Robots for Rehabilitation, Assistance and Assessment

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About me

- Senior lecturer in adaptive systems
- Background in rehabilitation robotics (since 1999)
- PhD in Cybernetics
- Prior to that, software engineering/system analysis (since 1989)

- Currently supervise 4 PhD students – one PhD student is a Doctor now.
- Coordinate two EC-funded projects (€9M) and contribute to a 3rd project.
- Part of a 4th project started this Year on robot safety
- Member of AMT/-/2 team on robotics standardisation (BSI/ISO)

Where is Hertfordshire University?

Human-Robot Interaction Research @ UH:

- Research Staff
  - Prof Kerstin Dautenhahn
  - Prof Chrystopher L. Nehaniv
  - Dr Daniel Polani
  - Dr Lola Canamero
  - Dr Farshid Amirabdollahian

- PhD students
  - Tom Anthony
  - Constantinos Theodis
  - Mala Harder
  - Moritz Buck
  - Ori Novanda
  - Sen Arvan Dijk
  - Nathan Burke
  - Sue Atwood
  - Frank Forster
  - Kyron Du Casse
  - Claire O’Byrne
  - Ismael Duque
  - Michael Bowler
  - Radhika Chemuturi
  - Lisa Bowers
  - Luke Wood
  - Nauman Shah
My talk today

- Introduction and rationale
- Introduction to topics
- Selected ongoing project highlighting approaches

CHALLENGE QUESTION

Why Robotics?

WHY ARE ROBOTS AND TECHNOLOGICAL APPROACHES (ICT-BASED APPROACHES) ARE ON THE RISE?

Aging population

- According to Eurostat, the percentage of the European population aged 65 years and over will grow from 16% in 2010 up to 29.3% in 2060 (EUROSTAT, 2011).
Population projections for the 27 Member States, showing an almost doubling in number of people aged 65 and above (from 17.57% to 29.54%), while the number of people aged between 15-64 will see a decrease from 67.01% to 57.42%.

Areas where robots/advanced ICT can help?

- Physical support
- Cognitive support
- Social activity
- Re-ablement => a new way to do the same task
- Co-learner => robot and person learn together
- Rehabilitation
- Assessment & Telecare

OVERVIEW

Current state of the art

Assistive

Robot

Rehabilitation

Robot

Surgery

Robot

Social mediators

companion

CHALLENGE QUESTION

disability vs impairment, what is the difference?

DO YOU KNOW THE DIFFERENCE BETWEEN DISABILITY AND IMPAIRMENT?

WHAT DOES AN ASSISTIVE DEVICE HELP WITH?
WHAT IS THE USE FOR A REHABILITATIVE DEVICE?
CHAPTER 1

Assistive Robots

Handy 1

Personal Assist


CHAPTER 1

Handy 1

CHAPTER 1

Assistive Robots

Manus

Personal Assist

Manus from ExactDynamics
Or see Driessen et al. 2001
CHAPTER 1

Prosthetic limbs

Southampton hand
Hand that feels (ARTS labs, Italy)
Blatchford smart prosthetics (Endolite)

CHAPTER 2

Rehabilitation Robots

GENTLE/S: UPPER LIMB REHABILITATION
USED DOMAIN: STROKE THERAPY

CHAPTER 2

Rehabilitation Robots

Gentle/s

Stroke

MIT-MANUS (KREBS ET AL. 1998)
MIME (BURGAR ET AL. 2000)
ARM-GUIDE (REINKENSMEYER ET AL. 2000)
GENTLE/S (AMIRABDOLLAHIAN ET AL. 2007)
GENTLE/G (LOUREIRO ET AL. 2007)
IPAM DUAL ROBOT (CULMER ET AL. 2006)
SOUTHAMPTON WORKSTATION
  With ILC and FES (Freeman et al. 2009)

Check out our hand exoskeleton for stroke rehab at scriptproject.eu

CHAPTER 3

Social mediators

Kaspar

Autism

http://kaspar.feis.herts.ac.uk/
CHAPTER 3

Companion robots

http://paro.jp/english/index.html

Kaspar

Autism

Companion

Robots

CHALLENGE QUESTION

Existing studies

ARE YOU AWARE OF STUDIES WHERE MULTI-DISCIPLINARY ASPECT OF REHABILITATION IS CONSIDERED AND SOCIAL MEDIATION AS WELL AS PHYSICAL REHABILITATION IS UNDERTAKEN?

IS THE MOST TECHNOLOGICALLY ADVANCED APPROACH ALWAYS THE BEST APPROACH?

OVERVIEW

Current state of the art

Assistive

Rehabilitation

Robots

Surgery

Social mediators

companion

Robots
CHAPTER 4

Surgery Robots

DA VINCI
http://www.intuitivesurgical.com/

CYBER KNIFE
http://www.cyberknifecentrelondon.co.uk/

LAPAROSCOPIC MANIPULATORS
FOR MINIMALLY INVASIVE/
KEYHOLE SURGERY

MICRO & NANO BOTS
Bacteribots

CHALLENGE QUESTION

Question of ethics

IF A SURGERY ROBOT IS INVOLVED IN DEATH OR PERMANENT NEGATIVE IMPACT
ON A PATIENT, WHO IS RESPONSIBLE?

OVERVIEW

Current state of the art

Assistive   Rehabilitation
Assessment    Robots
Robot        Social mediators
Surgeon      Robotics
Robots       companion

CHALLENGE QUESTION

Assessment Robotics?

WHAT IS ASSESSMENT ROBOTICS?
What is in a Robot?

- Sensors
- Effectors and actuators
  - Used for locomotion and manipulation
- Controllers for the above systems
  - Coordinating information from sensors with commands for the robot’s actuators

The Robotics Primer, 2007. Author: Maja Mataric’

Assessment Robotics?

It depends on its sensors of course. In the context of rehabilitation and assistance, it is possible to measure many parameters, from biomechanical to physiological sensing.
Project & Partners

- 1. The University of Hertfordshire (UH), United Kingdom
- 2. Hogeschool Zuyd (HZ), The Netherlands
- 3. Fraunhofer (Fraunhofer), Germany
- 4. University of Amsterdam (UVA), The Netherlands
- 5. University of Siena (UNISI), Italy
- 6. Maintien en Autonomie à Domicile des Personnes Agées (MADOPA), France
- 7. University of Birmingham (UB), United Kingdom
- 8. University of Twente (UT), the Netherlands
- 9. University of Warwick (UW), United Kingdom

- Budget: €4,825,535
- EC funding: €3,653,929

Areas where robots can help

- Physical support
- Cognitive support
- Social activity
- Re-ablement => a new way to do the same task
  - Support people to do rather than doing to / for people
- Co-learner => robot and person learn together
  - Services for people with poor physical or mental health to help them accommodate their illness by learning or re-learning the skills necessary for daily living UK Department of Healths Care Services Efficiency Delivery [4].

User requirement elicitation - focus group method & Cognitive walkthroughs
User requirements analysis; 68 requirements

1. Execution task
   – 27 user requirements (no. 1 – 27)
2. Visitors
   – 5 user requirements (no. 28 – 32)
3. Information
   – 7 user requirements (no. 33 – 39)
4. Robot behaviour
   – 2 user requirements (no. 40 & 41)
5. Camera usage
   – 3 user requirements (no. 42 – 44)
6. Robot appearance
   – 6 user requirements (no. 45 – 50)
7. Environment
   – 1 user requirement (no. 51)
8. Additional robot functionalities
   – 17 user requirements (no. 52 – 68)


Social & Empathic interaction

• Would the robot provide social interaction?
• Would the robot provide empathic interaction?

Social and empathic interaction will be designed towards these. It will have aesthetic, perceptual and emotional interaction added to its functional and physical behaviours.

Stienstra, J.T., Marti, P. and Tittarelli, M. (2013); Dreamy Eyes: Exploring Dynamic Expression in Human-System Interaction, CHI2013
SOA3
Context awareness

Environment

Physical Context (activity, location, role)

Robot Task

Reminder

Notification

Fetch and Carry

User Context (activity, location, role, preferences, social situation)

Activity Location Preferences Proxemics User

Embedded Sensors

Robot Context (activity, location, role)


SOA5
Robot learning and adaptability

• What if the robot can remember its interaction history?
  – It needs to have ability to learn and recall
  – It needs to have a cognitive architecture for this

• Our research here focuses on dynamic computational long-term memory for the robot
  – Initially, domain knowledge is limited to scenario at real home environment – Robot House
  – How can robot visualise its memory and share with user?
Computational Memory

**EPISODIC memory**
- Events > History > Temporal Sequences
  - Individual event details that the robot encounters in a given moment or time period

**SEMANTIC memory**
- Facts about the world
  - The robot remembers available information about all objects and users, and commonsense knowledge required by specific task completion

**PROCEDURAL memory**
- Skills, sensorimotor and sensori-memory
  - Actions the robot needs to learn and carry out

Complex tasks - Architecture

Robot learning & adaptive interaction

**SOA5**
Learning and adaptability

- Used to encourage and motivate for re-ablement
- Used for co-learning, where user and robot learn together, user gaining cognitive and physical assistance while robot learning about the user’s daily activity and environment
Environment and activity monitoring

- Detects people and objects using robot and environmental sensors
- Activity recognition of household chores

- It needs ability to fuse data from the house sensors with those of the robot, i.e. ceiling camera and robot’s camera

Advantages are that this would allow robot to know where user is, so it can help being near or away from the users.


Environment & activity monitoring

Person Detection and Identification

- Person detection by head detection in two steps:
  1. Search for potential head locations in depth image (result: blue frame)
  2. Search for faces at the found head locations in the color image (result: green frame)

- High detection robustness through sensor modality fusion, almost no false detections
- Face identification based on the found face regions, i.e. the green frames (result: green identification numbers)

Object Recognition

- Recognition of previously modeled objects and 6 DOF pose estimation
- Object modeling with color and depth information
- Robust against occlusions and scale

Registration of the individual object images into a single 3D object model

Feature point model
Object model
Environment & activity monitoring

**Object Categorization**
- establishes recognition of the class of previously unseen objects
- allows to recognize a significantly larger number of objects than by using object recognition alone
- no need to model each individual object in advance

**Platform**
- Can be used at UvA, HZ and Hertfordshire

**Human Detection and Localization**
Data Fusion of Fish-eye and Laser (probabilistic fusion)

**SOA7**
Challenge of integration
- Many modules need to come in from many partners
- they all need to work together, in a timely and reliable manner
- Good architecture and good procedure for integration
Acceptability

- What are the factors that influence robot’s acceptability?
  - Trustworthiness
  - Loyalty
  - Un-intrusiveness
  - Helpfulness
  - What else?

New ethical norms

- Identifying new norms related to using robots as companions
  - Issues such as privacy
    - Who gets to decide what the robot would pass on?
    - How much does the robot need to know?
    - How much does the environment need to know?
  - What other norms are important here?
    - Autonomy, independence, enablement, safety and privacy, social connectedness
  - An example: Can the robot say I won’t do it?

What next in the project?

- Passed our first year review with Excellent mark

- Future work in next years
  - Progress in robot role identification and acceptable roles and behaviours
  - Progress in summative evaluation, comparing requirements to achievements => SOA10

Future challenges?

- Assistive technology
- Rehabilitation technology
- Social and companion technology
- Surgery robots
- Assessment technology
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http://SCRIPTPROJECT.EU & HTTP://ACCOMPANYPROJECT.EU

http://rehabilitationrobotics.net/ro-man14/

THANK YOU FOR YOUR ATTENTION!

FURTHER READING

References


