

Semantic Segmentation

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MACHINE LEARNING GROUP,

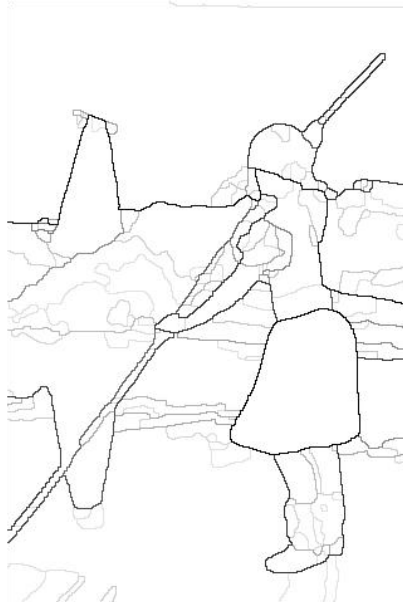
UNIVERSITY OF TORONTO

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 3. Make CRF Great Again?

What is semantic segmentation

1. What is segmentation in the first place?
 1. Input: images
 2. Output: regions, structures
 1. line segments, curve segments, circles, etc.



What is semantic segmentation

1. What is segmentation in the first place?
 1. Input: images
 2. Output: regions, structures
 3. Most of the time, we need to "process the image"
 1. filters
 2. gradient information
 3. color information
 4. etc.

That's not quite so human.

What if we want to **understand** the image?

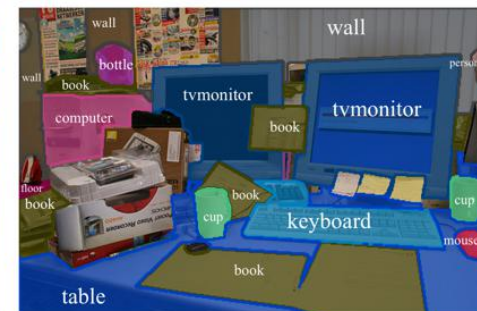
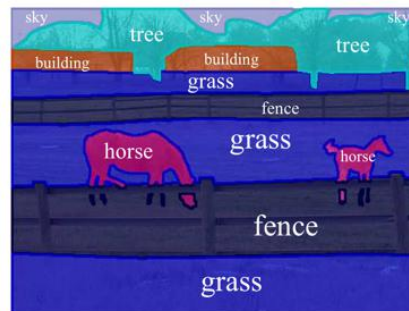
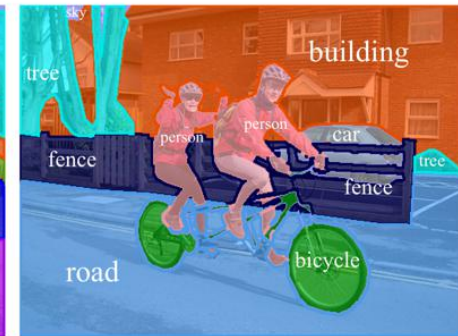
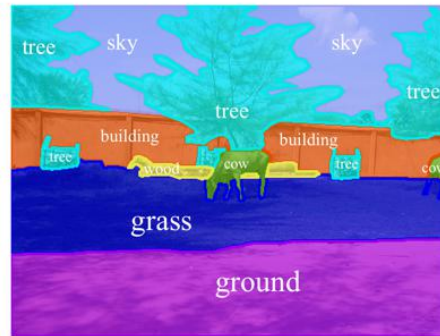


What is semantic segmentation

1. What is semantic segmentation?

1. Idea: recognizing, understanding what's in the image in pixel level.

"Two men riding on a bike in front of a building on the road. And there is a car."

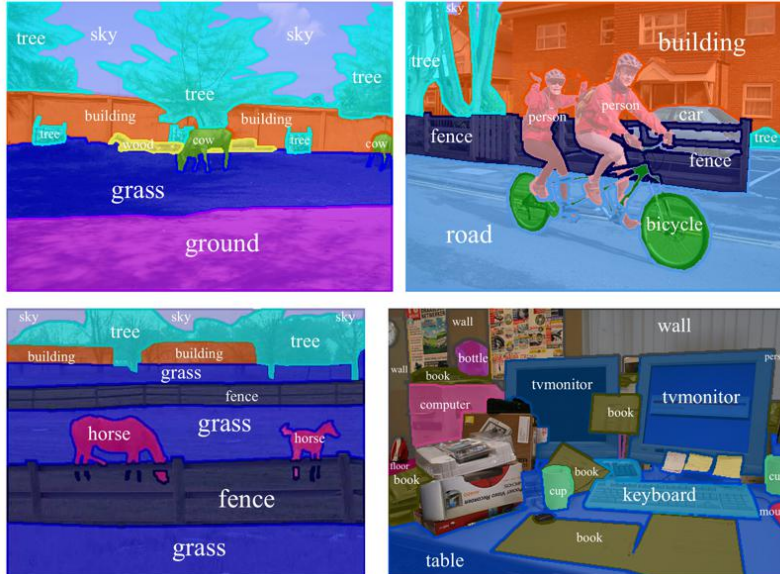


What is semantic segmentation

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2. A lot more difficult

(Most of the traditional methods cannot tell different objects.)



What is semantic segmentation

1. What is semantic segmentation?

1. Idea: recognizing, understanding what's in the image in pixel level.
2. A lot more difficult
(Most of the traditional methods cannot tell different objects.)

No worries, even the best ML researchers find it very challenging.

3. Output: regions with different (and limited number of) classes
 1. COCO detection challenge: 80 classes.
 2. PASCAL VOC challenge: 21 classes

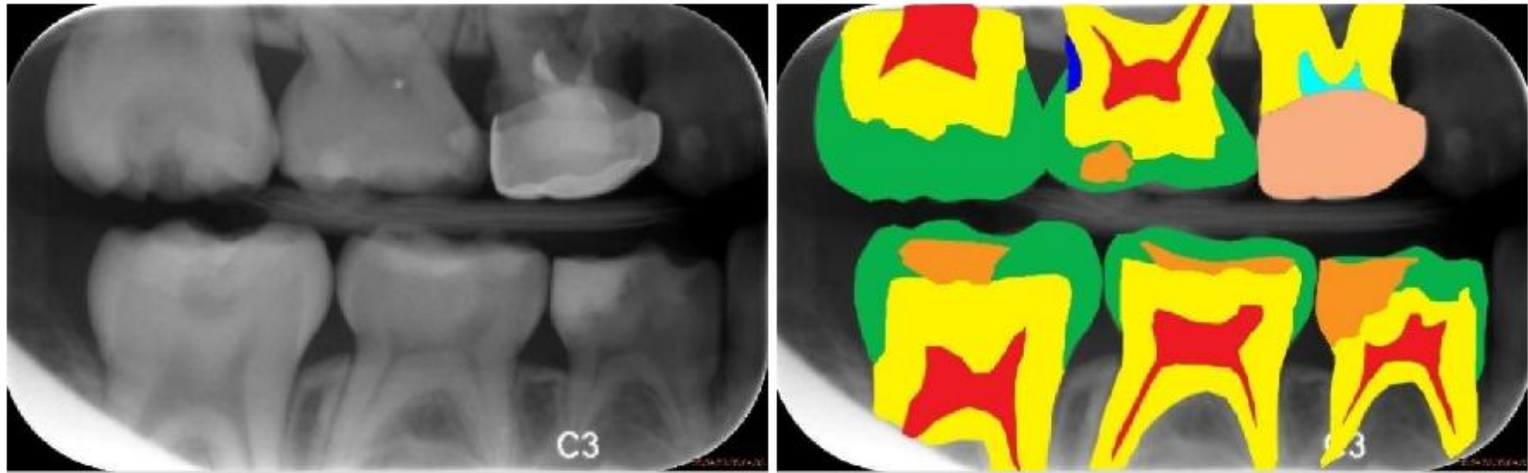
What is semantic segmentation

1. Why semantic segmentation?
 1. robot vision and understanding
 2. autonomous driving (remember your assignment?)



What is semantic segmentation

1. Why semantic segmentation?
 3. medical purposes (ISBI Challenge)

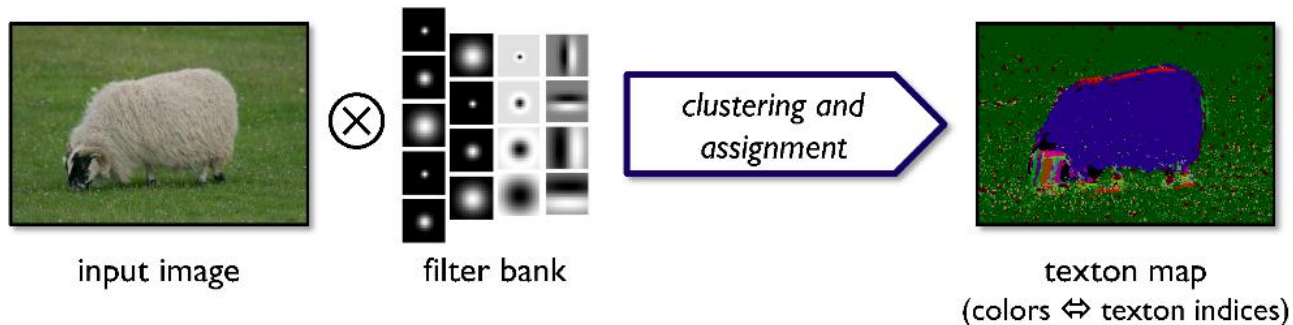


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Deep Learning in semantic Segmentation

1. Semantic segmentation before deep learning
 1. relying on conditional random field.
 2. operating on pixels or superpixels
 3. incorporate local evidence in unary potentials
 4. interactions between label assignments



Deep Learning in semantic Segmentation

1. What is conditional random field?
 1. probabilistic framework for labeling and segmenting structured data
 2. no need to understand the math, just know the idea

what it tries to model is the relationship between pixels, e.g.:

1. nearby pixels more likely to have same label
2. pixels with similar color more likely to have same label
3. the pixels above the pixels "chair" more likely to be "person" instead of "plane"
4. refine results by iterations

Deep Learning in Semantic Segmentation

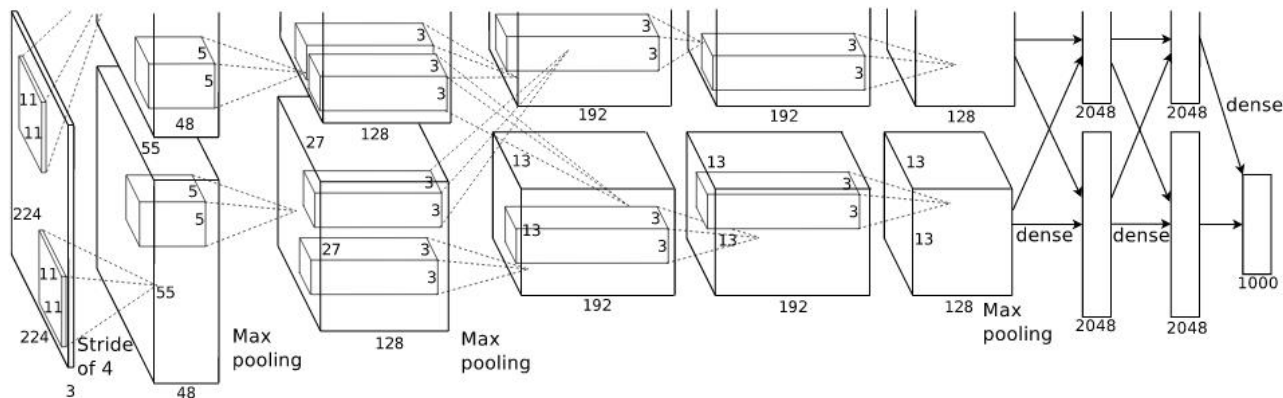
1. A Brief Review on Classification

0. Again, it is totally fine if you don't understand the deep neural network.

imagine it as a black magic box if you want :)

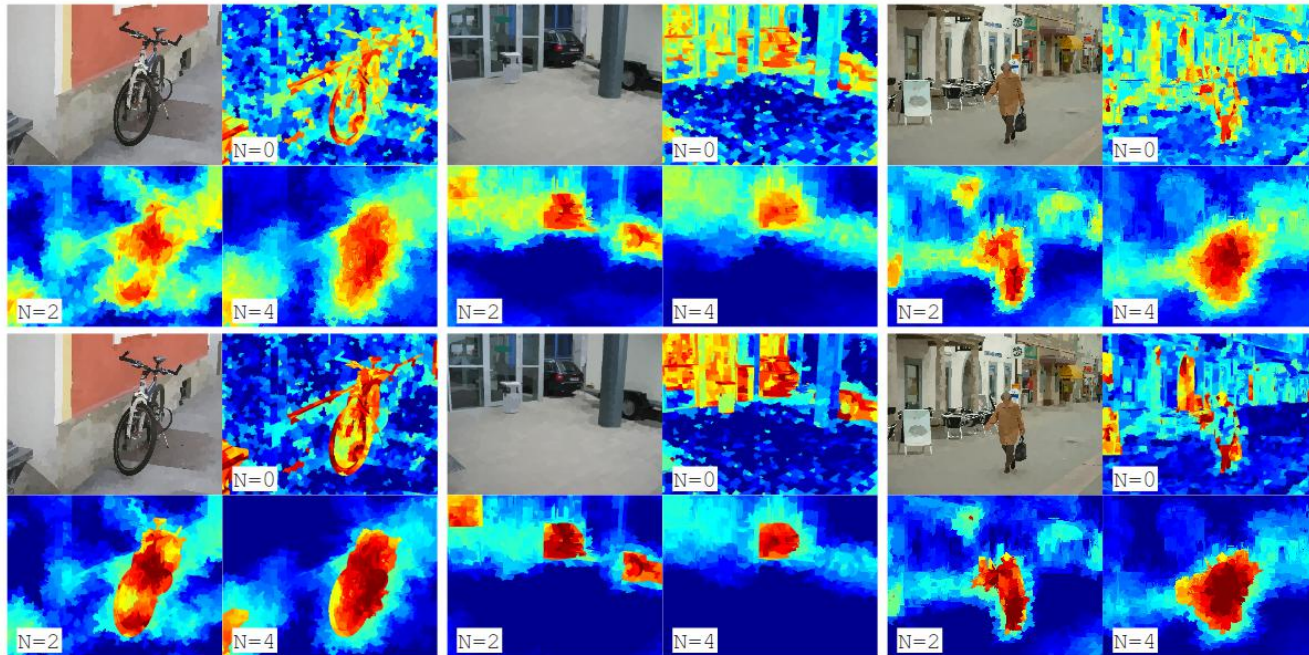
1. Deep learning in classification.

1. input: the whole image
2. output: the probability of each class (person, dog, cat, ...)
3. not applicable on semantic segmentation



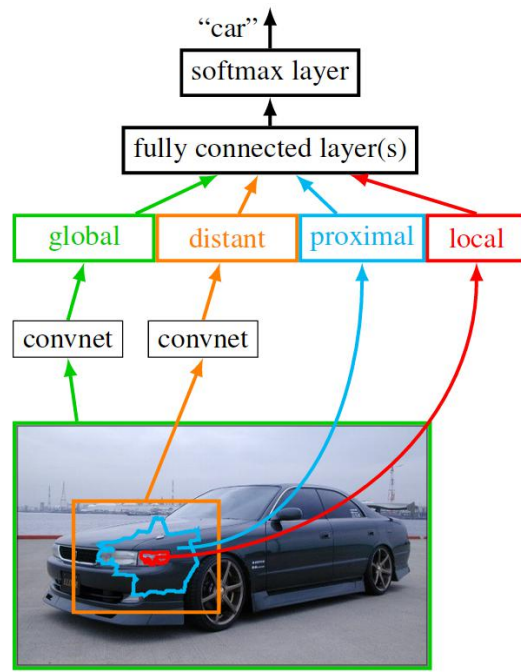
Deep Learning in Semantic Segmentation

1. How to move from classification to semantic segmentation?
 1. remember traditionally we use superpixels (Polygon)?



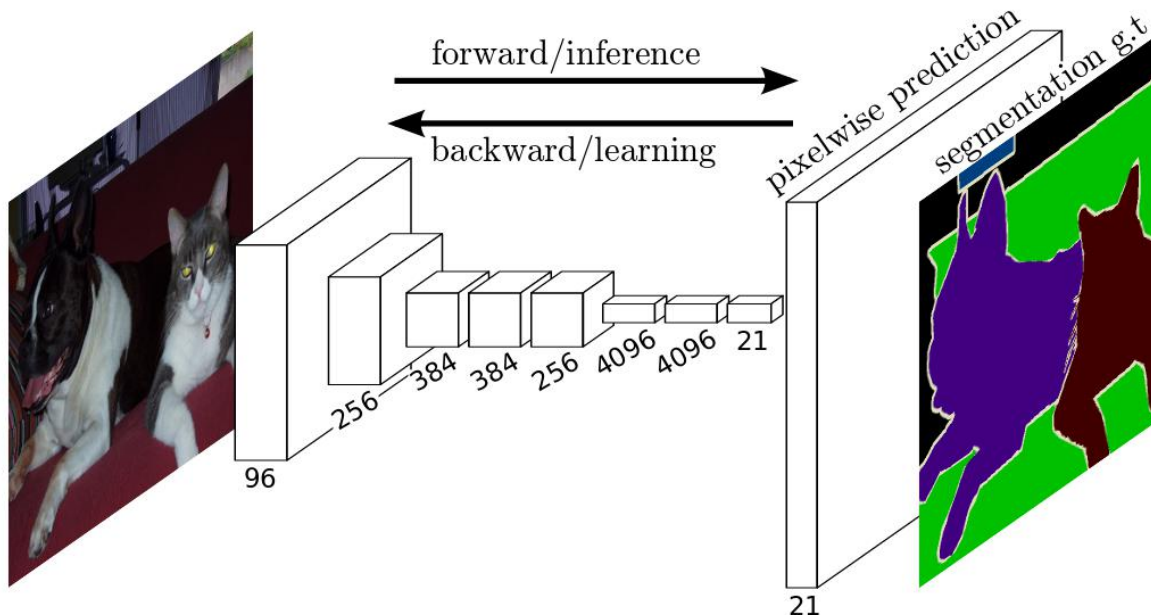
Deep Learning in Semantic Segmentation

1. Transition to segmentation; early ideas
 1. superpixel proposals
 2. do classification on each superpixel.



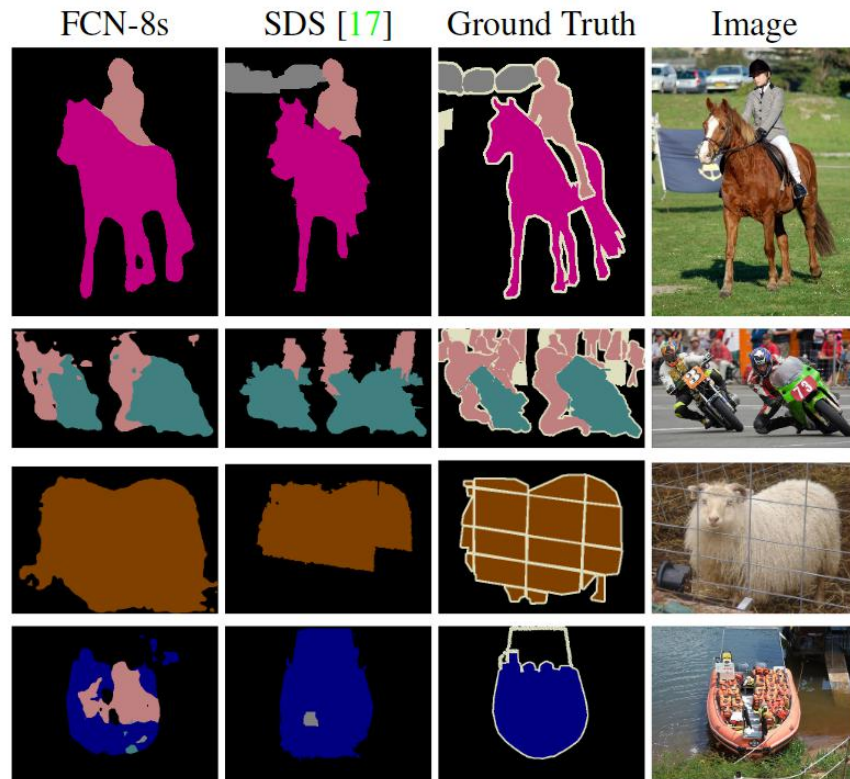
Deep Learning in Semantic Segmentation

1. Fully Convolutional Networks for Semantic Segmentation
 1. forget about pixels/superpixel input



Deep Learning in Semantic Segmentation

1. Fully Convolutional Networks for Semantic Segmentation

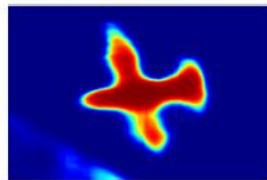
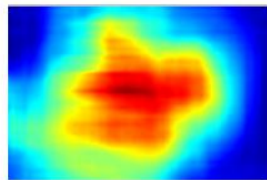


Deep Learning in Semantic Segmentation

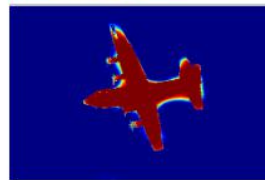
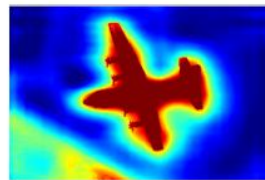
1. Fully Convolutional Networks + CRF
 1. the output from DCNN is blurry and inaccurate
 2. rediscovery of CRF



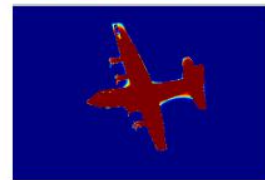
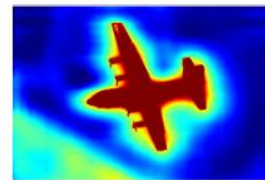
Image/G.T.



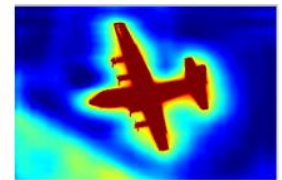
DCNN output



CRF Iteration 1



CRF Iteration 2



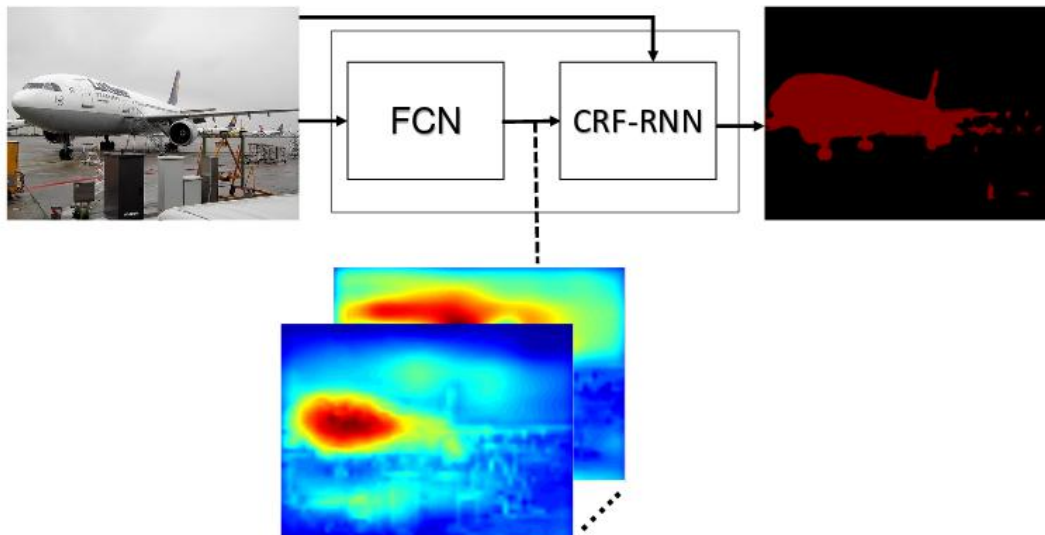
CRF Iteration 10

Deep Learning in Semantic Segmentation

1. Conditional Random Fields as Recurrent Neural Networks

1. end-to-end training

$\text{optimize}(A) + \text{optimize}(B \text{ given } A) < \text{optimize}(A, B \text{ together})$



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Discussions and Demos

1. Online Demos about CRF as RNN semantic segmentation

Discussions and Demos

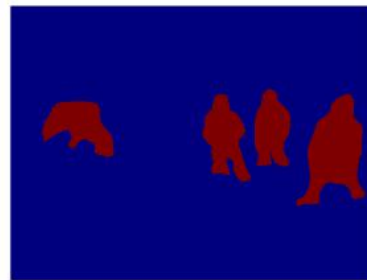
1. Segmentation from Natural Language Expression

1. what does it mean?

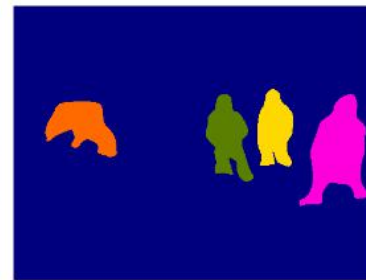
e.g., the phrase "two men sitting on the right bench" requires segmenting only the two people on the right bench and no one standing or sitting on another.



(a) input image



(b) object class
segmentation of
class *people*



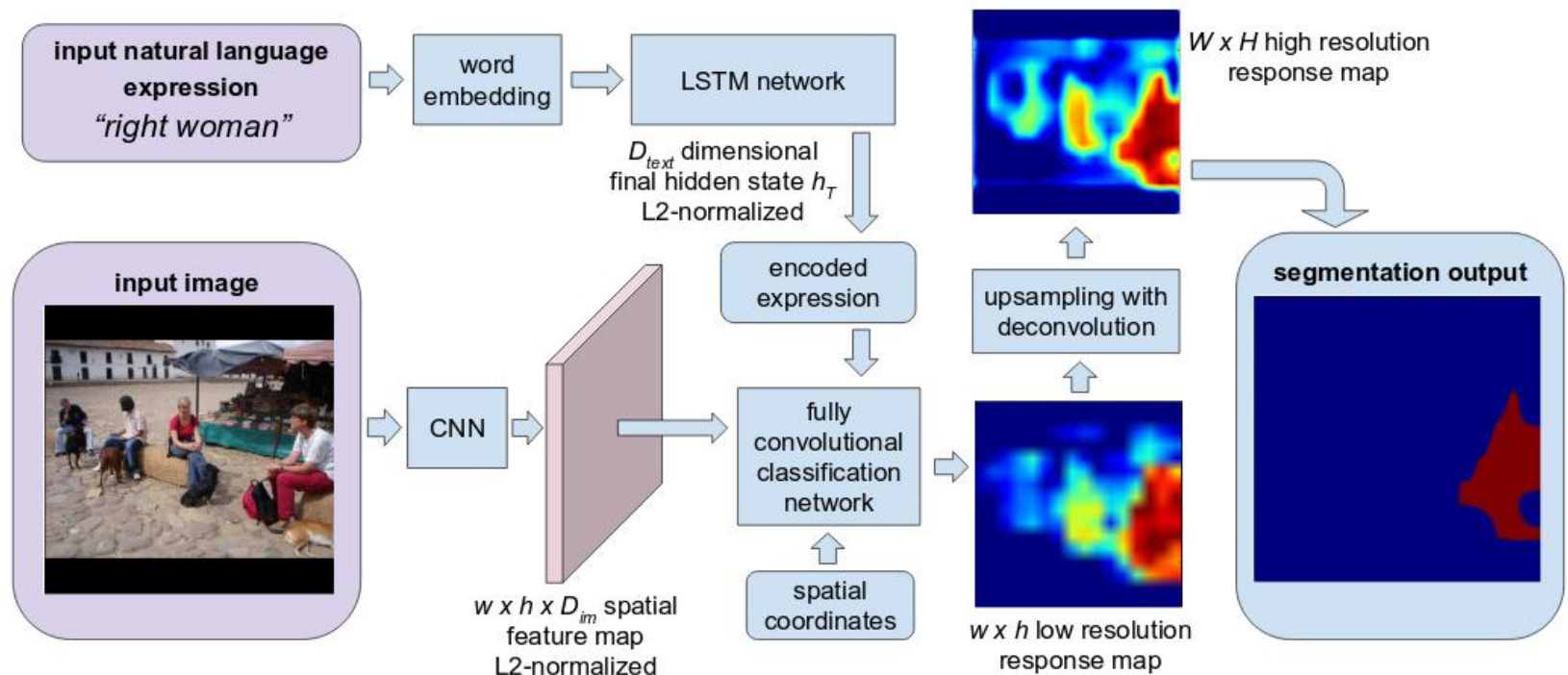
(c) object instance
segmentation of
class *people*



(d) segmentation
from expression
"*people in blue coat*"

Discussions and Demos

1. Segmentation from Natural Language Expression



Discussions and Demos

1. Make Probabilistic Graphical Model Great Again?
 1. what happened to DPM [12]
 1. mixtures of multiscale deformable part models
 2. later people found DPM could be placed by a CNN layer [13]
 3. no one uses dpm now.
 2. what happened to object proposals in detection
 1. Human designed proposals (selective search, edge box, ...) [14]
 2. later people found proposal generating could be replaced by a CNN layer [15, 16]
 3. no one (well, maybe still many people) uses human designed proposals now.
 3. what is happening to CRF in semantic segmentation
 1. pairwise relationship between pixels
 2. later people find CRF could be replaced by a CNN layer
 3. no one uses CRF? well, we don't know future

Discussions and Demos

1. The powerfulness of deep learning

Agent Smith: If you can't beat us...

Agent Smith Clone: Join us!



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Q&A

For those who are interested in CRF and want to know the math, I recommend this tutorial:

[17] Nowozin, Sebastian, and Christoph H. Lampert. "Structured learning and prediction in computer vision." Foundations and Trends in Computer Graphics and Vision 6.3–4 (2011): 185-365.

(might take a long time to understand. good luck ;P)