Depth Privileged Object Detection in Indoor Scenes via Deformation Hallucination

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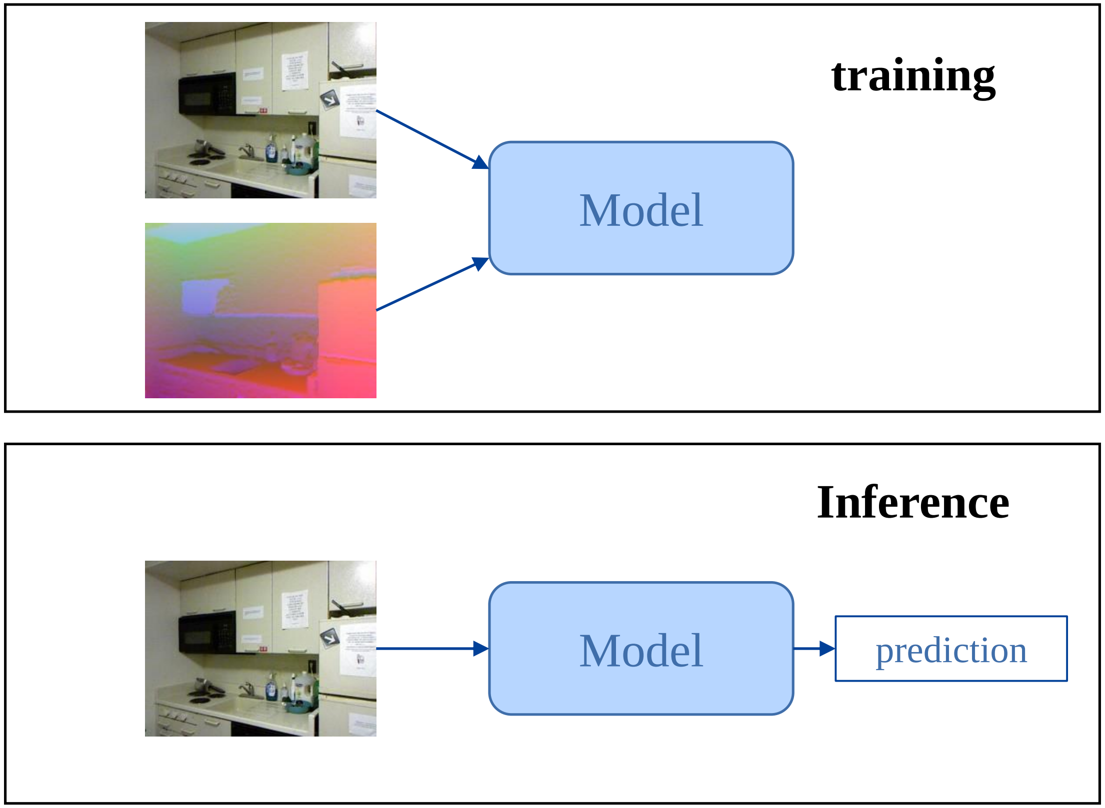
Motivations

- Cluttered objects remain difficult to be detected due to the large variations (e.g., occlusion and illumination)
- Depth information can provide additional geometric cues to complement RGB image
- While RGB image capturing devices are pervasive, depth capturing devices are much less prevalent.

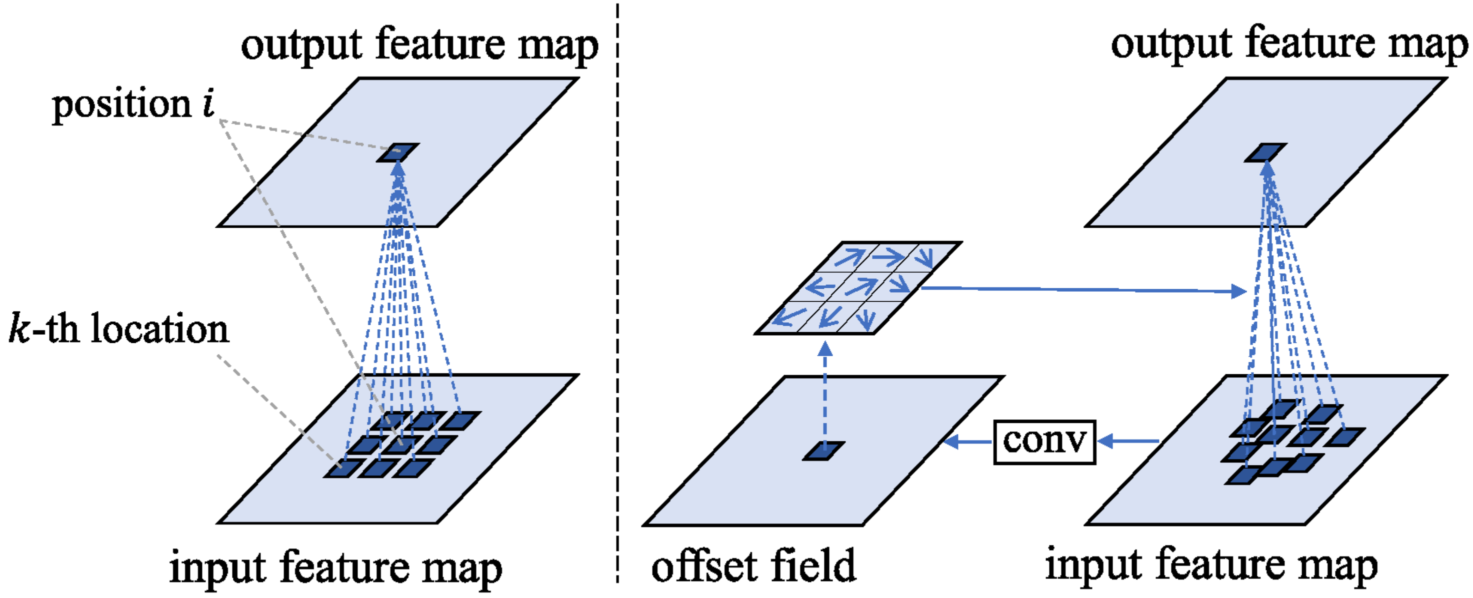
Learning Using Privileged Information

- Privileged information: can be accessed in training stage while be not available in inference stage.

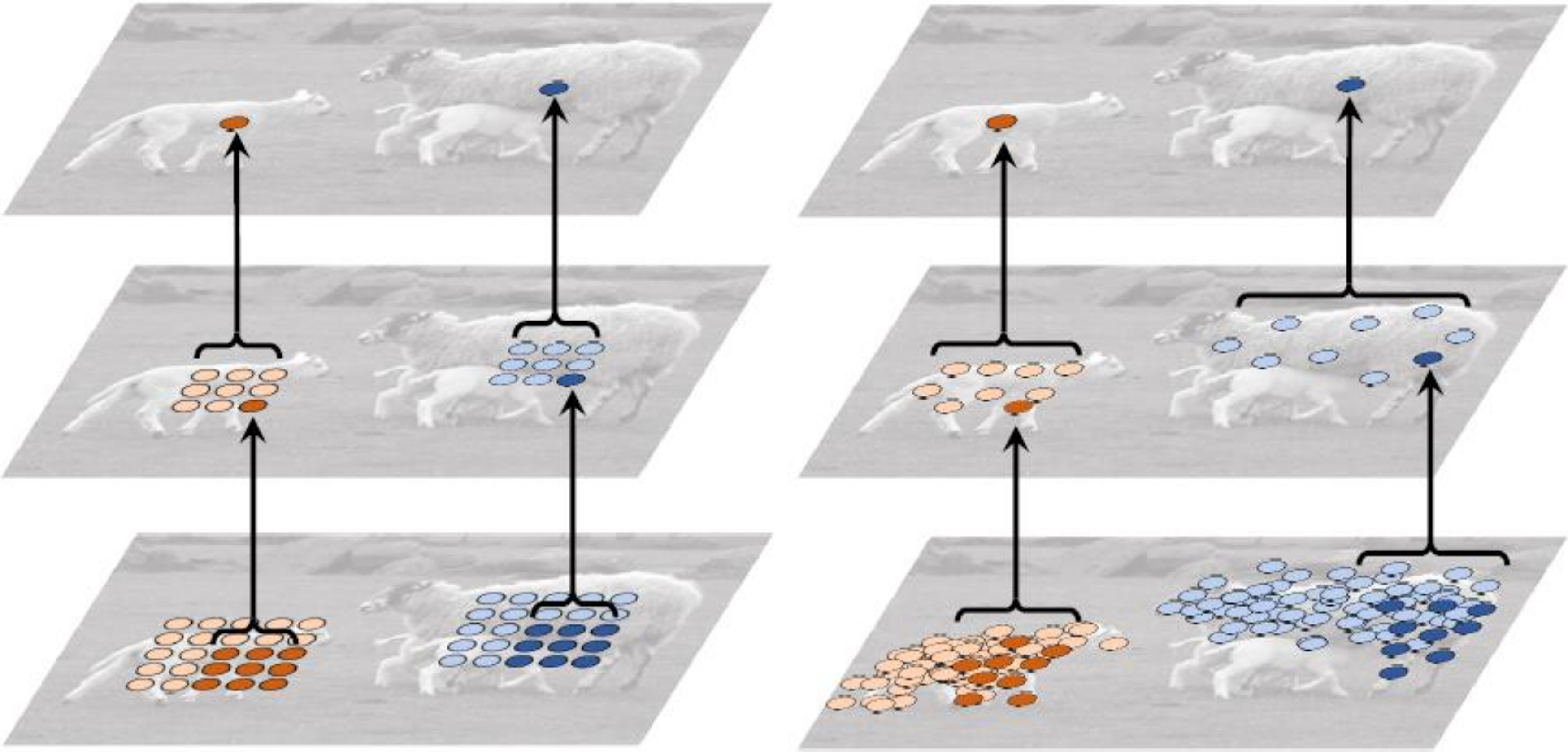


Deformable Convolutional Networks

Standard Convolution **Deformable Convolution**

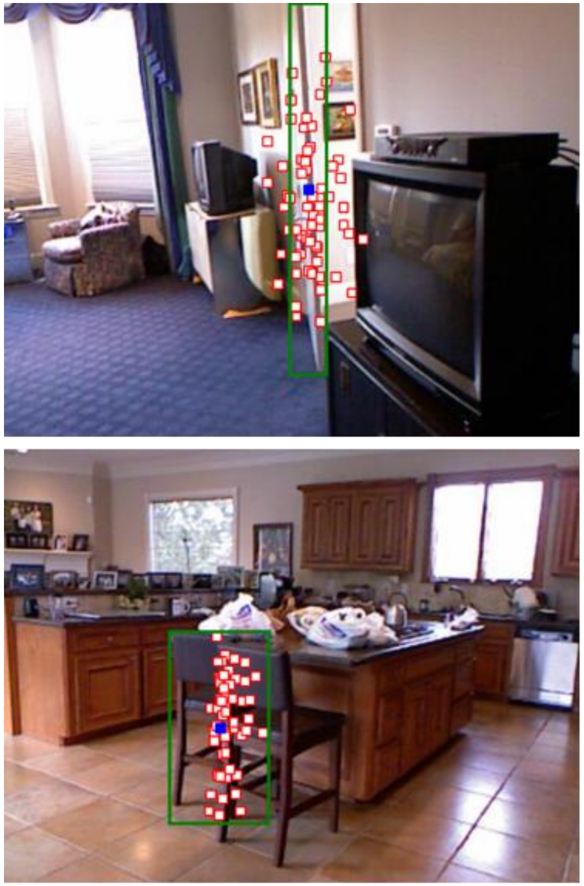


Deformable Convolutional Networks



(a) standard convolution (b) deformable convolution

Deformation in Different Modalities



(a) RGB Deformation

(b) Depth Deformation

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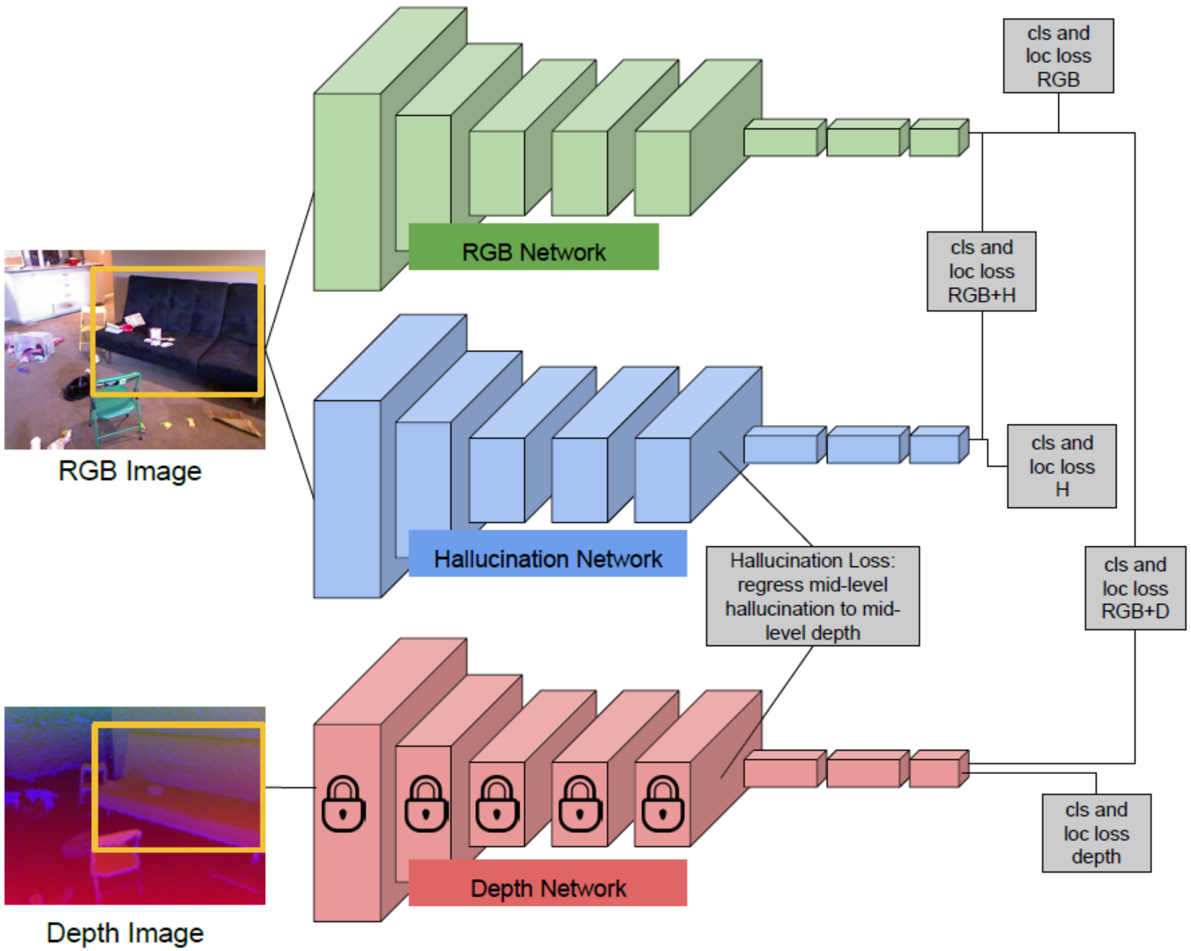
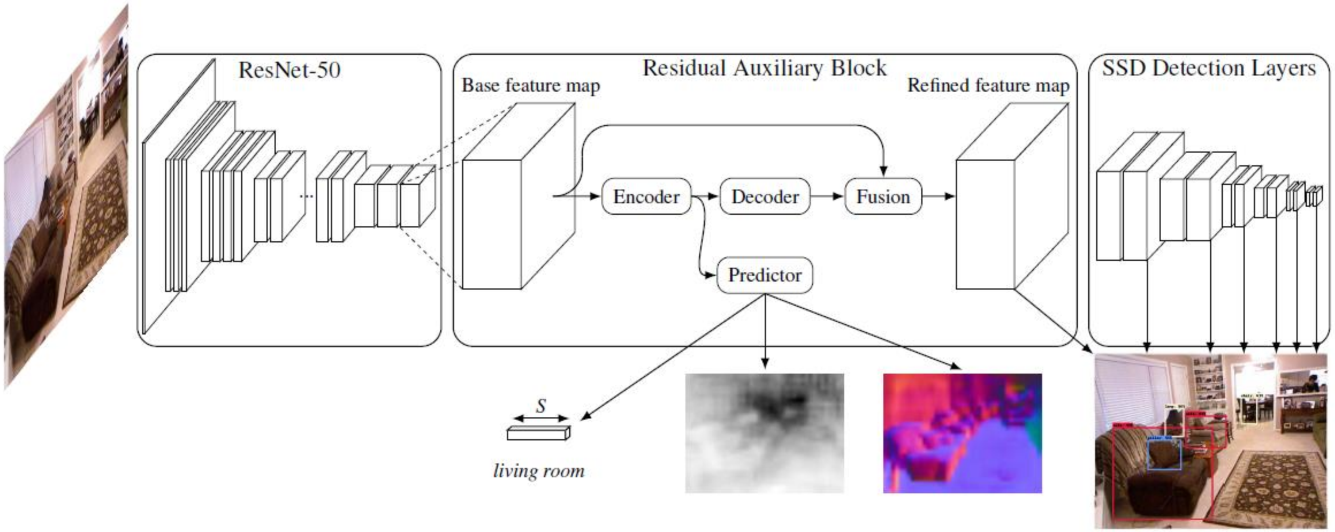
Depth Privileged Object Detection

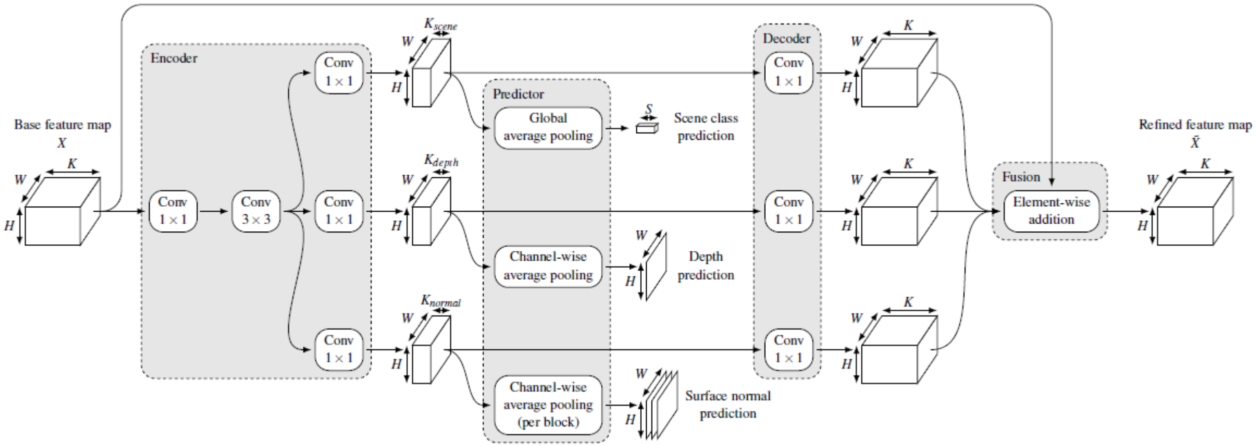
- Research lines:
  - Modality hallucination: HallucitantionNet , Cao et al. (2016)
  - Multi-task learning: ROCK

HallucinationNet



ROCK


ResNet-50
Residual Auxiliary Block
Base feature map
Refined feature map
SSD Detection Layers
Encoder
Decoder
Fusion
Predictor
S
living room


Base feature map
X
Encoder
Conv 1 × 1
Conv 3 × 3
Conv 1 × 1
Conv 1 × 1
Conv 1 × 1
Predictor
Global average pooling
Scene class prediction
Channel-wise average pooling
Depth prediction
Channel-wise average pooling (per block)
Surface normal prediction
Decoder
Conv 1 × 1
Conv 1 × 1
Conv 1 × 1
Fusion
Element-wise addition
Refined feature map

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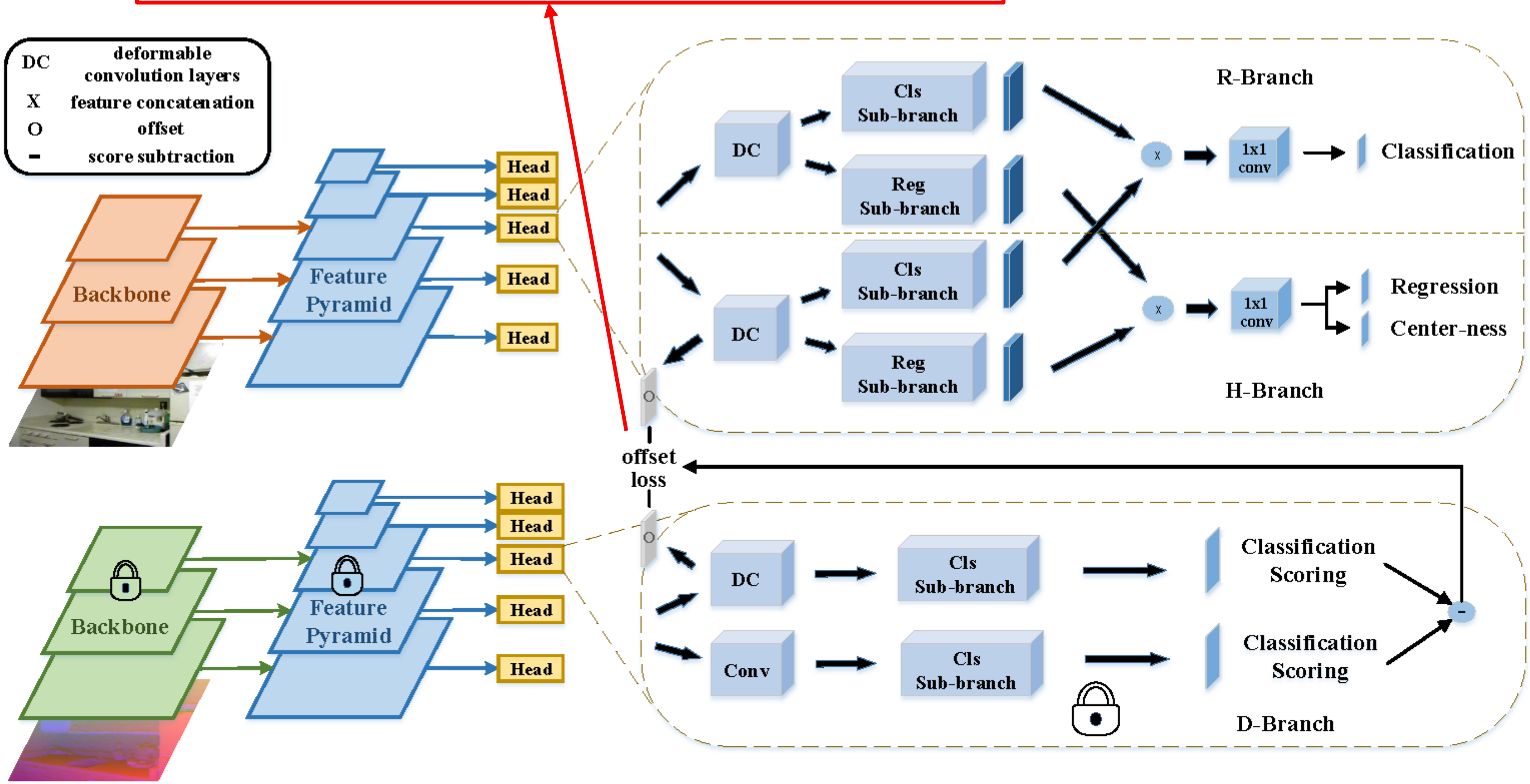
Framework

$$L_o = \sum_{s=1}^{S} \sum_{m=1}^{M} \sum_{i=1}^{h_s * w_s} \sum_{k=1}^{K^2} \left\| \Delta l_{s,m,i,k}^{D} - \Delta l_{s,m,i,k}^{H} \right\|_2^2$$



Positive Position Transfer

- The depth deformation is not always reliable, transferring noisy deformation is likely to degrade the performance.

- Positive samples, which are determined by ATSS algorithm, has a major influence on the results (classification, regression)

$$L_o^p = \sum_{s=1}^{S} \sum_{m=1}^{M} \sum_{i=1}^{h_s * w_s} \sum_{k=1}^{K^2} P_{s,m,i} \left\| \Delta l_{s,m,i,k}^{\mathrm{D}} - \Delta l_{s,m,i,k}^{H} \right\|_2^2$$

Avoid Negative Transfer

- Classification scores (with/without dcn) can reflect the quality of deformation

- we calculate the loss weights at different positions in previous DeformConvs by tracking their contributions to the classification score improvement.

$$w_{s,m,i} = \exp(\delta \cdot (f_{s,i}^{(w)} - f_{s,i}^{(w/o)}))$$

$$L_o^{pw} = \sum_{s=1}^{S} \sum_{m=1}^{M} \sum_{i=1}^{h_s * w_s} \sum_{k=1}^{K^2} w_{s,m,i} P_{s,m,i} \left\| \Delta l_{s,m,i,k}^{\mathrm{D}} - \Delta l_{s,m,i,k}^{H} \right\|_2^2$$

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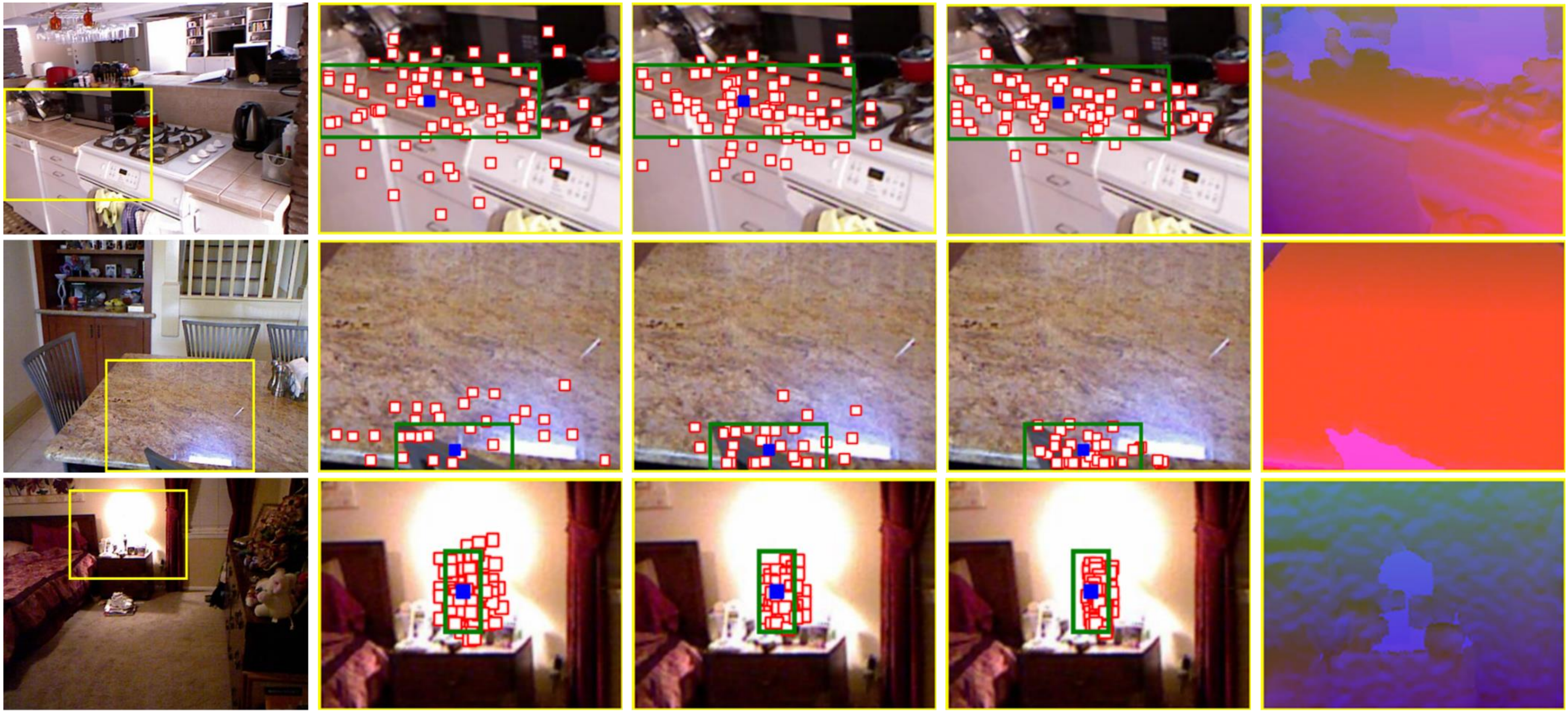
Visualization Results



(a) RGB images (b) RGB Deformation (c) Hallucinated Deformation (d) Depth Deformation (e) HHA-encoded images

Compared with SOTA Methods

L_d	L_o	L_o^p	L_o^{pw}	mAP(%)	
				NYUDv2	SUN RGB-D
√				44.01	53.93
√	√			46.26	56.15
√		√		46.50	56.47
√			√	46.88	56.84

Method	mAP(%)	
	NYUDv2	SUN RGB-D
FCOS+ATSS	42.73	52.94
HallucinationNet	45.22	55.35
ROCK	44.89	55.14
Cao et al.(2016)	44.96	55.27
Ours	46.88	56.84

Ablation Study

Configuration of DeformConvs

Configuration	mAP(%)	
	L_d	$L_d + \mu L_o$
B_1	43.66	45.34
B_2	44.17	45.93
B_3	44.43	46.19
H_1	43.35	45.36
H_2	44.04	46.26
H_3	44.21	46.30
B_3+H_2	44.25	46.32

Fusion Strategy Analyses

mAP(%)	After DeformConvs	After sub-branch
Concatenation	46.32	46.88
Addition	45.79	46.15

Evaluation on RGB-only dataset

Model	mAP(%)
RGB-only	38.96
Ours	40.68
RGB-only(ft)	81.01
Ours(ft)	82.57

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Thanks For Watching!

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