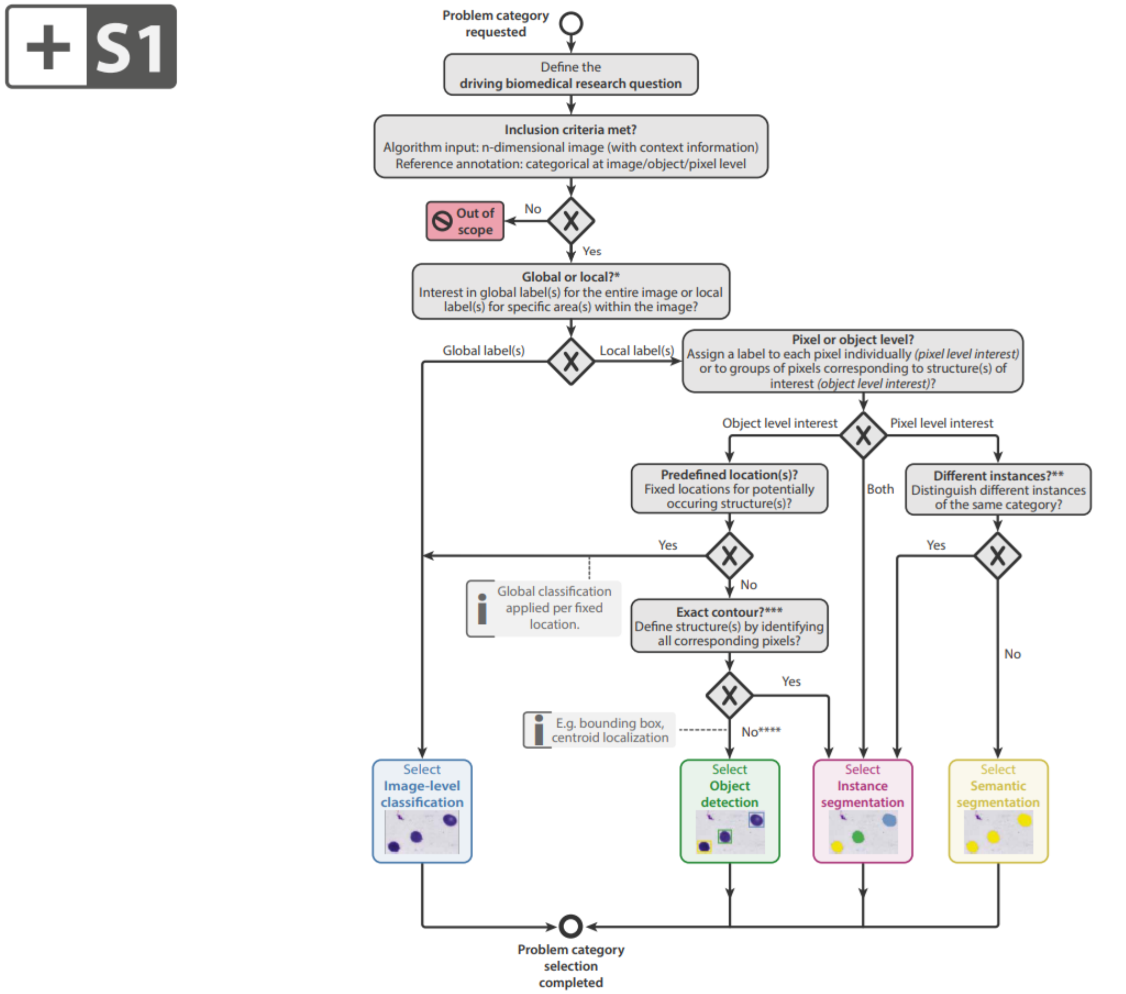
- Hamming distance

$$d_h = |A \cup B| - |A \cap B|$$
$$= |FP| + |FN|$$

What metric to use when?

- "Metrics reloaded: Pitfalls and recommendations for image analysis validation"
  Maier-Hein, Reinke et al. https://arxiv.org/abs/2206.01653





Exercise

- Use *The Segmentation Game* from Python to measure the quality of a segmentation algorithm applied to a folder of images.

```
metrics.jaccard_index_sparse(sparse_labels, labels)
```

```
0.8357392602053431
```

```
for image_filename in os.listdir(image_folder):
    print(image_folder + image_filename)
```

```
../../data/BBBC007_batch/17P1_POS0013_D_1UL.tif
../../data/BBBC007_batch/20P1_POS0005_D_1UL.tif
../../data/BBBC007_batch/20P1_POS0007_D_1UL.tif
../../data/BBBC007_batch/20P1_POS0010_D_1UL.tif
../../data/BBBC007_batch/A9 p7d.tif
../../data/BBBC007_batch/AS_09125_040701150004_A02f00d0.tif
```