Robust Manipulation and Sensing for Human Environments

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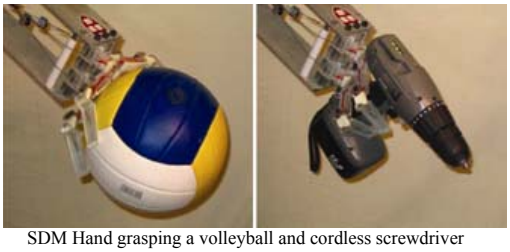
Grasping and Manipulation under Uncertainty

Robots without the ability to physically interact with human environments are severely limited in their applications. To fully realize the potential of robots as domestic assistants, they must be able to reliably grasp and manipulate objects in the home and workplace. However, in unstructured human environments, object properties are not known a priori and sensing is prone to error. The resulting uncertainty in the relationship between the object and gripper makes it difficult to control contact forces and establish a successful grasp.

Much of the reason for the current limitations is that traditional robot hands, which typically involve complex mechanisms, sensing suites, and control, are difficult to use, fragile, and impractical. Alternatively, by carefully designing the mechanical structure of the hand to appropriately incorporate features such as compliance and adaptability, the uncertainty inherent in unstructured grasping tasks can be more easily accommodated. These features can reduce the need for complicated sensing and control by passively adapting to the object properties and positioning, making the hand easier to operate, more robust, and less expensive.

A main thrust of my research has been focused on investigating how the challenges associated with grasping under uncertainty can be addressed by careful mechanical design of robot hands with a focus on simplicity and robustness. The results of in-depth design studies were implemented in hardware to build a novel, four-fingered robot hand that is both compliant and highly underactuated (see figure). The hand uses only a single actuator for the eight joints yet is able to passively adapt to large variations in object geometry. Experimental work with the prototype hand showed that even with three positioning degrees of freedom and open loop hand control, target objects spanning a large range of size, shape, and mass could be reliably grasped even with large positioning and orientation error due to inexact sensing.



SDM Hand grasping a volleyball and cordless screwdriver

The hand is constructed using polymer-based Shape Deposition Manufacturing, with joints formed by elastomeric flexures and actuator and sensor components embedded in tough rigid polymers. The hand has superior robustness properties, able to withstand large impacts without damage and capable of grasping objects in the presence of large positioning errors. This type of durability and reliability is essential for commercial domestic robotics applications.

Robust Sensing

Contact sensors are essential in enabling physical interaction with the human environment. However, typical sensors are fragile – unplanned contact during manipulation tasks in the presence of uncertainty can damage or destroy many of the most common contact sensors. We must therefore develop sensing hardware that can withstand the mistreatment typical of a domestic appliance. Furthermore, current sensory transducers are often too expensive for practical implementation into commercially-viable robot hardware. While there will certainly be economies of scale at play, new paradigms for the design and fabrication of inexpensive robot sensors must be developed.

Physically-Assistive Robots

One of the largest societal and market drivers for robotics in the home will be to assist the elderly and disabled. Many of the users of domestic assistant robots will also have the need for physically assistive or rehabilitative robotic devices. Due to the expense and complexity of robot hardware, we will naturally see these two application areas addressed by multi-purpose platforms. For example, a device capable of manipulating objects to help tidy a house might also be used to assist during sitting and standing. A socially assistive robot companion might also double as a smart walking aid.