On Object Symmetries and 6D Pose Estimation from Images

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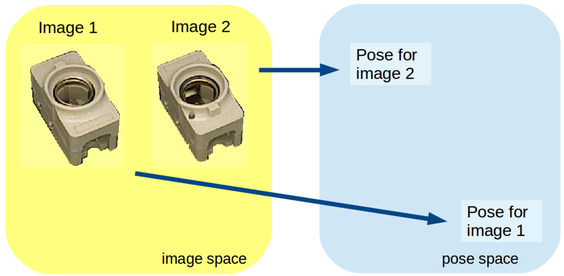
Abstract

In this work we explain why symmetrical objects can be a challenge when training machine learning algorithms that aim at estimating their 6D pose from images. We propose an efficient and simple solution that relies on a normalization of the pose rotation. This approach is general and can be used with any 6D pose estimation algorithm.

Motivation

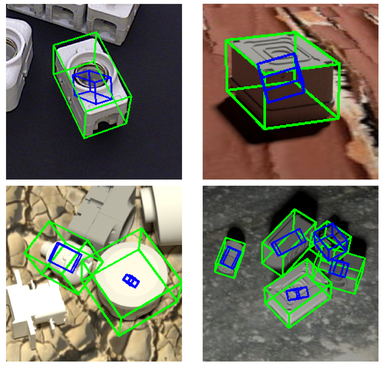
Regress the pose estimation function $f : \boldsymbol{Image} \mapsto \boldsymbol{Pose}$



Definition: Two rotations R_1 and R_2 of an object O are **ambiguous** ($R_1 \sim R_2$) if they result in the same object appearance under a rendering $\mathcal{R}$:

$$R_1 \sim R_2 \Leftrightarrow \mathcal{R}(O, [R_1, T_1]) = \mathcal{R}(O, [R_2, T_2]) \quad (1)$$

Problem: f cannot be learned for **symmetrical objects**, as it is **not** a 1-1 mapping for ambiguous poses.



Method

Mapping Ambiguous Rotations

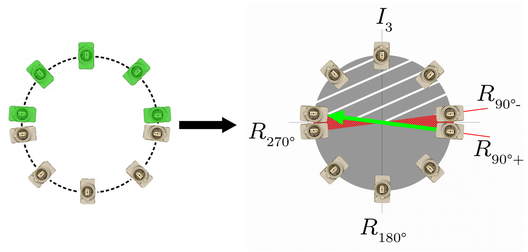
- **Objective:** Mapping all ambiguous rotations to a canonical one.
- **Solution:** Introduce mapping Map such that:

$$\text{Map}(R) = \hat{S}^{-1} R\,, \quad \forall R \in \text{SO}(3), \quad (2)$$

$$\hat{S} = \underset{S \in \mathcal{M}(O)}{\arg\min} \|S^{-1} R - I_3\|_F\,, \quad (3)$$

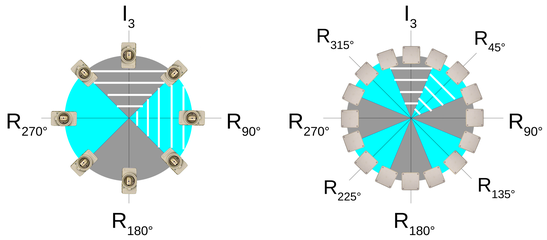
$$R_1 \sim R_2 \Leftrightarrow \text{Map}(R_1) = \text{Map}(R_1) \quad (4)$$

- **New problem:** Mapped pose discontinuities due to ambiguity



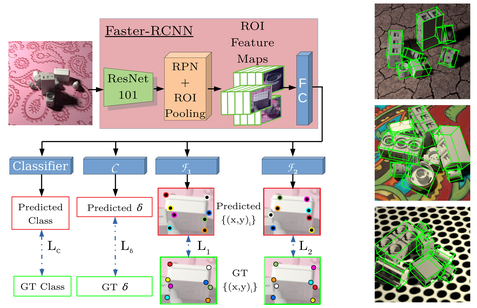
Solving Pose Discontinuities

- **Solution:** Split the pose space into **unambiguous** subspaces with dedicated pose regressors

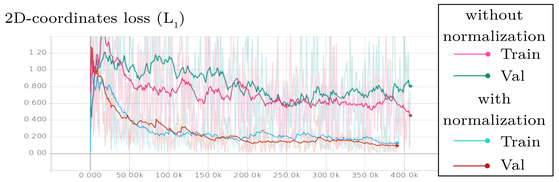


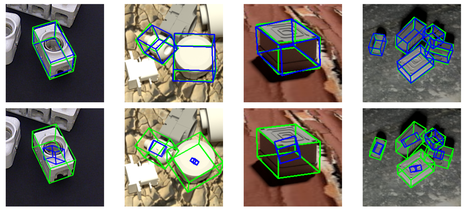
Implementation

- Prediction of the objects' 6D poses via localization of 2D reprojections of 3D bounding box corners
- Integration of our approach into Faster R-CNN, adding one regressor branch per regression subspace
- Generated SyntheT-Less, a 30K samples synthetic dataset with annotated depth, normals, edges, instance/semantic segmentation masks, 3D pose

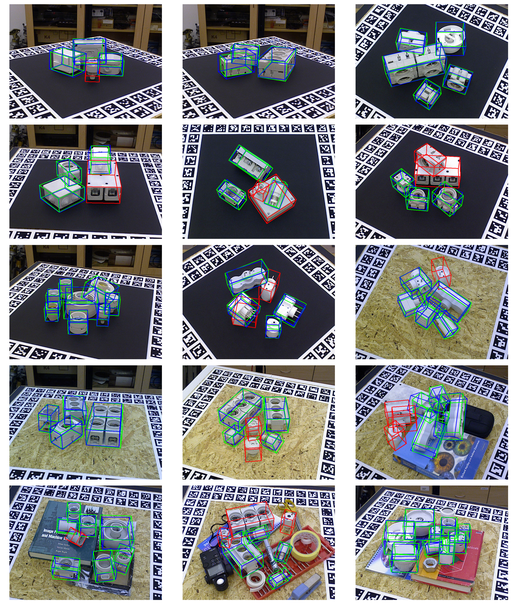


Effectiveness of our approach





Qualitative results



Conclusion

We propose a simple method to solve the problems that arise when training a machine learning method to predict the 6D pose of an object with symmetries. Our method is agnostic to the exact pose representation and the pose prediction model.

References

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Acknowledgements

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