H+O: Unified Egocentric Recognition of 3D Hand-Object Poses and Interactions

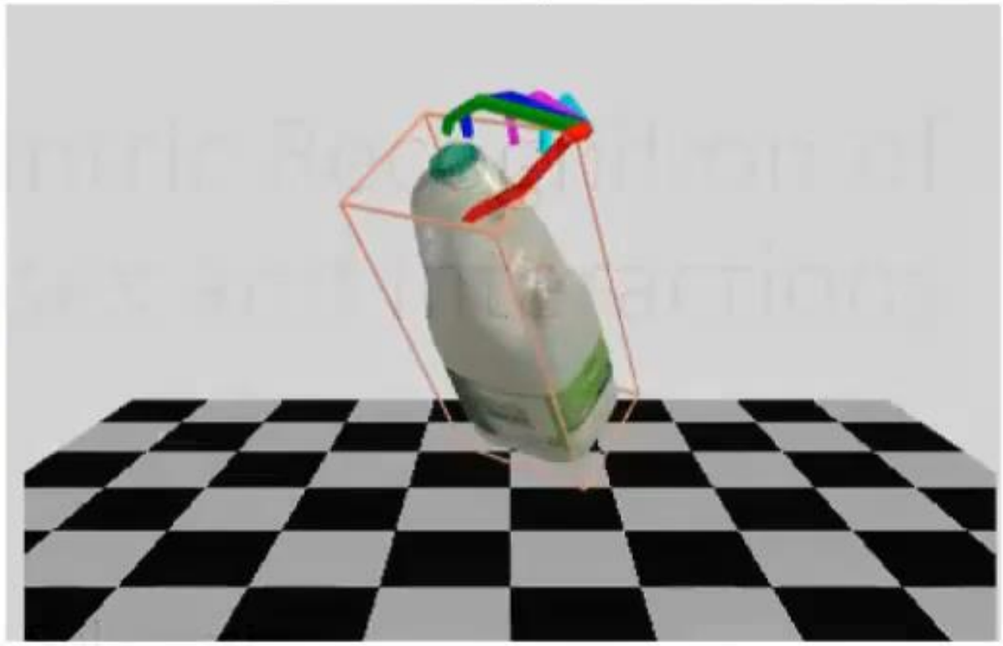
Buğra Tekin

Microsoft MR & AI Lab, Zürich

Hand & Object Interactions

2D Hand + Object Pose

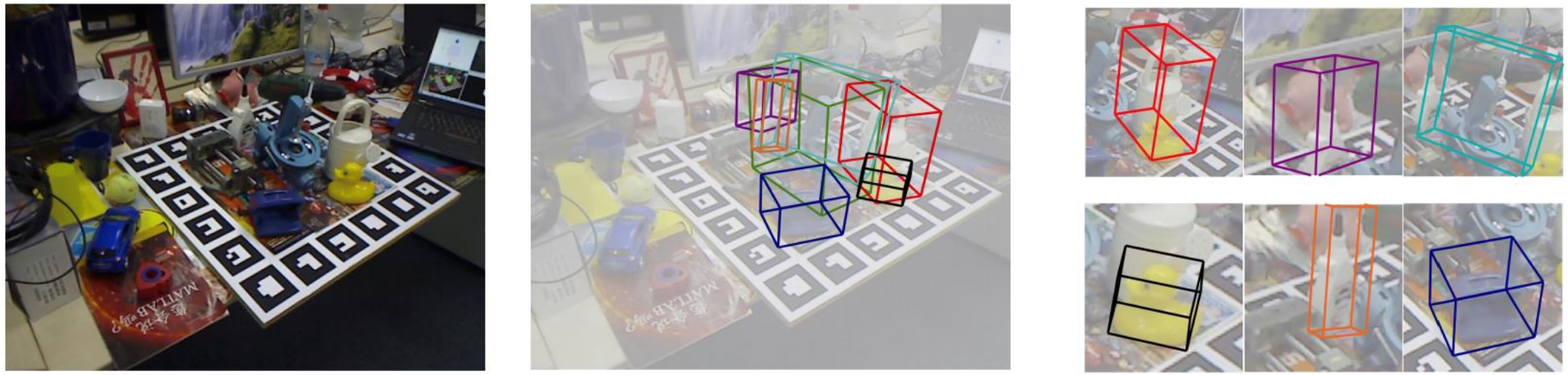
3D Hand + Object Pose



Per-frame predictions

Outline

1. Object Understanding

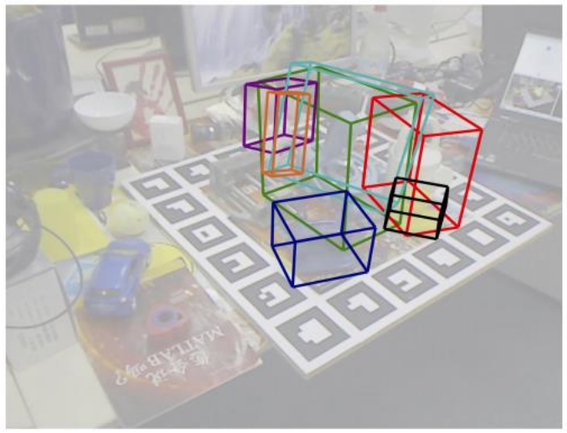


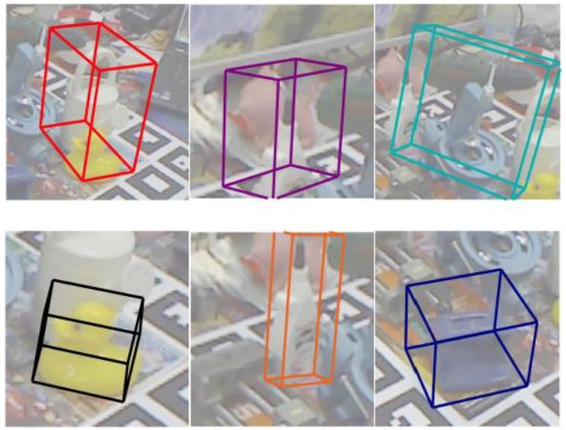
2. Hand + Object Understanding

1. B. Tekin, S. Sinha, P. Fua, “Real-time Seamless Single Shot 6D Object Pose Prediction”, **CVPR’18**
2. B. Tekin, F. Bogo, M. Pollefeys, “H+O: Unified Egocentric Recognition of 3D Hand-Object Poses and Interactions”, **CVPR’19**

Outline

1. Object Understanding





1. B. Tekin, S. Sinha, P. Fua, “Real-time Seamless Single Shot 6D Object Pose Prediction”, CVPR’18

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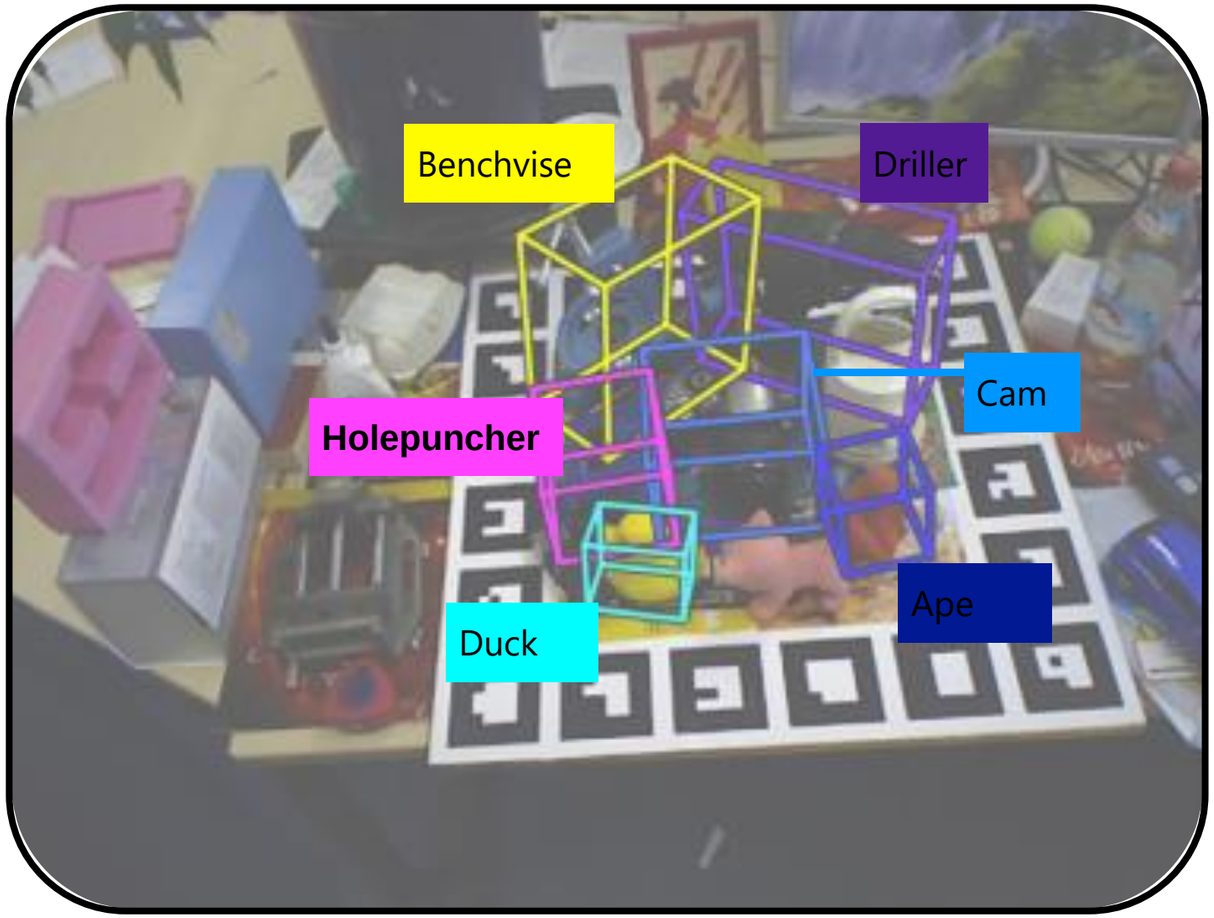
Real-time Seamless Single Shot 6D Object Pose Prediction



Buğra Tekin, Sudipta Sinha, Pascal Fua, “Real-time Seamless Single Shot 6D Object Pose Prediction”, CVPR’18

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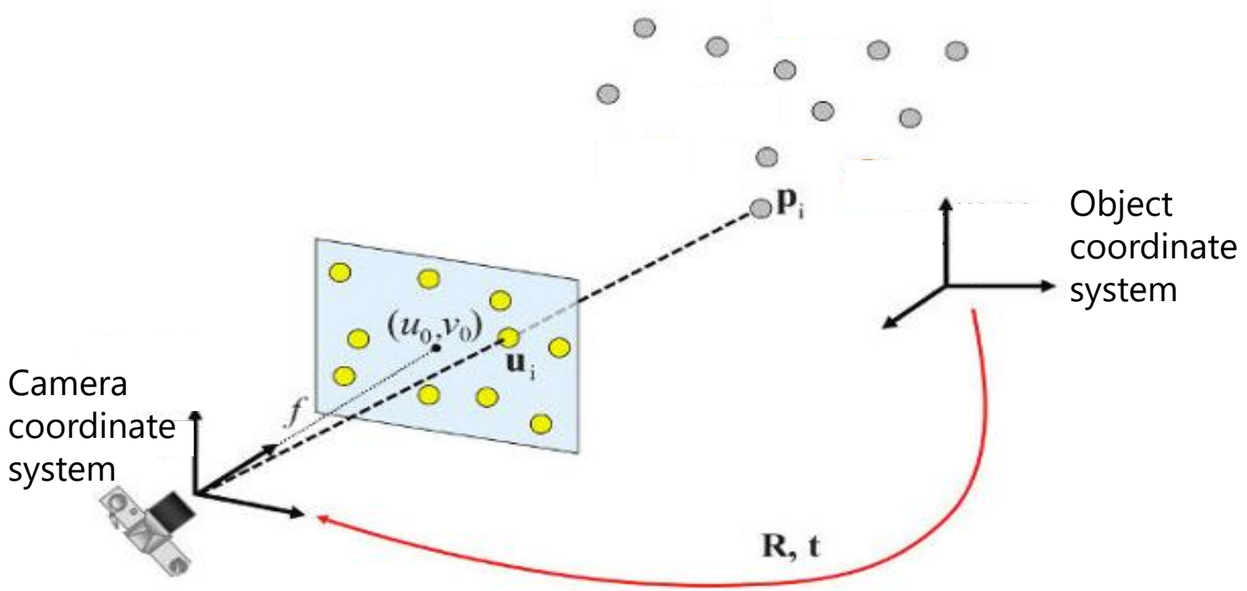
6D Object Pose Estimation

Estimating the pose (rotation and translation) of an object instance in the camera coordinate system



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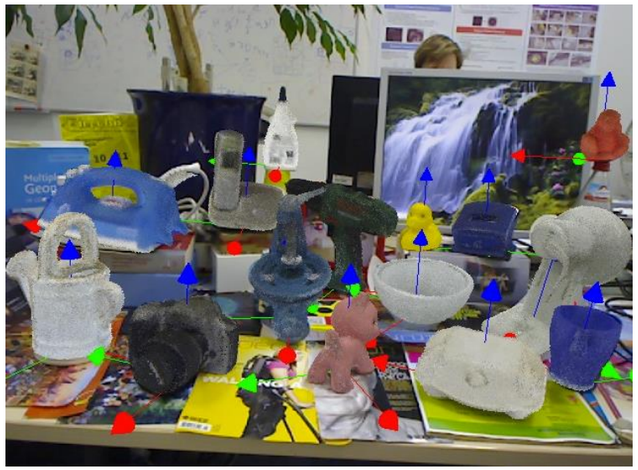
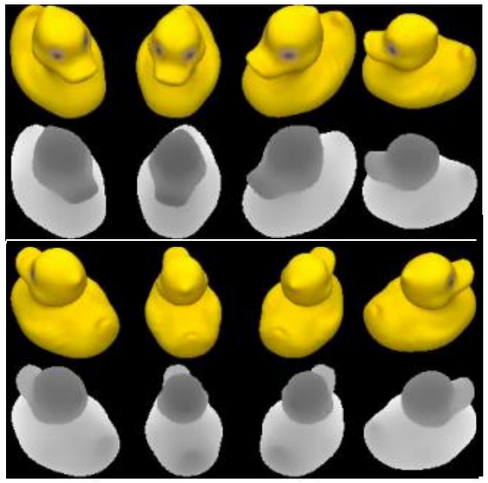
Challenges

Variation in illumination

Occlusion



Clutter



Variation in viewpoint

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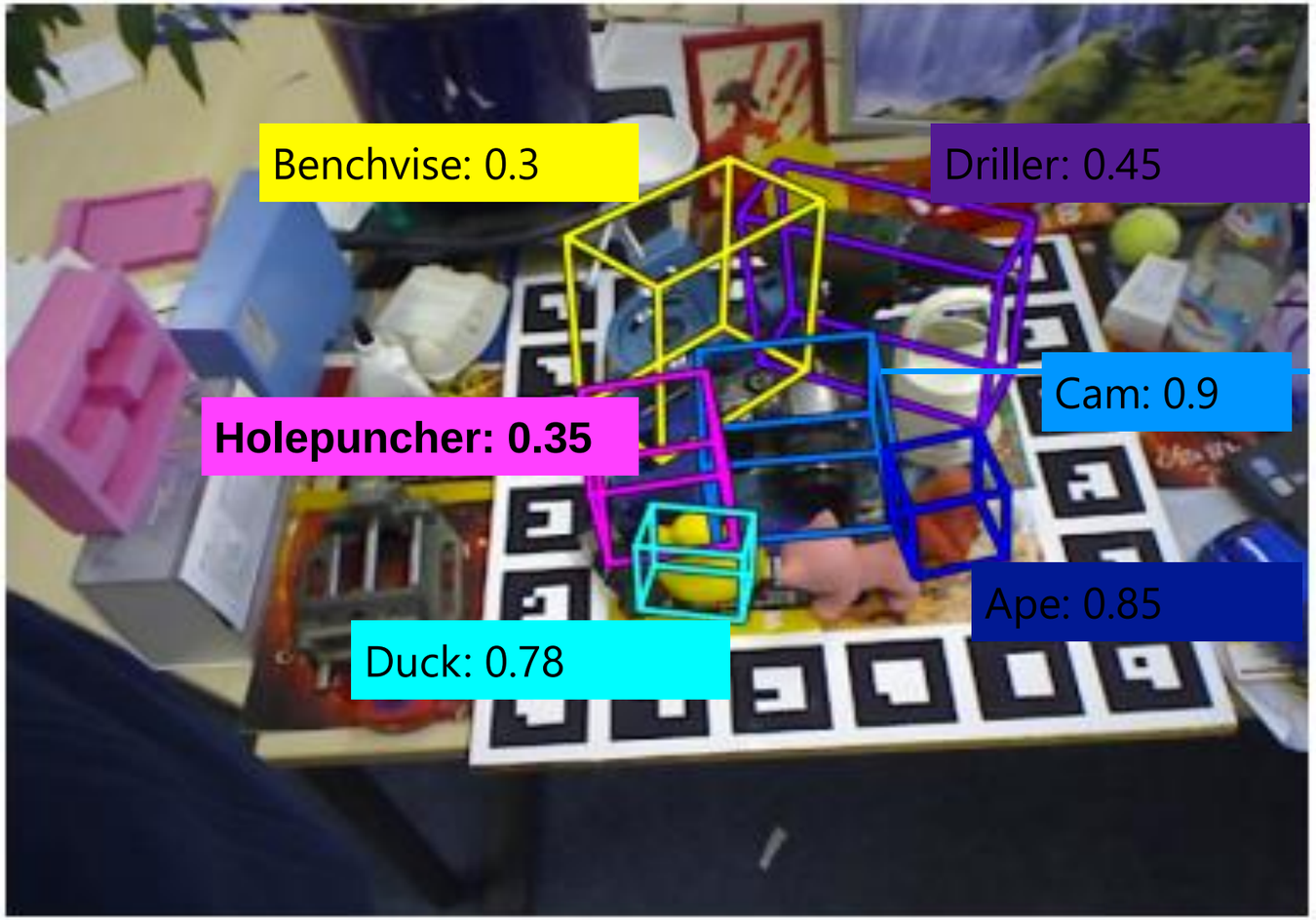
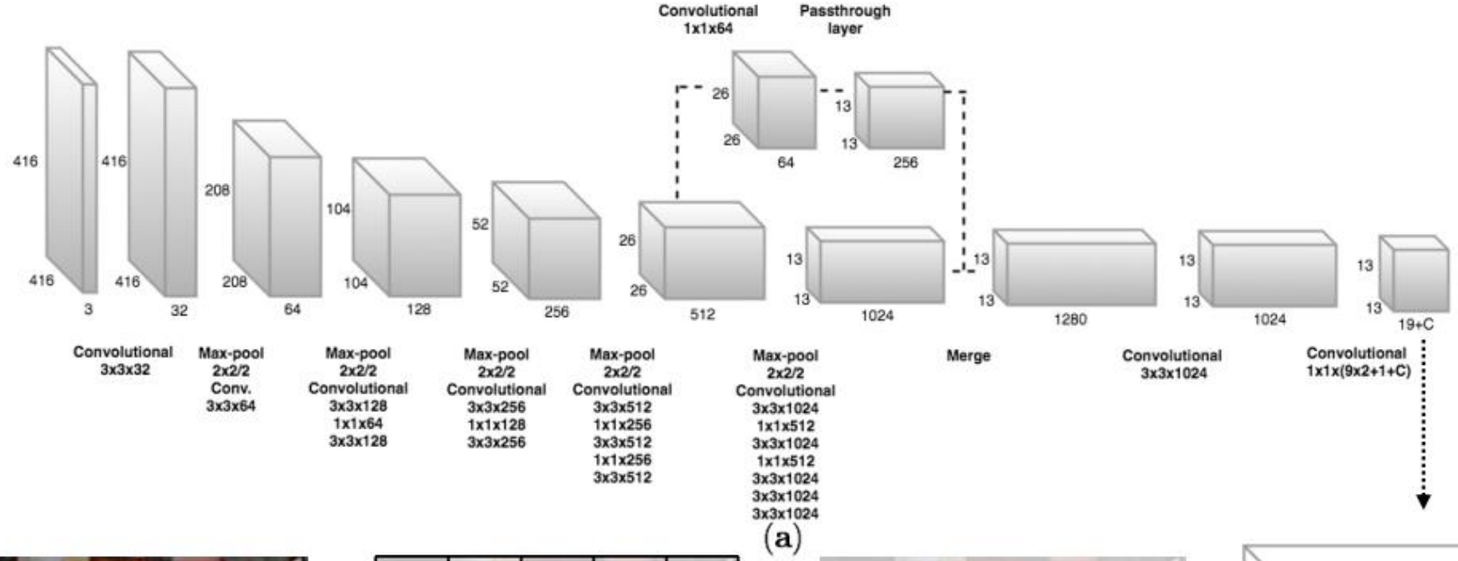
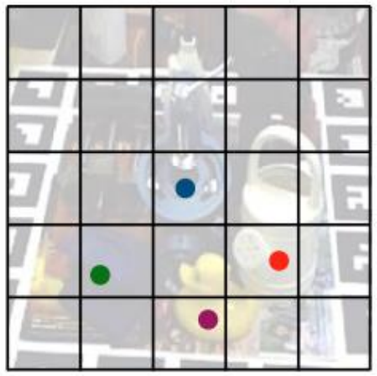
Our Goal

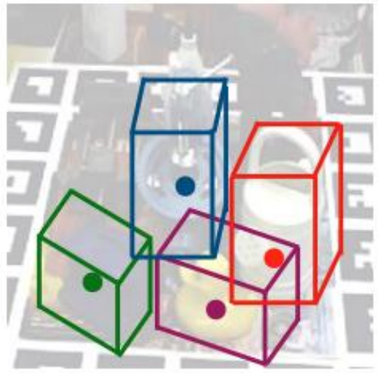


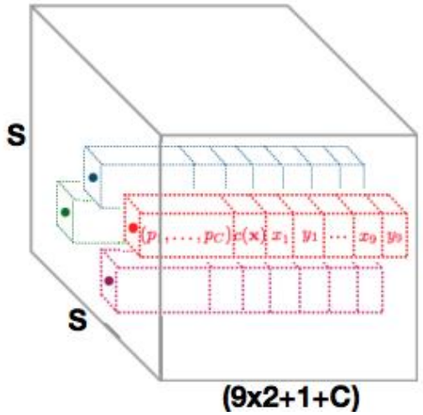
Predict the object pose, the class and the detection confidence on the full image with a CNN in a single shot

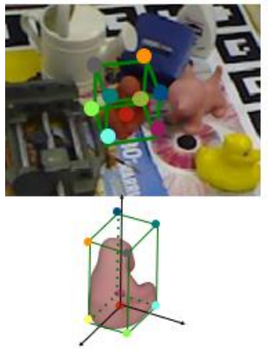
Our Approach











PNP

[R, t]

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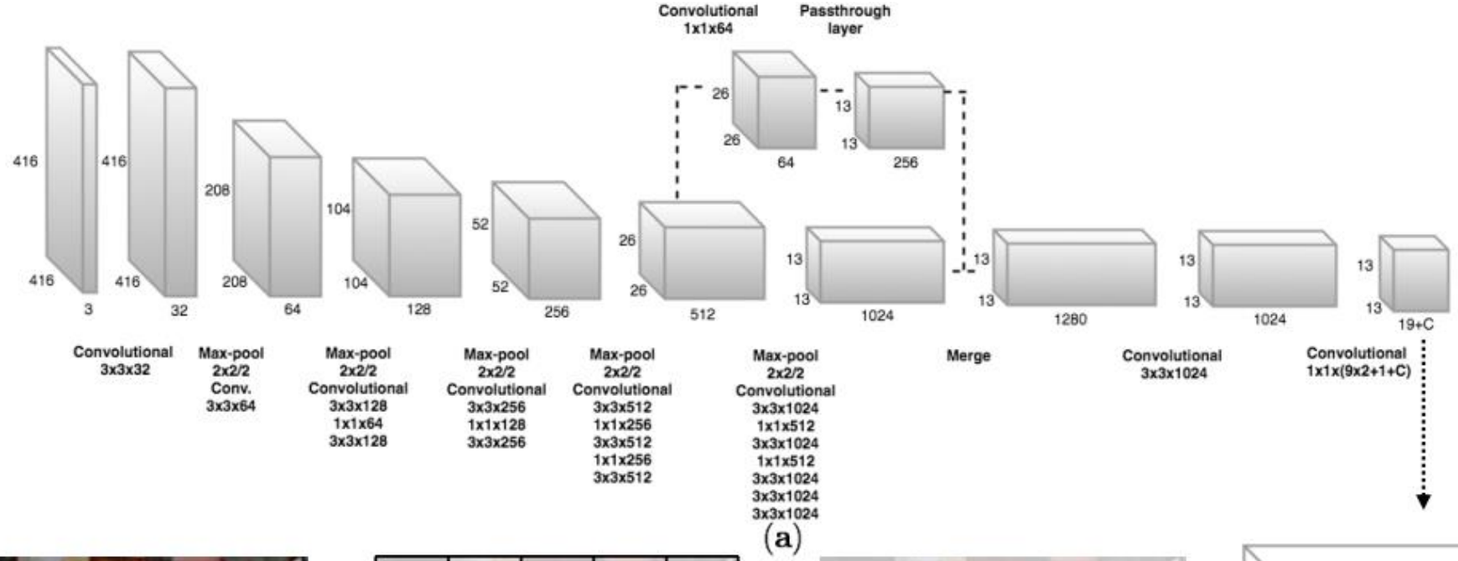
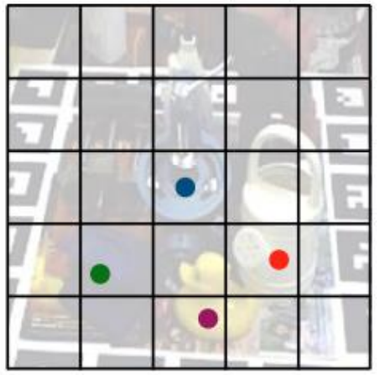
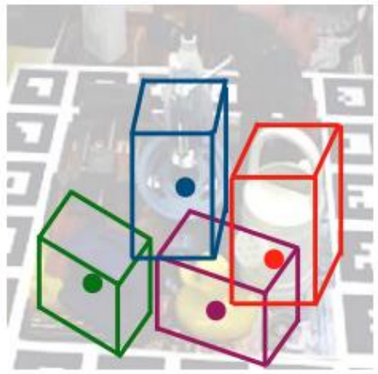
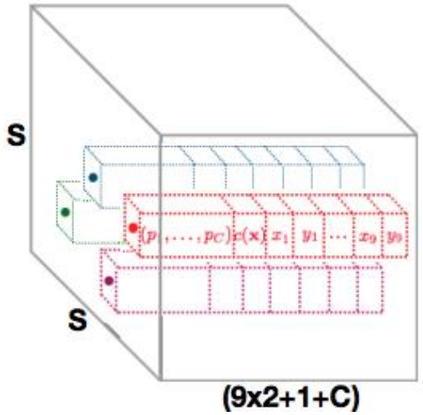
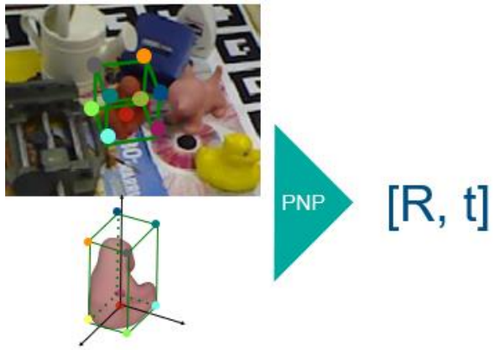
Our Approach











- Predict relative **coordinates of the 8 2D corner points**
- Also predict the **confidence and class probabilities**
- At inference time, recover the pose of the object with **PnP**

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Sequence “Ape”

Sequence “Benchvise”

Sequence “Cat”

Quantitative Results

- Evaluation metric: Percentage of correctly estimated poses

	Method	Avg PCP
w/ Refinement	Brachmann et al., CVPR'16	73.7
	Rad & Lepetit, ICCV'17	89.3
w/o Refinement	Brachmann et al., CVPR'16	69.5
	Rad & Lepetit, ICCV'17	83.9
	OURS	**90.4**

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	OURS	**90.4**

- Runtime efficiency

Method	FPS/object	Refinement runtime
Brachmann et al., CVPR'16	2 fps	100 ms/object
Rad & Lepetit, ICCV'17	3 fps	21 ms/object
Kehl et al., ICCV'17	10 fps	24 ms/object
OURS	50 fps	-

Real-time

Method	2D projection metric	Speed
416 × 416	89.71	94 fps
480 × 480	90.00	67 fps
544 × 544	90.37	50 fps
608 × 688	90.65	43 fps

94 fps speed

Quantitative Results

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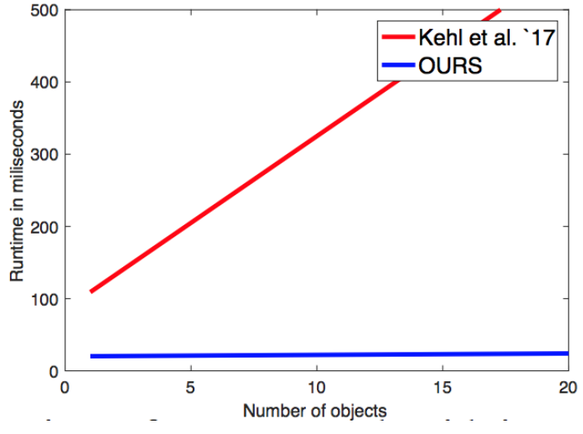
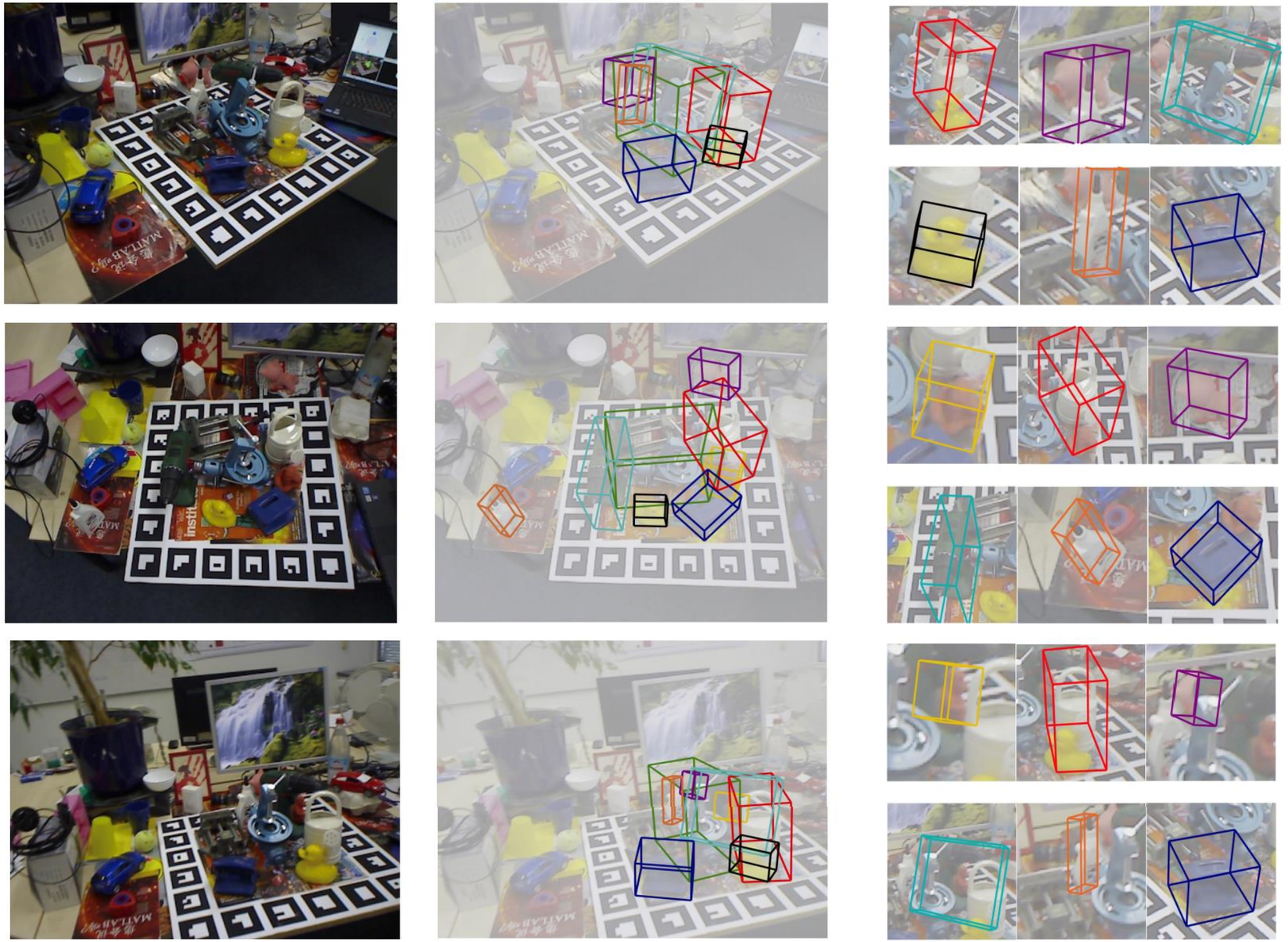


Multi-Object 6D Pose Estimation



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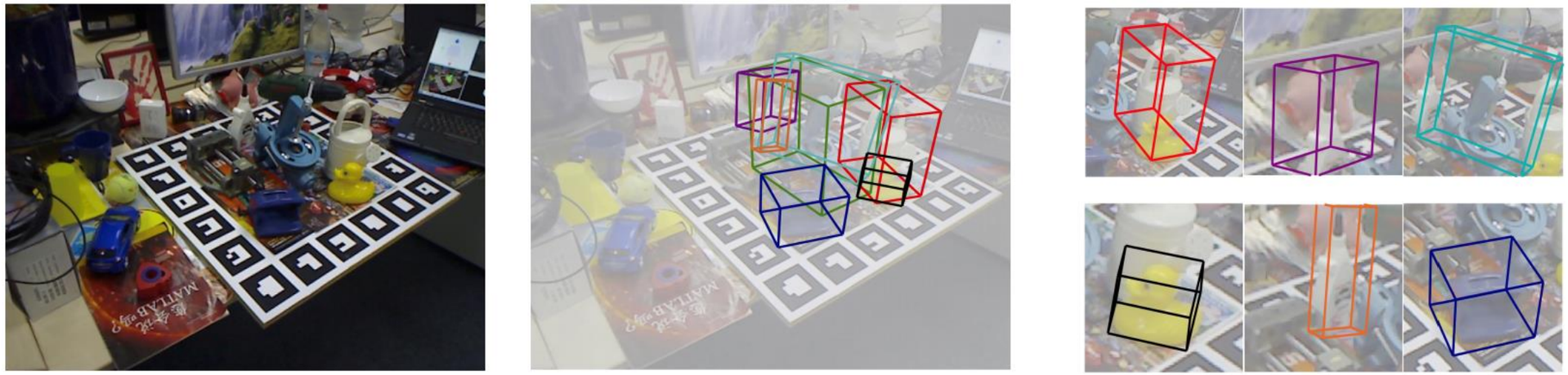

2. Hand + Object Understanding

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H+O: Unified Egocentric Recognition of 3D Hand-Object Poses and Interactions

B. Tekin, F. Bogo, M. Pollefeys, “H+O: Unified Egocentric Recognition of 3D Hand-Object Poses and Interactions”, **CVPR’19**

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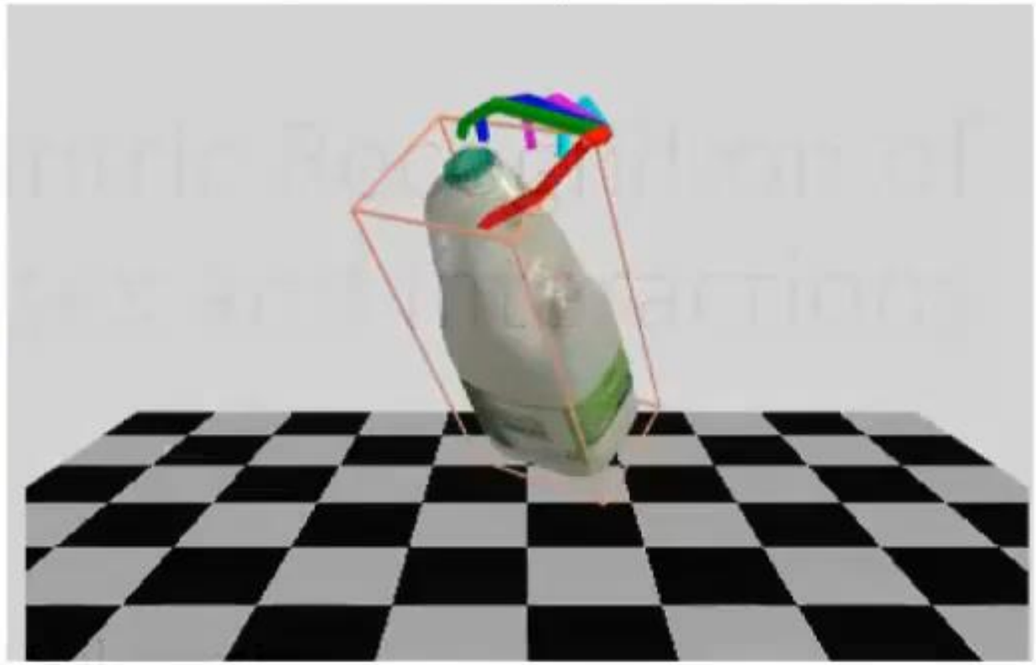
H+O

2D Hand+Object Pose

3D Hand+Object Pose



Per-frame predictions

Hand

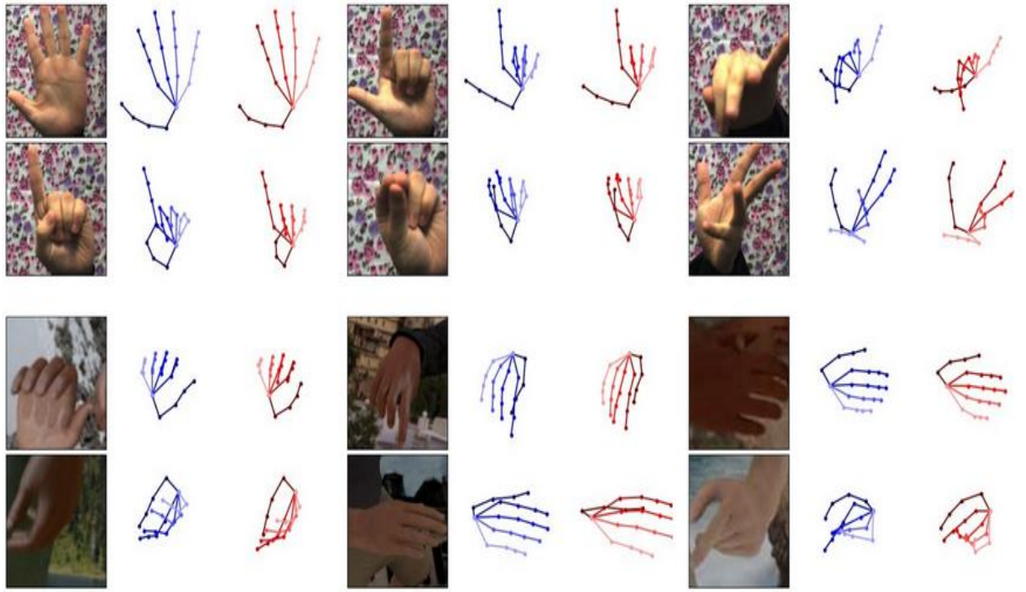
Zimmermann & Brox, ICCV’17

Müller et al., CVPR’18

Spurr et al., CVPR’18

Iqbal et al., ECCV’18

…



Object

Brachmann et al., CVPR’16

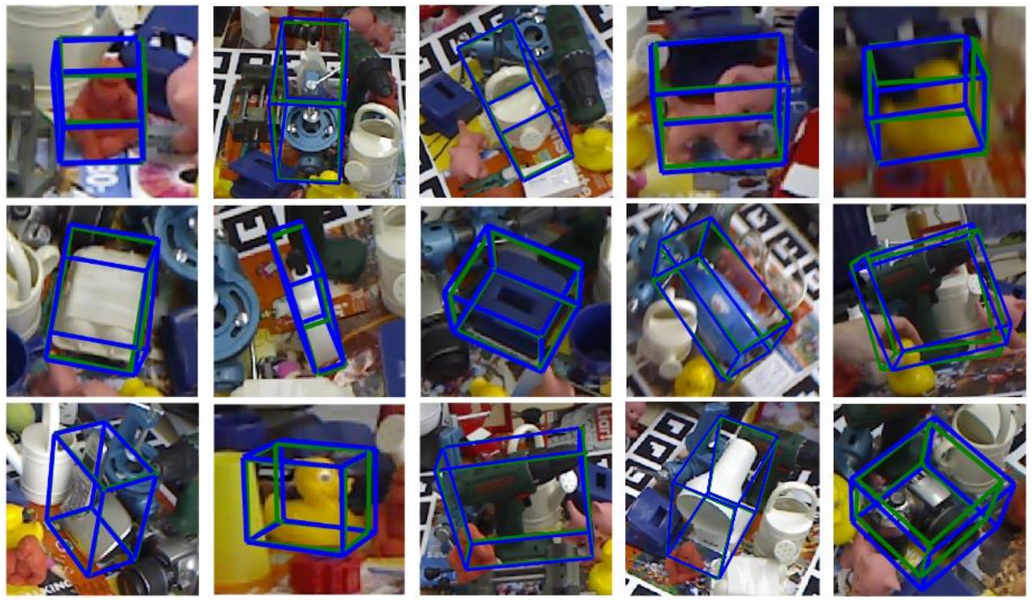
Rad & Lepetit, ICCV’17

Kehl et al., ICCV’17

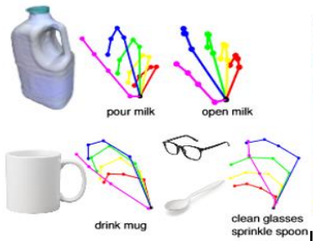
Tekin et al., CVPR’18

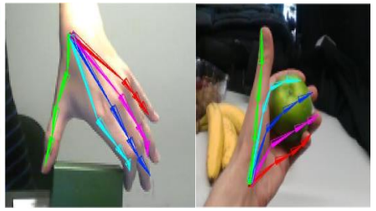
Sundermeyer et al., ECCV’18

…



Hands in Interaction with Objects

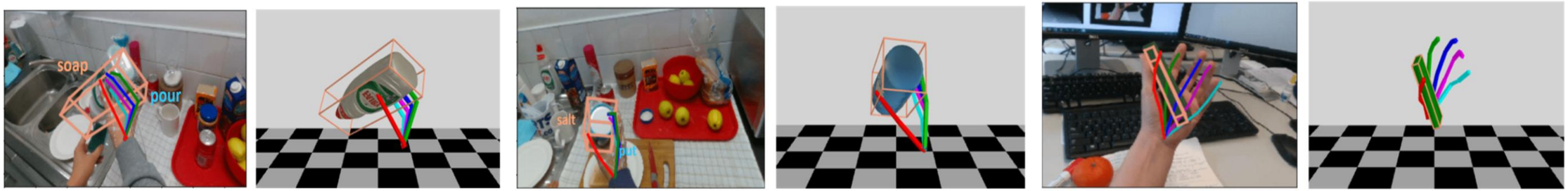




	RGB	Action Recognition	Object Pose	Hand Pose
Hamer et al., ICCV'09				●
Oikonomidis et al., ICCV'11			●	●
Sridhar et al., ECCV'16			●	●
Tzionas et al, IJCV'16			●	●
Müller et al., ICCV'17				●
Garcia-Hernando et al., CVPR'18		●		●
Hasson et al. CVPR'19	●		●	●
OURS	●	●	●	●

Microsoft

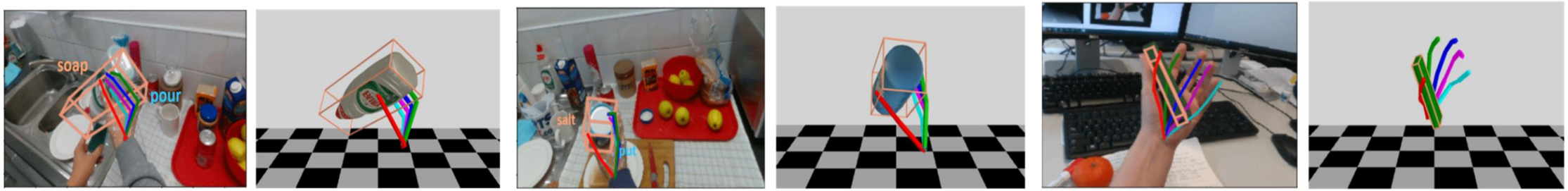
Hand+Object



1. Unified framework for recognizing 3D hand and object poses and interactions, by simultaneously solving 4 tasks

    a) 3D hand pose estimation
    b) 6D object pose estimation
    c) Object recognition
    d) Activity recognition

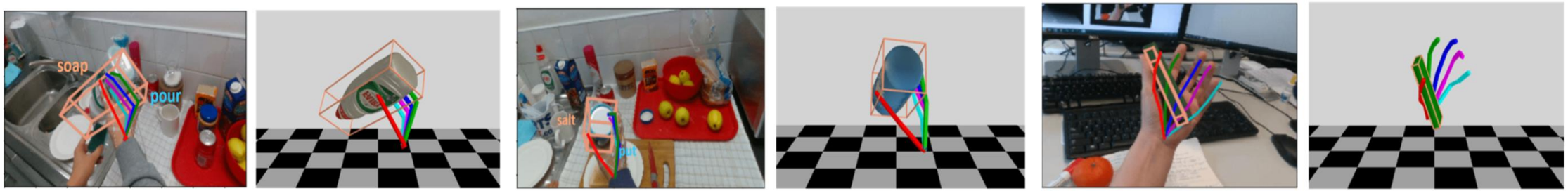
Hand+Object



1. Unified framework for recognizing 3D hand and object poses and interactions, by simultaneously solving 4 tasks

2. A single-shot deep architecture that jointly solves for articulated and rigid pose estimation

Hand+Object

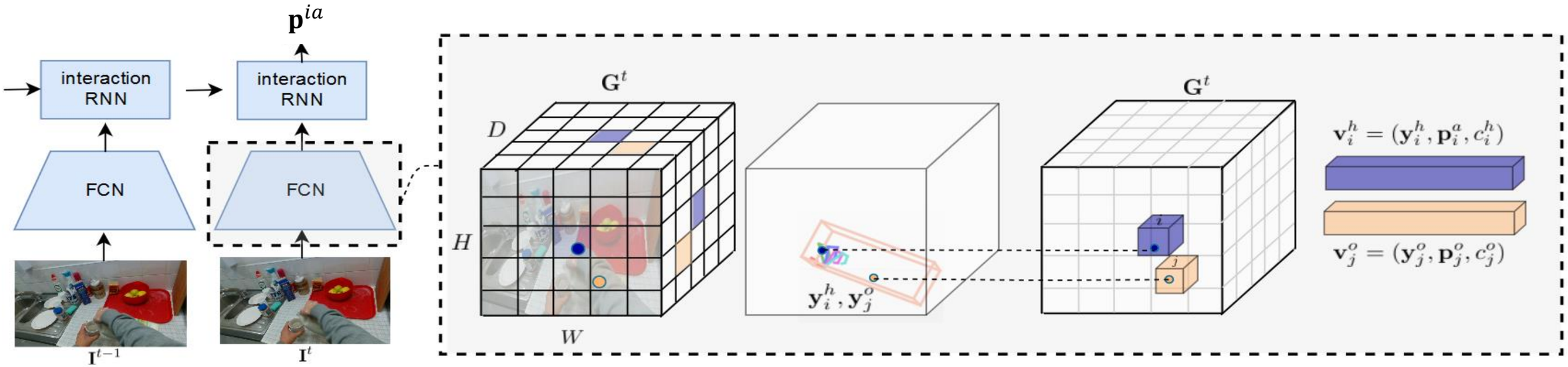


1. Unified framework for recognizing 3D hand and object poses and interactions, by simultaneously solving 4 tasks

2. A single-shot deep architecture that jointly solves for articulated and rigid pose estimation

3. A temporal model to explicitly model interactions in 3D between hands and objects

Hand+Object



Unified Egocentric Scene Understanding

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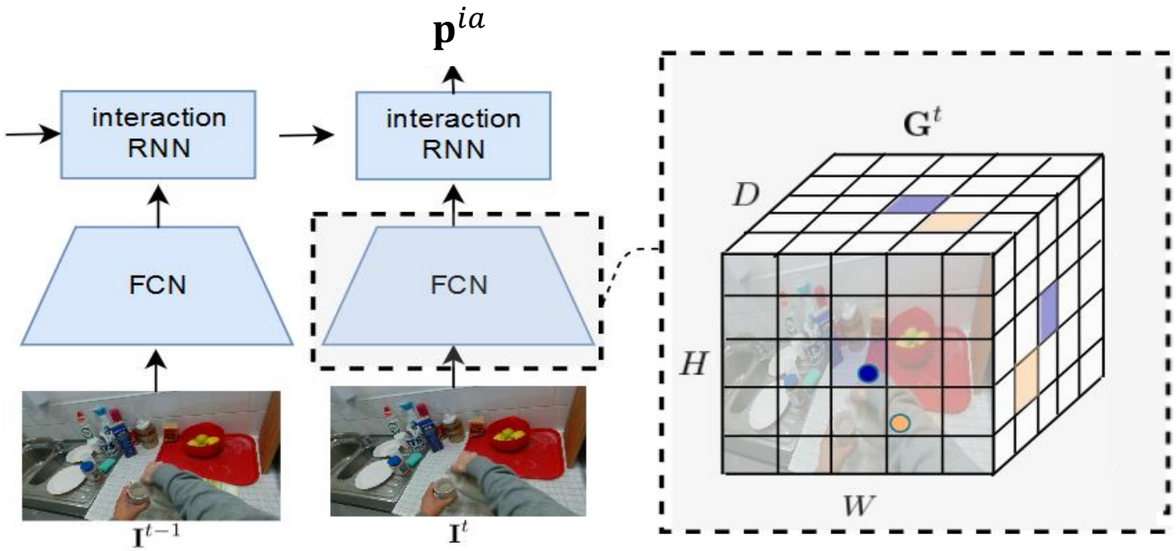
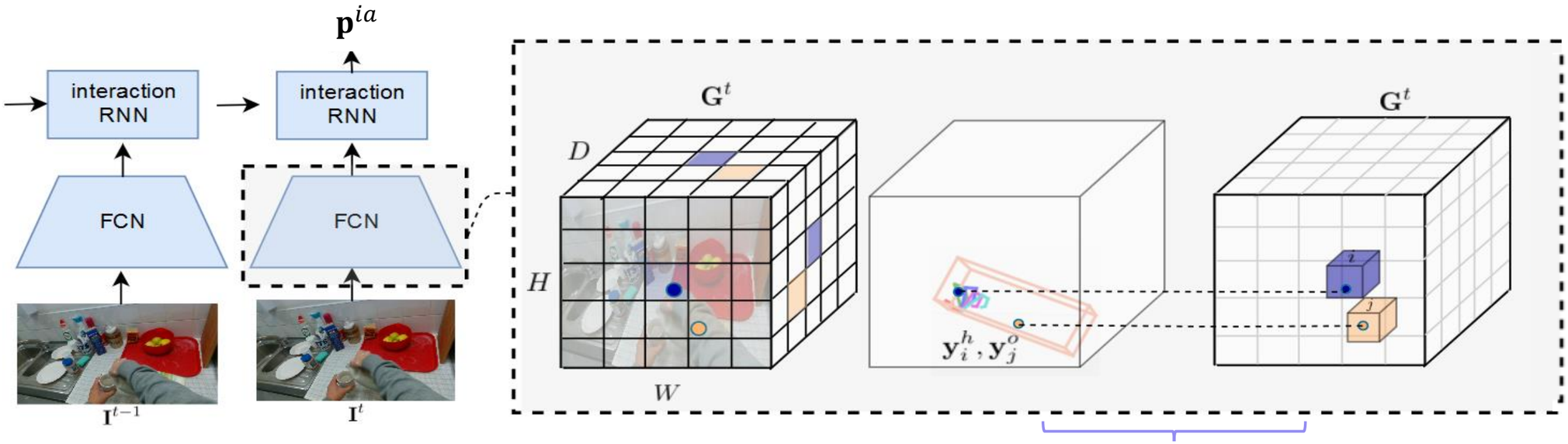
Hand+Object



store 3D locations
in a 3D grid

Hand+Object



3D hand skeleton
and 3D object BB
at the corresponding cell

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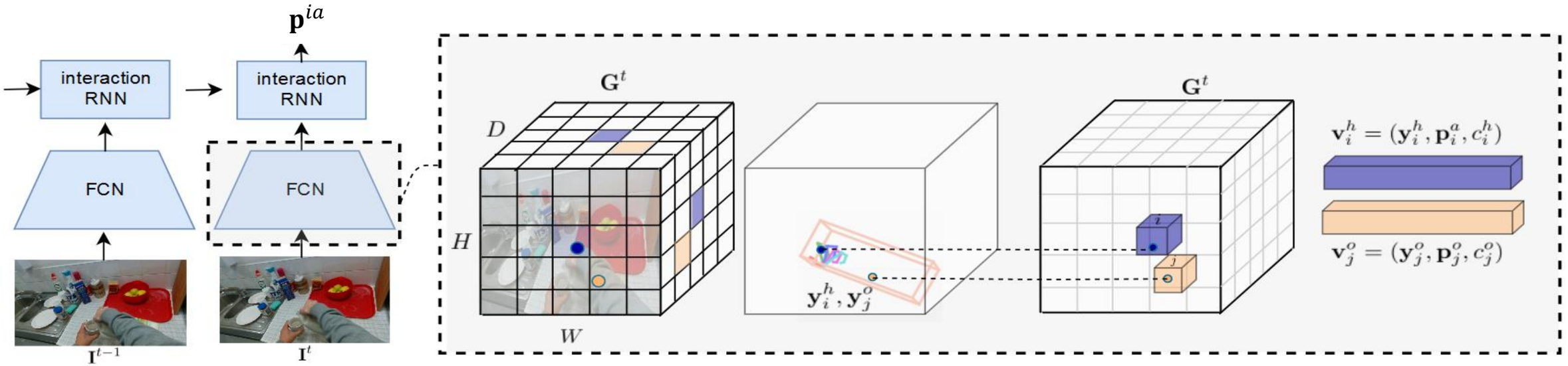
Hand+Object



encode 3D poses,
estimation confidence,
object and activity classes

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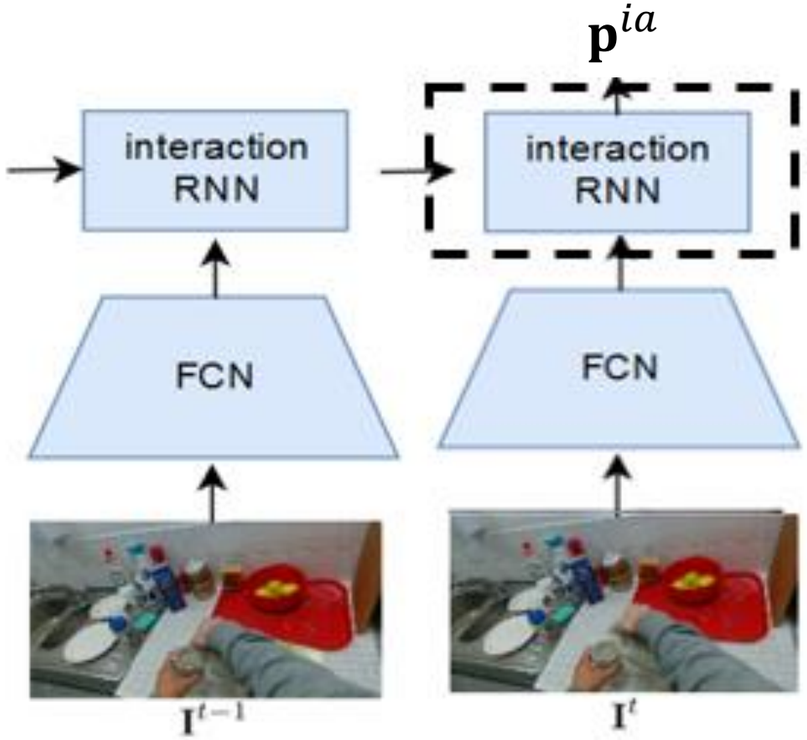
Hand+Object



$f_\phi(g_\theta(\hat{\boldsymbol{y}}^h, \hat{\boldsymbol{y}}^o))$

explicitly model hand-object interactions, directly in 3D

Santoro et al., "A simple neural network module for relational reasoning", NIPS'17.

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Ablation Studies

Method	Model	Action Accuracy (%)
Hernando et al., CVPR'18	Ground-truth Hand Pose	87.45
	Ground-truth Object Pose	74.45
	Ground-truth Hand + Object Pose	91.97
OURS	SINGLE-IMAGE	85.56
	HAND POSE	89.47
	OBJECT POSE	85.71
	HAND + OBJECT POSE	94.73
	HAND + OBJECT POSE + INTERACT	**96.99**

← Jointly using hand and object poses improves activity recognition

Ablation Studies

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	OBJECT POSE	85.71
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	HAND + OBJECT POSE + INTERACT	**96.99**

Network	HP error	OP error
HAND ONLY	16.15	-
OBJECT ONLY	-	28.27
HAND + OBJECT	16.87	25.54
HAND + OBJECT + INTERACT	**15.81**	**24.89**

← Unified framework yields better accuracy than task-dedicated individual networks

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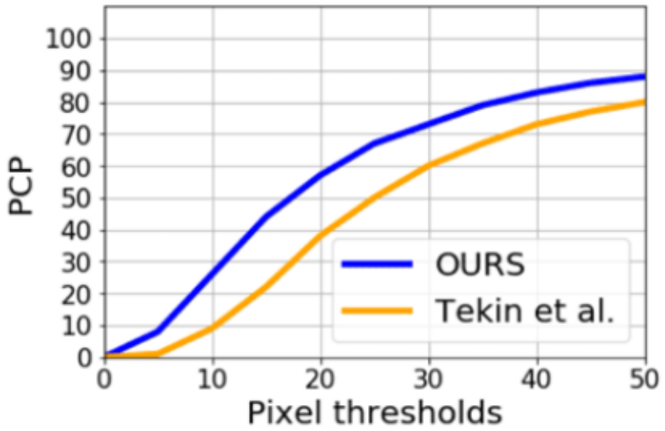
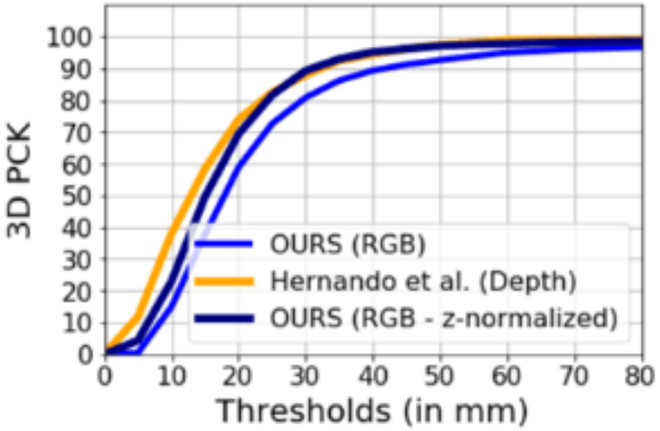
State-of-the-Art Comparison

Model	Input modality	Accuracy
Two-stream-color	Color	61.56
Two-stream-flow	Color	69.91
Two-stream-all	Color	75.30
Joule-color	Color	66.78
HON4D	Depth	70.61
Novel View	Depth	69.21
Joule-depth	Depth	60.17
GT-Pose + Gram Matrix	Depth	32.22
GT-Pose + Lie Group	Depth	69.22
GT-Pose + LSTM	Depth	72.06
OURS - HP	Color	62.54
OURS - HP + AC	Color	74.20
OURS - HP + AC + OC	Color	**82.43**

Activity Recognition



Object pose estimation



Hand pose estimation

FPHA dataset

Garcia-Hernando et al., "First-Person Hand Action Benchmark with RGB-D Videos and 3D Hand Pose Annotations", CVPR'18.

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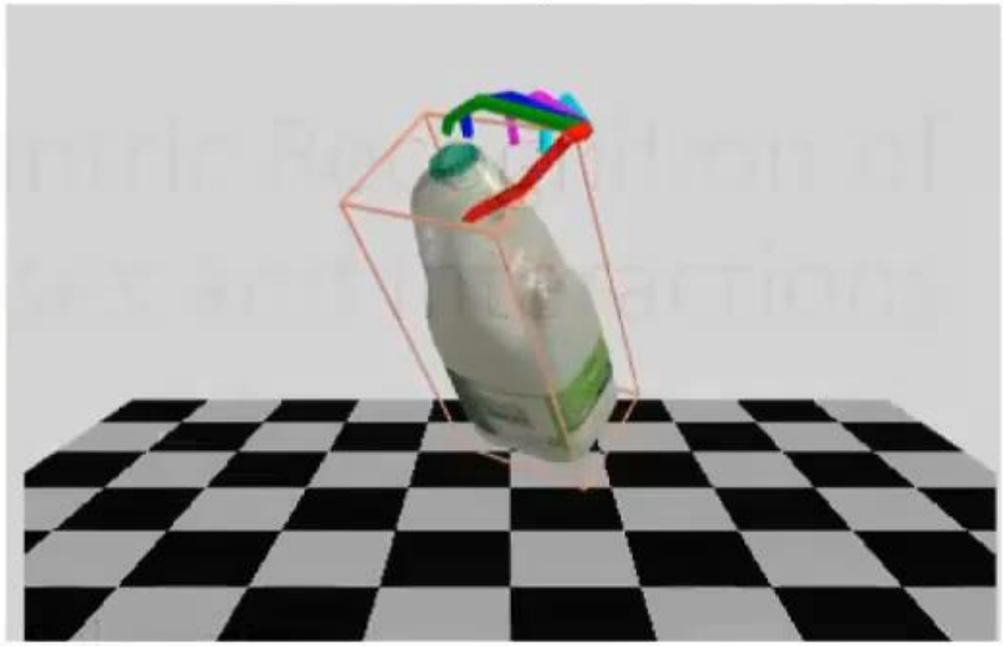
Thanks!

2D Hand + Object Pose

3D Hand + Object Pose



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