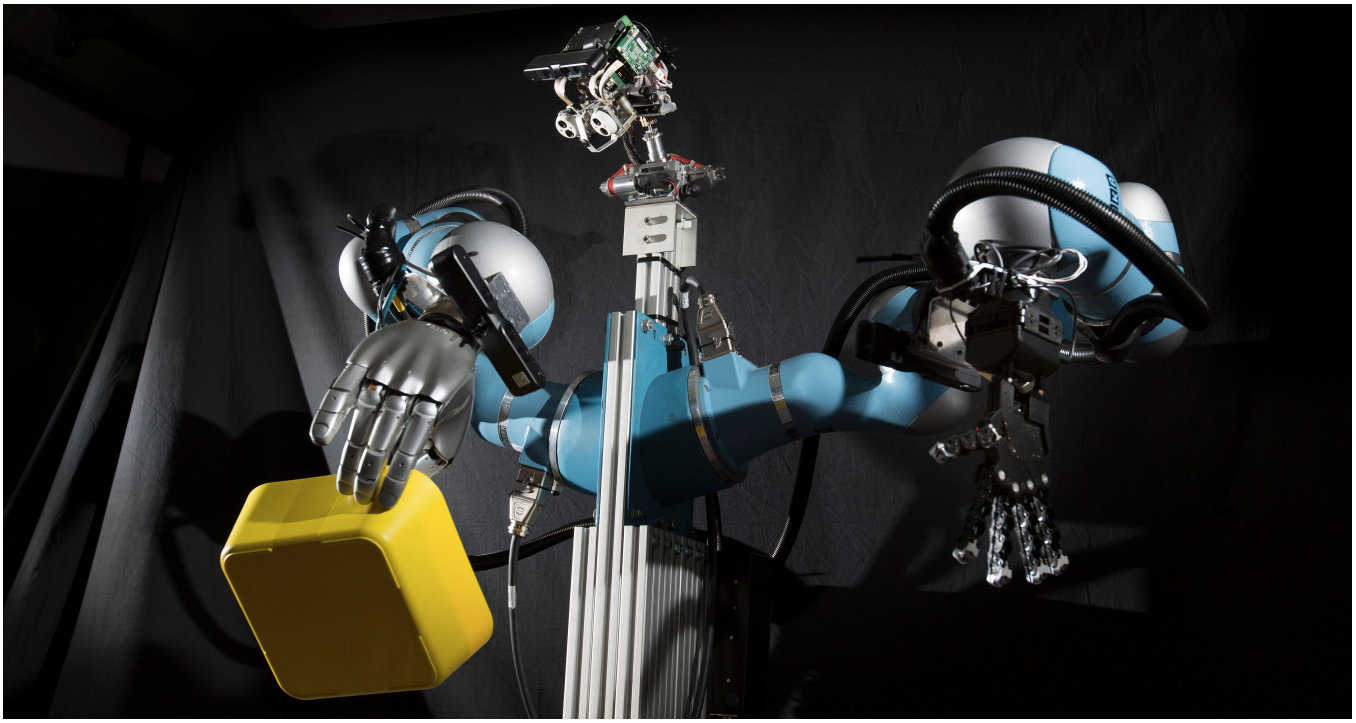
PACMAN

Probabilistic and Compositional Representations for Object Manipulation

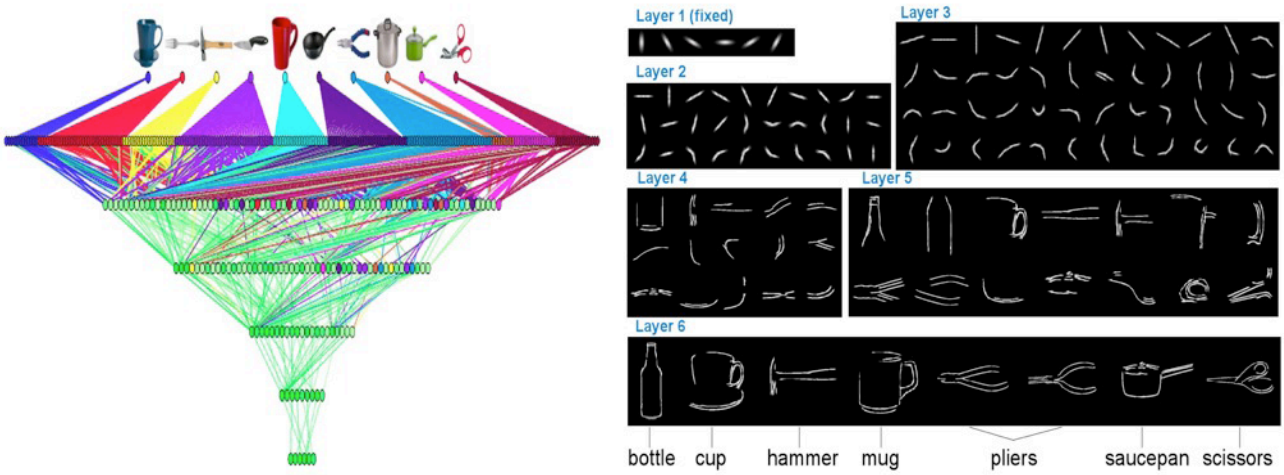


The challenge

Manipulation in robotics is effective in structured and controlled conditions, such as a factory, where the positions, shapes, and masses of the objects to be manipulated are known. But most manipulation by humans is done in unstructured settings, where objects are new, and the pose, mass and frictional properties of the objects to be manipulated are unknown. Robots are still far worse than humans.

The solution

PaCMan is meeting this challenge by using three core ideas: *compositionality,* reasoning about *uncertainty* and mechanisms for *soft manipulation* using under-actuated hands. **Compositionality** means that objects can be thought of as made of a hierarchy of parts. By using a part based representation the robot transfers information between quite different objects that have similar parts. This part of the project is about learning and using part based models of objects from vision and touch.



A part based representation of household objects. The objects share many parts. The simplest parts are just edges, the more complex parts include handles useful for grasping.

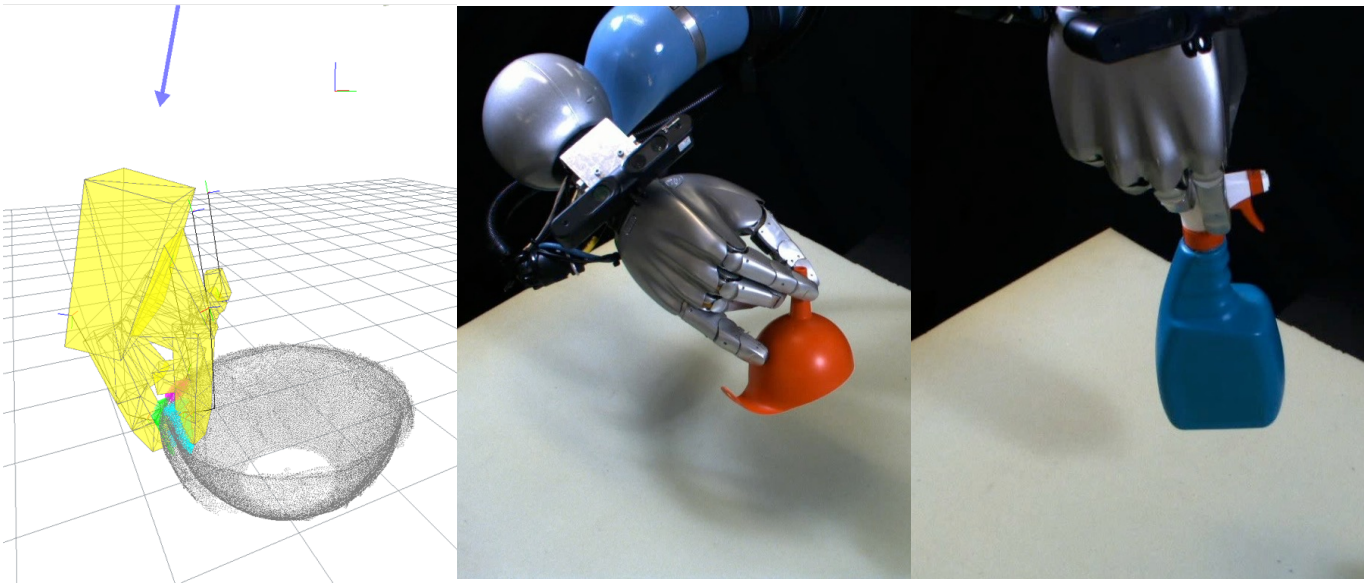
Uncertainty is important in several ways. First the robot must know how uncertain it is about the object's position or shape. Second it needs to know how this uncertainty will affect its planned actions and plan to gather task relevant information to reduce uncertainty that affects performance. Third we can also cope with uncertainty by use new hand designs based on the ideas of **soft manipulation** and control strategies to further reduce the effect of remaining uncertainty.

Results

Part Based Models of Objects. We have learned part based models of object shape from multiple views, and from depth cameras. Our algorithms can learn a hierarchy of parts for recognition and reconstruction.

Models from Vision and Touch. We have developed a method for linking grasps to object parts. This allows learning of grasps that can be generalised to new objects with similar parts. We have learned to recognise objects on the basis of the hand shape when grasping them.

Active Information Gathering. We have developed controllers that enable a robot to roll and slide its finger across an object. These allow recovery of friction and shape. We have also developed a method for a robot to decide where to look when manipulating.



Our grasp learning method is able to learn to adapt a grasp from the bowl on the left, to very different objects such as the funnel or the spray bottle on the right.

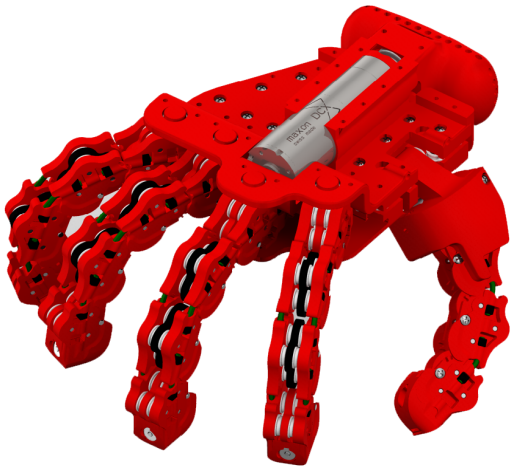
Grasping under Uncertainty. We have developed a new method for a robot to learn to grasp many novel objects from a handful of example grasps taught by a human guiding the robot. We have also developed methods that control a robot's grasp using a soft hand, and exploiting the fact that many objects can be grasped using only a small proportion of possible hand shapes.

Integration. We have constructed three robot platforms and developed a software and hardware framework to control them. Using this the robots can clear a table of cluttered objects, load a dishwasher rack and pass objects from one hand to another.

Dissemination. In the first 24 months 15 papers have appeared, and another 3 have been submitted or accepted. We have given more than 29 interviews in the national and international media, given a public lecture available on the web, and a further 30 invited talks and seminars.

Benefits and Impact

The outcomes of this project are more robust manipulation of familiar and unfamiliar objects. Extending manipulation to unstructured environments is one of the key scientific challenges left in robotics. This is required for most applications of service robots.



The Pisa-IIT soft hand. This is able to grasp objects easily by complying to the shape of the object mechanically as it grasps.

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