The Design of an Underactuated Wheelchair-Mounted Robotic Arm to Unlatch Door Knobs and Handles

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NEMS 2009
Motivation

- People who use power wheelchairs may not be able to use their arms or hands well.

- Electronic door openers are not installed in everyone’s home or workplace.

- General purpose WMRAs have been designed for activities of daily living.

- WMRAs are not used often by people in power wheelchairs.
  - Too expensive
  - Drawbacks with power wheelchair mounting
  - Difficult to control
Robot Arms

Georgia Tech

Raptor (Phybotics)

University of South Florida

Exact Dynamics, Manus ARM
How DORA is Different

• 7 DoF WMRA that uses only 4 motors.
  – 3 DoF as motorized joints in the robot arm (3 motors)
  – 2 DoF as passive joints in the wrist (0 motors)
  – 2 DoF in the gripper (1 motor)
Problem Statement

Design a robot arm with a minimal number of motors to unlatch a door without the user needing to precisely align their wheelchair.
Robotic Arm Joint Configuration
DORA Functional Design

- Underactuated gripper (1 motor)
- Spring-loaded universal joint
- Lead screw & collar (1 motor)
- Worm gear (40:1) (1 motor)
- Spur gear reduction (1 motor)
Gripper & Universal Joint

- **Gripper**
- **Horizontal Stroke** (sliding link)
- **Vertical Swing** (rotational joint)
- **Sweep Around Waist** (cylindrical joint)
Tufts University Gripper

Tufts University robotic door knob gripper

Position 1: Approach
Position 2: In Position
Position 3: Begin Grasping
Position 4: Grasping
Position 5: Full Constraint
Position 6: Turning
DORA Gripper Design

STRUCTURAL ASSEMBLY CONNECTING OUTER RING GEAR TO GRIPPER ROTATION

MOTOR

PLANETARY GEAR BOX

LEAD SCREW

COLLAR COUPLED TO LINKAGE

LINKAGE (OPEN & CLOSE FINGERS)

GRIPPER FINGER
Geometrical Design

- Claw opening over knob
- Claw finger length
- Diameter of collar & linkage connection
- Linkage connection along finger from base
- Claw base offset distance
Mechanical Assembly

- Neoprene Fingers
- Carriage Bolt
- Teflon Slide Bearing
- Plastic Hub
- Lead Screw
- Aluminum Linkage
- Clevis Rod Ends
- Lead Screw Collar
- Deep Groove Bearing
- Planetary Gearbox
- Planet Gears
- Sun Gear
- Ring Gear
Final Gripper Assembly

1. Neoprene fingers wrapped in rubber grip
2. Aluminum linkage assembly
3. Lead screw collar
4. Housing for planetary gear box and bearings
5. Motor used for actuation
Gripper Demonstration
Testing

- 15 Doors
  - 5 Handles
    - Twisting angles between 30° and 60°
    - Torques between 9 lb-in and 21.25 lb-in
  - 10 Knobs
    - Twisting angles between 14° and 82°
    - Torques between 1.75 lb-in and 4.5 lb-in
Results: Handles

- Can not hold the twisted handle at unlatched position to push open
- Can not clamp around the handle tightly enough to pull open
- Universal joint allowed the gripper to release the handle
Results: Knobs

- Planetary gear box could not continue to turn when the claw fully compressed around the knob
- Fingers were too wide to fit between the door knob and the door jam
- Fingers easily slipped off the knob when DORA pulled backwards on the door
Fault Tree Analysis

- **Gripper does not unlatch door knob or handle**
  - **Motor failure**
    - **Electronics and controls**
      - Disconnected wire
      - Motor does not produce enough torque
        - Poor motor selection
    - **Collar connecting motor to lead screw**
      - Linkage does not hold finger against surface
        - Clevis rod ends deform or break
    - **Planetary gearbox disengagement**
      - Planet gears skip or misalign
      - Lead-screw collar not sliding along structure
    - **Jostling between linkage connections**
      - Flexible fingers move side-to-side as well
      - Fingers are fully closed
  - **Clamping failure**
    - **Twisting failure**
Future Work

• Separate clamping and twisting actions.
  – Stiff fingers (smaller form)
  – Torque limiter or slip clutch

• Arrange fingers so they have smaller gaps between them so handles/knobs cannot pass through
Questions?

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