Edge Detection
State of The Art

P. Dollar and C. Zitnick

Structured Forests for Fast Edge Detection

ICCV 2013

Code: http://research.microsoft.com/en-us/downloads/389109f6-b4e8-404c-84bf-239f7cbf4e3d/default.aspx

(Time stamp: Sept 15, 2014)

Testing the Canny Edge Detector

- Let's take this image
- Our goal (a few lectures from now) is to detect objects (cows here)

Testing the Canny Edge Detector

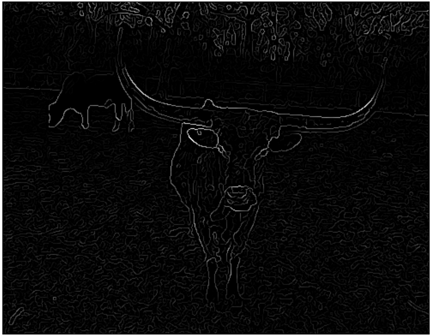
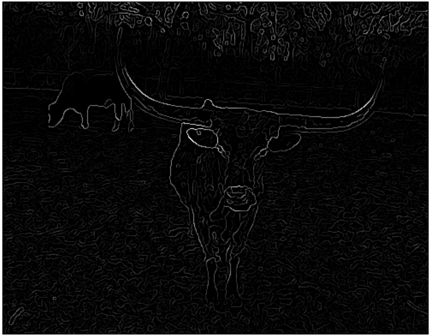


image gradients + NMS

Canny's edges

Testing the Canny Edge Detector



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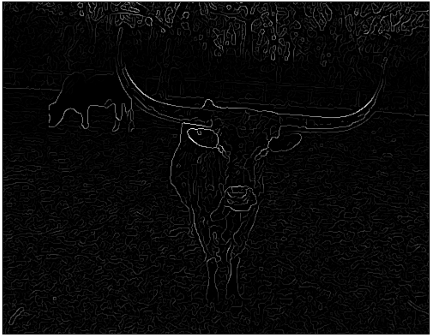

image gradients + NMS

Canny's edges

- Lots of "distractor" and missing edges
- Can we do better?

Annotate...

- Imagine someone goes and **annotates** which edges are **correct**
- ... and someone has:

Annotate...

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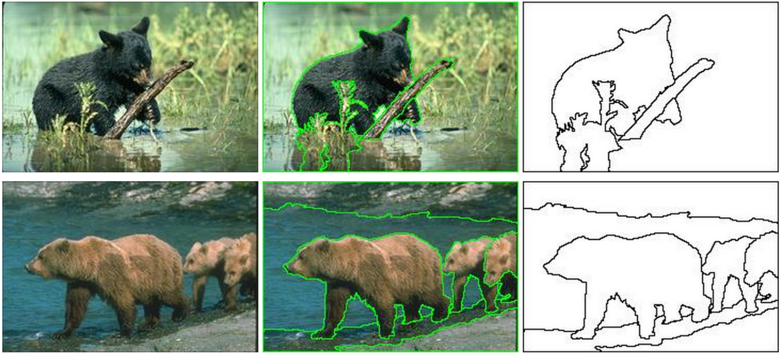
- ... and someone has:

The Berkeley Segmentation Dataset and Benchmark

by D. Martin and C. Fowlkes and D. Tal and J. Malik



… and do Machine Learning

- How can we make use of such data to **improve** our edge detector?

... and do Machine Learning

- How can we make use of such data to **improve** our edge detector?
- We can use Machine Learning techniques to:

Train classifiers!

- Please **learn what a classifier /classification is**
- In particular, learn what a **Support Vector Machine** (SVM) is (some links to tutorials are on the class webpage)
- With each week it's going to be more important to know about this
- You don't need to learn all the details / math, but to understand the concept enough to know what's going on

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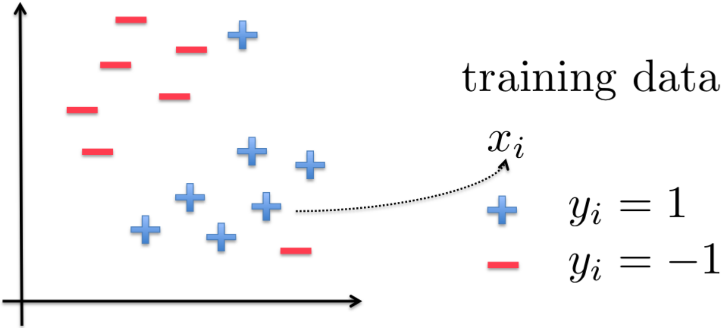
Classification – a Disney edition (pictures only)

- Each data point **x** lives in a *n*-dimensional space, $x \in \mathbb{R}^n$
- We have a bunch of data points $\mathbf{x}_i$, and for each we have a **label**, y_i
- A label y_i can be either 1 (positive example – correct edge in our case), or -1 (negative example – wrong edge in our case)



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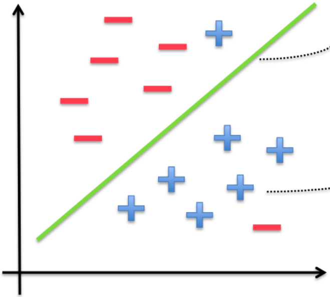


separating hyperplane

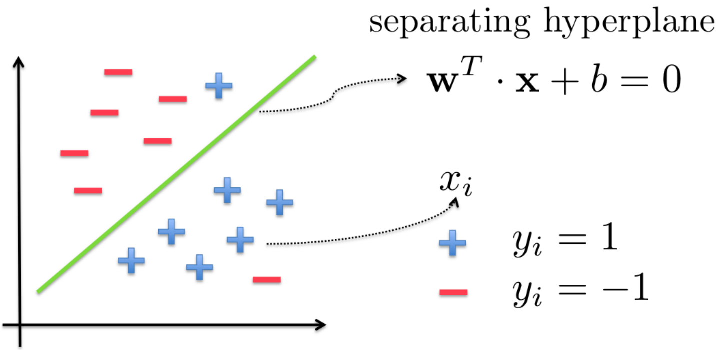
$$\mathbf{w}^T \cdot \mathbf{x} + b = 0$$

x_i

$+$ $y_i = 1$

$-$ $y_i = -1$

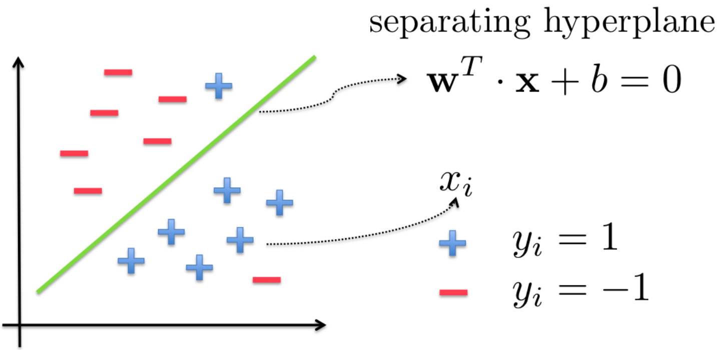
Classification – a Disney edition (pictures only)



At training time:

Finding **weights w** so that positive and negative examples are optimally separated

Classification – a Disney edition (pictures only)



At **test** time:

$$\mathbf{w}^T \cdot \mathbf{x} + b > 0 \rightarrow \mathbf{x} \text{ is a positive example}$$

$$\mathbf{w}^T \cdot \mathbf{x} + b < 0 \rightarrow \mathbf{x} \text{ is a negative example}$$

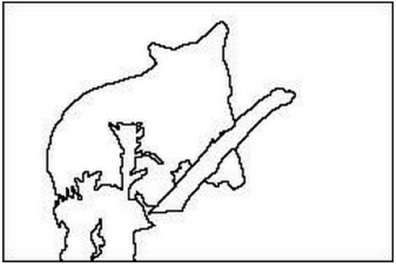
Training an Edge Detector

- How should we do this?

Training an Edge Detector

- How should we do this?

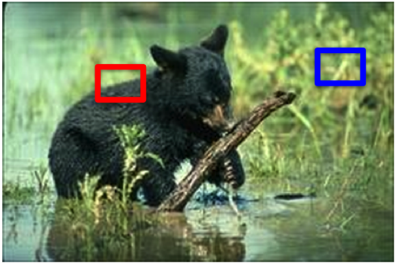
image

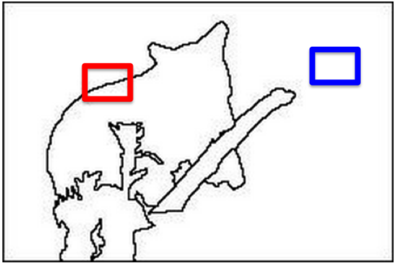


annotation

Training an Edge Detector

- We extract lots of image patches

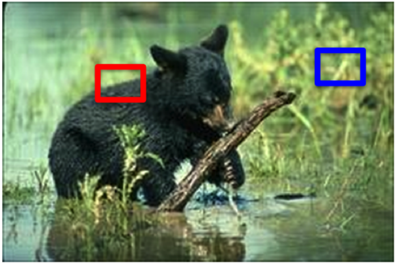


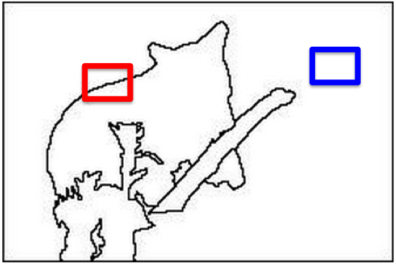


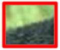
We call each such crop an **image patch**

Training an Edge Detector

- We extract lots of image patches
- These are our training data





 → edge

 → no edge

} our training data

Training an Edge Detector

- We extract lots of image patches
- These are our training data
- We convert each image patch **P** (a matrix) into a vector **x**

$$\rightarrow \quad \mathbf{x} = \mathbf{P}(:)$$

matrix $\mathbf{P}$

Training an Edge Detector

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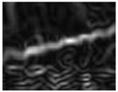
- Well... This works better: Extract **image features** for each patch

matrix $\mathbf{P}$

$$\xrightarrow{\text{compute gradients}}$$



matrix $\mathbf{G}$

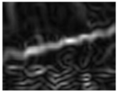
$$\mathbf{x} = \mathbf{G}(:)$$

Training an Edge Detector

- We extract lots of image patches
- These are our training data
- We convert each image patch **P** (a matrix) into a vector **x**
- Well... This works better: Extract **image features** for each patch
- Image features are mappings from images (or patches) to other (vector) meaningful representations. More on this in the next class!

matrix $\mathbf{P}$

compute gradients $\longrightarrow$



matrix $\mathbf{G}$

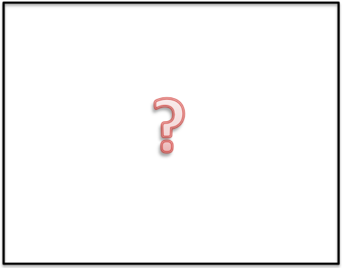
$\mathbf{x} = \mathbf{G}(:)$

compute color $\longrightarrow$

Using an Edge Detector

- Once trained, **how can we use** our new edge detector?

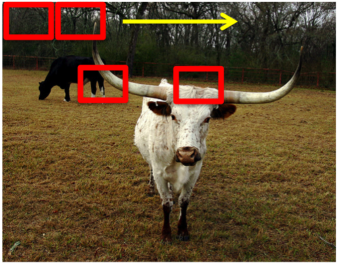
image



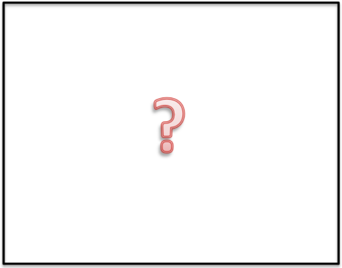
prediction

Using an Edge Detector

- We extract all image patches



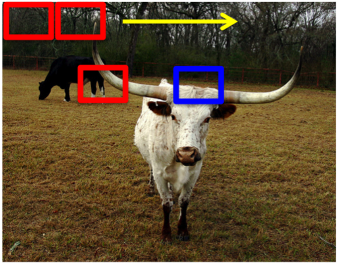
image



prediction

Using an Edge Detector

- We extract all image patches
- Extract features and use our trained classifier



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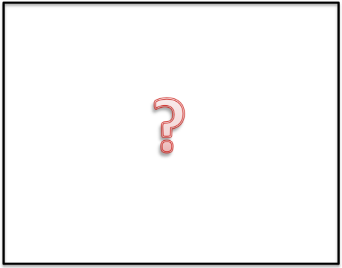
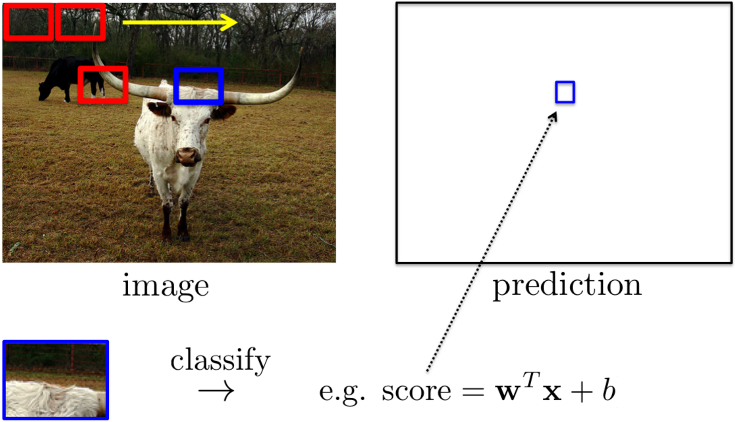


prediction

$$\xrightarrow{\text{classify}} \qquad \text{e.g. score} = \mathbf{w}^T\mathbf{x} + b$$

Using an Edge Detector

- We extract all image patches
- Extract features and use our trained classifier
- Place the predicted value (score) in the output matrix



Comparisons: Canny vs Structured Edge Detector

image

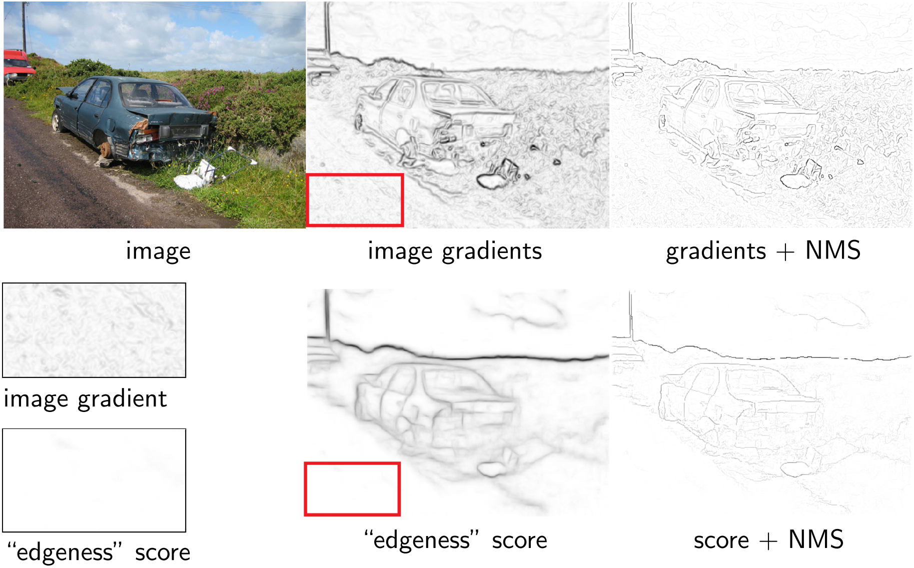
image gradients

gradients + NMS

"edgeness score"

score + NMS

Comparisons: Canny vs Structured Edge Detector



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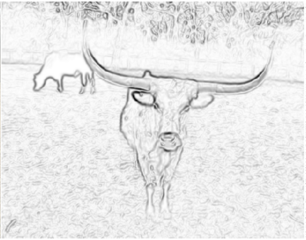
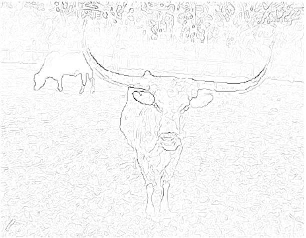
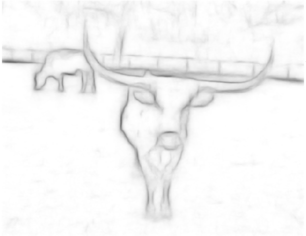


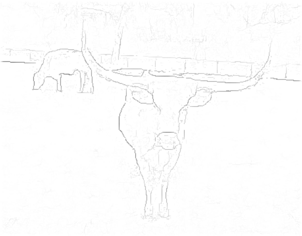
image gradients



gradients + NMS



“edgeness” score



score + NMS

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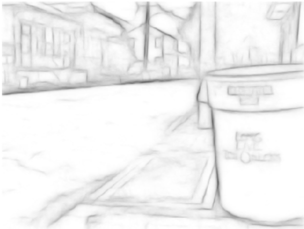

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gradients + NMS

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Evaluation

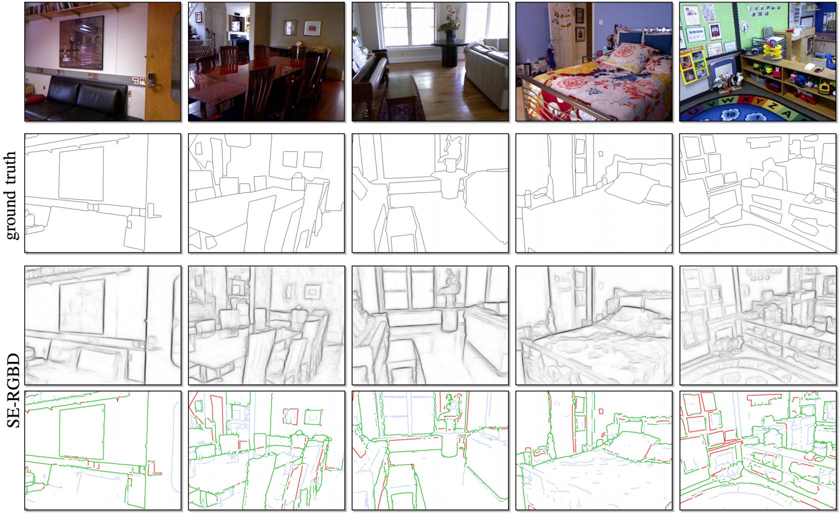
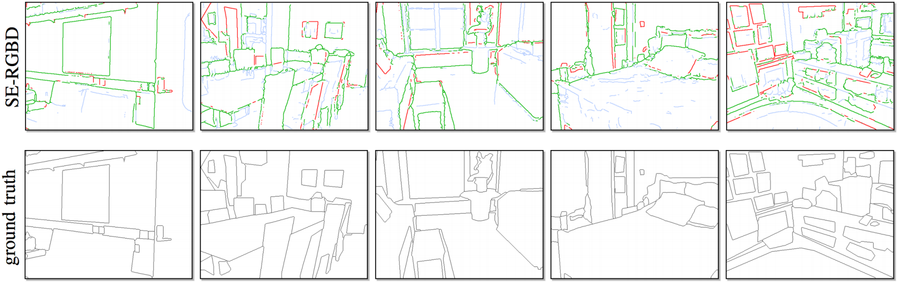


Figure: green=correct, blue=wrong, red=missing, green+blue=output edges

Evaluation

- **Recall:** How many of all **annotated** edges we got correct (best is 1)
- **Precision** How many of all **output** edges we got correct (best is 1)

$$\textbf{Recall} = \frac{\#\text{ of green (correct edges)}}{\#\text{ of all edges in ground-truth (second picture)}}$$



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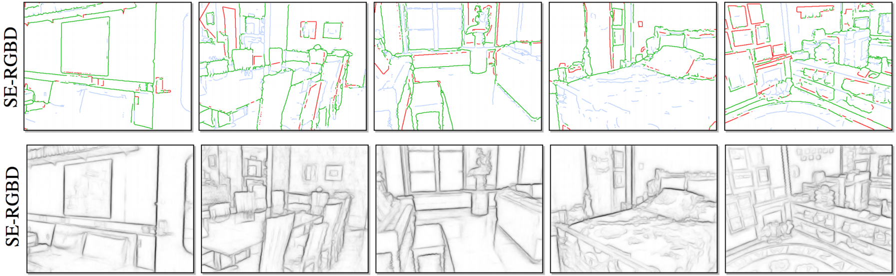

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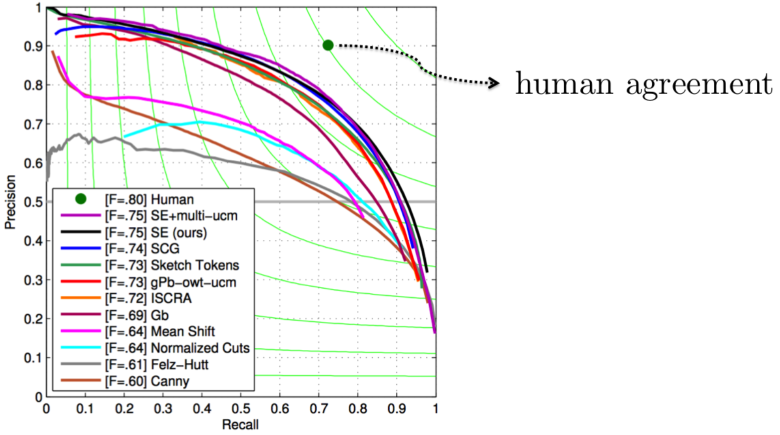

Lesson 1

- **Trained detectors** (typically) perform better (true for all applications)
- In this case, the method seems to work better for finding object boundaries (edges) than finding text boundaries. Any idea **why**?
- What would you do if you wanted to detect text (e.g., licence plates)?
- **Think about your problem**, don't just use code as a black box