

Paper Title: “An Underactuated Gripper to Unlatch Door Knobs and Handles”

Authors: Erin Rapacki, Dr. Holly Yanco, Dr. Christopher Niezrecki

Abstract: Robotic grippers generally fall into one of two different categories: (1) grippers designed to handle an object of a specific size and shape, such as grippers used for manufacturing, and (2) grippers designed to handle a variety of objects, such as two-pronged clamps or human-like hands found on multi-purpose robots. This paper describes a gripper that fits both categories, a gripper designed to unlatch door knobs and handles of different sizes and shapes. Such a gripper would be useful for robotic applications in healthcare, rehabilitation, reconnaissance, and rescue. For example, healthcare robots need attend to their patients and reconnaissance robots are required to inspect areas in suspected buildings.

This paper describes the evolution of an underactuated gripper designed to unlatch doors knobs and handles through two prototypes. The second prototype, which was far more successful at unlatching door knobs and handles than the first prototype, is detailed in Figure 1(a). Both gripper prototypes were built with added compliance to compensate for the different sizes, torque loadings, and twisting angles expected of each individual door knob or handle by using one motor to both close and twist three gripper fingers that were arranged in a conical shape. A door knob was actuated by being placed in the relative center of this three fingered cone, as shown in Figure 1(b), and a door handle was rotated by nesting it in the slots between the fingers. The gripper prototypes were compact in design for mounting on a custom designed wheelchair mounted robotic arm.

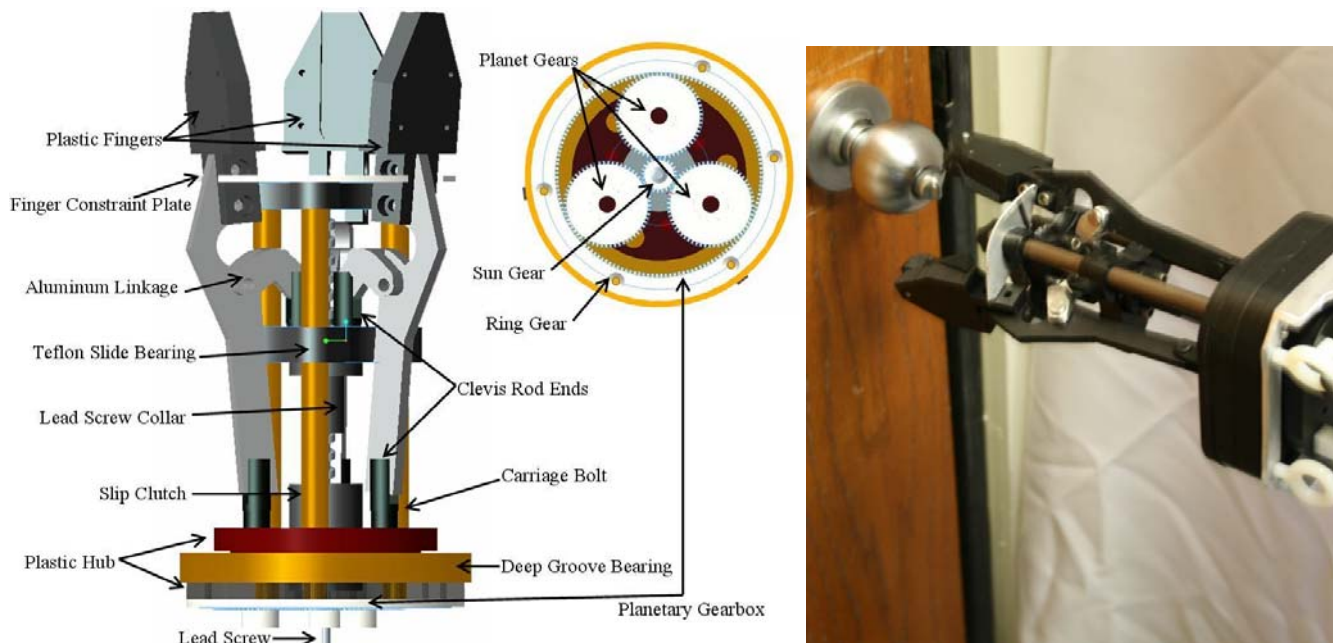


Figure 1. (a) Schematic of the second gripper prototype and (b) the gripper on approach to a door knob.

The gripper's mechanical design on both prototypes involved the combination of a planetary gear box for rotation and a lead-screw linkage assembly that produced an opening/closing motion for its three fingered cone. The three fingered cone rotation was connected to the rotation of the outer ring of a planetary gear set. The sun gear of the planetary gear set was coupled with the lead screw and both

rotated at the same angular velocity. The planet gears reduced the angular velocity and reversed the direction of the outer ring gear. A collar was threaded around the lead screw and was also constrained to a linear slide located along the structure connected to the outer ring gear of the gripper. The difference in angular velocities between the lead screw collar and the gripper structure allowed the collar to move linearly, forwards and backwards, along the screw as if the collar was attached only to a linear slide. The fingers then closed and spun at the same time, spinning at the same rate as the outer ring gear and actuating due to the linear motion of the lead screw linkage. However, as designed, the gripper could not continue to spin when the fingers were fully closed around the door knob or handle. The first prototype compensated for this by using flexible fingers. However, when tested, the first prototype only managed to unlatch two out of the fourteen selected doors (tested doors consisted of four doors with handles, ten doors with knobs, and trials on the push and pull side of each door). Based upon the findings of these tests, a second prototype was developed that used a slip clutch instead of flexible fingers allowing the planetary gearbox to continue to rotate when the lead screw linkage fingers were fully constrained around the door knob or handle. The second prototype was able to unlatch twelve of the same fourteen doors.

Both gripper prototypes were delivered to the door knob or handle by a custom wheelchair mounted robotic arm attached to a power wheelchair named DORA (Door Opening Robot Arm). The goal of the research was to design a wheelchair mounted robotic arm to specifically open doors for a significantly lower price than a multi-purpose robot arm. DORA included a motorized Cartesian robot configuration that utilized a motorized side-to-side joint, a motorized up-down joint, and a motorized sliding link that extended the gripper forwards and backwards. The gripper was attached to the sliding link portion of the robot arm via a spring-loaded universal joint used to traverse the face of the gripper to the plane of the door. The purpose of using the spring-loaded universal joint was to keep motor usage and costs low within the entire DORA design. In the prototyping state, DORA was controlled via a custom built stepper motor controller by driving each motor joint individually using a push button keypad. The tests were conducted by both controlling the robot arm and driving the power wheelchair to a desirable location in front of the selected door.

The second and final version of the gripper, which utilized a slip clutch with three stiff fingers, had a high success rate on the tested doors. The gripper managed to unlatch and push open nine of the ten knobbed doors, unlatch and push open three of the four handled doors, compress tightly to pull open eight of the ten knobbed doors, and compress to pull open one of the four handled doors. Continued research and improvement in the specific gripper finger design would likely yield a higher success rate. For example, the gripper pulled off many of the handled doors because there was no contour or curve on the finger to constrain the door handle and instead relied only on compression between the sides of the fingers. This exploration into the design of an underactuated gripper for unlatching door knobs and handles yielded a final prototype that was intrinsically compliant, simple, used a single motor, and compact for mounting to any kind of robotic arm or platform. This gripper design could be used in a wide variety of applications in robotics today.

Author Contact Information:

Erin Rapacki
UMass Lowell
Mechanical Engineering
38 Simon Rd
Enfield, CT 06082
Phone: 857-222-7926
Fax: 978-934-3551
erapacki@gmail.com

Holly Yanco, Ph.D.
UMass Lowell
Computer Science
1 University Ave
Lowell, MA 01854
Phone: 978-934-3642
Fax: 978-934-3551
holly@cs.uml.edu

Christopher Niezrecki, Ph.D.
UMass Lowell
Mechanical Engineering
1 University Ave
Lowell, MA 01854
Phone: 978-934-2963
Fax: 978-934-3048
christopher_niezrecki@uml.edu