Wheelchair Robot Workshop

September 27-28, 1996

duPont Hosptial for Children

Sponsored by

Rehabilitation Engineering Research Center on Rehabilitation Robotics
NIDRR Grant #H133E30013

Report submitted by

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ASEL Technical Report #ROB9607

October 8, 1996

asel

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Summary

The Rehabilitation Engineering Research Center on Rehabilitation Robotics hosted a Workshop from September 27-28, 1996, the focus of which was assistive robots specifically designed to mount on wheelchairs. Invitations were extended to individuals from throughout the world who have extensive experience in the research, design, development, and evaluation of wheelchair robots. These experts tended to be associated primarily with the Manus and Helping Hand manipulators, due to their prominence as current commercial products.

The objective of the workshop was to identify key areas of success and failure in the development of wheelchair robots towards wide-spread commercial products. The observations of the workshop participants are documented in this report. Note that this workshop focused sharply on wheelchair-based systems. For this reason, the information contained in this report does not include other applications of assistive robots.

Two specific outcomes of this workshop are highlighted. Through discussion and consensus-building, the workshop participants identified seven key areas that require further attention in order to achieve commercial success and to improve the usability of wheelchair robots. These areas are:

1. Specification of an open architecture
2. Evaluation and assessment leading to improved supporting data
3. Creation of consumer demand
4. Increase in functionality
5. Reduction of cost
6. Robustness / reliability / technical support
7. Integration with wheelchair

Extended discussions were held on the first three points above. The second outcome of the workshop was identification of three action items to be carried out by smaller working groups composed of the workshop participants. These items are as follows:

1. Establish internet resources.
2. Create a white paper on the specification of an open architecture.
3. Formulate a proposal to carry out an extensive North American study.

The outcomes and progress on the action items will be presented at the 5th International Conference on Rehabilitation Robotics, to be held in Bath, England, in April of 1997.

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1 PARTICIPANTS

1.1 Invited

Chris Cobb
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(Please note that Chris Cobb was forced to withdraw from the workshop for health reasons.)

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1.2 Affiliated with the Rehabilitation Engineering Research Center on Rehabilitation Robotics

Dan Chester,
Associate Professor
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R.S. Rao, Graduate Student, Applied Science and Engineering
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Sean Stroud, Staff, Applied Science and Engineering

Lee Leiber, Graduate Student, Applied Science and Engineering
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Zunaid Kazi, Graduate Student, Applied Science and Engineering
University of Delaware

Rungun Ramanathan, Graduate Student, Applied Science and Engineering
Drexel University

Shoupu Chen, Staff, Applied Science and Engineering

Randy Glass, Staff, Applied Science and Engineering

Brandon Higgins, Undergraduate Student, Department of Electrical Engineering
University of Delaware

Rich Mahoney, Staff, Applied Science and Engineering

Tariq Rahman, Staff, Applied Science and Engineering

Julia Mercier, Staff, Applied Science and Engineering

Anjaly Weber, Rehabilitation Engineering Wheelchair Clinic
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Sunil Agrawal, Associate Professor, Department of Mechanical Engineering
University of Delaware

Rami Seliktar, Assistant Professor, Department of Mechanical Engineering
Drexel University

Jill Schuyler, Graduate Student, Applied Science and Engineering
University of Delaware

2 PARTICIPANT OVERVIEW

The first morning of the workshop consisted of an introductory presentation by each of the invited participants. The purpose of the presentation was to provide an update on each individual's current activities. The appendix contains a copy of the overheads used by Harry Stuyt of Exact Dynamics, which contain valuable initial data on the commercialization of the Manus manipulator.

3 AGENDA

The following agenda was provided to the participants on arriving. This agenda was followed for the most part, but some flexibility was allowed to accommodate the group's desire to discuss specific topics.

Friday, September 27

8:30–9:45 Breakfast Buffet
Radisson Hotel Restaurant, 4727 Concord Pike

Gather in groups and drive to A.I. duPont grounds.

Classroom 3, 3rd floor of Hospital building--all sessions except Robotics Lab Tour

10:00-11:00 Introductions
Attendees will explain what they've been working on. VCR, overhead projector, slide projector available for visual aids.

11:00-11:15 Coffee/Refreshment break

11:30-12:00 Where are we now? Rich Mahoney, moderator
We will be taking a hard look at wheelchair robots. What have we really accomplished? What are the barriers keeping us from where we would like to be? Which robots are being used? And by how many people?

12:00-12:30 Group discussion of workshop objectives/goals

12:30-1:45 Lunch: A.I. duPont Cafeteria

2:00-4:00 Robotics Lab Tours & Device Demos (Manus, Helping Hand, Magpie, Rapid Prototyping) Coffee & refreshments will be served in the lab. This is a robotics lab open house more than a demo tour.

Visitors to the hotel for a break.

Dinner: Brandywine Brewing Company

Saturday, September 28

9:00-10:00 Continental breakfast at A.I. duPont Institute, Classroom 3, Third floor of hospital

10:00-11:00 Topical Discussions

11:00-11:15 Coffee Break

12:30-1:45 Lunch

2:00-3:00 Draw up lists & recommendations for the future.

3:00-3:45 Break: Refreshments

3:45-5:00 Summarize workshop outcomes

5:00 Dinner

4 WHEELCHAIR ROBOTS: THE PAST AND THE PRESENT. WHERE ARE WE NOW, AND HOW DID WE GET HERE?

The utility of mounting a robot on a wheelchair is obvious. The resulting assistive device provides a person with a severe disability with an aid that augments both mobility and manipulation. Whereas the powered wheelchair has achieved a high level of acceptance with a corresponding population of consumers, distributors, and developers, the wheelchair robot has achieved only nominal success and is not widely available to consumers.

This workshop will provide us with an opportunity to discuss the real accomplishments, and real failures, of wheelchair robots. It is important to share a common understanding of the history of the field and what is considered to be the state-of-the-art. This review is intended to be reflective, and not necessarily comprehensive. Feel free to add to the information and to share your experiences to complete our understanding of where along its development the wheelchair robot really is, and what has happened to bring it to this point.

4.1 Historical perspective

Participants were provided with a binder that contained copies of a large majority of the published journal and conference papers relating to wheelchair robots. These papers are listed in the bibliography of this report. This session provided the group with an opportunity to review the state of the field and to share information about early developments in this field.

The following devices and organizations were highlighted as significantly contributing to the knowledge relating to wheelchair robots. (Note that this list is not intended to be comprehensive, but represents the primary knowledge base of the participants):

General Teleoperators Manipulator (see Corker, Lyman, and Sheredos, 1979)
Magpie (Oxford Othopedic Engineering Centre, Oxford, England)
Cobra System (see Zeelenburg, 1986)
Spartacus (see Guittet, et al., 1979)
RoboArm (see Cheetham, et al., 1994)
Papworth Arm (see Hennequin & Platts)
Queen Alexandra Arm
Middlesex University (see Prior, et al., 1990
Helping Hand (see Sheredos, et al., 1995)
Manus (see numerous articles by Kwee, Verburg)

4.2 Timeline

The historical discussion was facilitated by reviewing the time during which key research and development took place in both North America and Europe, which is depicted in the timeline shown in Figure 1.

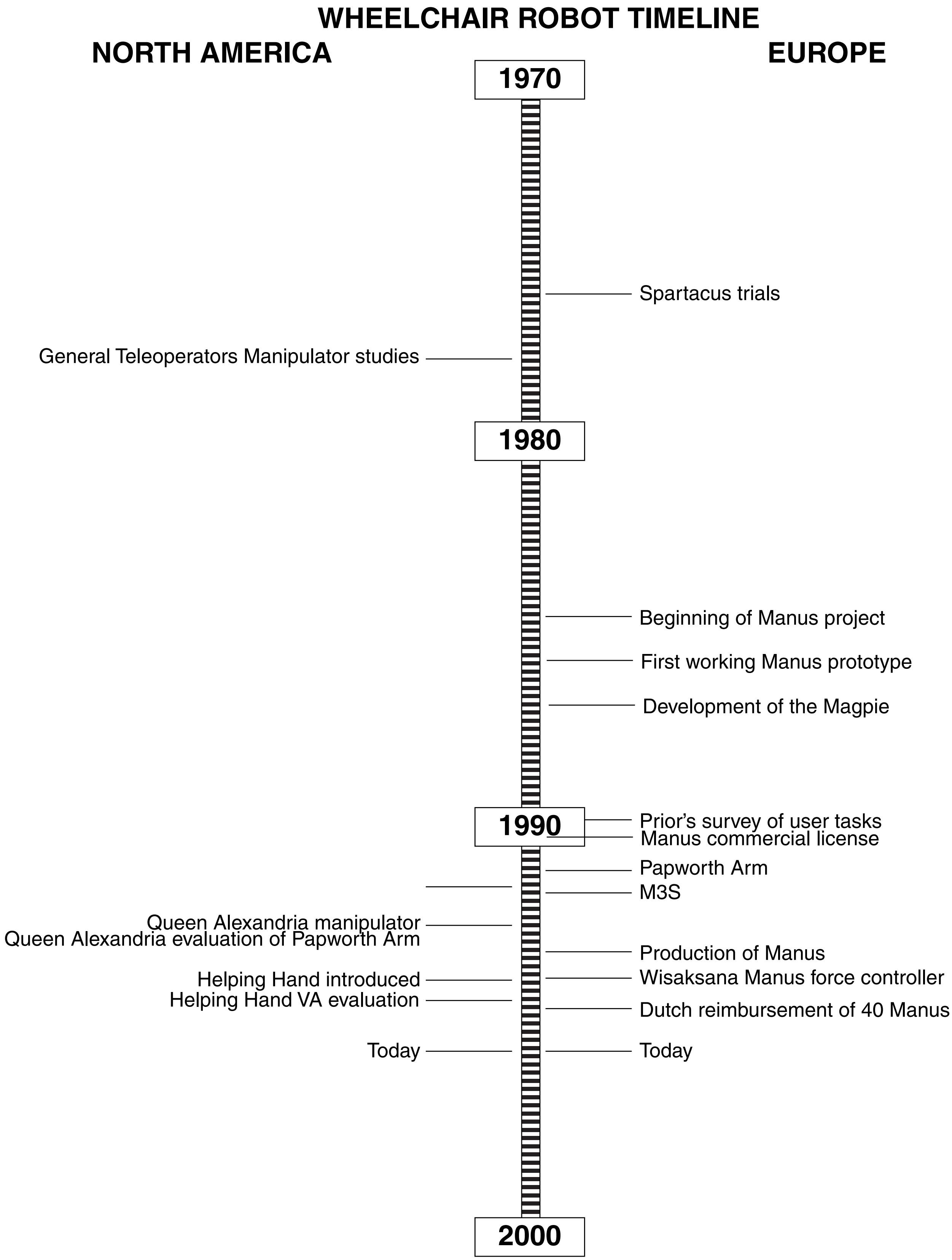

Figure 1: Timeline of significant events in the development of wheelchair robots.

5 CRITICAL REVIEW OF WHEELCHAIR ROBOT STATUS

Participants were asked to provide their top five answers to the following points relating to wheelchair robots.

- Top successes
- Top disappointments
- Top areas still requiring research
- Top criteria for commercial success

The information was recorded on the chalkboard as each person took turns listing their responses. A summary of the combined responses of the group is contained in Table 1.

5.1 Discussion of Responses to review

Based on the compilation of the participant's responses, further discussion was carried out to identify key need areas in terms of advancing the state of wheelchair robots. The discussion focused on the research and commercial success point. From these two lists, the following seven key areas were formulated as representing the primary need areas.

1. Reducing cost through
   - Improvement of the service delivery infrastructure, including technical support and funding.
   - Improvements in the design and manufacturing of devices.

2. Evaluation leading to data to support
   - measurement of the cost benefit to third party providers.
   - measurement of functional benefits to users.
   - risk assessment.
   - user training and assessment.
   - prescription of devices in a rehabilitation program.

3. Specification of an open architecture, to include
   - layered protocols.
   - bi-directional interaction between interface devices and the manipulator.
   - a generalized interface.

4. Increasing functionality through investigation of
   - user interface.
   - control approaches.
   - intelligent/sensor-aided/shared control.
   - constrained control/force feedback.
   - mechanical improvements.

5. Create consumer demand by
   - identifying funding to support initial introduction to market.
   - increasing public relations efforts.

Table 1: Summary of Responses to Session on Critical Review of Wheelchair Robots

ACCOMPLISHMENTS	DISSAPOINTMENTS	RESEARCH ISSUES	COMMERCIAL ISSUES
• Commercial device exists (40 in use) • Proof of concept • VA & FDA approval of KRI • Space ball control of Manus • Engineering of Manus • Breadth of Approaches • M3S (introduction of open architecture • Individual progress because of Manus • First evaluation (Exsact Dynamics survey of 20 users) • Level of Co-operation	• No widespread use • Manus not configurable in commercial version • Lack of clinician support • Poor reliability/ perception of • Expensive • Price-performance ratio • Lack of sticktoitivenss • No structured financing • Lack of intuitive control • Failure of Mason's project • User interface • Ease of repair • Lack of supporting data • Not enough consumer involvement	• Integration (Robot and wheelchair) • Improve functionality • User / robot interface • User requirements (what to present consumers say they need) • Cost reducing techniques • Open architecture • Modularity-mechanical,software • Safety - consensus on what constitutes adequate user safety • More intelligence • Gripper design • Size and location • Development of layered, modular, open arch. system library... • Alternative actuators • Sense of force • Control in constrained condition • Generalized interface (geometry control etc) • Integrating structured commands for eg.docking • Interaction between multi-dof devices • Alternate inputs • Evaluation of manus to provide functional data • Risk assessment • By adding & integrating sensors • Powerful but compact motors • Applications beyond rehabilitation	• Lower cost • Stakeholder buy in • Infrastructure - repair etc • Greater functionality • Better dissemination/ PR/Marketing • Cost benefit ratio • Functional • Interface-decent interface • Adaptability • Reliability/ Robust performance • Prescription protocols - related to rehab - progressive condition • Funding • Active consumer group • Approvals • User education • Integration of robot-wheel chair • Desirable to consumers • Aesthetically pleasing

- identifying the appropriate Infrastructure for implementation.
- identifying and supporting active consumer groups.
- finding other ways to increase stakeholder buy-in. Stakeholders include not only users, but also family members, physicians, therapists, rehabilitation engineers, and third party payers.

6. Improve robustness / reliability / technical support through
   - identifying techniques for monitoring robustness.
   - investigating remote diagnosis.
   - making maintenance and technical support much easier.

7. Integrate device more closely with wheelchair
   - control.
   - design.
   - standards.
   - interface.
   - stability.

Notes: For example, how does the weight of a wheelchair manipulator effect stability, braking, and control of a wheelchair.

8 TOPICAL DISCUSSIONS

Due to time constraints, the workshop participants selected three areas for extended discussion and for the specification of action items to be carried out by the participants in smaller working groups. The areas and discussion are summarized below. Action items were described in the next section.

8.1 Open architecture considerations (moderated by Randy Glass)

In the simplest sense, an open architecture defines the lowest common denominator of the inputs and outputs that are part of the system.

An architecture is composed of a set of layers that define the protocols for communication relevant to each layer.

How far does M3S go in meeting the criteria of what an open architecture should include? M3S includes the following: mapping of dof to input device capabilities; local intelligence; domain oriented?

CURL approach uses device drivers; is a layer that links onto M3S.

Problems with Manus: not able to have access to all necessary information.

Helping Hand has no architecture.

An open architecture definition would allow a manufacturer or developer to plug a standard input device into any robot, or it would allow a number of manufacturers to design a new input device for a person or population with special needs.

8.2 Evaluations leading to data (moderated by Geb Verburg)

What:

- Credible data regarding effectiveness. Effectiveness in terms of cost payback and quality of life.
- Studies should be anthropomorphic in that the environment must be closely matching the real environment in which the person will exist.
- Maybe a description of what people can do now that they could not do before is sufficient.
- It's important that the data is obtained for a device that can be commercially available to avoid further frustration.
- Endorsement of credentialling associations for rehab engineers and occupational therapists in running a study of how such a device would be prescribed in a rehabilitation program.
- Need to run a prescription study which includes rehabilitation physicians, occupational therapists.
- Need to fund a major North American study that includes up to 200 users of a wheelchair robot, to possibly include Bloorview McMillan Center, ASEL, VA Palo Alto Research Center, OSU, Bob Erlandson - who would fund it? (Easter Seals, VA, Department of Education, North American joint funds)

Who:

- Veterans Administration (Rich Mahoney will contact Sal Sheredos)
- Charles Williams running a European project
- Other organizations: AJOT, CJOT, PVA, NIDRR, MDA

Where:

- ASEL
- Stanford
- BMC

How:

- Helping Hand
- Manus

8.3 Create consumer demand (moderated by Harry Stuyt)

Recommend that funding to introduce wheelchair robot to market could be facilitated through the evaluation study. Also, the outcome of the open architecture efforts could be evaluated as part of the last effort. The project could bring in other aspects of the creating consumer demand:

Infrastructure would support project devices.

Active consumer groups would consist of those who would be funding the project.

And therefore this would also meet the other criteria of obtaining funding for introduction into the market.

The outcome of the project would be the PR.

Need to initiate active discussion.

9 ACTIONS TO BE TAKEN

Based on the discussions described above, the workshop participants identified three action items that could be initiated by smaller working groups, comprised of individuals who attended the workshop and others who may be interested. These items and some description follow:

Set up internet resources to include:

- web pages containing information on wheelchair robots.
- a listserver to facilitate communication.
- ensuring that relevant data is deposited in AbleData.

The RERC on Robotics has already created a listserver called assistive-robots that should meet the second item. The RERC also agreed to host web pages for any manufacturer who was interested in having information about their device placed on the web.

The individual manufacturers would contact AbleData to provide information on their device.

Create a white paper on the specification of an open architecture:

A working group was formed, consisting of

- Andre Wisaksana (agreed to be initial chairperson)
- Bart Driessen
- Hok Kwee
- Randy Glass
- John Dallaway (would be contacted to see if he is interested)

The working group will write a white paper on the open architecture, including a definition of what the open architecture would include, and offer some recommendations for what those specifications should be. A goal should be to identify funding requirements.

Timeline is to have an outline of a document within two weeks and to have a complete document available by ICORR in April.

Formulate a proposal to carry out an extensive North American study:

A working group was formed, consisting of

- Geb Verburg

- Rich Mahoney
- Harry Stuyt

Working group will formulate a proposal that outlines the activities and interactions. The first business will be to identify the funding schedules of the agencies listed above. Study could be carried out so as to include the criteria listed under 'create consumer demand' (as noted above). Possibly running initial prescriptions through the new A.I.D.I. Center for Assistive Technology. Study to include administering a consumer survey.

10 FINAL SUMMARY OF WORKSHOP

Hok Kwee: Highly productive, provided a new perspective that seems may result in new collaboration.

Geb Verburg: Pleased to be invited. Chance to look more directly at a particular project. Time is right to focus on wheelchair robots. Hopes for new funding angles. Surprised by the substance that we addressed. Open architecture essential. Unfortunate that KRI was not able to participate.

Andre Wisaksana: Very good idea to get together. We covered good areas and have a good starting point. Disappointed that KRI, consumers, clinicians were not able to attend. We need them all to be involved for this to succeed.

Julie Mercier: If possible, please keep her up to date. There is a need for a central place to come to for information.

Tariq Rahman: Thank you all. Hope that information will translate into other projects. Good, but wish for more critique on specific decisions on success.

Dan Chester: Looking forward to seeing the outcomes.

Harry Stuyt: Thank you. Hopes for North American pilot project to come into existence and hopes to participate in its organization.

Bart Driessen: Liked international information exchange. We are at a dangerous point because we need our actions to actually be done, in spite of the fact that there are no sharp timelines.

Lee Leiber: Happy to meet everyone. Surprised at how much we discussed on the consumer side. Hope that the enthusiasm can continue.

Mike Hillman: Wearing two hats: developer of robot; organizer of conference. He has benefited on both fronts. Please forward progress on actions, if possible in time for ICORR.

Rich: Thanks to everyone for making the effort. Hopefully outcomes will be useful and maybe lead to more wide acceptance in the long run.

11 BIBLIOGRAPHY

Bach, JR, Zeelenberg, AP, Winter C. Wheelchair-Mounted Robot Manipulators -- Long Term Use by Patients with Duchenne Muscular Dystrophy, American Journal of Physical Medicine and Rehabilitation, 1990.

Bush, G., Al-Temen, I.,Hancock, J., Bishop, J., Slack, M., Kurtz, I. (1994). Development of a Myoelectrically Controlled Wheelchair-Mounted Object Manipulator for Quadriplegics. ICORR '94 (pp. 103-106). Wilmington, Delaware.

Cheetham, A., Milner, M., Verburg, G. (1994). Eye Movement Control of the Manus Manipulator. Proceedings of the 17th Annual RESNA Conference, Nashville, Tennessee, June 17-22.

Corker, K., Lyman, JH., Sheredos, S. (1979). A Preliminary Evaluation of Remote Medical Manipulators. Bull Prosth. Res., BPR 10-32, Fall 1979, pp. 107-134.

Guittet, J., Kwee HH., Quetin N, Yclon J. (1979). The Spartacus Telethesis: Manipulator Control Studies. Bull. Prosth. Res., BPR 10-13, pp 69-105.

Hennequin, JR, Platts, RGS, The Institution of Electrical Engineers Colloquim: "Robotics and its Role in Helping Disabled People", "The Wheelchair-Mounted Manipulator and Palatal Tongue Controller".

Kwee HH., Tramblay, M., Barbier, R., Dupeyroux, M., Vinceneux, MF., Semoulin, P., Pannier, S. (1983). First Experiment of the Spartacus Telethesis in a clinical Environment. Paraplegia, 21, pp.275-286.

Kwee HH. (1995). Rehabilitation Robotics: Softening the Hardware. IEEE Engineering in Medicine and Biology Magazine, 14(3), pp.330-335.

Kwee HH. (1986b). Spartacus and Manus: Telethesis Developments in France and in the Netherlands. In: Foulds R (Ed.). Interactive Robotic Aids - One Option for Independent Living: an International Perspective, Monograph 37, World Rehab. Fund, New York, 7-17.

Kwee HH. (1995). Rehabilitation Robotics at IRV. Forum for European Rehabilitation Robotics, FTB, Wetter, Germany, May 1995.

Leifer, L. (1981). Rehabilitative Robots. Robotics Age, May/June 1981.

Oderud, T., and Bastiansen, JE. (1992). Integrating a Manus Manipulator and an Electric Wheelchair. Practical Experiences. Proc. 15th Ann. RESNA Conference, Toronto, Ontario, June 1992, pp. 595-597.

Prior, SD (1990), An Electric Wheelchair Mounted Robotic Arm -- A Survey of Potential Users, Taylor & Francis Ltd., 1990.

Prior, SD (1990), A Survey of Potential Users of An Electric Wheelchair Mounted Robotic Arm, Proceedings of the 13th Annual RESNA Conference, Washington, D.C., 1990.

Sheredos, SJ., Taylor, B., Cobb, CB., et al. (1995). The Helping Hand Electro- Mechanical Arm. Proceedings Rehabilitation Engineering Society of North America, RESNA '95 pp. 493-495.

Verburg, G., Milner, M., Naumann, S., Bishop, J., Sas, O. (1992). An Evaluation of the Manus Wheelchair-Mounted Manipulator. Proc. RESNA International '92, Toronto, PP. 602-604.

Verburg, G., Kwee, HH., Wisaksana, A., Cheetham, A., van Woerden, JA. Manus: The Evolution of an Assistive Technology.

Wisaksana, A., Verburg, G., Naumann, S. (1995). The Development of an Interface Between the Spaceball 6DOF Isometric Joystick and the Manus Rehabilitation Robot. Proc. RESNA '95. 1995, Vancouver, pp.478-480.

Zeelenberg, AP.(1986) Domestic Use of a Training Robot-Manipulator by Children With Muscular Dystrophy, In: Foulds R (Ed.). Interactive Robotic Aids - One Option for Independent Living: an International Perspective, Monograph 37, World Rehab. Fund, New York, pp.29-33.

APPENDIX

Presentation Overheads, Harry Stuyt, Exact Dynamics