

Research Statement

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I am currently a Master student and Research Assistant working with Dr. Andrew Fagg in the Symbiotic Computing Lab. My research area focuses on tactile-based robotic grasping, feature-based object recognition and their integration.

Robotic grasping is a main branch of robotic manipulation. A classic way to deal with this problem is to use an *a priori* model of the manipulated object. However, we would like the robot to be able to figure out by itself how to grasp an unknown object. The basic idea is that a robot can haptically explore an object until a quality grasp is found. A quality grasp can be defined as one that minimizes the total force and torque applied to the object by the hand at the set of contacts. Then we can formulate this in terms of a gradient descent problem, in which the robot successively probes an object and then moves the contacts (Coelho and Grupen 1997). Based on this idea, I have reformulated the Coelho and Grupen's algorithm to operate strictly in Cartesian space (as opposed to a more cumbersome polar coordinate system). The force controller, moment (torque) controller and any other high level controllers can be combined together using null space projection (Platt, Fagg and Grupen 2002). However, in the previous work, the force control law assumes that the finger moves on a convex surface. This will cause the finger to move in the wrong direction when the local surface is concave. In our current research, we have developed a heuristic to detect local concavity based on tactile feedback. As a result, the controller can choose a different control law depending on whether the local surface is convex or concave. Experiments are carried out on both real hardware and software simulation. The preliminary results suggest that our controller with concavity detection consistently outperforms the old one at a wide range of parameter settings. Currently, our lab has a single robot finger test bed, mounted on a 6-axis force & torque sensor. For the next step, we are combining a set of fingers into a robot hand, which is called the Redundant Array of Inexpensive Digits (RAID). One of our goals is to implement higher level robotic manipulation by using relatively inexpensive hardware.

Another area I focus on is using visual features to predict successful grasp types. I have finished a semester long project on this subject and achieved some preliminary results. The algorithm works like this: 1) constellations of features (each feature is an oriented edge in an image) are randomly generated from training images. 2) Given the

feature constellation set and training image set, the system will construct a classifier to predict grasp type class from the feature constellation responses. 3) Constellations that do not contribute to classification are removed from the feature constellation repository and new constellations are regenerated to fill in removed constellations. Then the system will iterate on steps 2 and 3 until the prediction achieves an acceptable degree of accuracy. At each iteration, the system performance is evaluated using a test set. This is a supervised learning approach (a kind of machine learning) and the system will perform asymptotically better as the number of iteration increases. In our experiment, images for training and testing are taken using a robot head with two cameras. After a certain amount of learning, the system can successfully predict the grasp types associated with an object contained in a test image.

Several future research directions can be developed based on the grasp controller mentioned above. First, we need a systematic way to sense multiple contacts on a single finger and to reason about these contacts in the grasping process. Second, with the idea of virtual fingers (e.g. several fingers can be treated as a single finger), a robot can reduce the complexity of dealing with so many combinations of grasps. Then some immediate questions are: how to calculate the contact locations and forces for each of the fingers, how many force & torque sensors are needed, and where should we mount them. Finally, our goal is to integrate tactile-based grasping with robotic vision as mentioned above. Instead of initializing the hand location and orientation randomly for the grasping process, if a robot successfully recognizes the object to be grasped by vision, it can pre-shape its hand to increase the chance of success greatly.

Two conference papers based on the above research are in preparation. One is focused on the grasp controller and one is on contact detection. My master thesis will focus on using visual features to guide tactile grasping, which combines visual feature learning and force & torque grasp controller.

References

- [1] Coelho, Jr., J. A., and Grupen, R. A. *A control basis for learning multifingered grasps*. Journal of Robotic Systems 14, 7 (1997), 545--557.
- [2] Platt, Jr., R., Fagg, A. H., Grupen, R. A. (2002), *Nullspace Composition of Control Laws for Grasping*, Proceedings of the International Conference on Intelligent Robots and Systems (IROS'02).