Abstract

The capabilities of human hands in performing various grasping and manipulation tasks greatly motivated the development of robotic alternatives. Robotic grasping can be very challenging for unknown objects even in completely known environments. Such challenges mainly originate from the limitations in existing robotic gripper designs, lack of efficient grasp planners for handling unknown 3D objects, dearth of reliable 3D object perception systems due to which there is a gap between the existing grasp planners and their implementations on real robots. Keeping the above challenges in mind, the work reported in this thesis presents the development of a robotic system for grasping unknown 3D objects. The proposed work includes design of adaptive robotic grippers, development of a novel grasp planner and a 3D object perception system using two depth cameras, and their implementations on an industrial robot platform.

Adaptive grippers are useful for grasping objects of varied geometric shapes by wrapping fingers around the object. Two simple underactuated mechanisms using tendon wires, pulleys and joint springs are proposed in this work. Based on the above actuation mechanisms, two different adaptive grippers having two fingers and three fingers are designed, ensuring a stable grasp on a wide variety of objects, especially, lightweight objects. Further, the gripper designs are optimised to improve the graspability and they are fabricated by 3D printing. Furthermore, a position-based impedance controller is developed for the proposed adaptive grippers. The integration of actuators and sensors, type of materials used for manufacturing different gripper parts, and the manufacturing method are also discussed.

A framework for computing the best grasp based on a novel object slicing method is also presented. It is capable of quickly finding contact points using an object slicing technique and uses a grasp quality measure to find the best grasp from a pool of pre-grasps. The pool of pre-grasps is generated by dividing the objects into parts and organising them in a decomposition tree structure. Further, the results are compared with the state-of-the-art in grasp planning and the proposed grasp planner has been found to be computationally less expensive and equally effective on both point clouds and polygonal mesh.

Finally, this work also presents a complete framework for implementation of the developed grippers and the grasp planner on an industrial robot platform, comprising of a 3D object perception system, a module for finding the best grasp by the slicing based grasp planner, and a module for robot trajectory generation for pick and place operations. The proposed 3D object perception captures the complete geometry information of the target object using two depth cameras placed at different locations. A hole-filling algorithm is proposed to quickly fill the missing data points in the object point cloud. The object-slicing based grasp planner is further capable of handling obstacles posed by neighbouring objects in a cluttered tabletop environment. The proposed framework is tested on common household objects by performing pick and place operations by the industrial robot fitted with the developed adaptive grippers. Moreover, finding the best feasible grasp in the presence of neighbouring objects is also demonstrated by considering scenarios such as avoiding the tabletop and surrounding objects.

Keywords: Robotic grippers, Underactuation, Grasp quality metric, Grasp planners, 3D perception, Point cloud