Not All Pixels Are Equal: Difficulty-Aware Semantic Segmentation via Deep Layer Cascade

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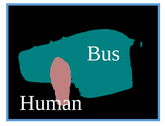
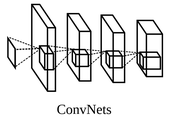
1. Introduction

- **Task & General Approaches**:
  Semantic Segmentation

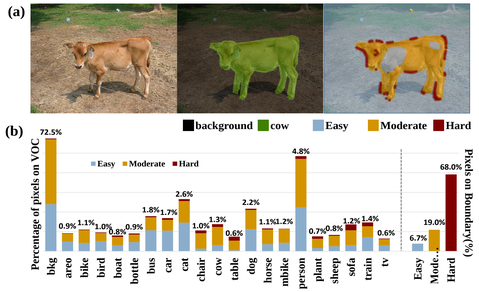




ConvNets

- **Existing Works:**
  Increase the model capacity to achieve promising results
  High runtime complexity

Backbone Network	Speed(300*500 image)
VGG16	5.7 fps
ResNet-101	7.1 fps
Inception-ResNet	9.0 fps
Layer Cascade	**14.7 fps**
Layer Cascade (fast)	**23.6 fps**

- **Motivation:**
  Partition all pixels into three sets by classification confidence

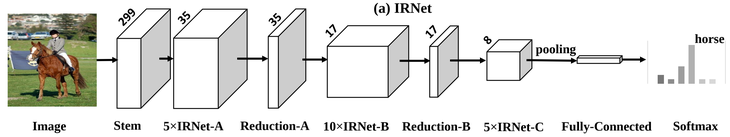


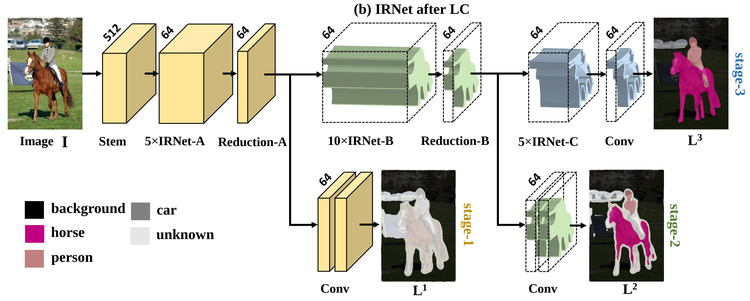
Nearly 40% easy region

- **Our Idea:**
  Treats a single deep model as a cascade of several sub-models
  Earlier sub-models are trained to handle easy and confident regions
  Feed-forward harder regions to the next sub-model for processing

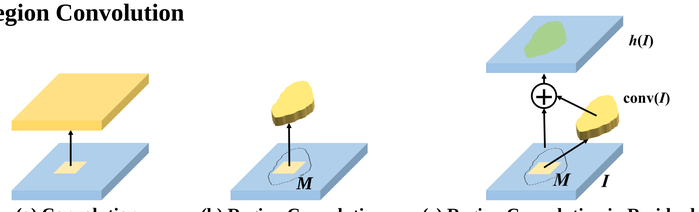
2. Approach

- **Turning Inception-ResNet into Deep Layer Cascade (LC)**





- **Region Convolution**



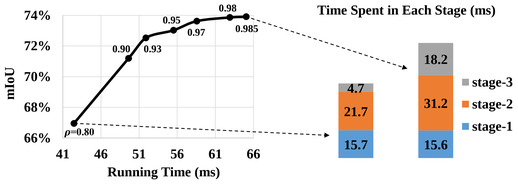
(a) Convolution (b) Region Convolution (c) Region Convolution in Residual

3. Experiments

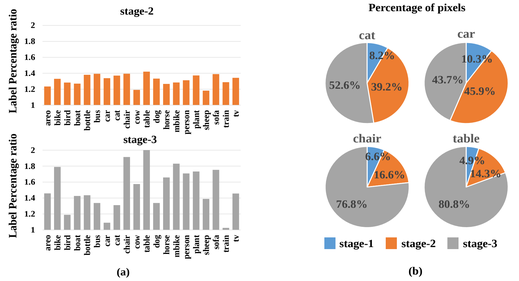
- **Ablation Study on Probability Thresholds ρ**
  ρ controls percentage of easy and hard regions

ρ	1	0.995	0.985	0.970	0.950	0.930	0.900	0.800
stage-1 (%)	0	15	23	30	35	35	44	56
stage-2 (%)	0	14	29	31	30	41	31	29
mIoU (%)	72.70	73.56	73.91	73.63	73.03	72.53	71.20	66.95

- **Performance and Speed Trade-off**



- **Stage-wise Label Distribution**

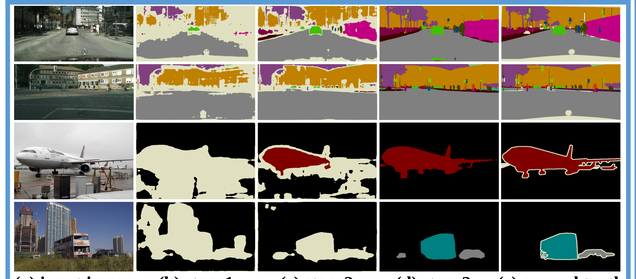


Stage-1 handles the easy regions (background)
Stage-2 focus more on the foreground than stage-1 does
Stage-3 further focus on harder classes

- **Comparisons with DeepLab & SegNet**

	mIoU(%)	runtime(ms)	FPS
DeepLab-v2	70.42	140.0	7.1
SegNet	59.90	69.0	14.6
LC	73.91	65.1	14.7
LC (fast)	66.95	42.5	23.6

4. Stages' Outputs


(a) input image (b) stage1 (c) stage2 (d) stage3 (e) ground truth

5. Overall Performance

	areo	bike	bird	boat	bottle	bus	car	cat	chair	cow	table	dog	horse	mbike	person	plant	sheep	sofa	train	tv	mIoU
FCN	76.8	34.2	68.9	49.4	60.3	75.3	74.7	77.6	21.4	62.5	46.8	71.8	63.9	76.5	73.9	45.2	72.4	37.4	70.9	55.1	62.2
DeepLab	84.4	54.5	81.5	63.6	65.9	85.1	79.1	83.4	30.7	74.1	59.8	79.0	76.1	83.2	80.8	59.7	82.2	50.4	73.1	63.7	71.6
RNN	87.5	39.0	79.7	64.2	68.3	87.6	80.8	84.4	30.4	78.2	60.4	80.5	77.8	83.1	80.6	59.5	82.8	47.8	78.3	67.1	72.0
Adelaide	91.9	48.1	93.4	69.3	75.5	94.2	87.5	92.8	36.7	86.9	65.2	89.1	90.2	86.5	87.2	64.6	90.1	59.7	85.5	72.7	79.1
RNN†	90.4	55.3	88.7	68.4	69.8	88.3	82.4	85.1	32.6	78.5	64.4	79.6	81.9	86.4	81.8	58.6	82.4	53.5	77.4	70.1	74.7
BoxSup†	89.8	38.0	89.2	68.9	68.0	89.6	83.0	87.7	34.4	83.6	67.1	81.5	83.7	85.2	83.5	58.6	84.9	55.8	81.2	70.7	75.2
DPN†	89.0	61.6	87.7	66.8	74.7	91.2	84.3	87.6	36.5	86.3	66.1	84.4	87.8	85.6	85.4	63.6	87.3	61.3	79.4	66.4	77.5
DeepLab-v2†	92.6	60.4	91.6	63.4	76.3	95.0	88.4	92.6	32.7	88.5	67.6	89.6	92.1	87.0	87.4	63.3	88.3	60.0	86.8	74.5	79.7
LC	94.1	63.0	91.2	67.9	79.5	93.4	90.0	93.8	37.4	83.7	65.9	90.7	86.1	88.8	87.5	68.5	86.9	64.3	85.6	72.2	80.3
LC†	85.5	66.7	94.5	67.2	84.0	96.1	89.8	93.5	47.2	90.4	71.5	88.9	91.7	89.2	89.1	70.4	89.4	70.7	84.2	79.6	82.7

Per-class results on VOC12 test set. Approaches pre-trained on COCO are marked with †.

6. Conclusion

- LC adopts a "difficulty-aware" learning paradigm.
- LC accelerates both training and testing by the usage of region convolution. It is capable of running in real-time.
- LC is an end-to-end trainable framework that jointly optimizes the feature learning for different regions.