Object Modeling and Grasping Pipeline based on Superquadric Models

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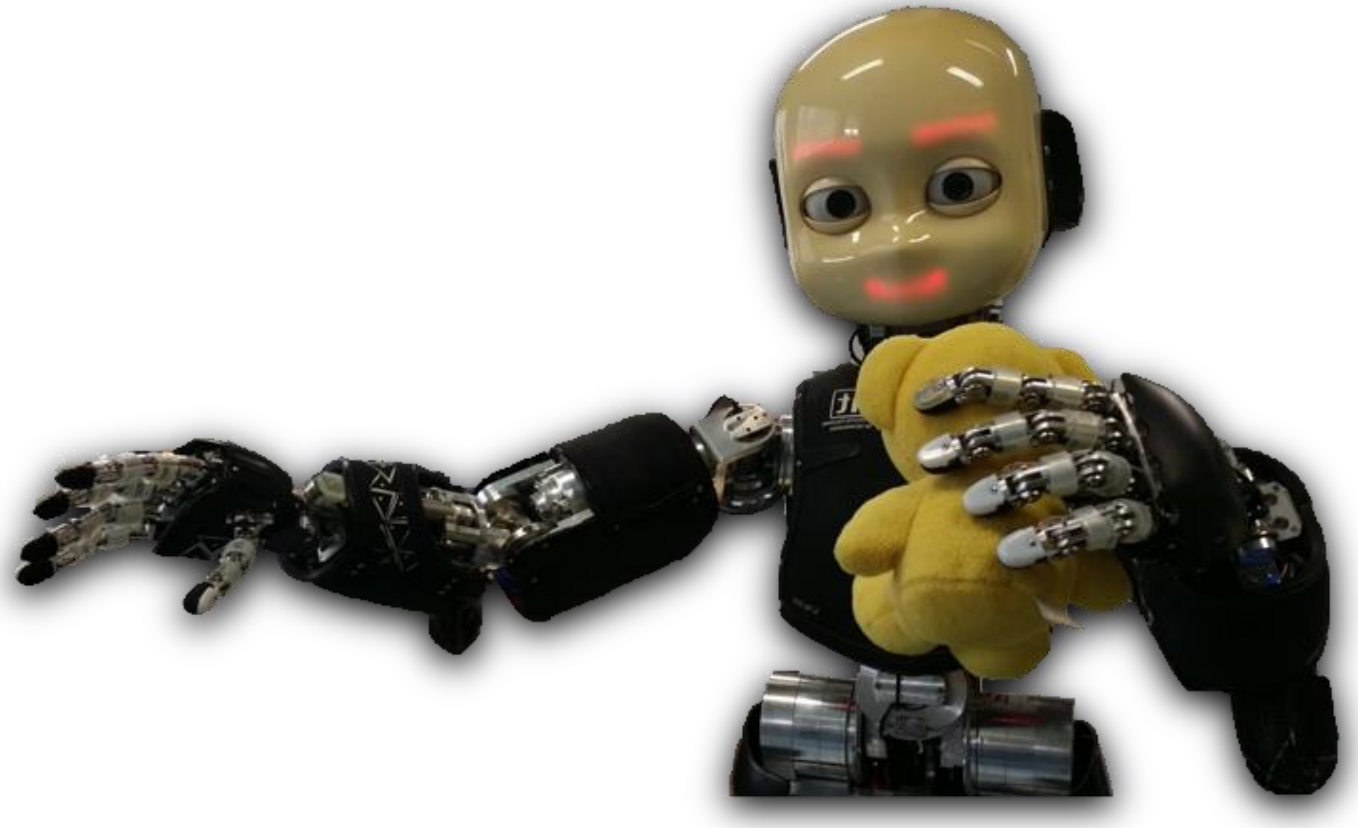
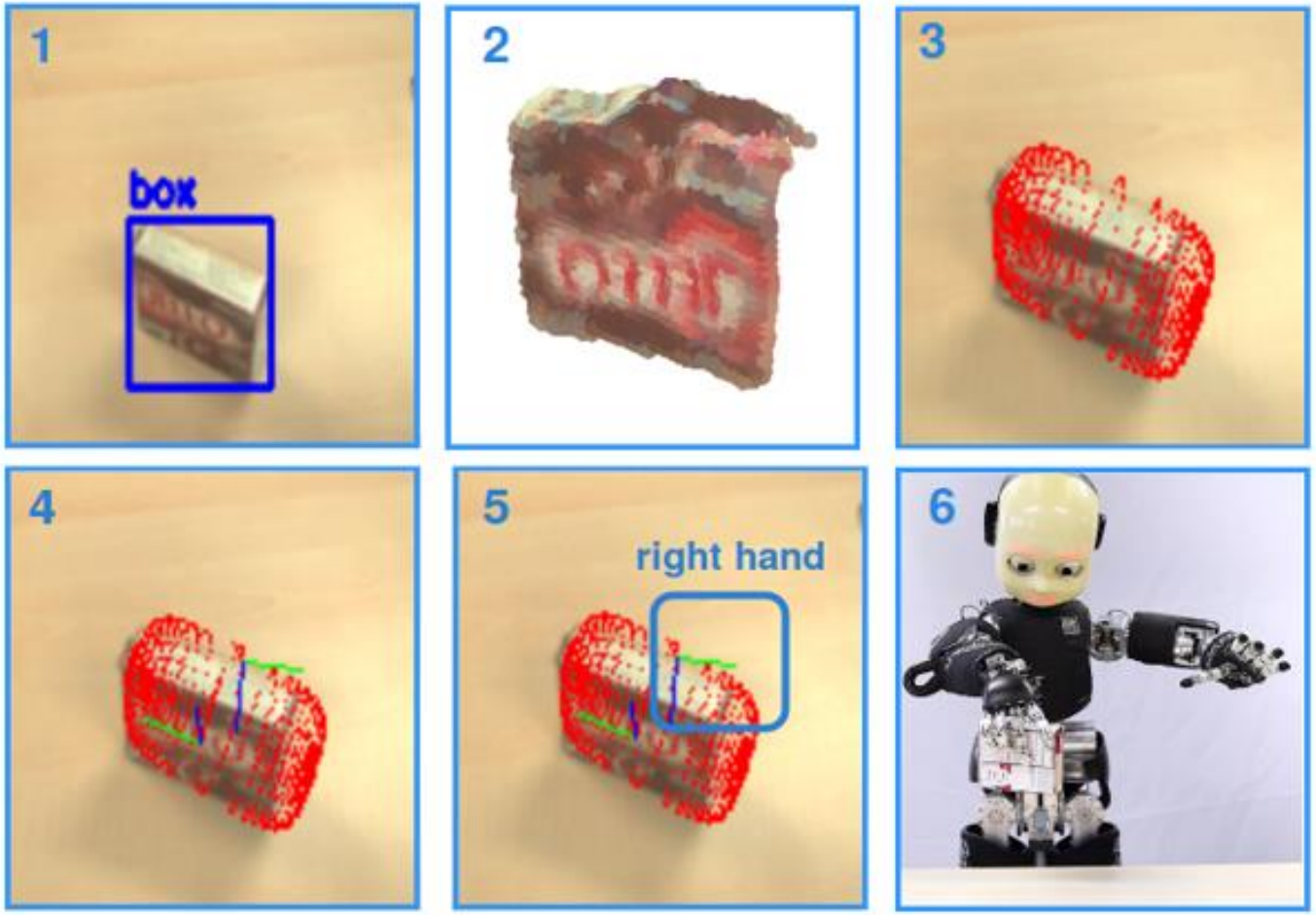


Pipeline overview

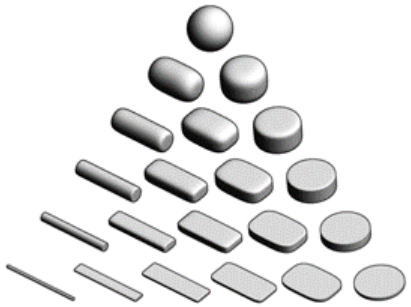


1. Object classification
2. Point cloud extraction
3. Object modeling
4. Grasping pose computation
5. Best hand selection
6. Object grasping

Superquadric Modeling and Grasping [ICRA2017]

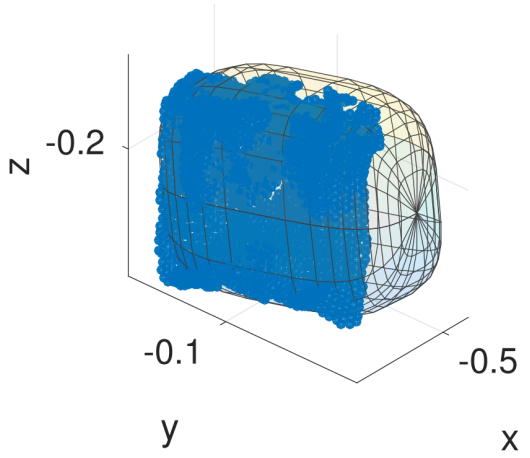
Superquadric function

$$F(x,y,z,\boldsymbol{\lambda}) = \left(\left(\frac{x}{\lambda_1} \right)^{\frac{2}{\lambda_5}} + \left(\frac{y}{\lambda_2} \right)^{\frac{2}{\lambda_5}} \right)^{\frac{\lambda_5}{\lambda_4}} + \left(\frac{z}{\lambda_3} \right)^{\frac{2}{\lambda_4}}$$



Superquadric estimation

$$\min_{\boldsymbol{\lambda}} \sum_{i=1}^{N} \left(\sqrt{\lambda_1 \lambda_2 \lambda_3} \left(F(\boldsymbol{s}_i, \boldsymbol{\lambda}) - 1 \right) \right)^2,$$

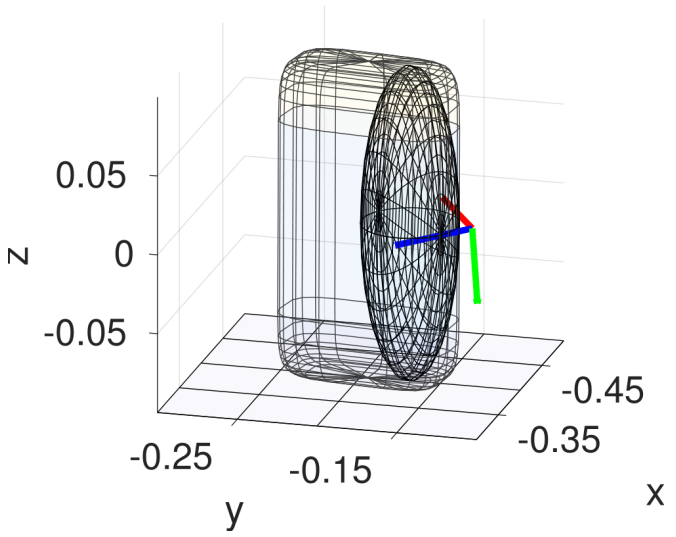


$$\min_{\boldsymbol{x}} \sum_{i=1}^{L} \left(\sqrt{\lambda_1 \lambda_2 \lambda_3} \left(F(\boldsymbol{p}_i^{\boldsymbol{x}}, \boldsymbol{\lambda}) - 1 \right) \right)^2,$$

subject to:

$$h(\boldsymbol{a}, f(\boldsymbol{p}_1^{\boldsymbol{x}}, \ldots, \boldsymbol{p}_L^{\boldsymbol{x}})) > 0.$$

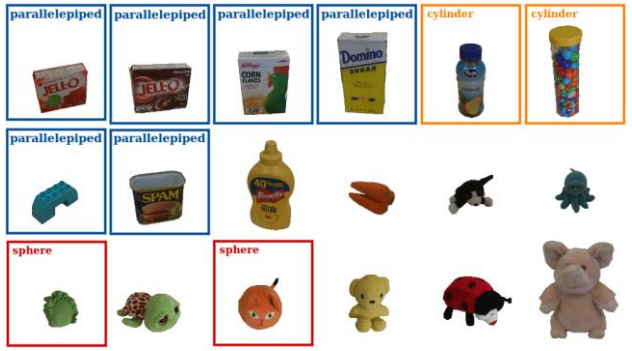
$$a\, \bar{p}_{x_p}^{\boldsymbol{x}} + b\, \bar{p}_{y_p}^{\boldsymbol{x}} + c\, \bar{p}_{z_p}^{\boldsymbol{x}} + d > 0,$$
$$\text{with } (\bar{p}_{x_p}^{\boldsymbol{x}}, \bar{p}_{y_p}^{\boldsymbol{x}}, \bar{p}_{z_p}^{\boldsymbol{x}}) = \arg\min_{p_{z_p,i}^{\boldsymbol{x}}} \boldsymbol{p}_{i,p}^{\boldsymbol{x}}.$$



Novel pipeline: modeling with prior on object shape

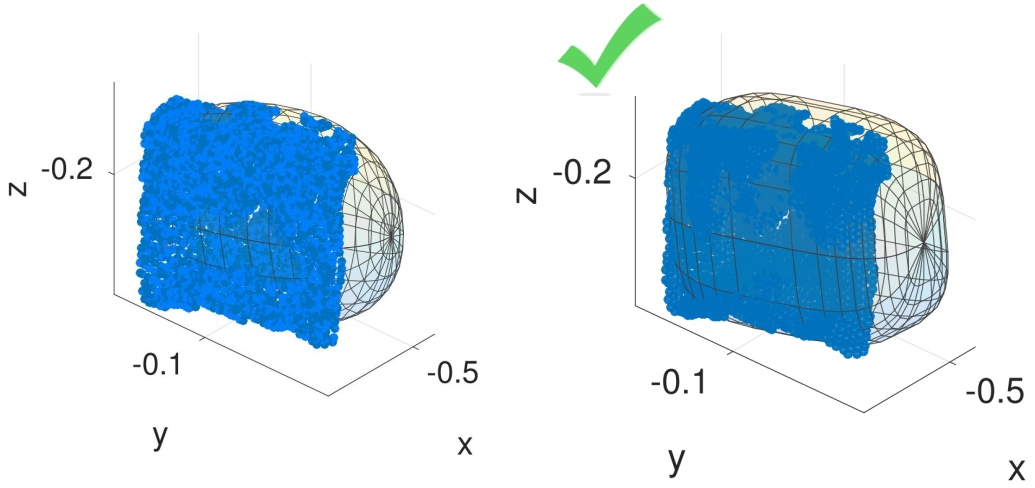
- Object classification: cylinder, sphere, box

Training set: 30 objects

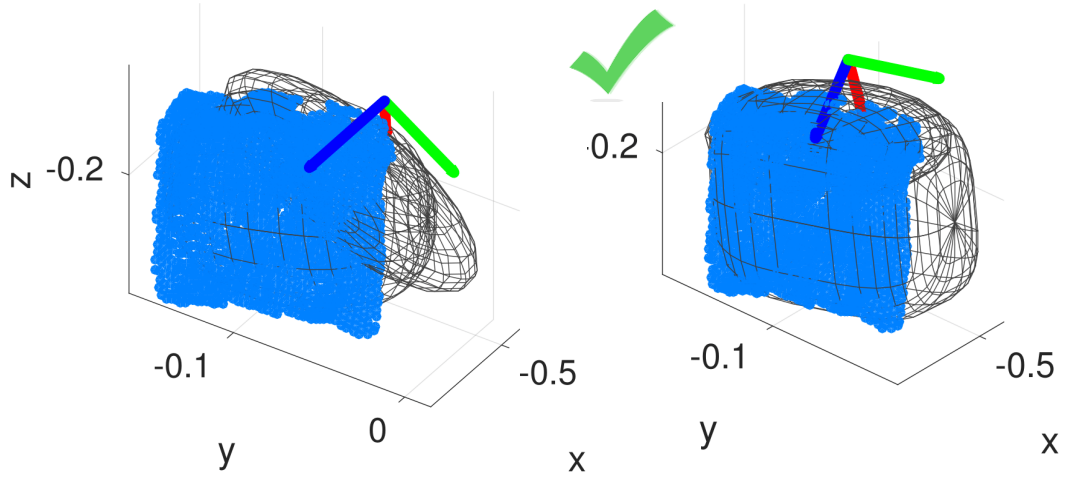


Test set: 18 objects (YCB & iCubWorld)

- Sharp cornered shapes lead to better grasping poses



Models

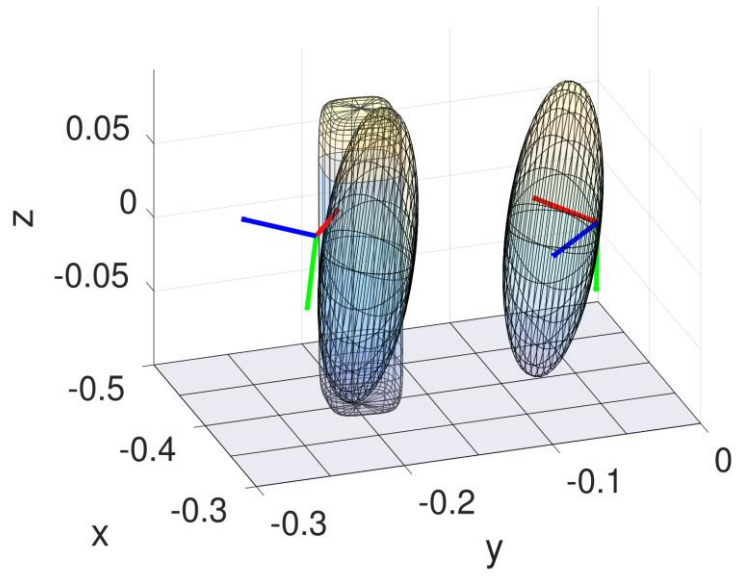


Poses

Novel pipeline: automatic hand selection

$$\mathcal{I}_{P,hand} = w_1 F_{f,hand} + w_2 \left(z_{hand} \cdot z_{root}\right)$$

Overlapping between object and hand model



To favour top and lateral grasps