Object Boundary Refinement Using Level Sets

CS 554 - Computer Vision Project Presentation

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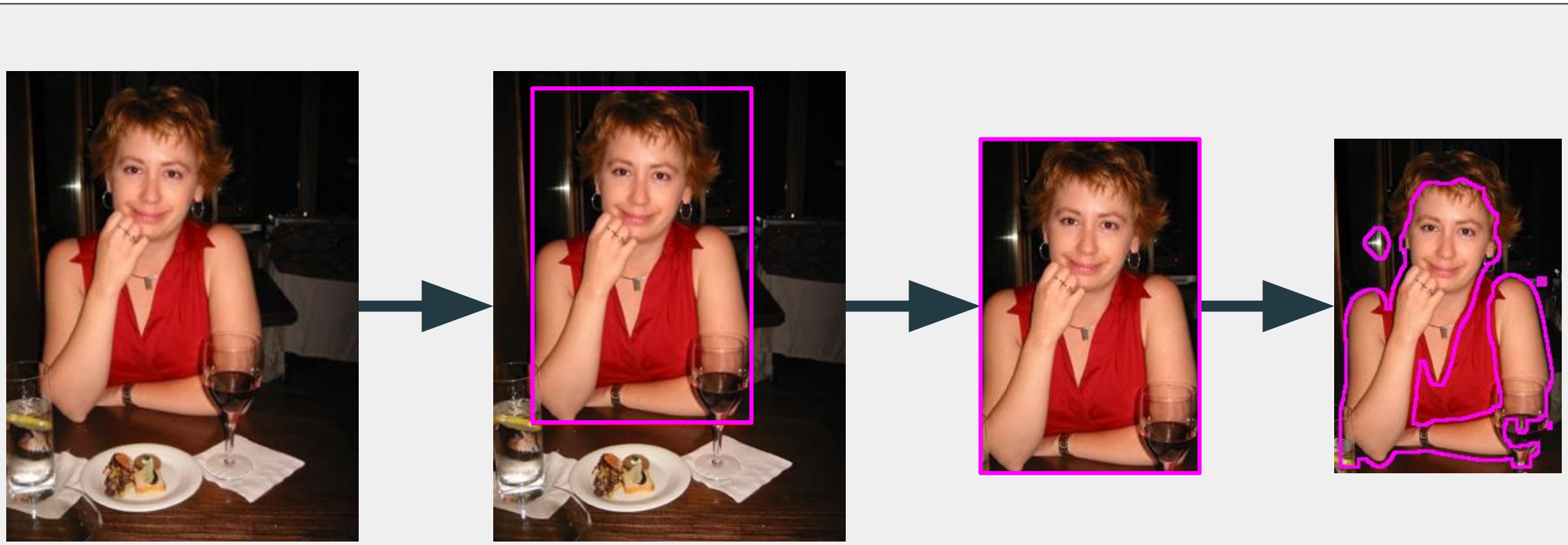
Introduction



Active Contour Models (Snakes)

Minimizes energy functional:

$$E_{snake} = \int_{\Gamma} \left(\alpha|\mathbf{v}'(s)|^2 + \beta|\mathbf{v}''(s)|^2 - I(\mathbf{v}(s))\right) ds$$

Internal Energy **External Energy**

Challenges:

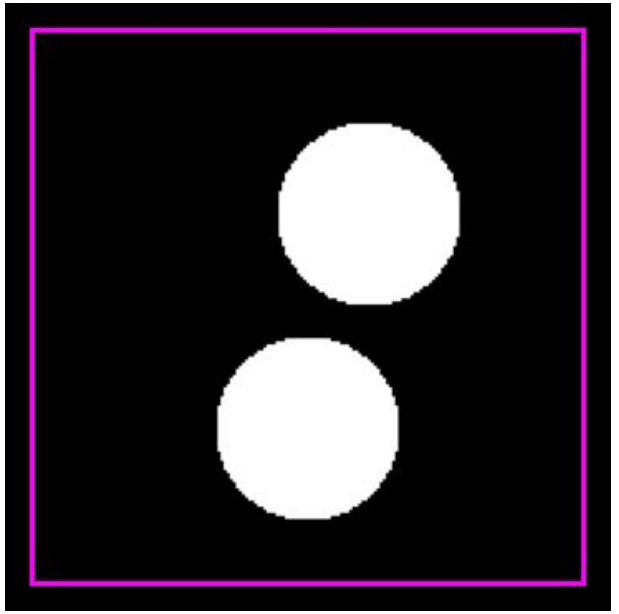
- Noise
- Initialization.

Kass, M., Witkin, A., & Terzopoulos, D. (1988). Snakes: Active contour models. International Journal of Computer Vision, 1(4), 321-331.

Level Set Method

Contour evolution governed by:

$$\frac{\partial \phi}{\partial t} = \delta(\phi(x)) \cdot (\alpha \nabla \phi \cdot \nabla I + \beta I)$$



Advantages:

- Topological changes

Challenges:

- Computation
- Noise

Osher, S., & Sethian, J. A. (1988). Fronts propagating with curvature-dependent speed. Journal of Computational Physics, 79(1), 12-49.

Enhanced Level Set with Sobel Filters

Sobel filter:

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Advantages:

- Noise
- Edge

Sobel, I., & Feldman, G. (1968). An isotropic 3x3 image gradient operator. Machine Vision for Three-Dimensional Scenes, 271-272.

Contour Initialization Strategies

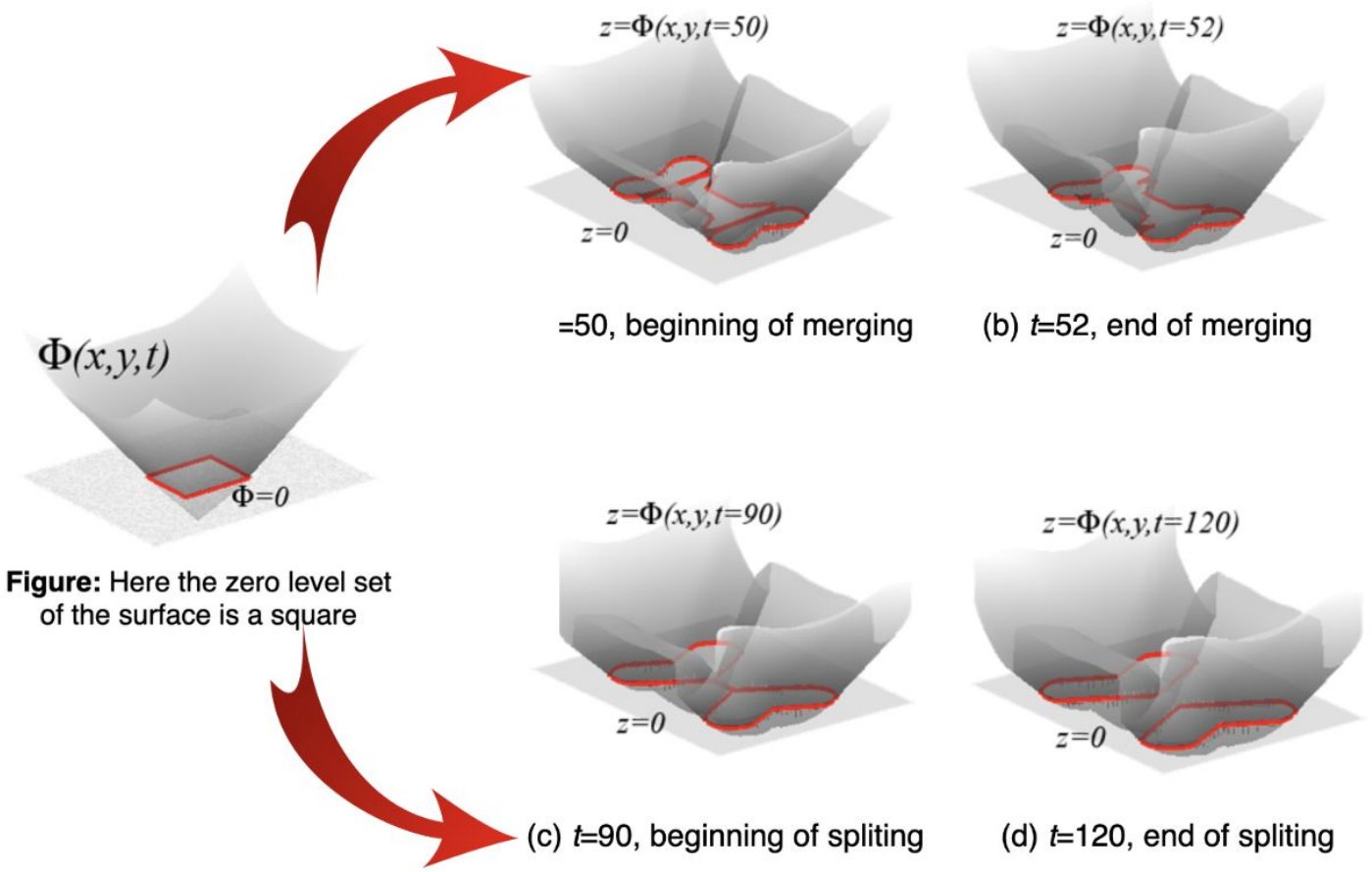
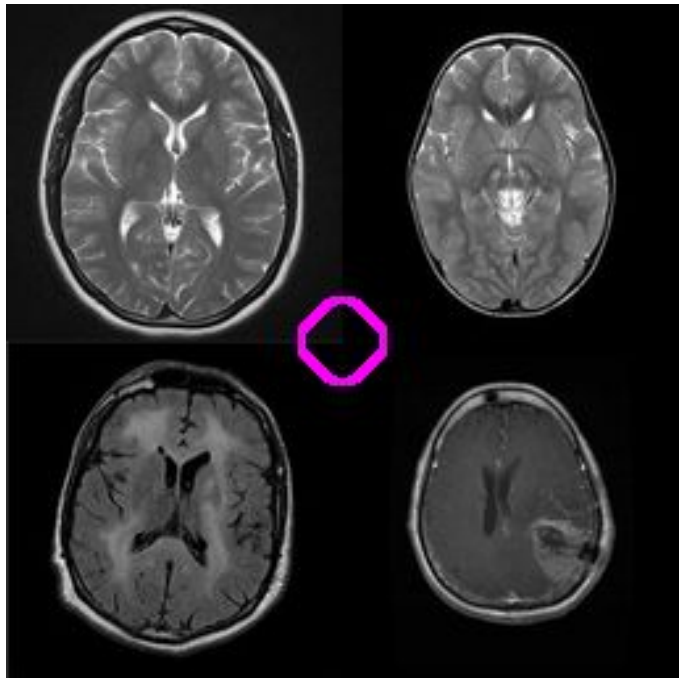


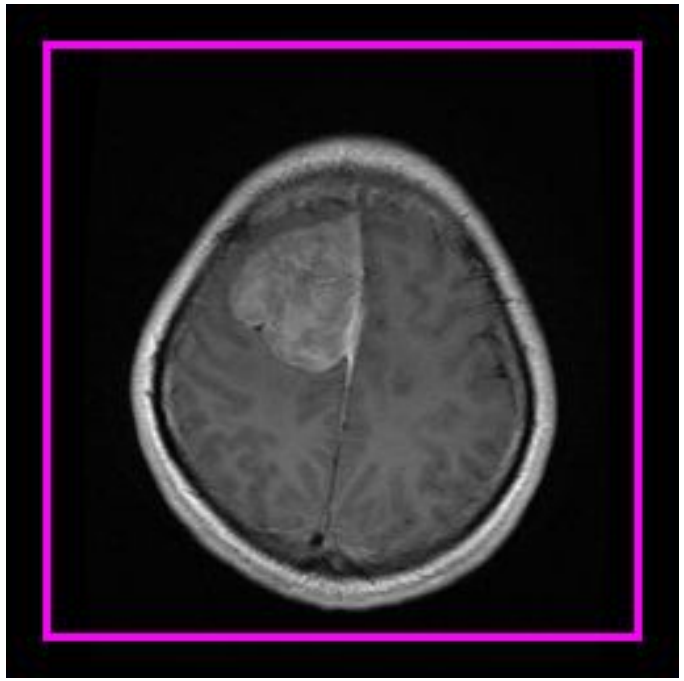
Figure: Here the zero level set of the surface is a square

Contour Initialization Strategies

(a) Default initial boundary initialization - mode 1



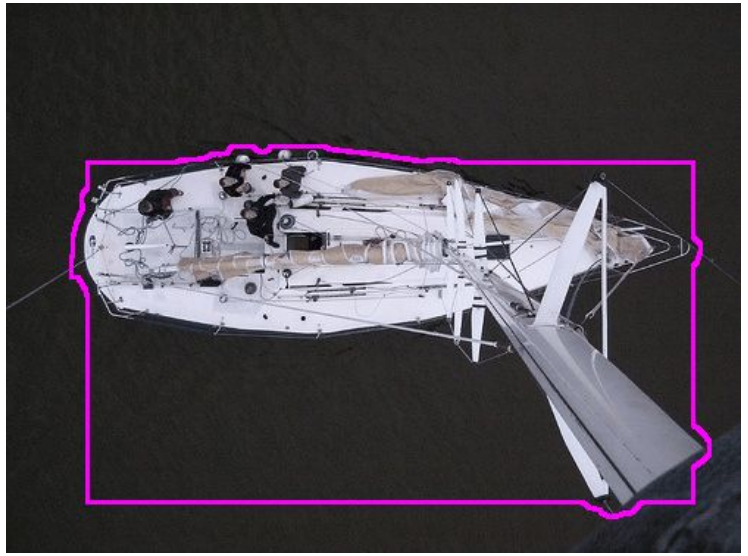
(b) Default initial boundary initialization - mode 2



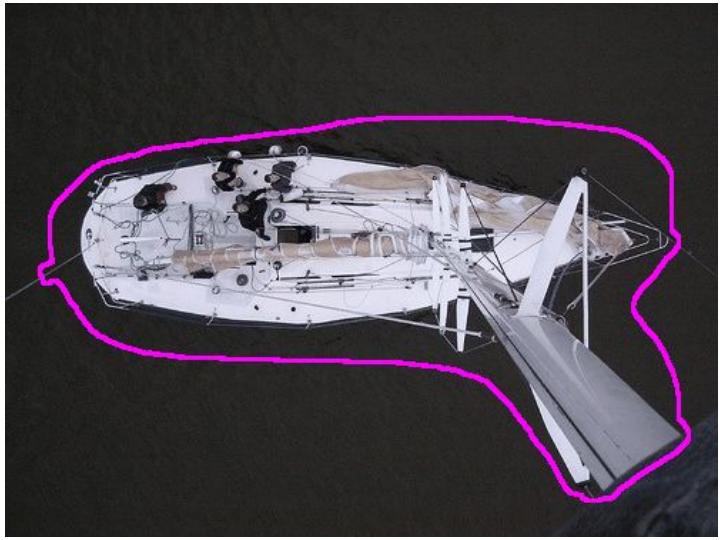
Contour Initialization Strategies

(a) Default initial boundary initialization

(b) user-defined rectangle boundary initialization



(c) user-defined free-form boundary initialization



Contour Initialization Strategies

XGBoost Model Training and Feature Extraction

Dataset Used: Pascal VOC

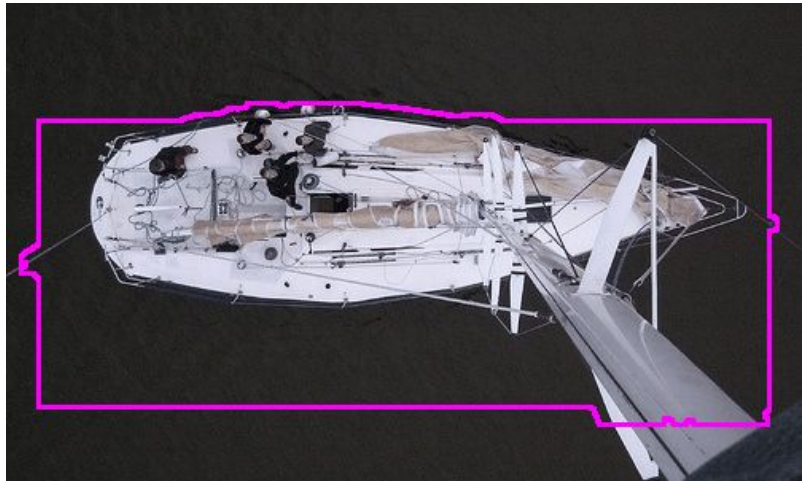
Purpose: Train the model to predict bounding boxes for level set initialization.

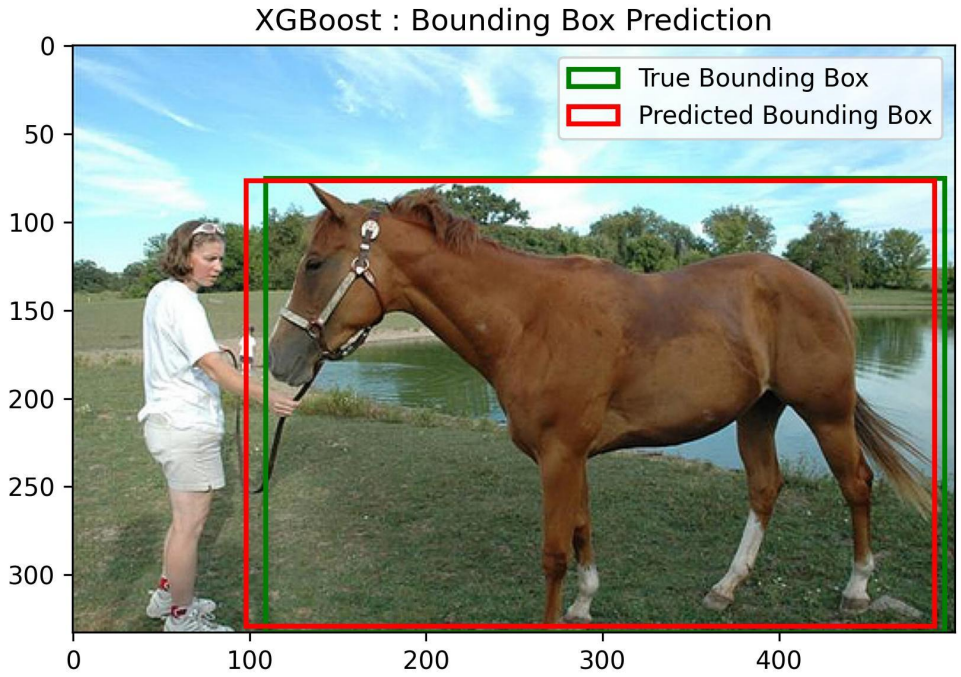
Feature Extraction: Pixel Intensity + HOG Features

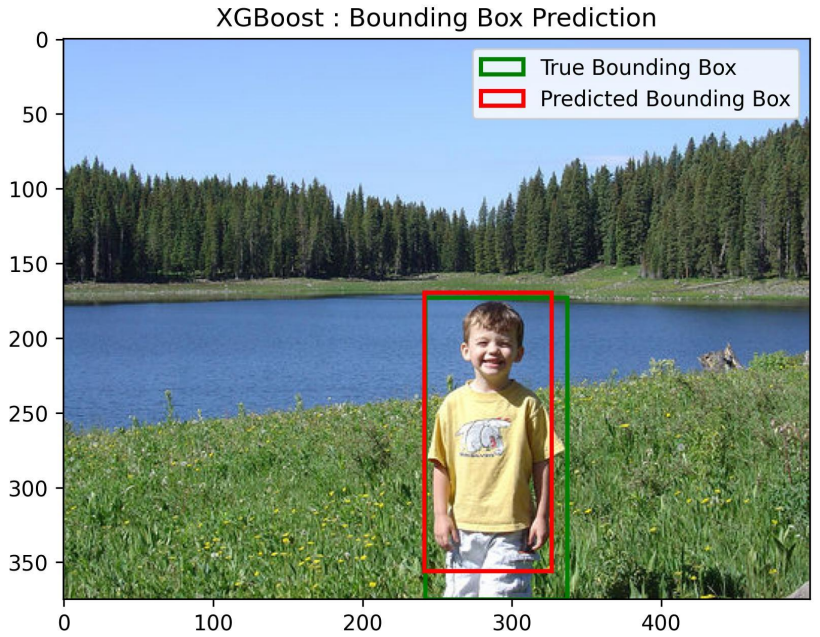
Target: Bounding box coordinates [xmin,ymin,xmax,ymax]

Contour Initialization Strategies

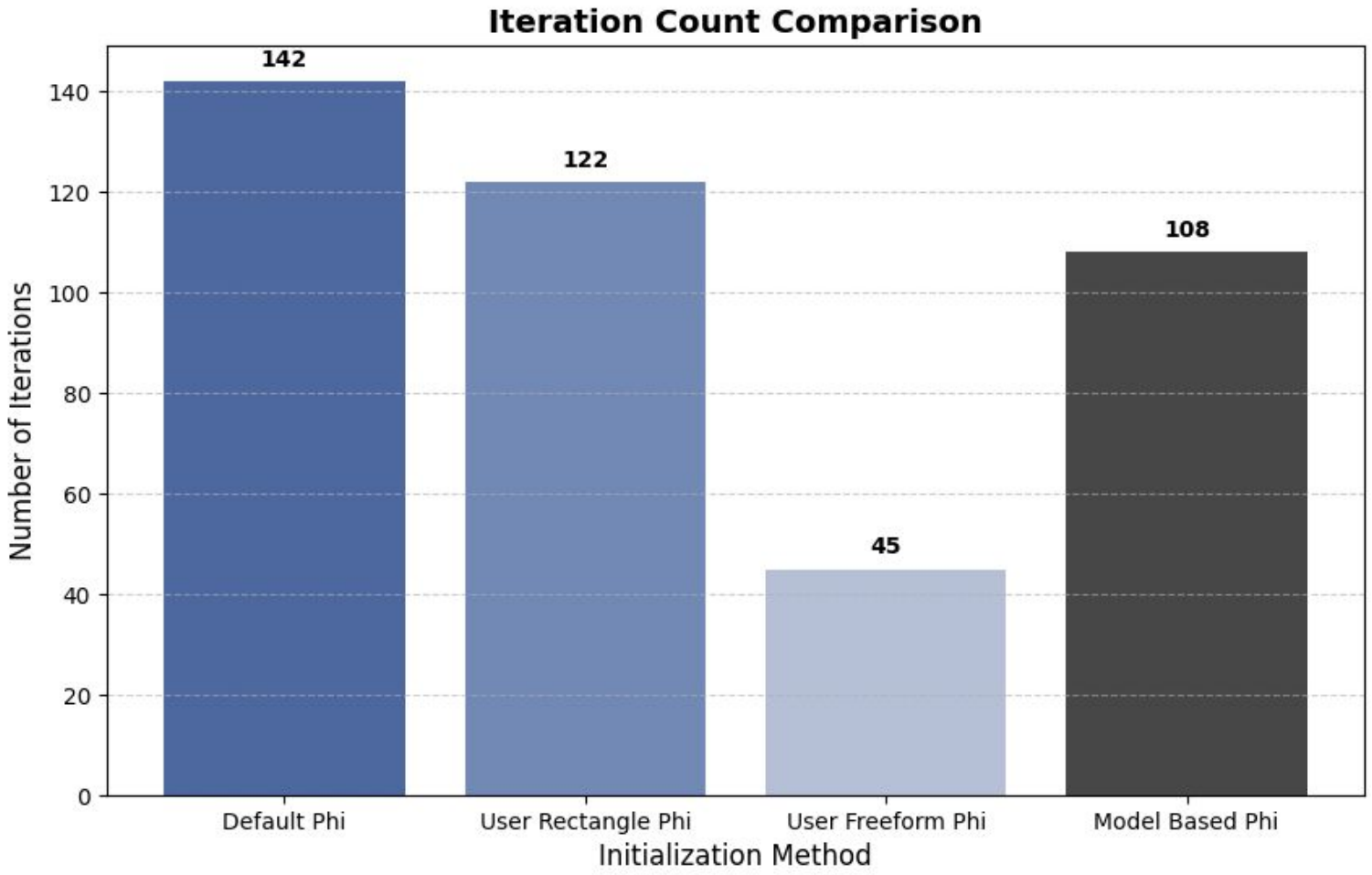
(d) Predicting initial bounding box using XGBoost





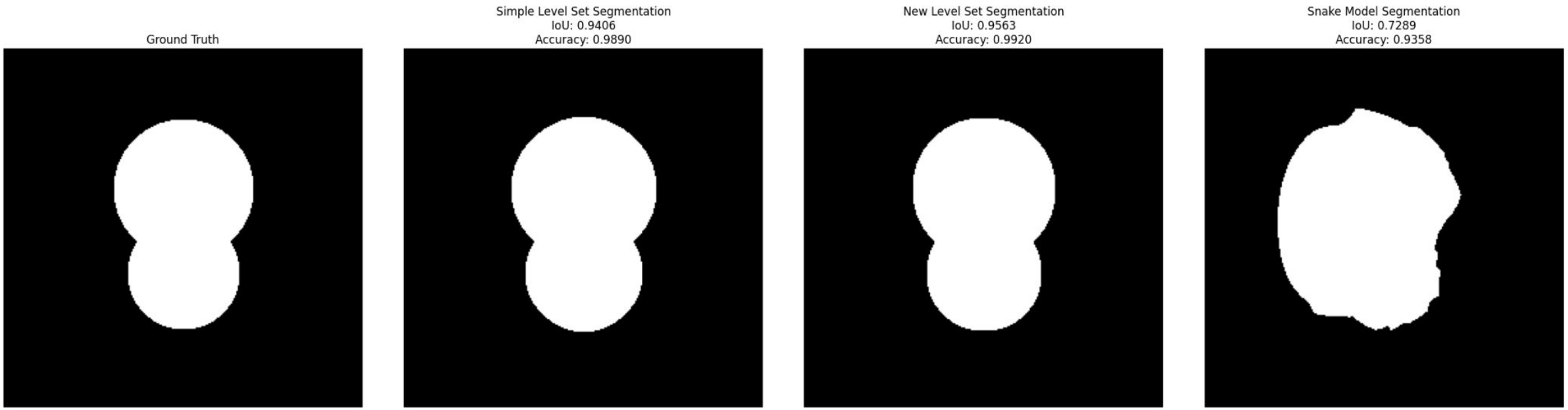


Contour Initialization Strategies



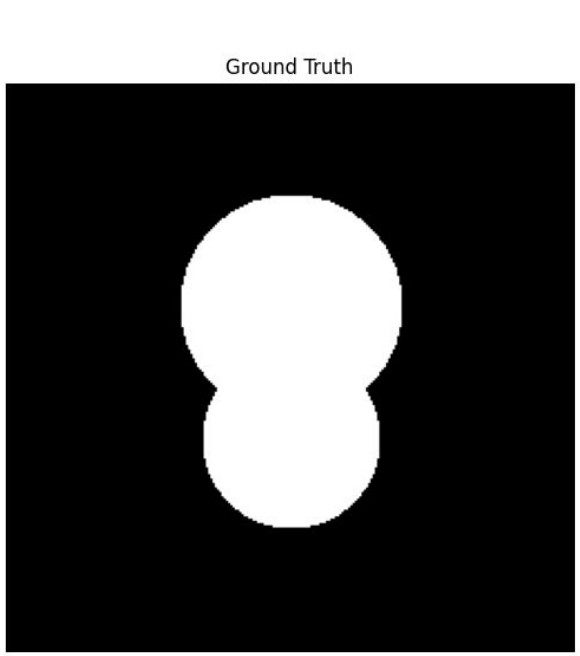
Results

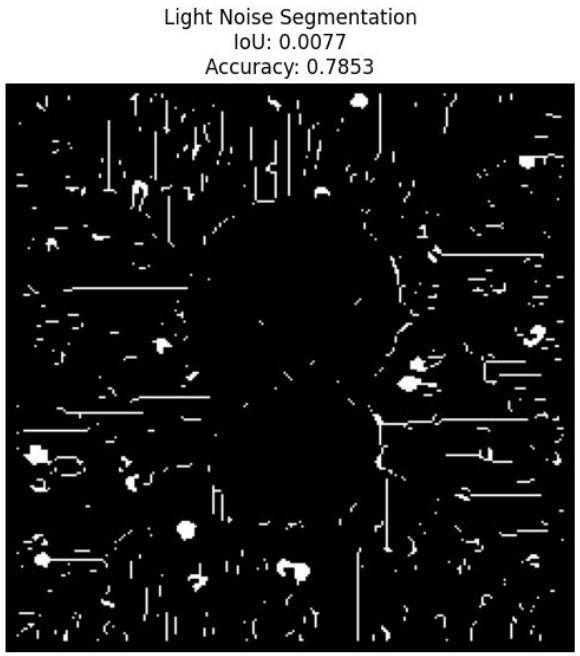
Segmentation Result after applying the old level set, the Sobel level set and snakes.

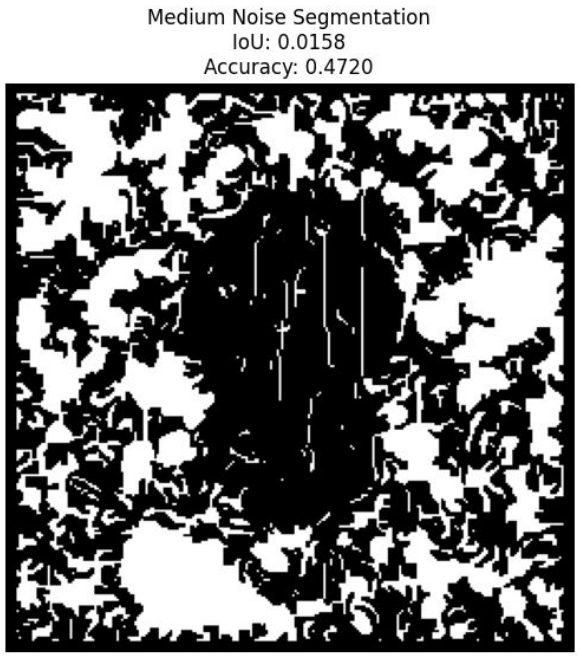


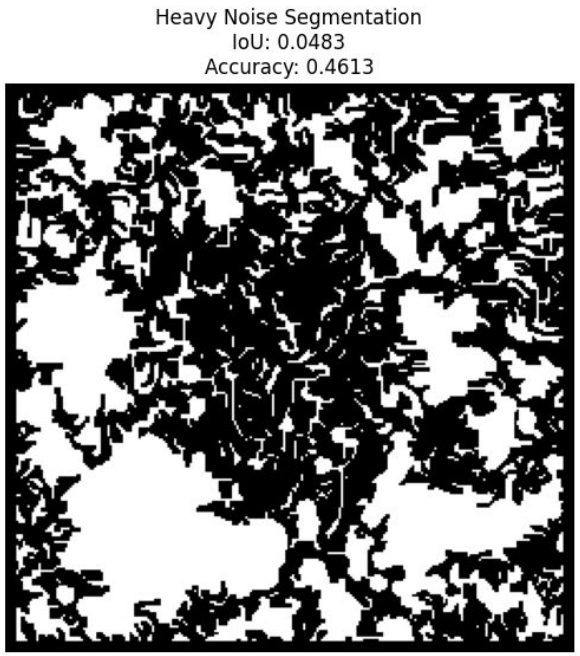
Results

Adding different level of noise and segmenting using the old level set



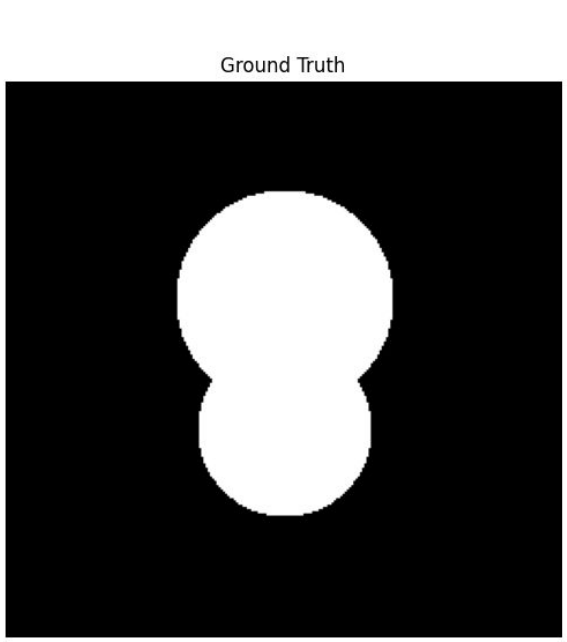


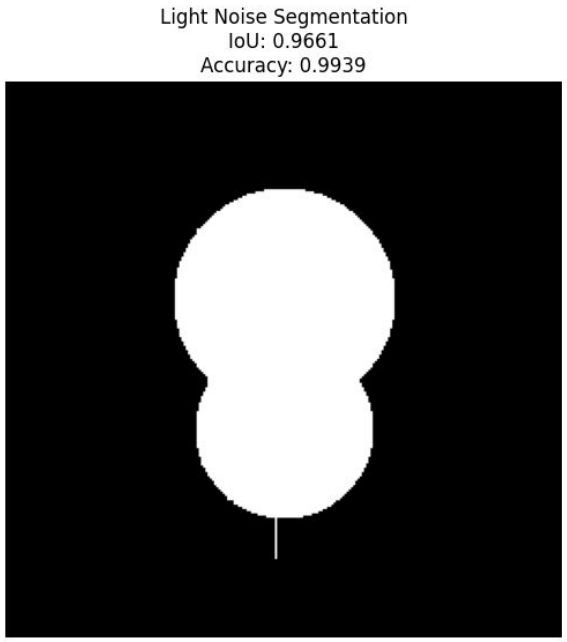


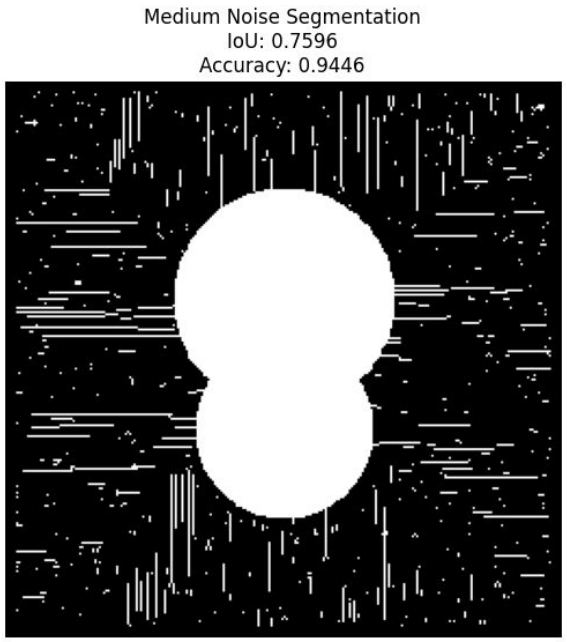


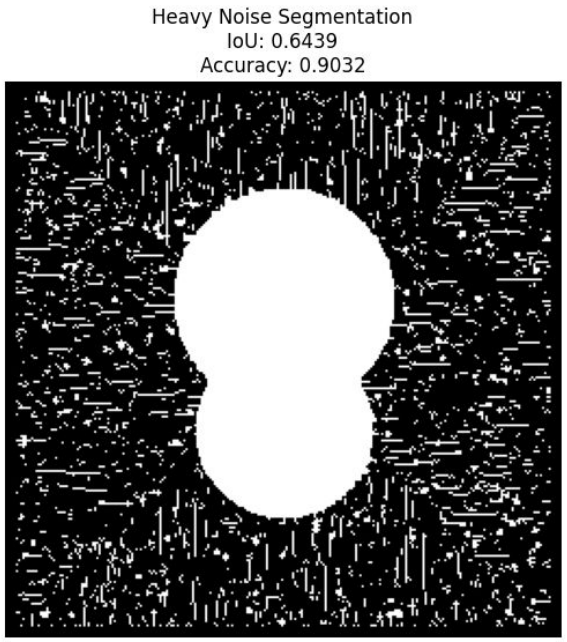
Results

Adding different level of noise and segmenting using the Sobel level set









Results

Real World data Segmentation

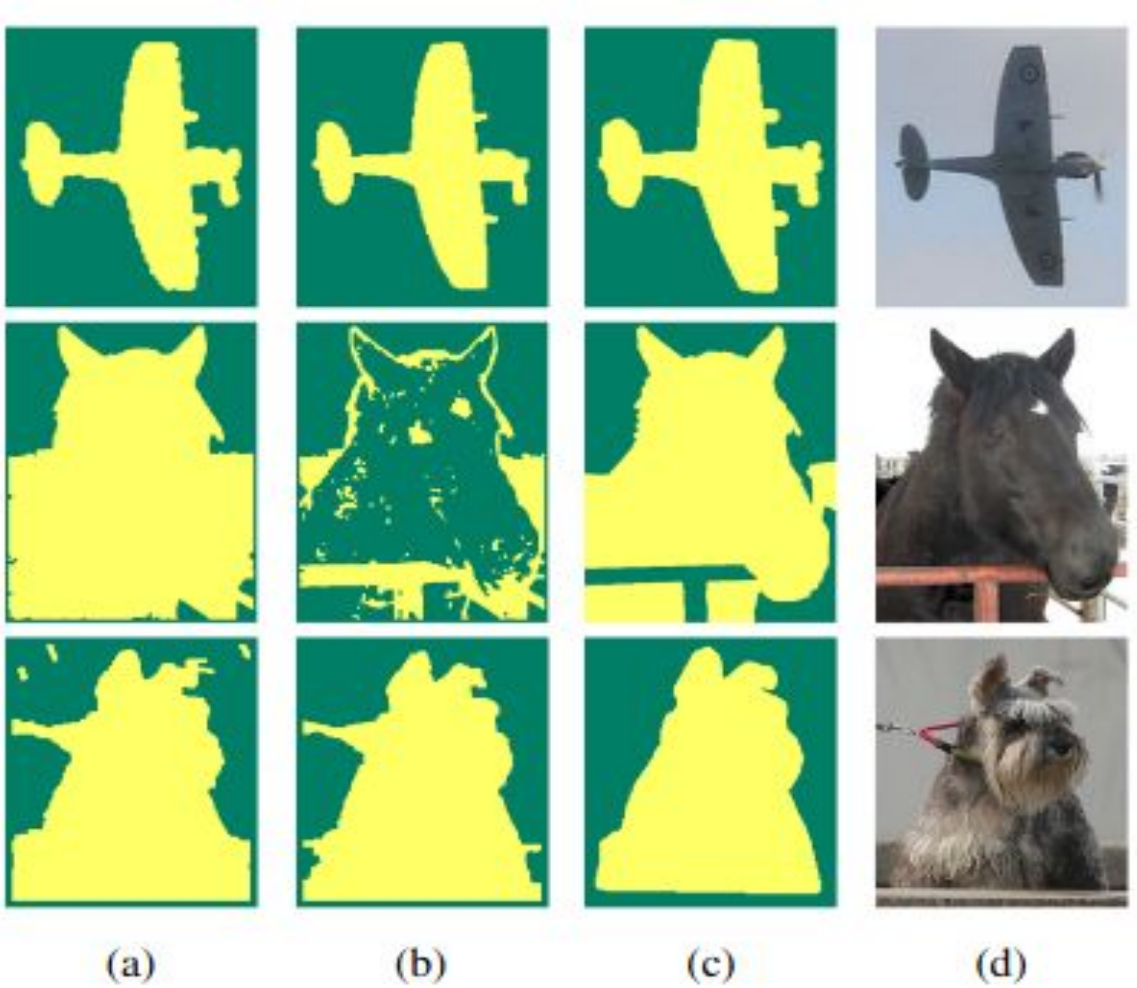


Fig. 8: Segmentation results on the Pascal VOC dataset. (a) refers to the traditional level set, (b) refers to level set with sobel filter, (c) refers to ground truth, and (d) refers to the image

Results

Method	Light Noise	Medium Noise	Heavy Noise	Pascal VOC
LS	0.007	0.01	0.04	0.63
LS (Sobel)	0.96	0.75	0.64	0.60

Why Sobel Level Set Struggles on Real-World Images

- **Texture Variations:** Confused by **complex** textures and smooth transitions.
- **Edge Ambiguity:** Struggles with unclear or **blended** edges.
- **Parameter Sensitivity:** Requires fine-tuned **parameters** for each scenario.