Emerging Technologies for Aging and Disability

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University of Heidelberg, Oct. 9, 2013
Overview

1. QoLT Philosophy & Overview
2. Core Technologies & Systems under Development
3. Privacy, System Demand, and Cost Issues
I. QoLT Philosophy & Overview
Creating intelligent systems that enable older adults and people with disabilities to live independently

From "autonomous" to "symbiotic" systems with balanced involvement of person and technology

- Person-System Symbiosis
- Person-Aware and Environment-Aware

New technologies:

- Robust perception of the person and unstructured environment
- Soft, safe manipulation of person and everyday objects
- Dynamic and adaptive interaction
QoLT Core Research Thrusts

Interaction & Usability

Human System Interaction

Perception & Awareness

Mobility & Manipulation

Person & Society

Cost, Benefit, Acceptance & Market

Person & Environments

Assistance & Effect
QoLT Testbed Systems

**QoLTbots**
Provide reactive and proactive manipulation assistance for activities of daily living.

**Virtual Coach**
Provide cognitive and memory assistance and enhanced motivation in contexts ranging from exercise to daily tasks.

**Safe Driving**
Provide ways to make driving safer for older adults and people with disabilities.

**Home & Community Health and Wellness**
Combine person and task awareness to support healthy independent living.
Quality of Life Technology Center
a National Science Foundation Engineering Research Center

**Testbed Systems**

- Home & Community Health & Wellness
- QoLTbots
- Safe Driving
- Virtual Coach

**Requirements**

**Technologies & Insights**

**Basic Research**

- Mobility & Manipulation
- Perception & Awareness
- Person & Society
- Human-System Interaction

**Proving Ground**

- Needs & Feedback
- Products

**Industry/Practitioner Collaboration & Spin-off Company Creation**

- Allstate
- BOSCH
- ETRI
- Intel
- Panasonic
- etovia
- Honeywell

**Education, Outreach & Diversity Enhancement**

- first person vision
- VibeAttire
# QoLT Systems: Functionalities and Target Populations

<table>
<thead>
<tr>
<th>Sample systems</th>
<th>Key Functionalities</th>
<th>Targeted Populations (size)</th>
<th>Target Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virtual Coach</strong></td>
<td>Navigation for public buildings</td>
<td>retrieve signage information</td>
<td>people with visual impairments (&gt;3M)</td>
</tr>
<tr>
<td></td>
<td>Medical device usage coach</td>
<td>provide appropriate guidance, feedback and reinforcement communicate with clinicians</td>
<td>people with Mild Cognitive Impairment (&gt;6M)</td>
</tr>
<tr>
<td></td>
<td>Personal rehab coach</td>
<td>recognize correct movements track performance</td>
<td>survivors of stroke (3M)</td>
</tr>
<tr>
<td></td>
<td><strong>Home / Community Health and Wellness</strong></td>
<td>Cognitive Kitchen</td>
<td>recognize kitchen activities provide cues for actions</td>
</tr>
<tr>
<td></td>
<td>Health Kiosk</td>
<td>measure and record vital signs allow interaction with clinicians</td>
<td>older adults living alone (4M)</td>
</tr>
<tr>
<td></td>
<td><strong>QoLTbots</strong></td>
<td>Personal Mobility &amp; Manipulation Appliance</td>
<td>manipulate objects on behalf of the user</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home Exploring Robot Butler</td>
<td>retrieve and place objects prepare meals do household chores</td>
</tr>
<tr>
<td></td>
<td><strong>Safe Driving</strong></td>
<td>DriveCap</td>
<td>continually assess a person’s capability to drive a vehicle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DriveCap Navigator</td>
<td>provide route instructions tailored to user’s driving capability and prevailing road/environmental conditions</td>
</tr>
</tbody>
</table>
Product Development and Evaluation Timeline

User-centered Design Prototype → Robust Prototype → Laboratory Prototype → Field-deployed System → Commercially-viable Application → Commercial Product

Evaluation Design Strategies

LAB

User-centered design methods (Iterative)
Prototyping design and testing
Observation of task performance w/technology
Laboratory testing
Storyboarding
Rich stimulus displays
Scenario testing
“Wizard of Oz” studies
Individual in-depth interviews / “think aloud”
Focus groups/ Group-individual synthesis

FIELD

Field testing
Pilot trial
Randomized efficacy trial
Effectiveness trial
Comparative effectiveness trial
Acceptance and adoption study

Measurement Strategies

Ease of use; Acceptability; Reliability; Learnability; Effectiveness; Efficiency; Errors; Flexibility; Memorability; User satisfaction; Safety; Confidence; Aesthetics; Convenience; Intrusiveness / privacy concerns

Adoption / uptake
Real-world task performance
Quality of Life
Technology-specific
Disease/condition specific
Generic
Secondary / broad outcomes
Need for formal/informal caregivers
Caregiver burden
Healthcare costs
Value to healthcare providers
Technology Characteristics

Generic QoL

Technology QoL

Disease/Condition QoL

Secondary Outcomes

General Measurement Strategies
II. Core Technologies and Applications
Core Technologies

• Perception and Awareness—Seeing and understanding the environment, inferring intent
• Mobility and Manipulation—moving, reaching, grasping, pushing, pulling, holding
• Human-system interaction—Interfacing with humans
• Individual and societal factors shaping acceptance and adoption
Everyday Life Scene Recognition

Lowering the *Complex Interactions and Contextual Variability* barrier

In addition to recognize a *given* object, QoLT systems must discover in the first place *what* objects are there, and understand how they relate to the user:

- see partially *occluded* objects
- identify objects in *cluttered* env.

Discover objects that a person uses

Object #1: ⚫️ ⚫️ ⚫️

Object #2: ⚫️ ⚫️ ⚫️

Object #3: ⚫️ ⚫️ ⚫️
Cooperative Manipulation
Soft Robot—cooperative manipulation
HERB—Push Grab
HERB
HERB—Delicate Manipulation (Oreo)
Health Kiosk: Multiuser kiosk for standardized health screening, assessment, and treatment delivery.
Functionality of Health Kiosk

- Headphone
- Touch Screen
- Loudspeaker
- Blood-Pressure Monitor
- RFID reader
- Hand Dynamometer
- Computer & Printer
- Pulse Oximeter
- Seated Scale

![Kiosk Image]

![Kiosk Interface]

Welcome Kristie!
What would you like to measure today?

Wednesday, November 17, 2010

- Blood Pressure
- Weight
- Grip Strength
- Surveys
- Vision
- Blood Oxygen
- Pulse
- Hearing

Print History Settings Messages Exit

Blood Oxygen
Please follow the instructions below.

Step 1: Press the white button on top of the pulse oximeter.
Step 2: Place your finger in the clip by squeezing the end opposite the button.
Step 3: Wait until the device display looks similar to the picture.

4. Tap here when you're ready.
Kiosk: Home Page

Welcome Guest!
What would you like to measure today?

Wednesday, December 14, 2011

- Weight
- Grip Strength
- Surveys
- Blood Oxygen
- Pulse
- Blood Sugar
- Vision
- Blood Pressure

Today's Results
Past Results
Settings
Messages
Exit
4. Keep the pulse oximeter on and tap here.
HeadCoach
A “Dosage” Monitoring Device
For Home-Therapy Balance Exercises
Gaze Stabilization Exercise

Figure 2A: Look straight ahead.
Figure 2B: Turn your head 45 degrees towards the right.
Figure 2C: Turn your head 45 degrees towards the left.

Note: Business card should be positioned at eye level.

(c) T.C. Hain, 2002

Improves Vestibulo-Ocular Reflex (VOR)
Ideal Balance Treatment Cycle

Symptoms of Imbalance → Balance Clinic

- Patient Assessment → Exercise Prescription

Balance Clinic → Home

- Patient “Dosage” → Patient Response

Quality of Life Technology Center
Therapists cannot know what patients are actually doing at home
• “Dosage”
• Compliance
Common Problems and Mistakes

Performance
• Turning too fast or slow
• Moving eyes rather than head
• Turning too far to the sides and becoming dizzy
• Turning too little, negating the effectiveness of the exercise

Dosage
• Not following prescription outright
• Not remembering how much they did
Personal Intelligent Coach: A Sensor-Based Therapeutic Coach for Home Rehabilitation of Knee Osteoarthritis
The Problem

Problem:

- Knee OA is a degenerative disease
- Causes pain, swelling and decreased joint mobility
- Exercise is prescribed to lessen effects

- Home exercise intended as lifestyle change
- Poor adherence
- Incorrect performance
Measuring Quality

Collect data from subjects performing exercises
Classifier trained to detect errors in exercise performance
Integrating Quality Assessment

- Additional sensors can provide better measuring of quality
- Recognition of multiple errors in single performance
- Study possible forms of feedback to patient
Context Aware Virtual Coach
Context-Aware Virtual Coach

- Less than 35% of power-wheelchair users effectively use power-wheelchair functions to ease pressure sores [Lacoste et. al., 2003]

- The Virtual Coach artificial intelligence aims to help users better utilize the functions of their chair

- The chair must interact with the user in an adaptive and personalized manner

**Project goal:** Autonomously discover user preferences for modes and timing of instruction using onboard sensors.
Context-Aware Virtual Coach

- Evaluation will be performed in clinical trials, testing user satisfaction and exercise compliance.

- **Support Vector Machines** with 6-axis accelerometer data.
- 87% classification accuracy over 5 terrains

- **Gaussian Mixture Model**
  - using Cepstral coefficients
  - detects noise in the environment and conducts speaker recognition.
- 90% accuracy in speaker recognition

**Context Features**

<table>
<thead>
<tr>
<th>Physical location</th>
<th>Terrain type</th>
<th>Light sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Audio characteristics</strong></td>
<td>Date and time</td>
<td>Chair angles and posture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air temperature</td>
</tr>
</tbody>
</table>

- Evaluation will be performed in clinical trials and **exercise compliance**.
### Power Wheel Chair Virtual Coach

#### Pressure Ulcer

#### Sensing

#### Coaching

<table>
<thead>
<tr>
<th>Activity</th>
<th>Parameter</th>
<th>Duration</th>
<th>Gap</th>
<th>Alert after</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Ideal</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Tilt</td>
<td>25°</td>
<td>30°</td>
<td>35°</td>
<td>25 sec</td>
</tr>
<tr>
<td>Recline</td>
<td>10°</td>
<td>15°</td>
<td>20°</td>
<td>4 mins</td>
</tr>
<tr>
<td>Feet Elevation</td>
<td>25°</td>
<td>30°</td>
<td>35°</td>
<td>50 sec</td>
</tr>
<tr>
<td>Pressure</td>
<td>0</td>
<td>60mm</td>
<td>200mm</td>
<td>0 sec</td>
</tr>
</tbody>
</table>

General Tilt angle: Min 10, Ideal 20, Max 30
General Recline angle: Min 10, Ideal 30, Max 40

Prescription
Augmented Feedback using Personal Robotics for Neuro Rehabilitation

Andrew Tran, Jason Tsay, Sheng Bin
Collaborators: Steve Kelly, Ela Lewis
(Myomo)
Motivation

Stroke

- Number one cause of disability in US
- 776,000 per year, total of 6.6 Million
- Cost $65.5 B per year
- 35% after hospital care

Project goal: Restore Arm Functionality
Problem Definition

How do we improve compliance by controlling video games with the Myomo arm?
System Architecture

- Reader
- Virtual Controller
- Game App
- Myomo Arm
- Log Replayer
- Therapist App
Subject

Stroke victim – 6 years
Left side paralyzed
Likes Xbox and racing games
Tires in 3 minutes
5 repetitions suggested

Insights
Can use both hands – good for rapid movement, assisted for selection
Hand collaboration seems to have cognitive rehabilitation as well
First Person Vision-caregiver application
FPV Caregiver Study Design for Dementia Patient Problem Behaviors

Baseline Assessment (Self-Report) → FPV Data Capture (7 days, waking hours) → Clinical Evaluation → Intervention → Follow-up Assessment

Detection and Treatment Algorithm Development → Machine Processing of FPV Data
Repetitive Questioning
An Integrated Health Care Delivery System

Person with Illness, Disability

- Provide Feedback and Treatment
- Receive Health and Functional Status Inf.
- Receive Health, Behavior, Safety, Well-being Inf.
- Provide Support and Guidance
- Monitor and Support Caregiver
- Provide Feedback to Health Care Provider

Informal Caregiver
Family Member

Health Care Provider
III. Privacy/ System Demand and Cost
I. System Characteristic
Ease of Use: Hardware/Software Interface, Instructional Support
Esthetics
Engagement
Functionality
Controllability
Reliability
Safety

II. Individual Characteristics
Age, Gender, Education, Income
Health/Functional Status
Experience with Technology
Personality

III. Societal Factors: Policy and Regulatory Environment

User Perceived Costs and Benefits
Costs
Loss of Privacy
Reduced Efficiency
Training Requirements
Maintenance Requirements
Reduced Social Interaction
Personal Financial Costs
Stigma

Benefits
Enhanced Functioning
Autonomy/Independence
Reduced Burden on Others
Better Health
Entertainment
Personal Cost Savings
Enhanced Safety

Model of Technology Uptake: System, Individual, and Societal Factors
Privacy Concerns

• How acceptable are different types of home and individual monitoring?

• How willing are individuals to share monitoring information with various targets (e.g. family, doctor, insurance co.)?

• How do functional gains (i.e., different levels of loss of independence) affect privacy preferences?

• How does current age, disability level, experience with disability, and education affect preferences?
Privacy Results: Acquisition Method by Type of Data

- Video and video with sound less acceptable than sensors.
- Some types of information (e.g., toileting) may be totally out of bounds for visual access.
Privacy Results: Type of Data by Recipient

- Insurance companies and government least acceptable as recipient
- Driving information sensitive outside family contexts
Acceptability of Sharing /Recording Health Information by Disability Level and Age

Controlling for gender, education, race, general technology attitudes, and assistive device use.
Acceptance of Differing Levels of Home Monitoring and Sharing Information with Varying Targets to PREVENT GOING TO A NURSING HOME

<table>
<thead>
<tr>
<th></th>
<th>Family</th>
<th>Doctor</th>
<th>Insurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensors throughout home</td>
<td>91</td>
<td>92</td>
<td>57</td>
</tr>
<tr>
<td>Video - no bathroom/bedroom</td>
<td>82</td>
<td>83</td>
<td>49</td>
</tr>
<tr>
<td>Video throughout home</td>
<td>63</td>
<td>65</td>
<td>36</td>
</tr>
</tbody>
</table>
Significant Predictors of ACCEPTANCE OF VIDEO THROUGHOUT THE HOME to Provide IADL, ADL, or Transfer Assistance (Multivariante Logistic Model)

Odds Ratios

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio</th>
</tr>
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<tbody>
<tr>
<td>Post-Graduate Education</td>
<td>2.2</td>
</tr>
<tr>
<td>(vs. HS Grad)</td>
<td></td>
</tr>
<tr>
<td>ADL + IADL Disability</td>
<td>1.9</td>
</tr>
<tr>
<td>(vs. None)</td>
<td></td>
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</tbody>
</table>

(Model controls for gender, age, and race)
Acceptance of REDUCED OPPORTUNITIES FOR SOCIAL INTERCATION with Technology Providing Varying Levels of Assistance

- Personal ADL assistance: 28
- Household IADL assistance: 28
- Transfer assistance: 32
Who will pay? and How much will you pay?
Amount WILLING TO PAY PER MONTH for kitchen, personal care, and driving technology performing various tasks (5% trimmed mean)—baby boomers and elders

33% would not pay anything

- Monitors & shares info. w/family, doctor
  - Kitchen: 13
  - Personal Care: 13
  - Driving: 10

- Monitors & provides performance feedback
  - Kitchen: 15
  - Personal Care: 18
  - Driving: 17

- Monitors & coaches - gives advice
  - Kitchen: 13
  - Personal Care: 18
  - Driving: 17

- Monitors & helps complete task
  - Kitchen: 17
  - Personal Care: 25
  - Driving: 25

- Monitors & does task for you
  - Kitchen: 25
  - Personal Care: 25
  - Driving: 25
Amount ($) Willing to Pay Monthly Out-of-Pocket for Kitchen, Personal Care, and Safe Driving Technologies, by Level of Assistance Provided (Among Those Willing to Pay > $0): Caregivers

- Kitchen (N = 426):
  - Monitor & help: 77
  - Monitor only: 59
  - Keep license: 60

- Personal Care (N = 415):
  - Monitor & help: 80
  - Monitor only: 60
  - Keep license: 60

- Safe Driving (N = 150):
  - Monitor & help: 75
  - Monitor only: 63
  - Keep license: 69

14% would not pay anything.

5% Trimmed Mean:
- Kitchen (N = 426):
- Personal Care (N = 415):
- Safe Driving (N = 150):

Median:
- Kitchen (N = 426):
- Personal Care (N = 415):
- Safe Driving (N = 150):
Willingness to Pay Monthly Out-of-Pocket for QoLT to Receive Personal Help vs. to Aid in Caregiving for **Kitchen & Personal Care Tasks**

<table>
<thead>
<tr>
<th></th>
<th>Monitor and Help</th>
<th>Monitor Only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Not Willing to Pay ($0)</td>
<td>5% Trimmed Mean ($)</td>
</tr>
<tr>
<td><strong>Kitchen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boomers/older adults</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Caregivers</td>
<td>12</td>
<td>77</td>
</tr>
<tr>
<td><strong>Personal Care</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boomers/older adults</td>
<td>32</td>
<td>38</td>
</tr>
<tr>
<td>Caregivers</td>
<td>13</td>
<td>80</td>
</tr>
</tbody>
</table>

Boomers/older adults from **2011 PST KN National survey of baby boomers and older adults**

2013 Site Visit
“What percentage of the cost of this type of technology do you think the government should pay?”

- **Kitchen (N = 479)**
  - 66% say Government should pay at least half
  - 16% All of the cost
  - 31% 51%-99%
  - 19% Half of the cost
  - 19% 1%-49%
  - 15% None of the cost

- **Personal Care (N = 486)**
  - 66% say Government should pay at least half
  - 17% All of the cost
  - 20% 51%-99%
  - 20% Half of the cost
  - 18% 1%-49%
  - 15% None of the cost

- **Safe Driving (N = 175)**
  - 66% say Government should pay at least half
  - 16% All of the cost
  - 32% 51%-99%
  - 18% Half of the cost
  - 21% 1%-49%
  - 13% None of the cost
Summary : Facilitators/Barriers

- Respondents less accepting of video monitoring – especially in bedroom and bathroom – than sensors; and of sharing information with insurance companies, even if they would prevent loss of independence.

- Respondents generally rejected technology that limited social interaction and required intense training to learn how to use, regardless of the type of assistance provided by the technology.
Summary: Facilitators/Barriers

- Disabled individuals are more accepting of sharing / recording health information than non-disabled (replicated with computer users vs. not)
  - Dose-response effect: ADL > IADL > Non-disabled

- Few age differences between boomers (45-64) and older adults (65+)

- Tipping point for acceptance of time to perform task: twice as long as human attendant (30 % drop in acceptability)

- Tipping point for acceptance of time for daily maintenance: 1 hour (40 % drop in acceptability)
Summary / Conclusions

• Current assistive device use not predictive of acceptance

• More positive general attitudes towards technology related to more acceptance

• Less educated were less accepting

• Cost is major barrier;
Product Development and Evaluation Timeline

Evaluation Design Strategies

**LAB**
- User-centered design methods (Iterative)
- Prototyping design and testing
- Observation of task performance w/technology
- Laboratory testing
- Storyboarding
- Rich stimulus displays
- Scenario testing
- "Wizard of Oz" studies
- Individual in-depth interviews / "think aloud"
- Focus groups/Group-individual synthesis

**FIELD**
- Field testing
- Pilot trial
- Randomized efficacy trial
- Effectiveness trial
- Comparative effectiveness trial
- Acceptance and adoption study

Measurement Strategies

Ease of use; Acceptability; Reliability; Learnability; Effectiveness; Efficiency; Errors; Flexibility; Memorability; User satisfaction; Safety; Confidence; Aesthetics; Convenience; Intrusiveness / privacy concerns

Adoption / uptake
- Real-world task performance
- Quality of Life
  - Technology-specific
  - Disease/condition specific
  - Generic
- Secondary/broad outcomes
  - Need for formal/informal caregivers
  - Caregiver burden
  - Healthcare costs
  - Value to healthcare providers
Thank you—Questions?