Localizing Grasp Affordances in 3-D Points Clouds Using Taubin Quadric Fitting

Andreas ten Pas and Robert Platt

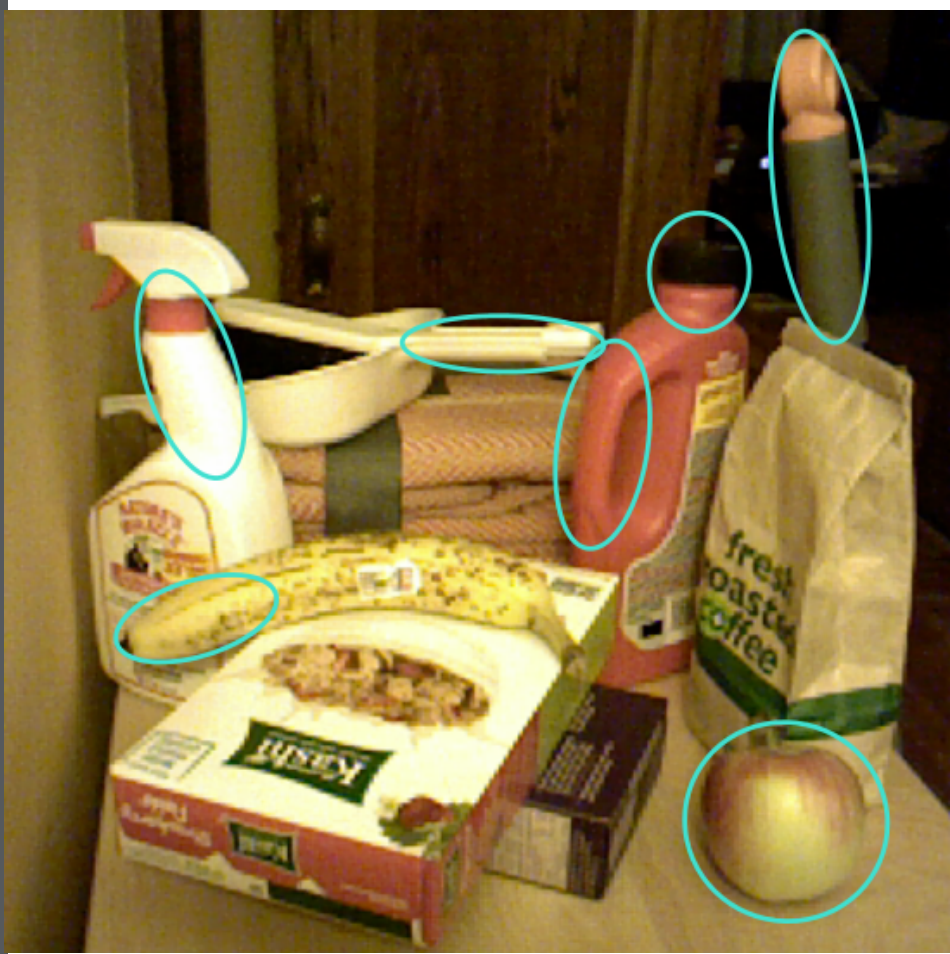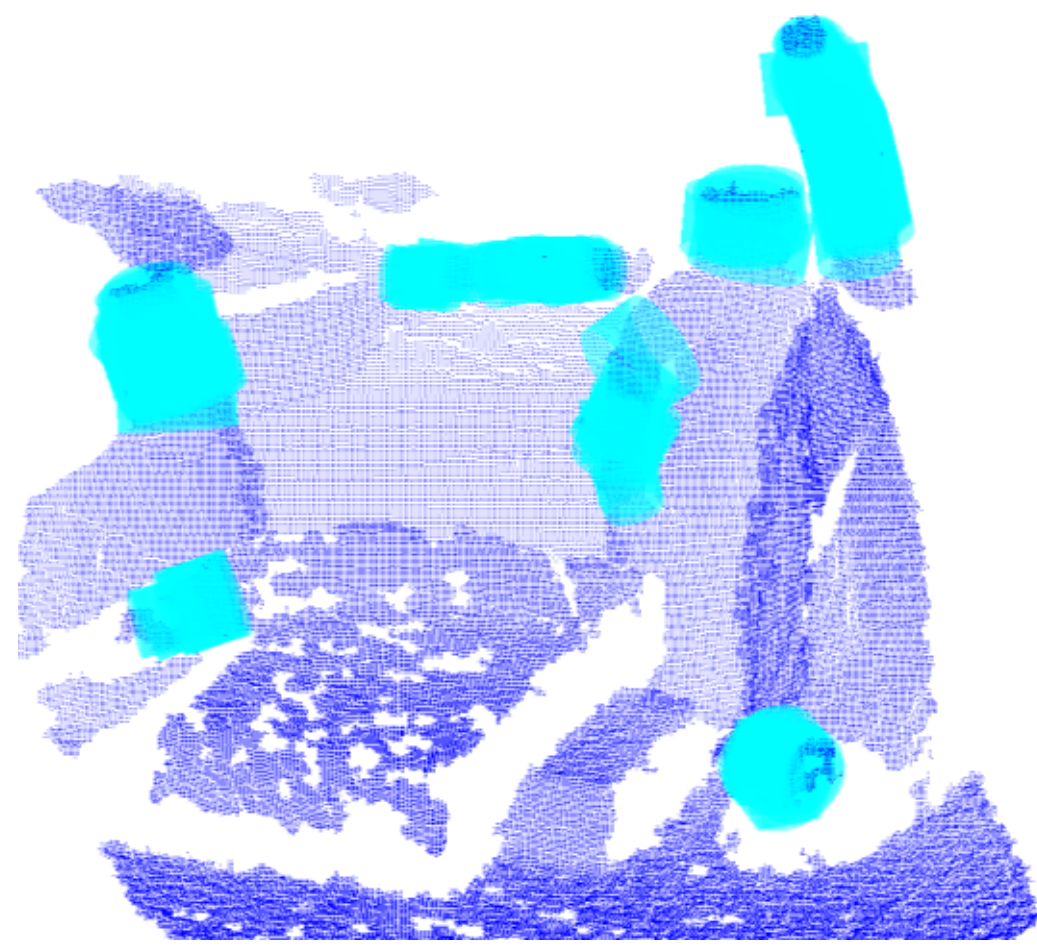College of Computer and Information Science, Northeastern University, Boston, USA

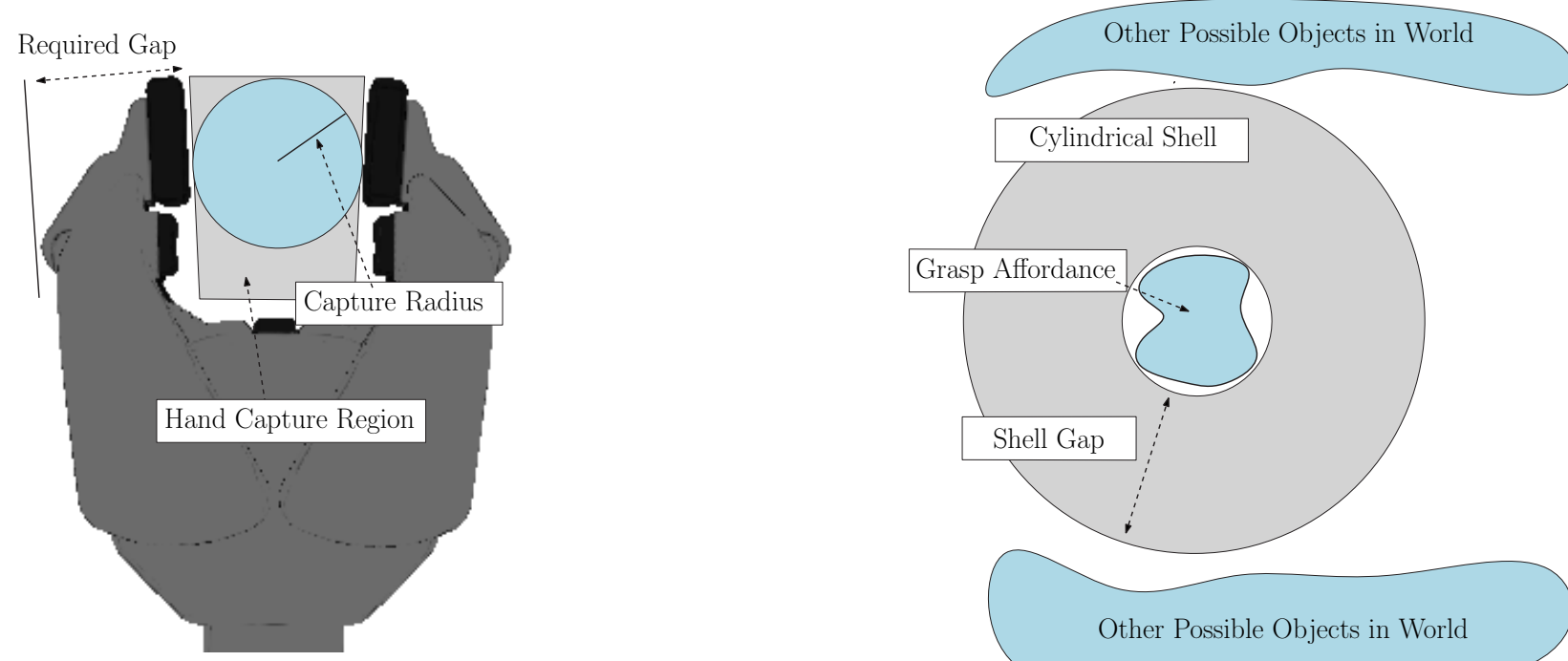## Perception for Grasping

► Enveloping grasp affordances circled in cyan

► Enveloping grasp affordances localized by our algorithm

Enveloping Grasp Affordances as Cylindrical Shells

► Affordances correspond to robot hand geometry

► Enveloping Grasp Affordance (EGA) conditions
  1. Points that lie on the object surface must be contained within a cylinder with radius no larger than the capture radius.
  2. This cylinder must be contained within a cylindrical shell that is clear of points and at least as thick as the finger thickness.

Grasp Affordance Perception Pipeline

1. Sample neighborhoods from the point cloud.
2. Filter out occluded neighborhoods.
3. Taubin quadric fitting and curvature calculation.
4. Filter out neighborhoods that validate the 1st EGA condition.
5. Cylinder fitting to those sets that satisfy the 2nd EGA condition.

Taubin Quadric Fitting

► Quadric fit to a curved surface

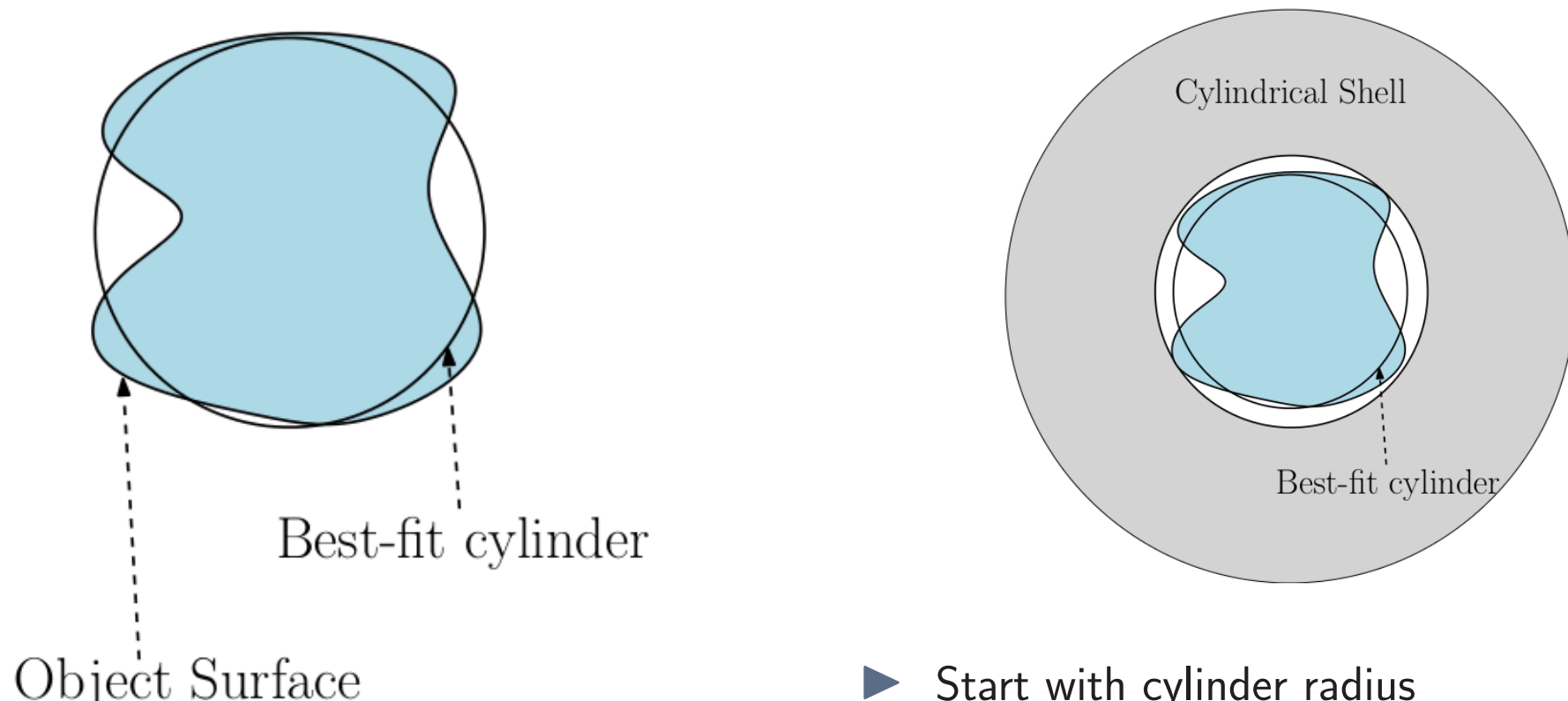► Quadric fit to a corner surface
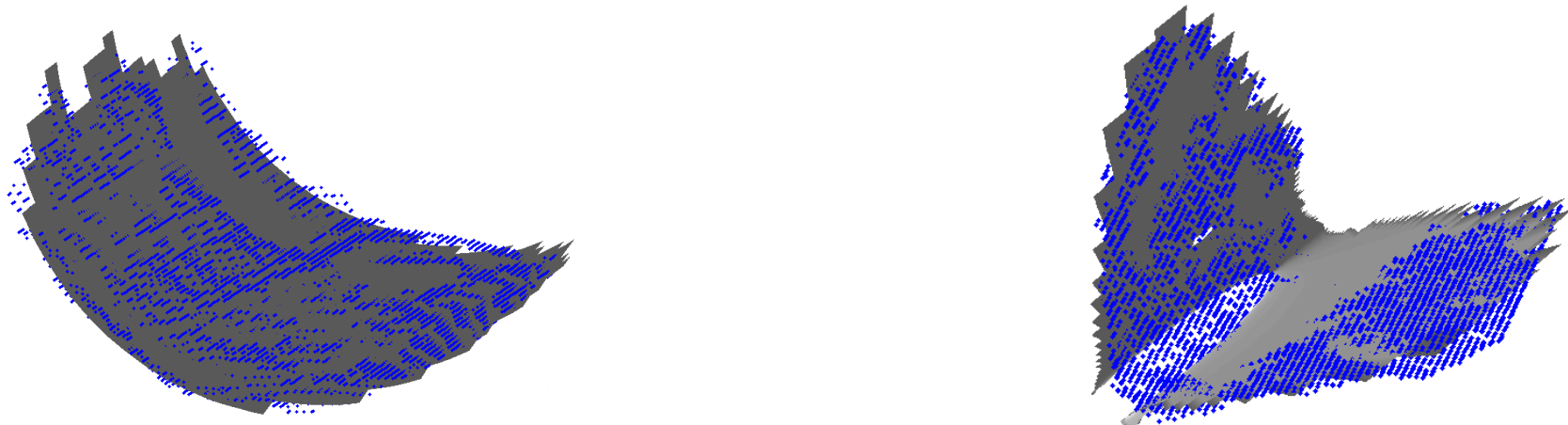
► Implicit quadric equation:

$$f(c, x) = c_1 x_1^2 + c_2 x_2^2 + c_3 x_3^2 + c_4 x_1 x_2 + c_5 x_2 x_3 + c_6 x_1 x_3 + c_7 x_1 + c_8 x_2 + c_9 x_3 + c_{10} = 0$$

► Algebraic fit:

$$\min \sum_{i=1}^{n} f(c, x^i)^2 = c^T M c$$

Cylinder Fitting

► Cylinder fitted to the object surface

► Cylindrical shell

► Project the point neighborhood onto the plane orthogonal to the curvature axis
► Find the best-fit circle:

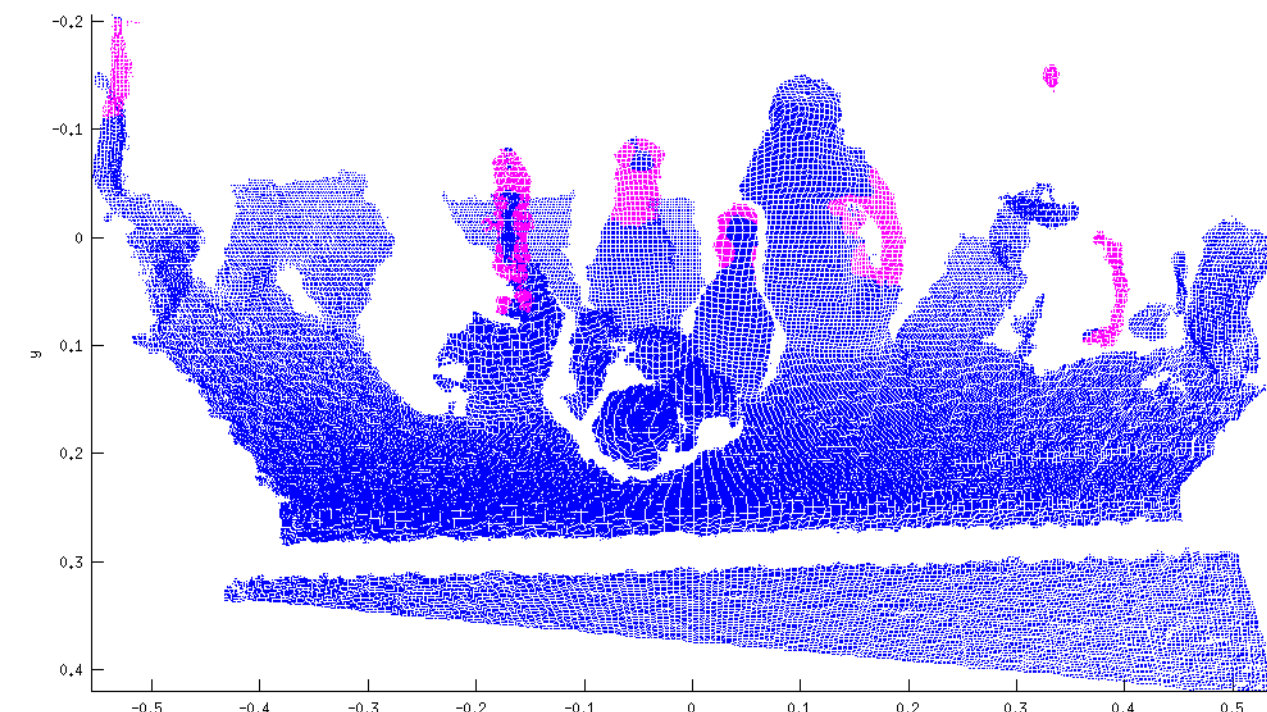$$\min \sum_{i=1}^{n} ((\bar{x}^i - h_x)^2 + (\bar{y}^i - h_y)^2 - r^2)^2$$

► Start with cylinder radius
► Iteratively increase shell radius
► Keep shell thickness = finger thickness
► Stop when a radius is found where few points are within the shell thickness

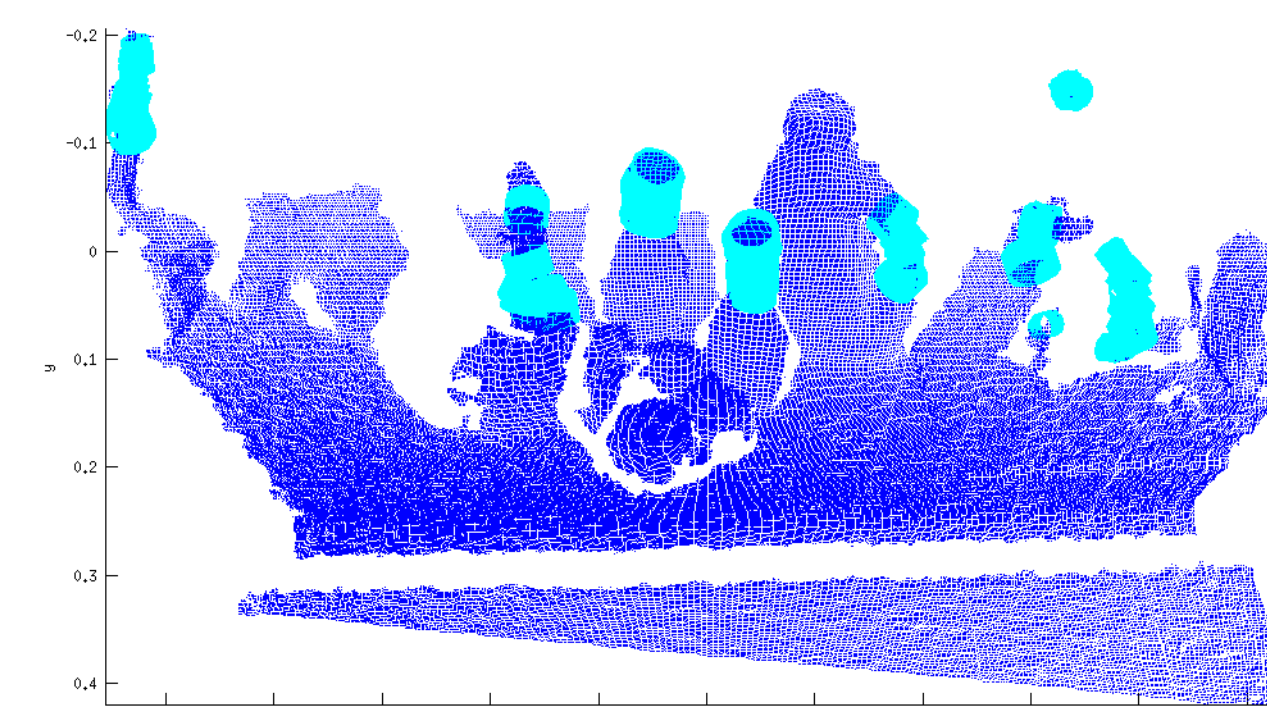## Evaluation Process

Image

Ground Truth

Grasp Affordances

Results: Precision in Cluttered Real-World Environments

► Dataset

(a) Mugs　(b) Cleaning1　(c) Kitchen1　(d) Cleaning2　(e) Household1

(f) Household2　(g) Kitchen2　(h) Kitchen3　(i) Luggage　(j) Cleaning3
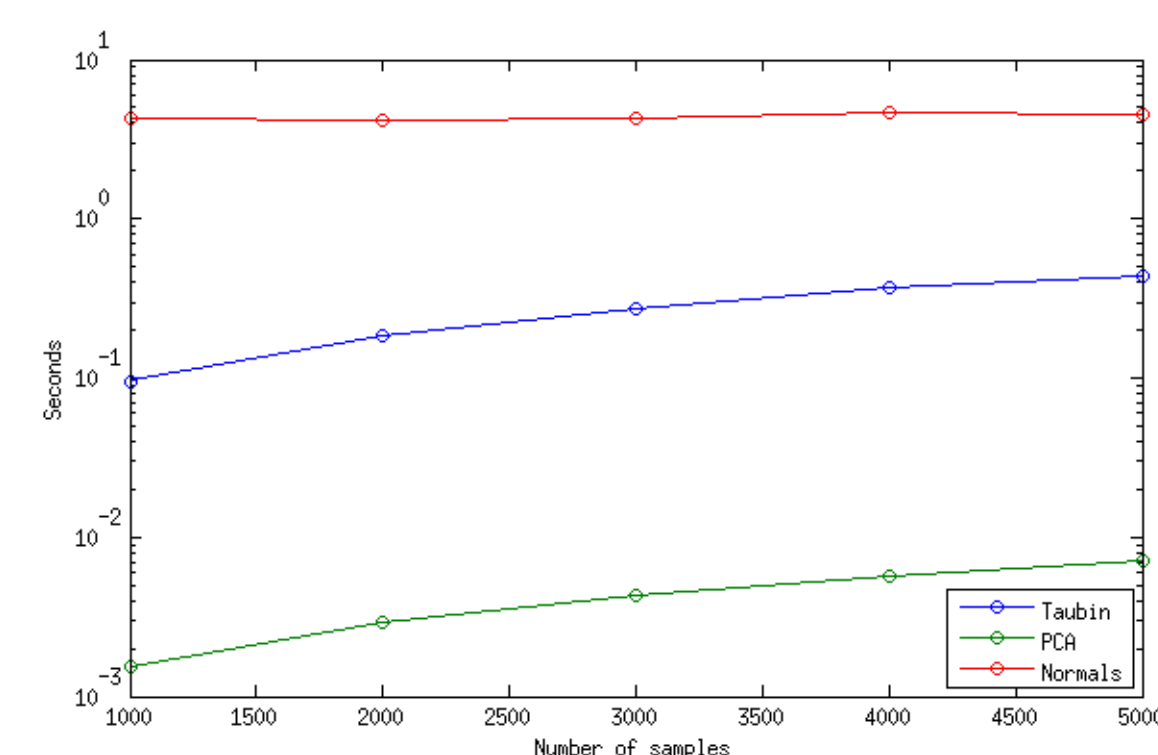
► Precision for Taubin (blue), PCA (green), and Normals (red)
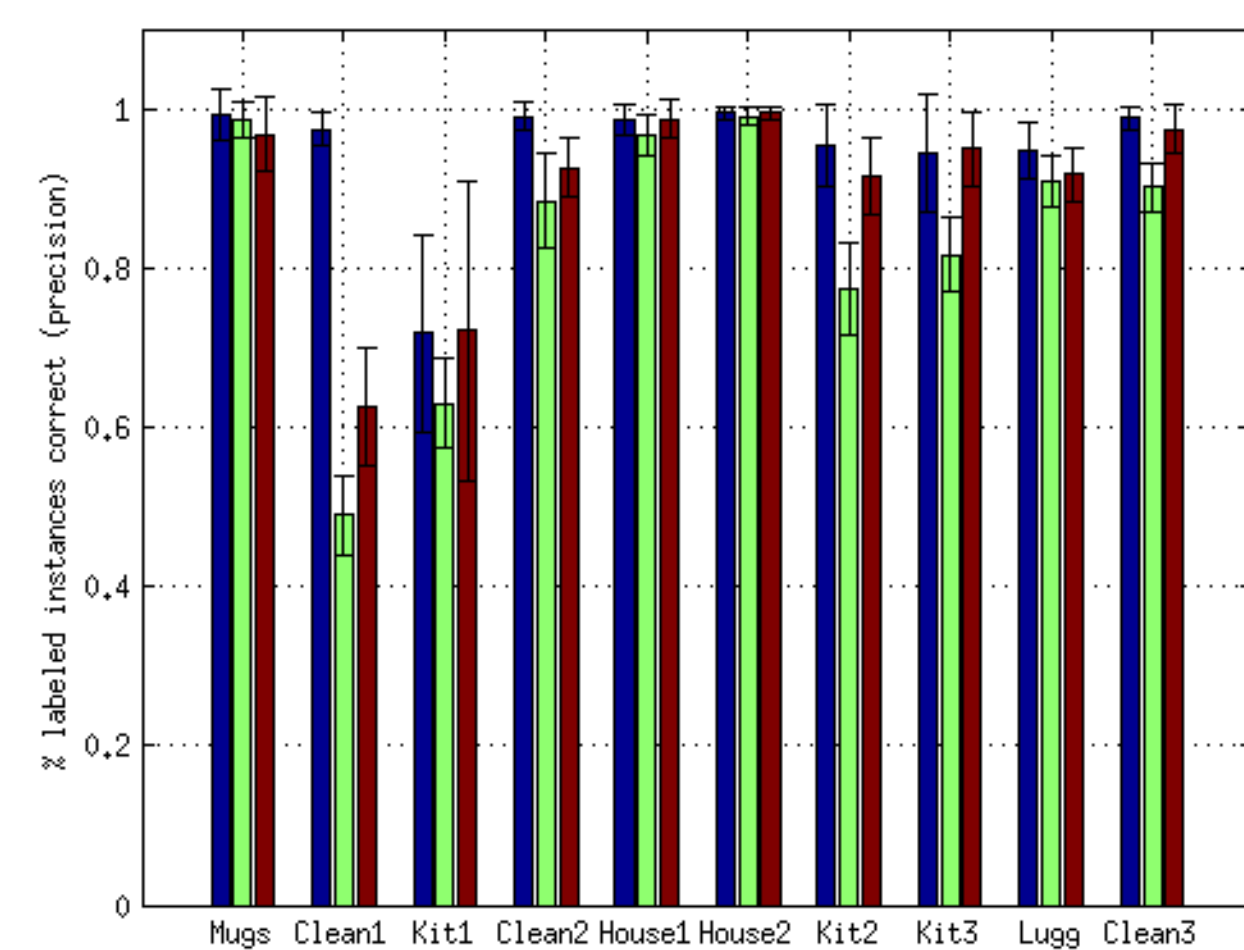
Results: Practical Running Time

► Average runtime for Taubin, PCA, and Normals

Conclusions

► Very accurate
► Fast enough to be applied to real-world scenarios