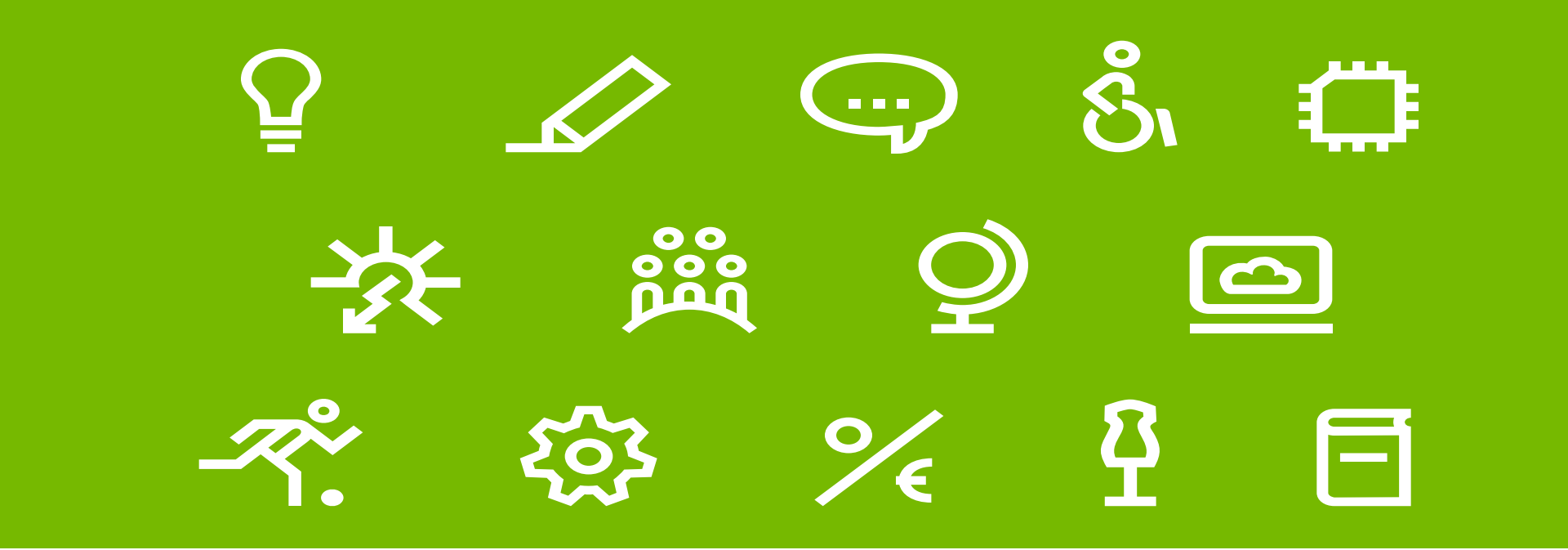


Hochschule für Technik und Wirtschaft Berlin

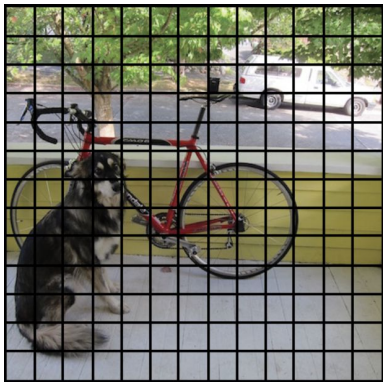
University of Applied Sciences

Region-based CNN (R-CNN) - Tuan Thanh Tran, Max Hager

Object detection

How does object detection work?

1

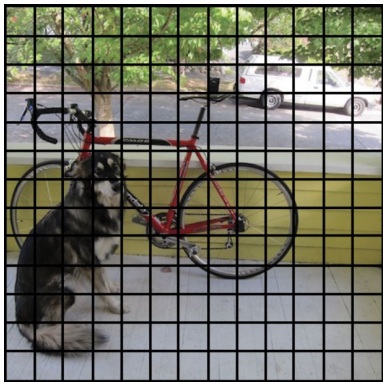


large set of bounding boxes

https://www.analyticsvidhya.com/blog/2020/04/build-your-own-object-detection-model-using-tensorflow-api/?utm_source=blog&utm_medium=Non_Max_Suppression_for_Object_Detection

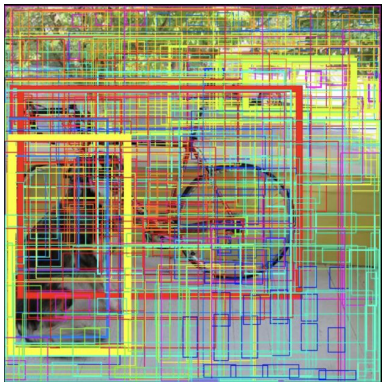
How does object detection work?

1



large set of bounding boxes

2

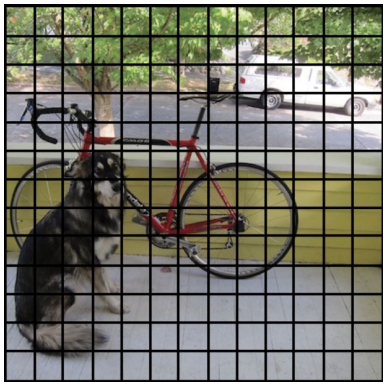


classification

https://www.analyticsvidhya.com/blog/2020/04/build-your-own-object-detection-model-using-tensorflow-api/?utm_source=blog&utm_medium=Non_Max_Suppression_for_Object_Detection

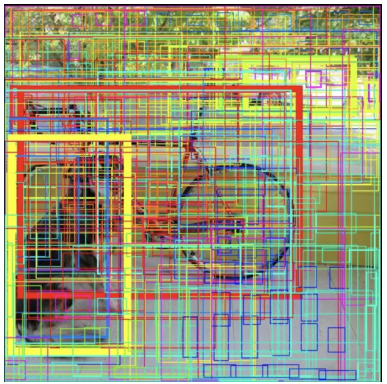
How does object detection work?

1



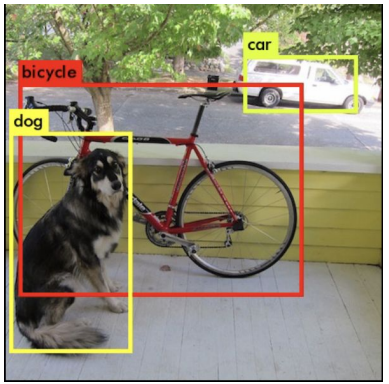
large set of bounding boxes

2



classification

3

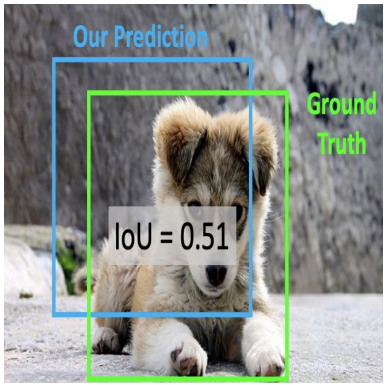


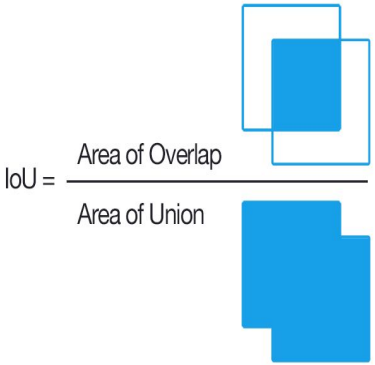
overlapping boxes are combined into single bounding box

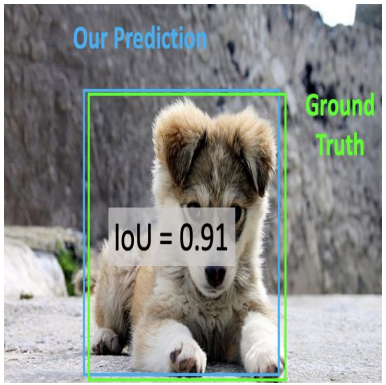
https://www.analyticsvidhya.com/blog/2020/04/build-your-own-object-detection-model-using-tensorflow-api/?utm_source=blog&utm_medium=Non_Max_Suppression_for_Object_Detection

How to select bounding boxes?

Comparing Boxes: Intersection over Union (IoU)







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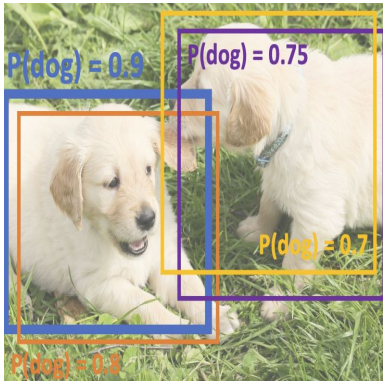
https://upload.wikimedia.org/wikipedia/commons/c/c7/Intersection_over_Union_-_visual_equation.png

Overlapping Boxes: Non-Max Suppression (NMS)



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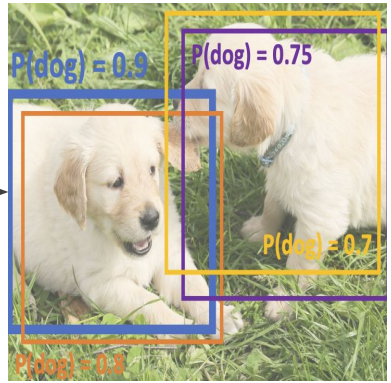
Overlapping Boxes: Non-Max Suppression (NMS)

1. Select next higher scoring box



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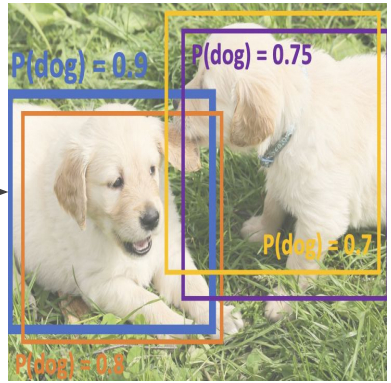
Overlapping Boxes: Non-Max Suppression (NMS)

1. Select next higher scoring box
2. Eliminate lower-scoring boxes with IoU > threshold



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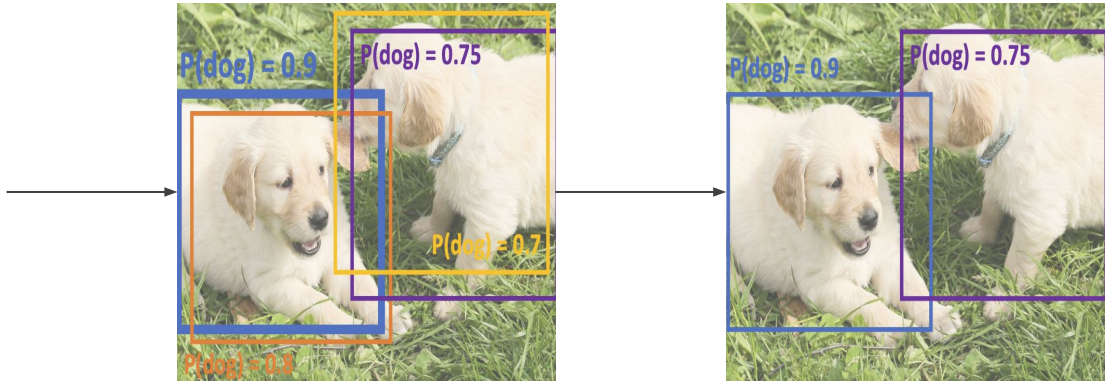

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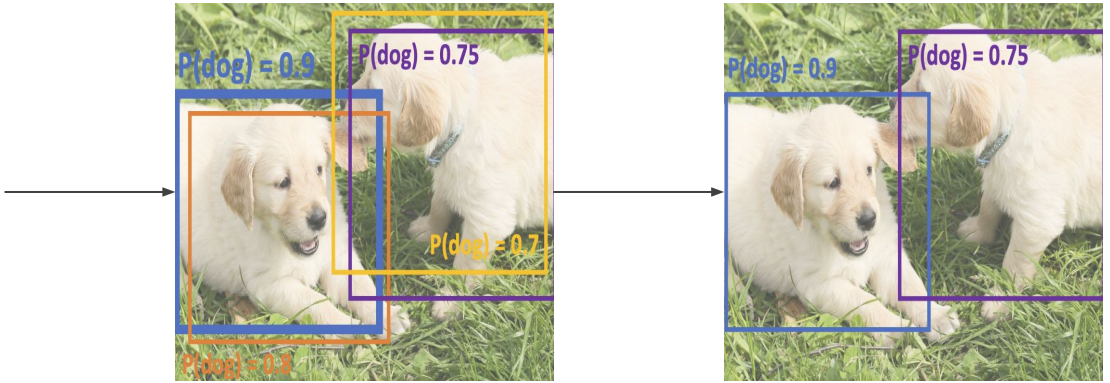
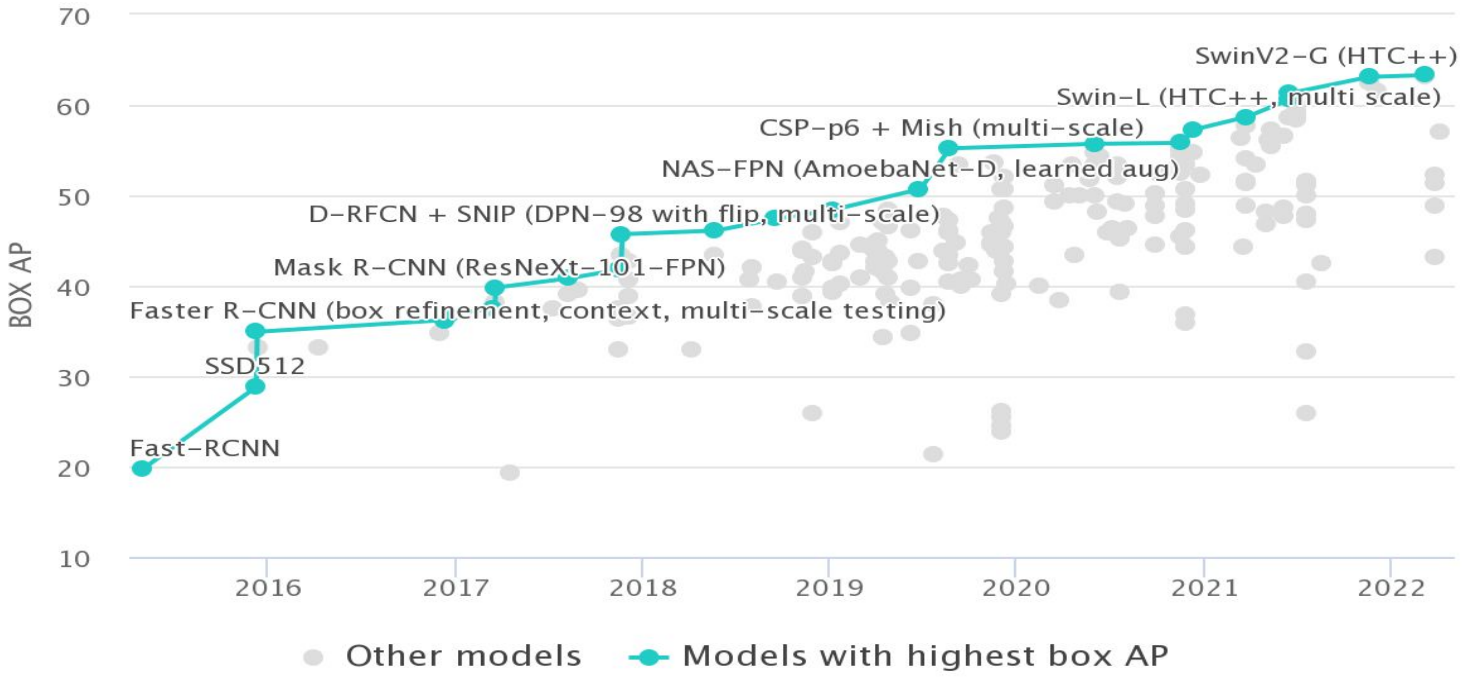
Overlapping Boxes: Non-Max Suppression (NMS)

1. Select next higher scoring box
2. Eliminate lower-scoring boxes with IoU > threshold
3. If any boxes remain, go to 1



https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture13.pdf

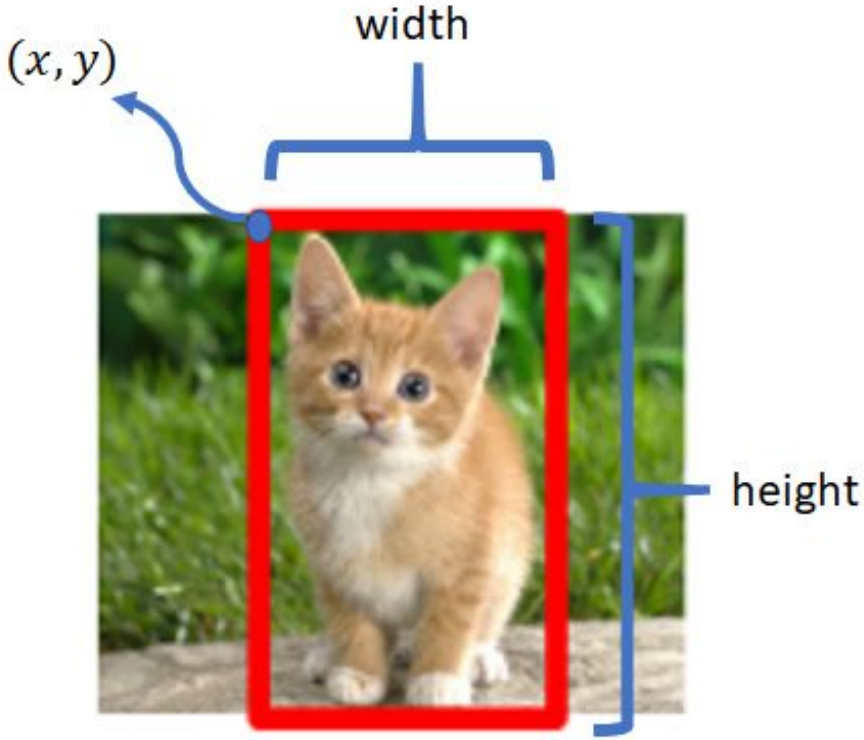
Overviews of famous models



https://paperswithcode.com/sota/object-detection-on-coco

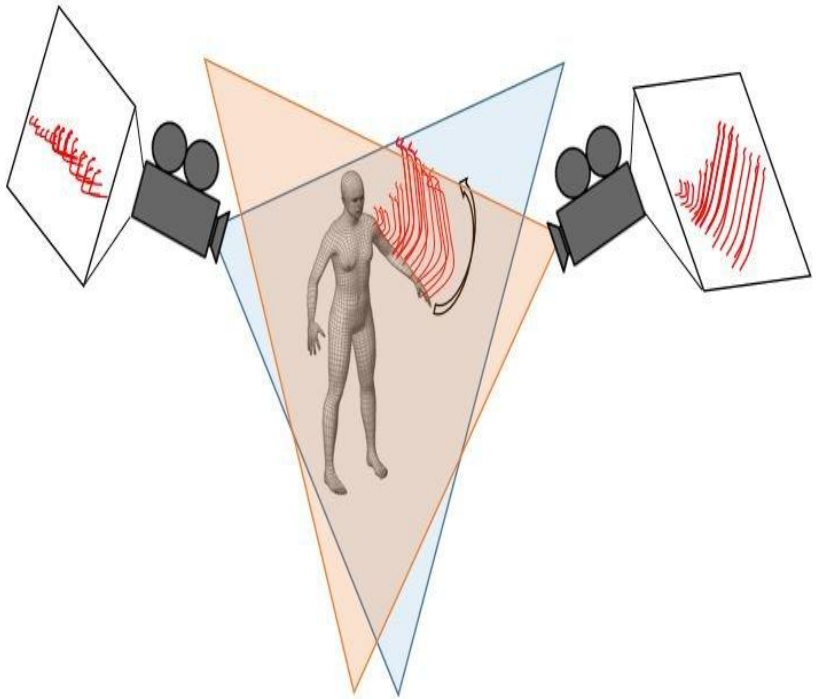
Challenges

Object localisation



https://medium.com/analytics-vidhya/object-localization-using-keras-d78d6810d0be

Viewpoint variation



https://www.researchgate.net/figure/Illustration-of-the-issue-of-viewpoint-variation-in-the-context-of-action-recognition_fig1_338913739

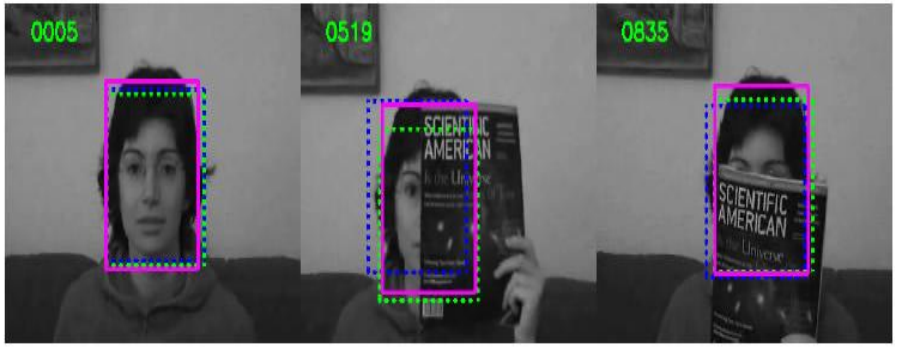
Multiple aspect ratios and spatial sizes

https://medium.com/the-space-ape-games-experience/aspect-ratio-scaling-mobile-and-tablets-d574ab20a943

Deformation

https://www.exposit.com/blog/computer-vision-object-detection-challenges-faced/

Occlusion



(a) Occluded Face 1

(c) Person

https://stackoverflow.com/questions/2764238/image-processing-what-are-occlusions

Lighting

https://www.researchgate.net/figure/An-example-of-low-illumination-objects-detection-Our-detector-have-achieved-amazing_fig1_342757964

Cluttered or textured background

https://becominghuman.ai/computer-vision-object-detection-challenges-faced-9a927f9c5623

Intra class variation

https://www.researchgate.net/figure/shows-an-example-of-Intra-Class-variation-on-the-Chair-class-But-how-will-a-machine_fig1_325311506

Limited data

https://stats.stackexchange.com/questions/233512/how-to-get-the-data-set-size-required-for-neural-network-training

RCNN

How does RCNN work?

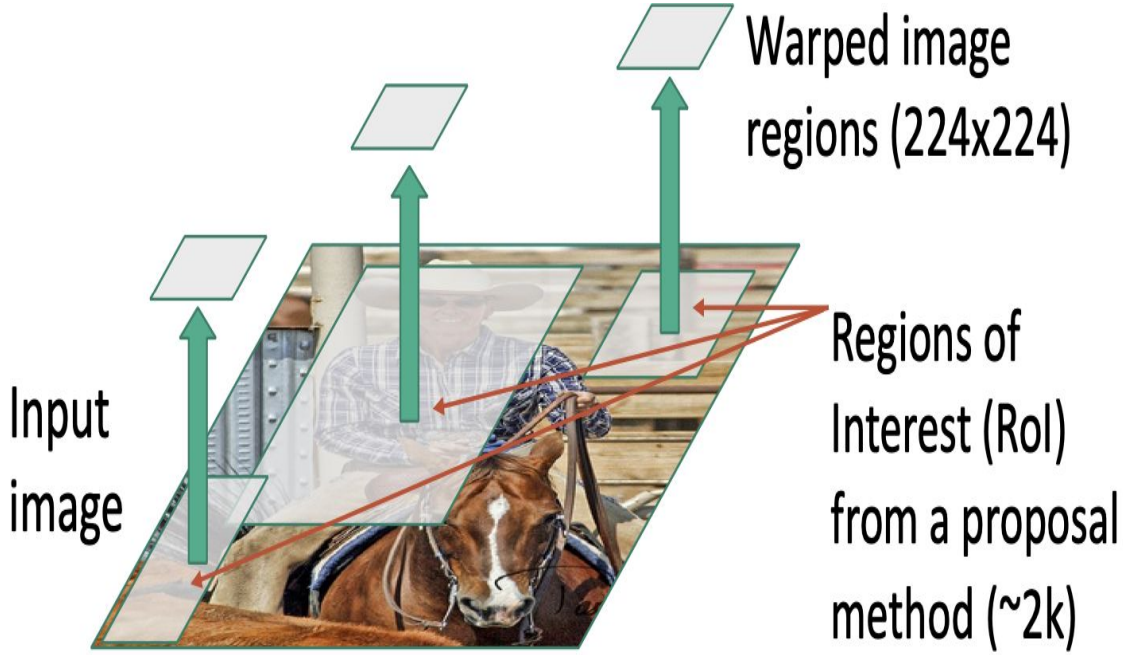
Input image

https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture13.pdf

How does RCNN work?

https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture13.pdf

How does RCNN work?



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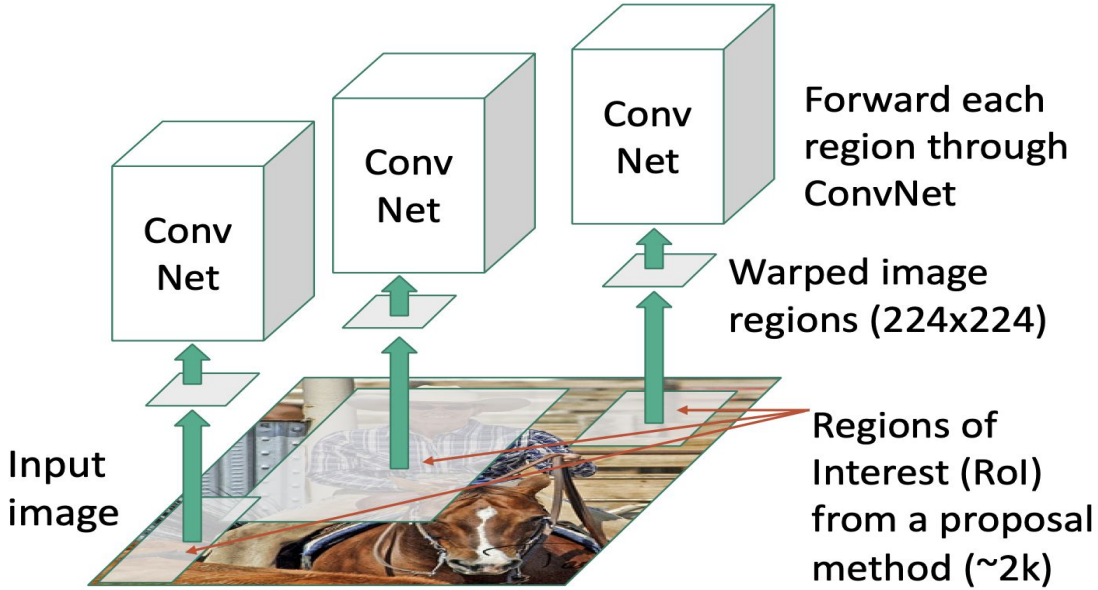
How does RCNN work?



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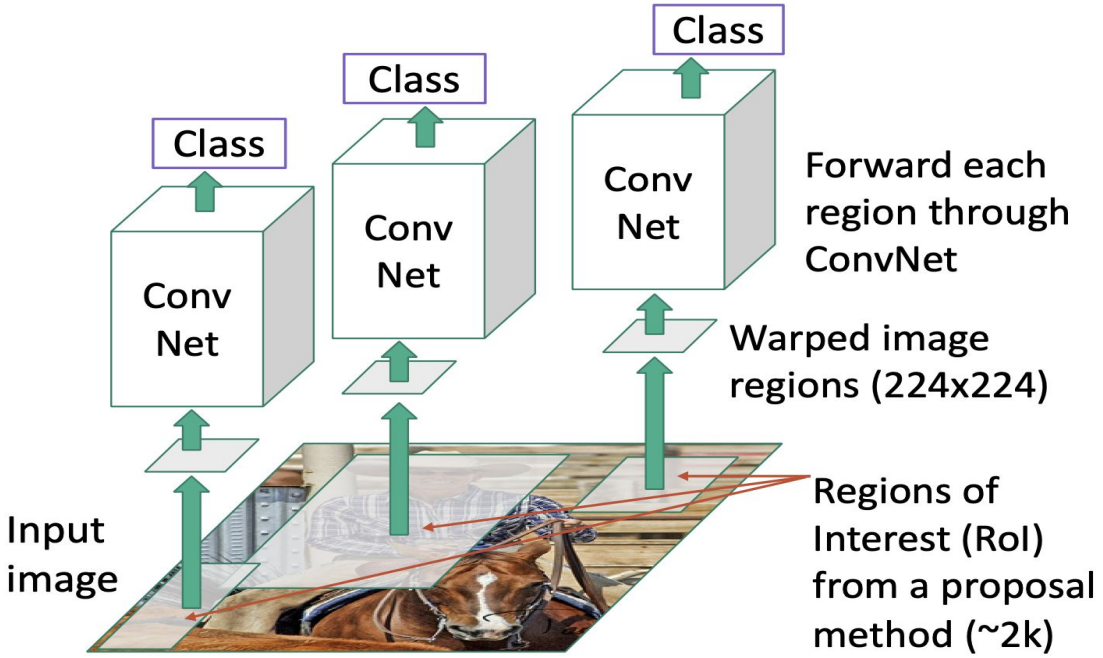

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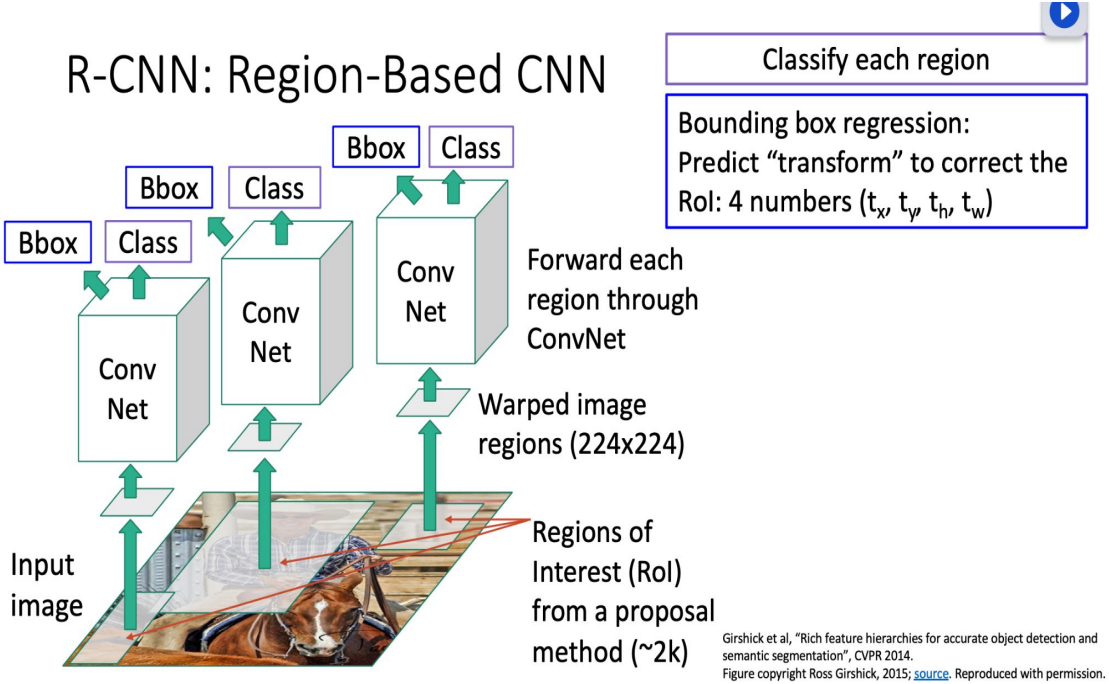


https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture13.pdf

Challenges

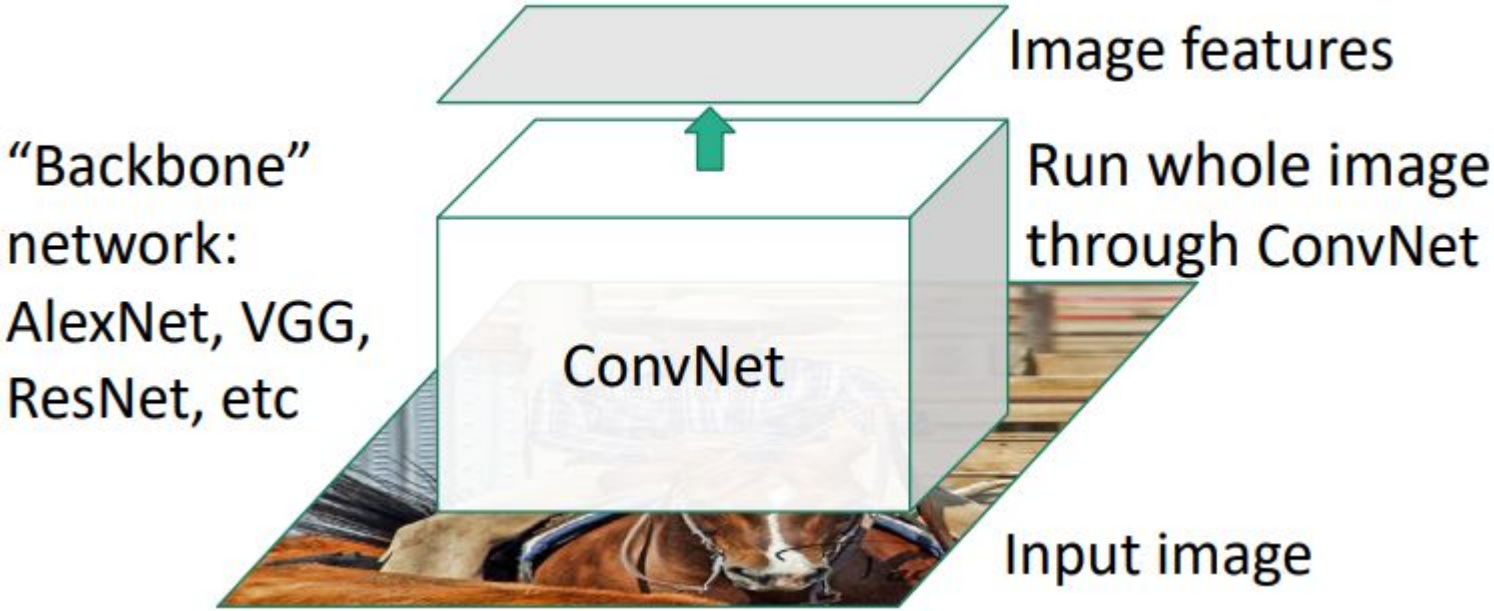
- Selective search no learning algorithm → sometimes result in bad region proposal generation for object detection
- Approx 2000 proposals → long training time
- Testing image with bounding box regressor takes 50 sec → no real time object detection

Fast RCNN

How does Fast-RCNN work?

https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture14.pdf

How does Fast-RCNN work?



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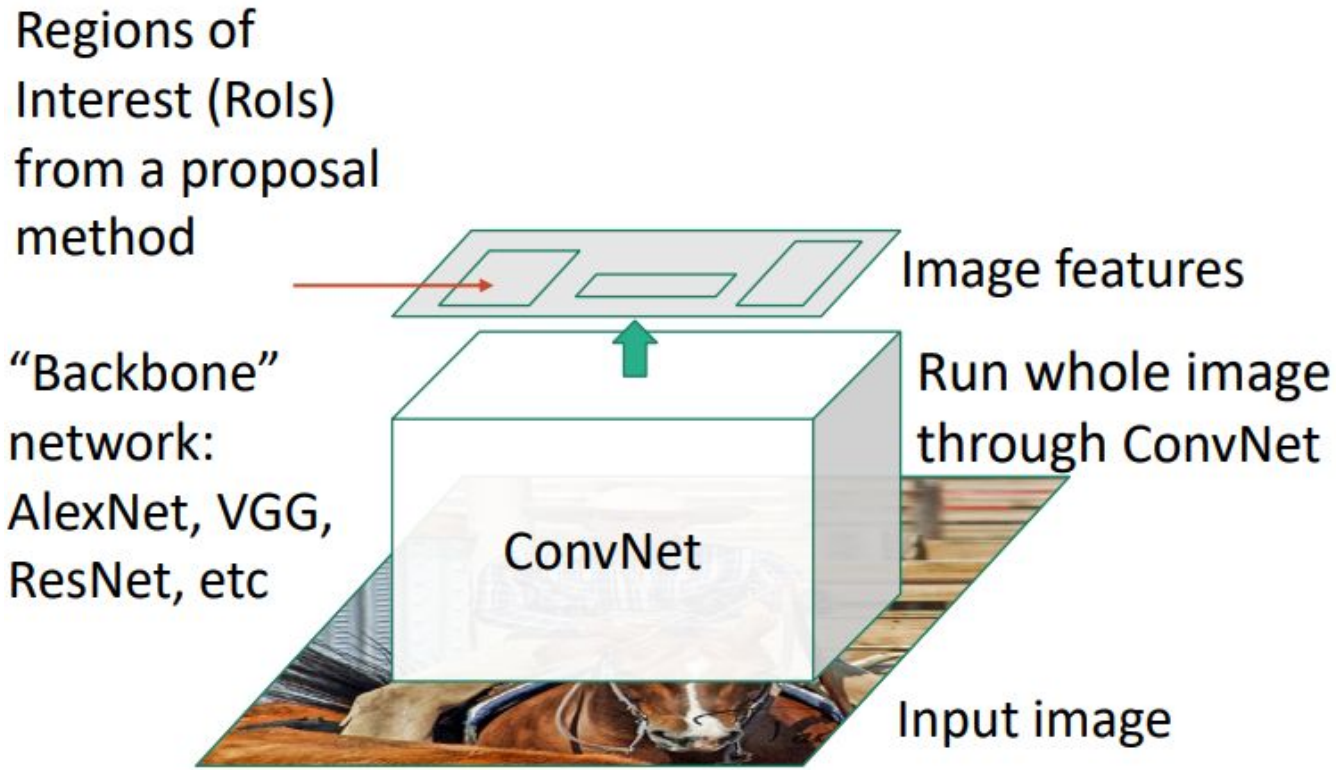

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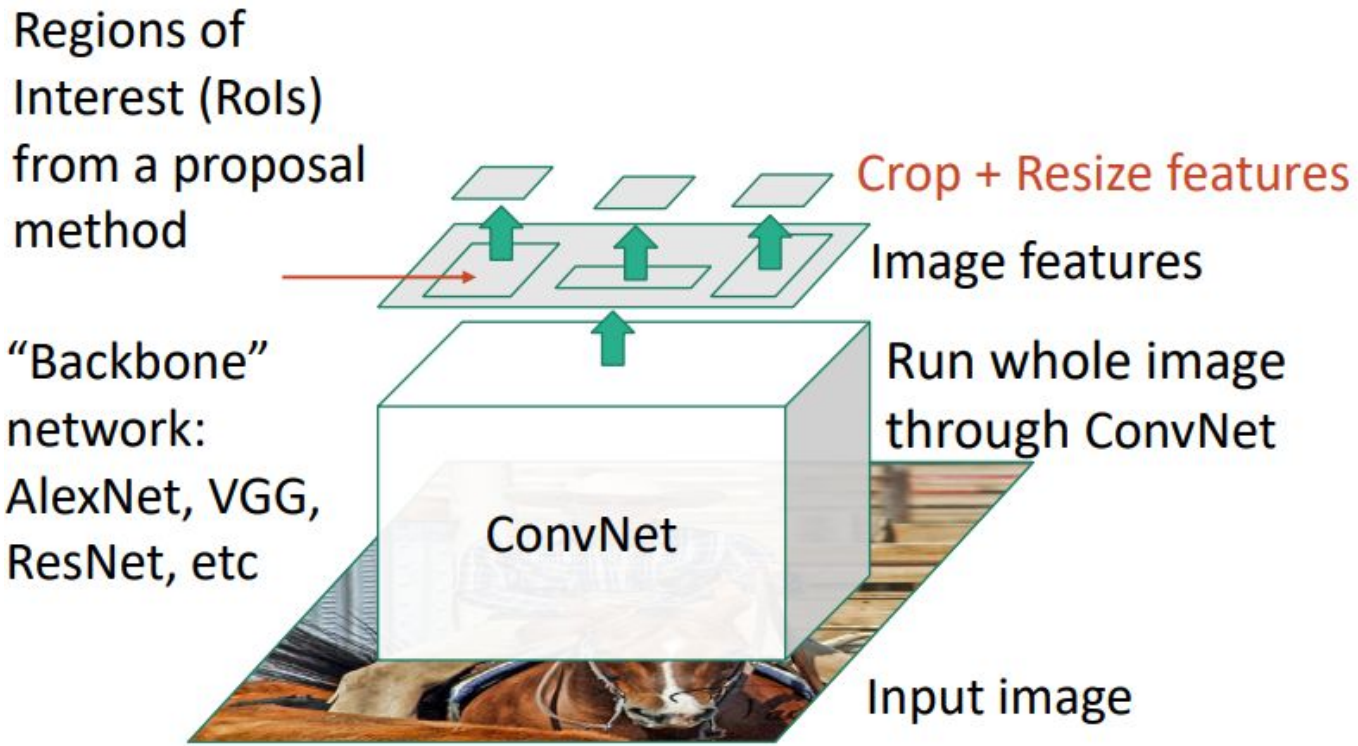
How does Fast-RCNN work?



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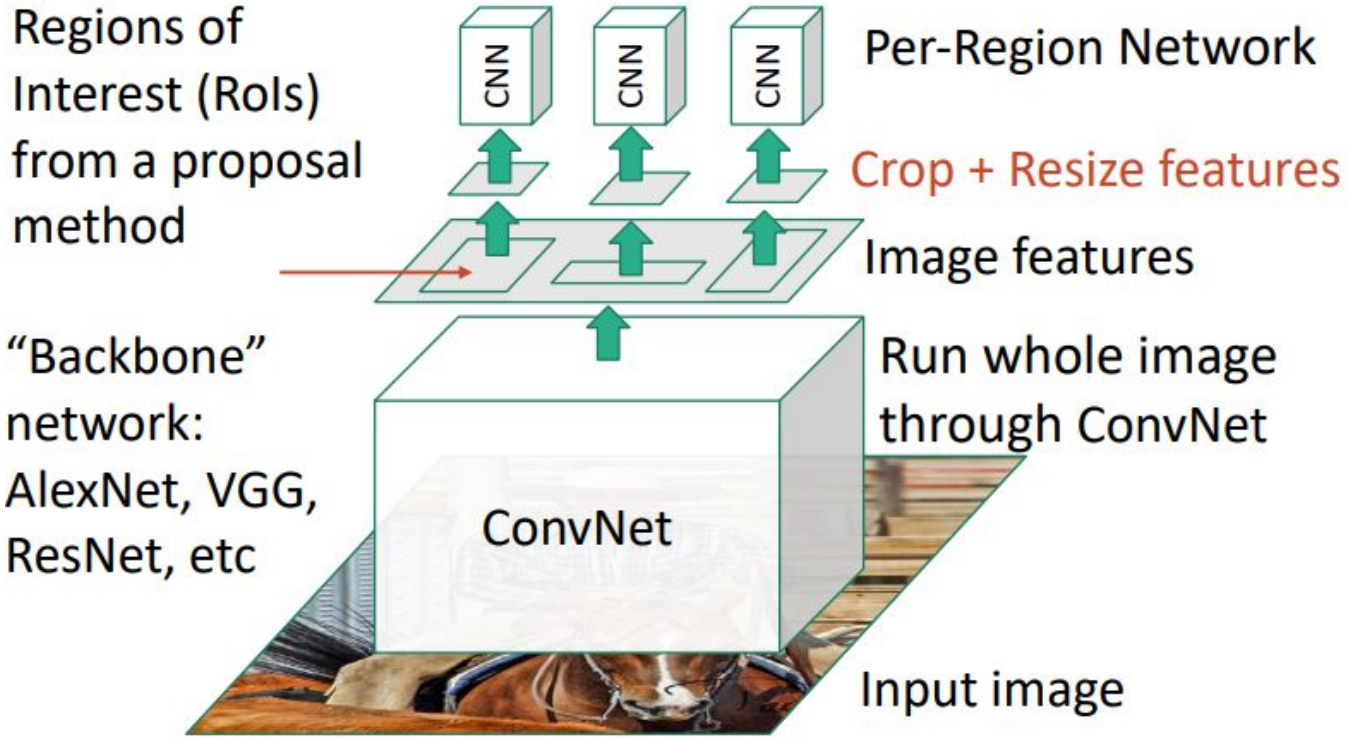

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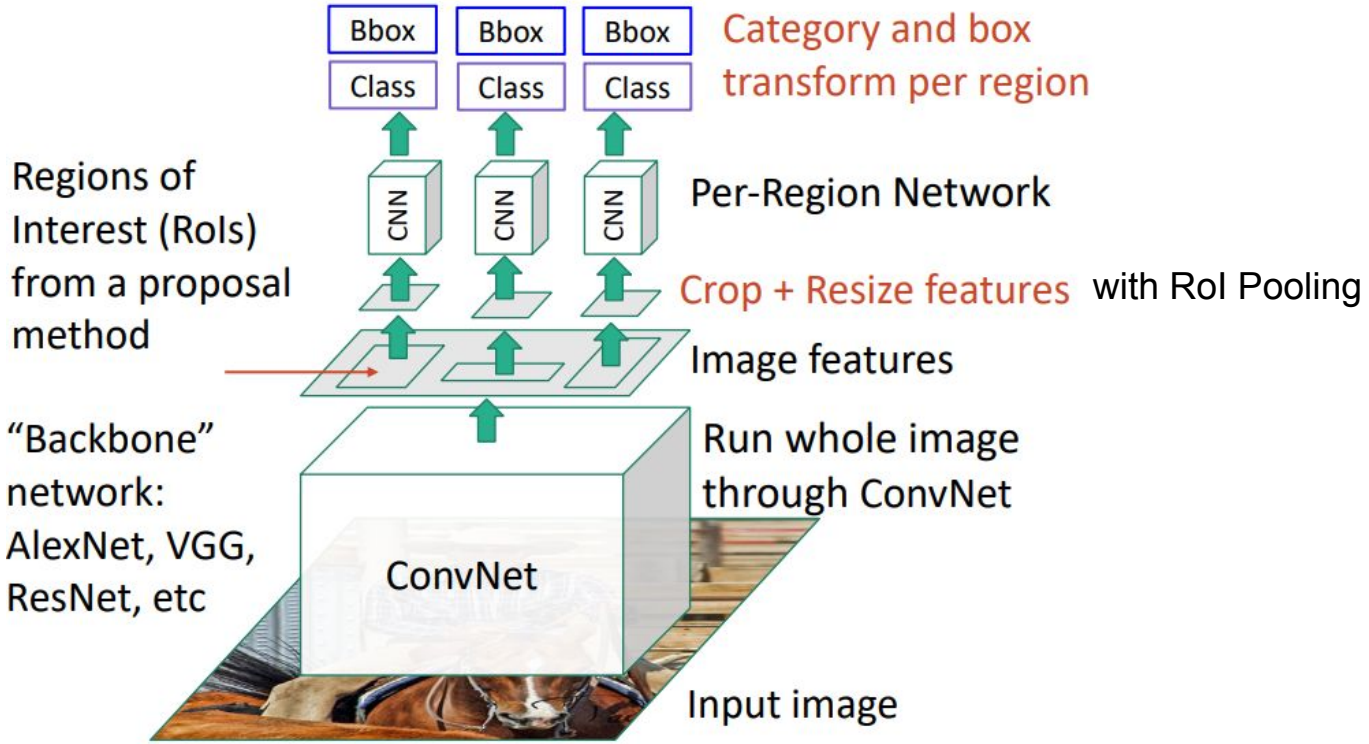


https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture14.pdf

Multi-task loss for training

$$L(p, u, t^u, v) = L_{cls}(p, u) + \lambda[u \geq 1]L_{loc}(t^u, v)$$

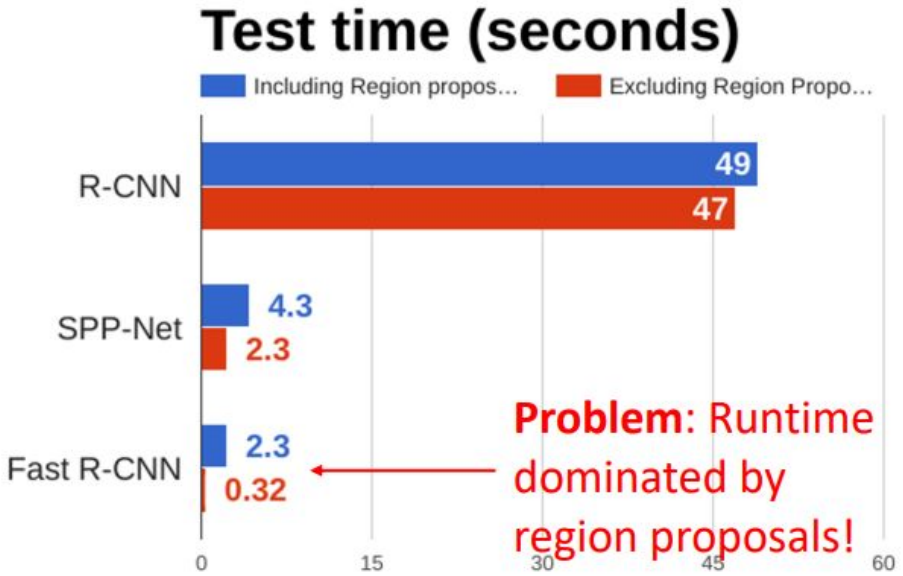
$$L_{cls}(p, u) = -\log(p_u)$$

$$L_{loc}(t^u, v) = \sum_{i \in \{x,y,w,h\}} \text{smooth}_{L1}(t^u_i - v_i)$$

For each region of interest (RoI):

- u: ground-truth class
- $p = (p_0, p_1, \ldots, p_K)$: probability distribution (per RoI) over K + 1 classes
- $t^u = (t^u_x, t^u_y, t^u_w, t^u_h)$: predicted bounding-box regression offsets for class u
- $v = (v_x, v_y, v_w, v_h)$: ground-truth bounding-box regression offsets
- $[u \geq 1]$: The Iverson bracket indicator function evaluates to 1 when $u \geq 1$ and 0 otherwise (Background class: u = 0)
- λ: Hyperparameter controls the balance between the two task losses.

Challenges



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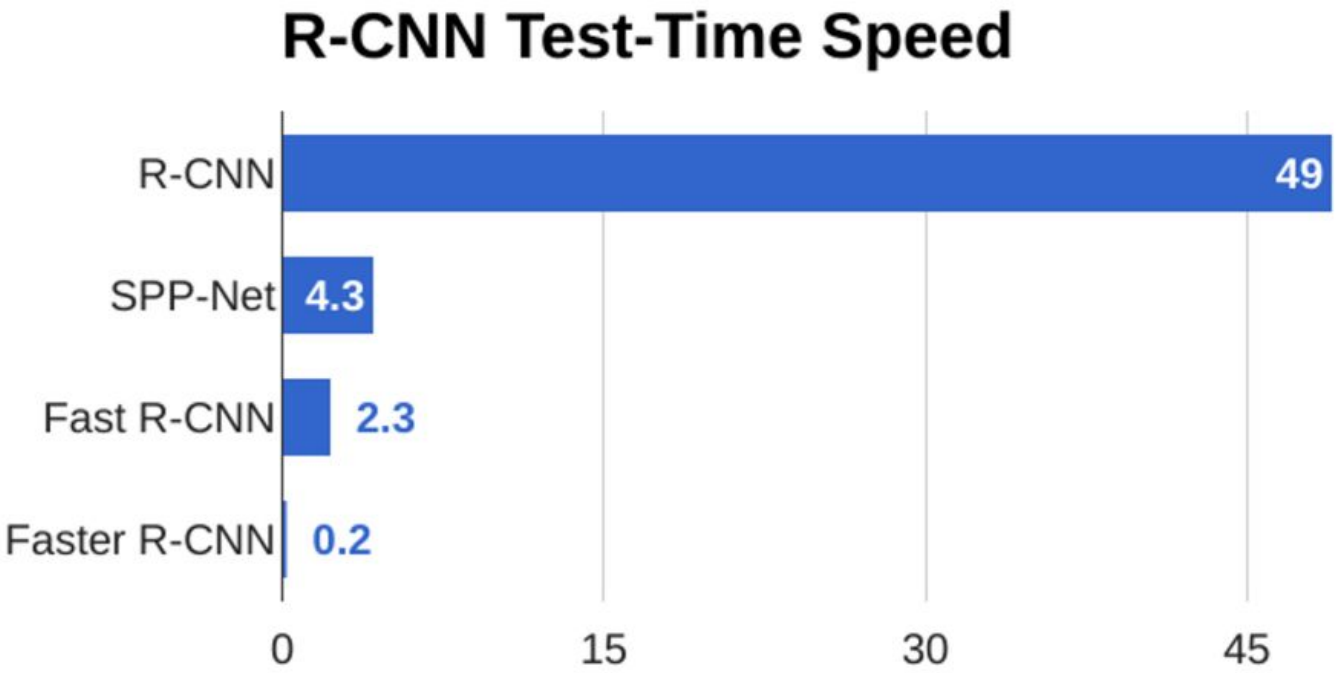
Faster RCNN

Faster-RCNN



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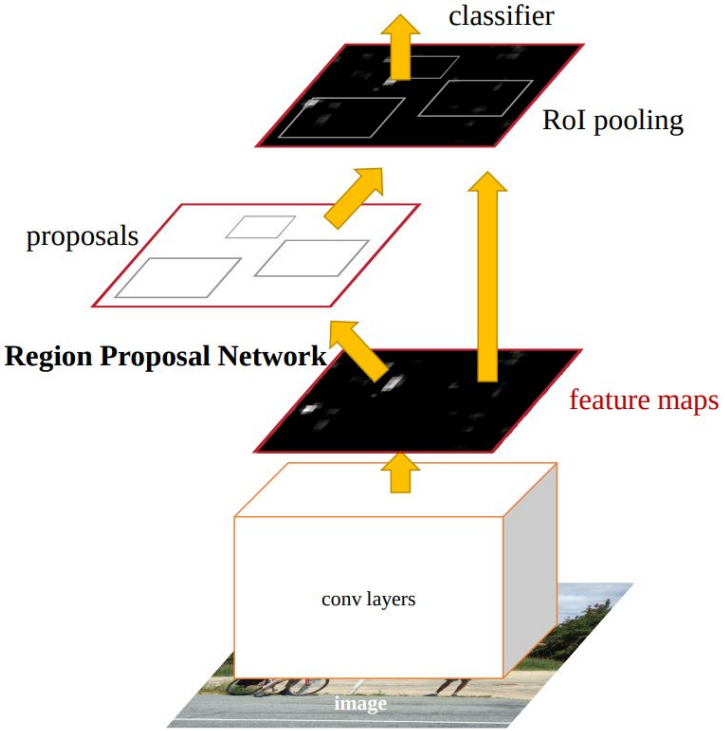
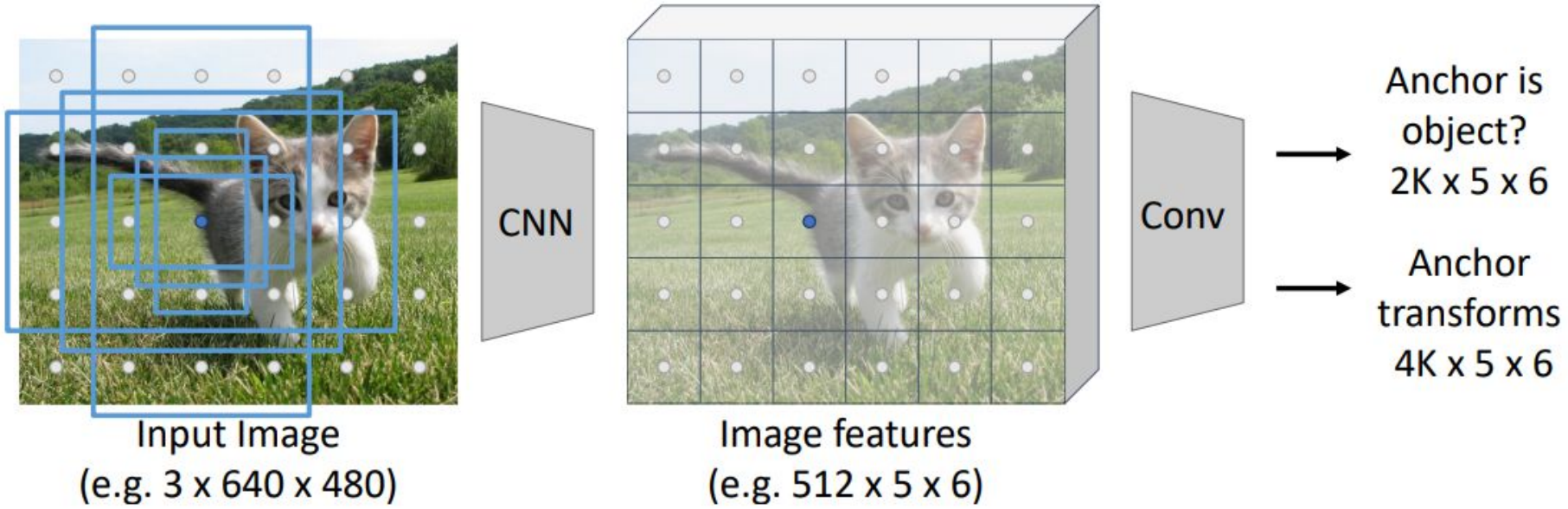
How does Faster-RCNN work?

- Same as Fast R-CNN
- Insert Region Proposal Network (RPN) to predict proposals from features



https://arxiv.org/pdf/1506.01497.pdf

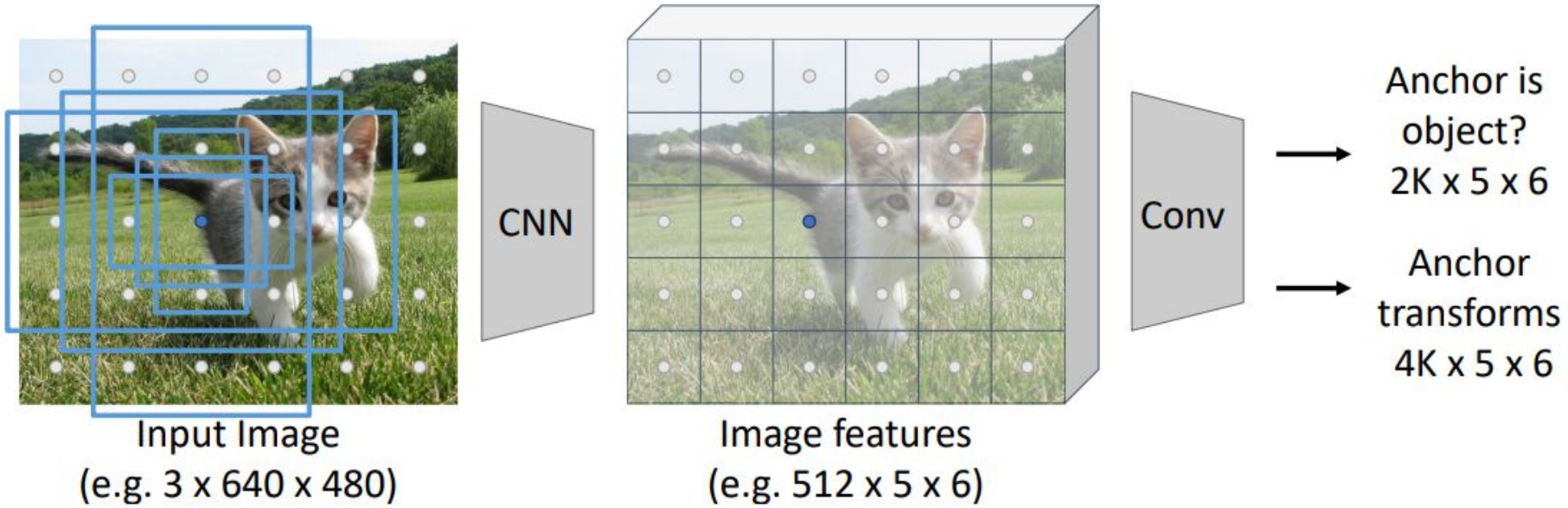
How does RPN work?



- Each feature corresponds to a point in the input
- K different anchors with different size and scale per point

https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture14.pdf

How does RPN work?



- Sort all K*5*6 boxes by their object score
- Take top n anchors as our region proposals

https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture14.pdf

Joint multi-task loss for end-to-end training

$L_{Faster\text{-}RCNN} = L_{RPN} + L_{Fast\text{-}RCNN}$

L_{RPN} same as $L_{Fast\text{-}RCNN}$

$$L_{RPN}(\{p_i\}, \{t_i\}) = \sum_i L_{cls}(p_i, p_i^*)/N_{cls} + \lambda \sum_i p_i^* L_{reg}(t_i, t_i^*)/N_{reg}$$

- i: the index of an anchor in a mini-batch
- p_i: the predicted probability of anchor i being an object
- p_i^*: the ground-truth label (1 if the anchor is positive, 0 if the anchor is negative)
- t_i: a vector representing the 4 parameterized coordinates of the predicted bounding box
- t_i^*: the ground-truth box associated with a positive anchor
- λ: hyperparameter controls the balance between the two task losses.
- N_{cls}: the mini-batch size
- N_{reg}: the number of anchor locations

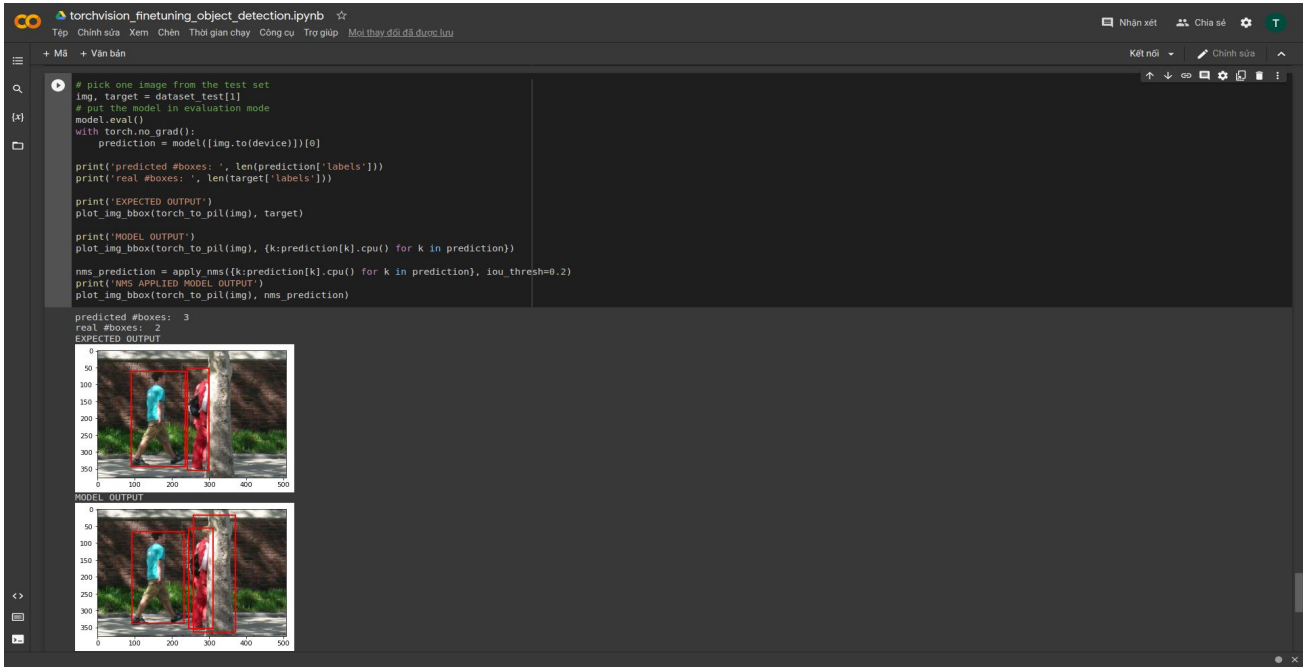
Challenges

2-stage object detector:

- First stage: run once per image
- Second stage: run once per RoI

⟶Accurate but slow for real-time detection

Practical notebook



Faster-RCNN fine-tuning tutorial

https://colab.research.google.com/drive/1l3p5FfYgMzWpo6vHYRN_OKF68HKBZW-F?usp=sharing

References

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- https://www.researchgate.net/figure/shows-an-example-of-Intra-Class-variation-on-the-Chair-class-But-how-will-a-machine_fig1_325311506
- https://www.researchgate.net/figure/An-example-of-low-illumination-objects-detection-Our-detector-have-achieved-amazing_fig1_342757964

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- https://stats.stackexchange.com/questions/233512/how-to-get-the-data-set-size-required-for-neural-network-training

Justin Johnson, Lectures from EECS 442 - Computer Vision course at the University of Michigan:

- https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture14.pdf
- https://web.eecs.umich.edu/~justincj/slides/eecs498/WI2022/598_WI2022_lecture13.pdf

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Ross Girshick, Fast-RCNN, https://arxiv.org/pdf/1504.08083.pdf

Shaoqing Ren et al., Faster-RCNN https://arxiv.org/pdf/1506.01497.pdf

Thank you for listening!

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