Upper Extremity Robotic Arms

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Disclosure

Presenters for this activity have been required to disclose all relationships with any proprietary entity producing health care goods or services, with the exemption of nonprofit or government organizations and non-healthcare related companies.

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Note

The products presented in these slides are not intended to be inclusive of every individual with upper extremity limitations and their inclusion in this presentation does not represent a product endorsement. Information in this presentation is intended solely for education purposes.

Objectives

- List three differences between traditional and assistive robots.
- Identify four activities of daily living that an individual could use an assistive robot to complete.
- Identify two indicators of individuals who could benefit from an upper extremity robot.
- Label three parts of the electrical and mechanical integration of an upper extremity robot with a Group 3 power wheelchair.
- Identify two possible funding options for assistive robotics.

Assistive vs Traditional robots

Traditional industrial robots

- Must be fast, precise and powerful
- Designed for use in industrial automation applications
- Are meant to be used in controlled areas
- Operate automatically or on a trajectory often programmed for repetitive movements
- Historically not designed for human collaboration

ISO-International Organization for Standardization, ISO 8373 robots and robotic devices-vocabulary. Geneva: ISO. 2012

HUMAN REPLACEMENT

Assistive Robots

- Must be safe, integrated, and agile
- Designed for use around and with humans
- Require human input to operate
- Designed for human-robot collaboration
- Defined as a robot that gives aid or support to a human user

ISO-International Organization for Standardization, ISO 8373 robots and robotic devices-vocabulary. Geneva: ISO. 2012

HUMAN EMPOWERMENT

Assistive solutions:

JACO Robotic Arm

iArm Robotic Arm

JACO

JACO Features

• 6 degrees of freedom to mimic human arm	• Max speed 20 cm/sec (7.8 in/sec)
• Weight 5.2 kg (11.5 lbs)	• Payload 1.5 kg (3.5 lbs)
• Finger force 20N (4.5 LbF)	• Reach 90 cm (35 inches)
• Three Fingers	• Integrated to wheelchair controller

iARM

iArm Features

• Integrated to wheelchair controls	• Max speed 15 cm/sec (5.9 in/sec)
• Weight 9.0 kg (19.8 lb)	• Payload 1.5 kg (3.3 lbs)
• Finger force 20N (4.5 LbF)	• Reach 90 cm (35 inches)
• Two fingers	

Specific capabilities and requirements of assistive robots

- Perform human tasks for medically necessary activities of daily living, independent activities of daily living, work and leisure activities
- Assistive robotics need to have enough flexibility to be used by a wide range of users
- Controls for the robot need to be compatible with user's condition and specific abilities
- Integrated with the wheelchair's electronics
- Robot must to be as small as possible to be able to access multiple environments
- Power consumption must be as low as possible

Cook A, Polgar J, Encarnacao P. Assistive Technologies: Principles and Practice Fifth Edition. 2020

Is it safe?

- Operation requires continuous user input
- No automated trajectories – just like power wheelchairs
- Safe zones: slow zone and/or no-go zone
- Flexible fingers, 4 lbs. Max closing pressure
- Efficient, Low-power DC motors
- Rounded design = no pinch points

ISO-International Organization for Standardization, ISO 13482 international standard: Robots and robotic devices- safety requirements for personal care robots. Geneva: ISO. 2014

Typical Diagnoses of Jaco Users

- Muscular dystrophy
- Spinal muscular atrophy
- Spinal cord injury
- ALS
- Cerebral palsy
- Quadriplegia
- Upper limb amputation

Qualifications for potential assistive robotic users

- Have upper extremity weakness and limited-to-no hand function, supination and pronation
- Have a strong desire to be independent.
- Have good cognitive and processing skills that allow for path planning
- Adequate visual field and acuity
- Use power mobility and have adequate driving skills

Bloom A, Stuyt H. Assistive robotic manipulators. In: Encarnacao P, Cook A.M, eds. Robotic assistive technologies: Principles and practice. Boca Raton (FL): CRC Press; 2017

Qualifications for potential assistive robotic users - Manipulation

- Reach
- Grasp
- Fine motor control

Who is involved in the evaluation/trial process

- Potential assistive robot user
- Caregiver or family member if applicable
- Physical Therapist or Occupational Therapist
- Assistive Technology Professional
- Robotic Prodcut Specialist

Cook A, Polgar J, Encarnacao P. Assistive Technologies: Principles and Practice Fifth Edition. 2020

What is involved in the evaluation/trial process

- Installation on the user's chair
- Connection to the user's existing controller (joystick, head array, chin stick, sip and puff, etc.)
- Training the potential user on operation of the robot
- Demonstration of functional tasks
- Therapist completion of a letter of medical necessity

Assessments utilized in assistive robotic arm research

- Task oriented performance evaluation tool (Chung et all 2013)
  - End user completed tasks: pushing large and small circular buttons, turning rectangular rocker light switch, flipping toggle switch, pushing down door handle, turning knob
  - Each task was timed and end user measured the level of difficulty
- Adapted Wolf Motor Function Test
  - Hand to table, hand to box, weight to top of box, position beverage to mouth, lift mouse stick, lift key, turn key in lock and lift basket
  - Measured by time

Assessments utilized in assistive robotic arm research

- Study done by Maheu et al (2011) evaluated the ability of end users to complete six tasks
  - Grasping a bottle located on left and right side of table
  - Grasping a bottle from the ground and placing bottle on the table
  - Pushing buttons of a calculator
  - Taking a tissue from a box on the table
  - Taking a straw from a glass on a table
  - Pouring water from bottle into a glass
- Canada Occupational Performance Module
- Qubec User Evaluation with Assistive Technology Questionnaire (QUEST)
- Caregiver Assistive Technology Outcome Measure

Assessments utilized in assistive robotic arm research

- A study completed by Chung et al. (2013) attempted to construct a standardized assessment tool for assistive robotics called TO-PET
- Another study by Chung et al. (2014), used an adapted version of the Wolf Motor Function Test
- Both studies were able to show functional benefits
- Replication may be difficult in clinical settings due to limited access to assessment objects and measurements/computations required by the standardized assessments

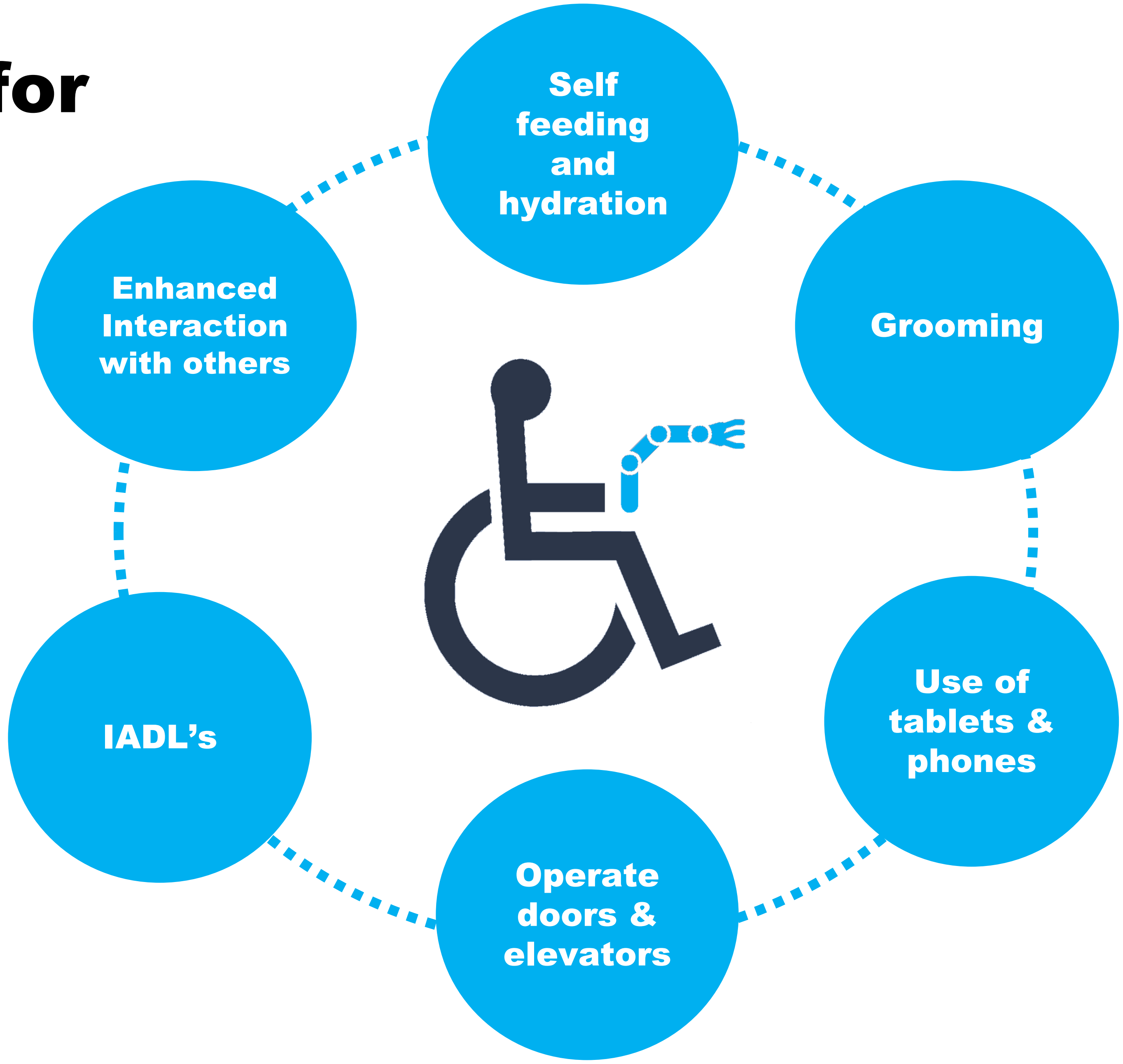
Chung C., Wang H., Cooper R. A. (2013). Functional assessment and performance evaluation for assistive robotic manipulators: Literature review. The Journal of Spinal Cord Medicine. Vol 36(4): 273-289

Chung C.-S, Hannan M. J, Wang J, et al. Adapted Wolf Motor Function Test for assistive robotic manipulators user interfaces: A pilot study. In proceedings of the RESNA Annual Conference. Indianapolis: RESNA; 2014.

Limitations

- There is not a standardized outcome method to assess functional benefits of assistive robots
- A majority of studies completed use non-standardized measures including:
  - Daily time of use of an assistive robot for functoinal tasks
  - Task success rate
  - Task difficulty indices
  - Time to complete task
  - Open-ended interviews assessing user experience
- Development of a standardized assessment would increase realiability and validity, justifying use of assistive robotics for ADL’s and IADL’s

Assistance for daily living activities



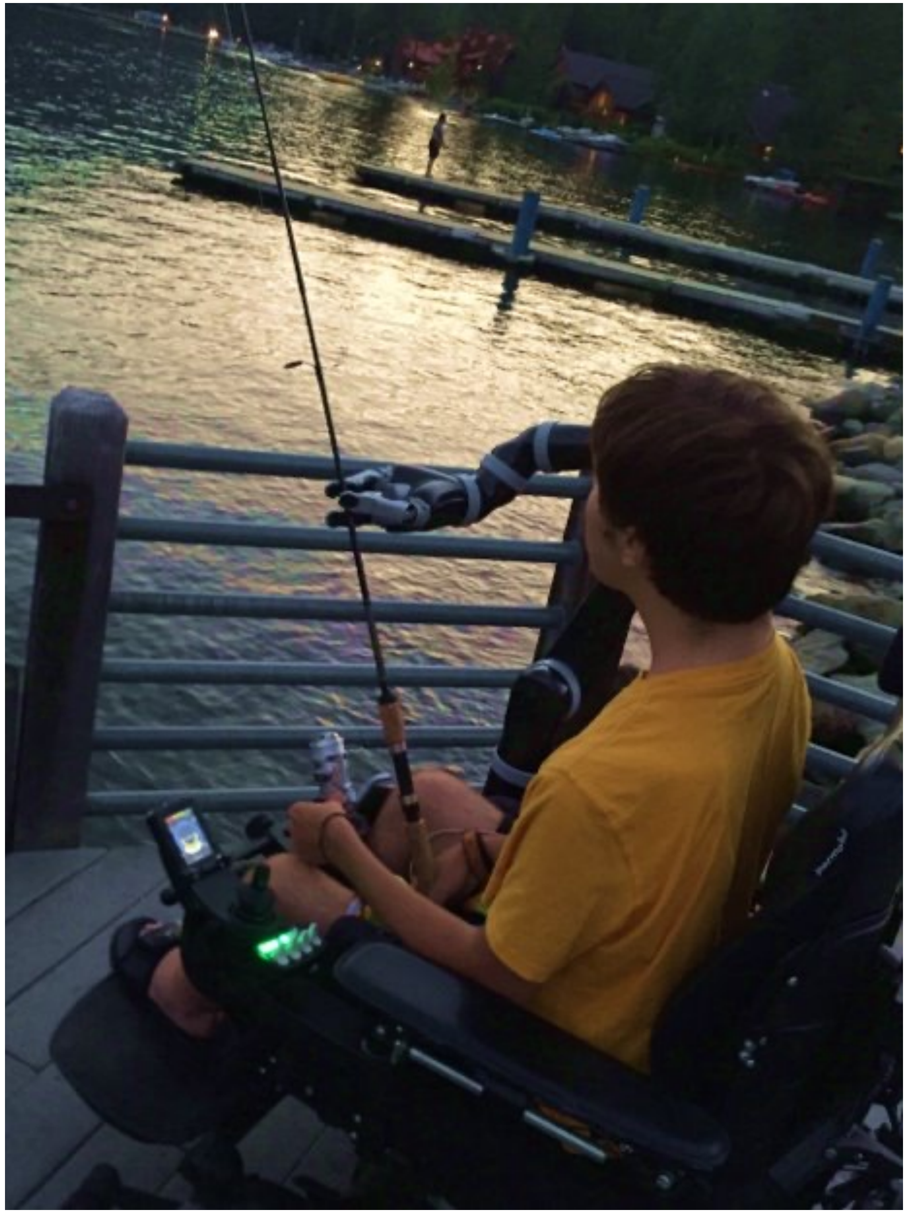
Additional assistance for daily living activities - Pediatrics

- The ability to grasp with the robot allows the child to directly manipulate objects
- Play allows children the opportunity to test capabilities, make decisions, learn cause/effect, enhance creativity and problem-solving skills
- Not being able to play and experiment, can limit children's ability to develop important cognitive skills
- Limited play can also lead to anxiety, frustration, decreased self-efficacy, confidence and well-being
- Upper extremity robotics allows children to explore their environment independently.

Use of robotics for pediatric cognitive development

- Using robots can allow children to play independently instead of playing by observation of others manipulating objects which in turn can lead to further development of cognitive skills including:
  - Binary relations and choice making
  - Sequencing of actions
  - Exploration and discovery
  - Cause and effect
  - Coordination of multiple variables
  - Reflectivity
  - Inhibition - knowing when to stop an action
- Use of tools and manipulation allow a child to develop cultural and social awareness, leading to increased participation in school, play and social interactions

Cook A, Encarnacao P, Adams K. Robots: Assistive technologies for play, learning and cognitive development. Technology and Disability. 2010

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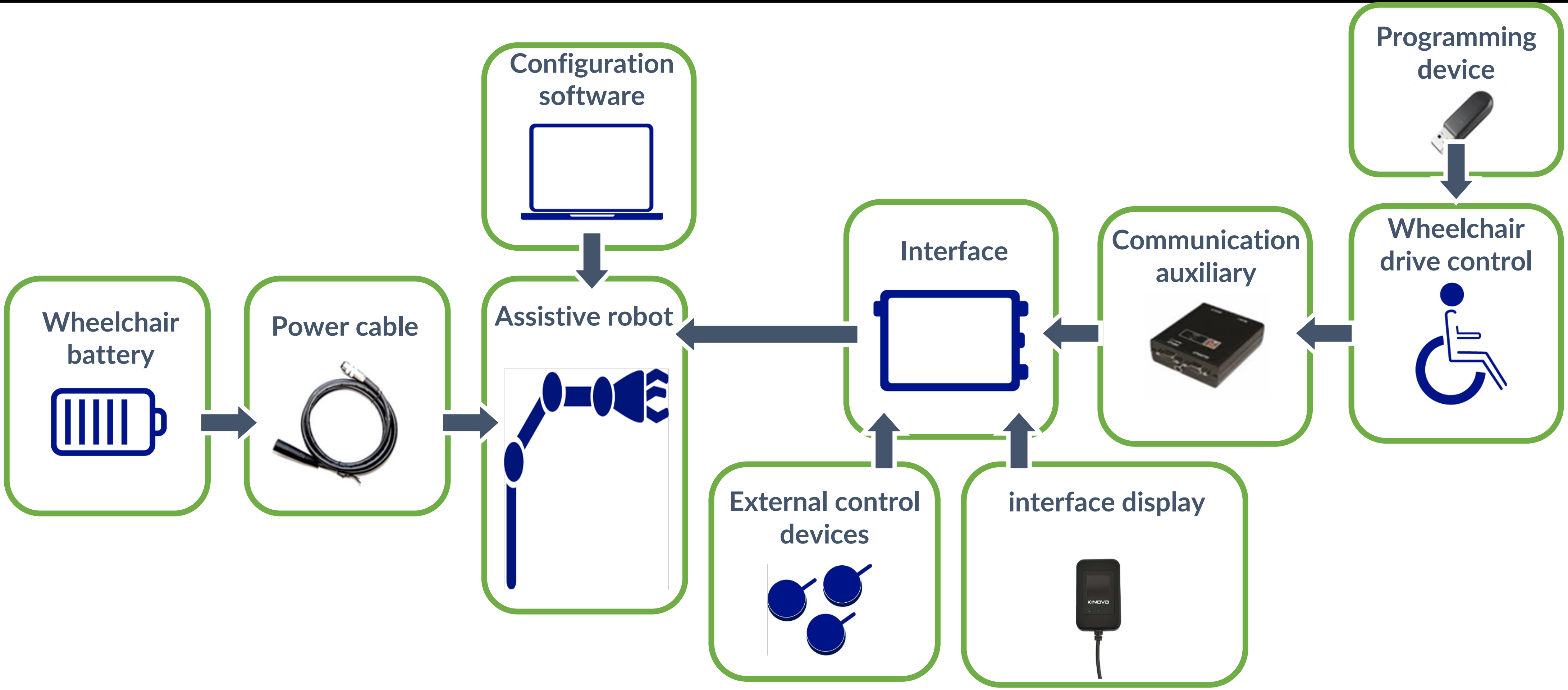
Power wheelchair integration

Electrical Integration



DG 2INE 0004 - Jaco Electrical integration guide. 2011.

Integration of robot with power mobility

- Requires an auxiliary control module (ECU or IOM)
- Auxiliary control module allows for the robot to communicate with the wheelchair electronics via a Universal Interface (Control Box)

Interfaces with multiple drive controls

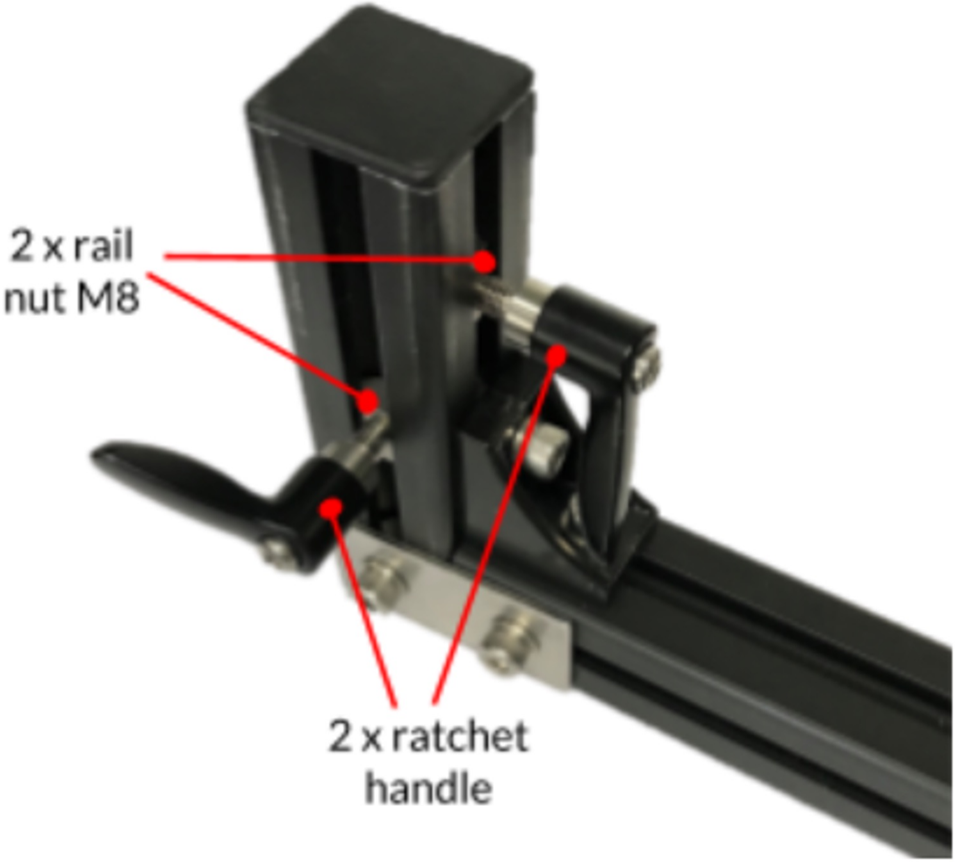
- Joystick
- Head array
- Chin control
- Foot control
- Sip and puff
- Fiber optic switches

Mechanical Mounting

- Minimize wheelchair width
- Maximize robot reach (down to the floor, up the top of user's head)
- Ensure good field of view in entire robot envelope
- No interference with elevating / tilting / reclining - backrest motions
- No interference with transfer methods
- No interference with adapted car / anchoring
- Allows individual to access car/desk/table for daily occupations (work, driving, etc)

DG 2INE 0002 - Jaco Mechanical integration guide. 2011.

Fixed Mounting



Lift Arm Mounting

Funding

Funding Process

- In the US robotic arms have been covered by Medicaid, Medicare PPOs, private insurers, the Veterans Adiministration, and Vocational Rehab
- Documentation for insurance includes
  - Physician prescription
  - Recent chart note documenting diagnosis
  - Letter of medical necessity
  - Price Quote

Economic Benefits

- Maheu et al. (2011) demonstrated that caregiver hours could be decreased at least 1.5 hours a day with the use of an assistive robot.
- Romer et. al (2005) identified potential benefits of using assistive robotics to decrease caregiving/professional services to one time a day, live-in facilities with decreased needed services, or allowing an individual to be employed.
- Schuyler and Mahoney (2000) anticipated that individuals with manipulation deficits could have better access to vocational opportunities with the use of an assistive robotic.

Demonstration

Questions?

Resources

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Thank you!

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