Virtual Coaches in Healthcare: A Vision of the Future

Dan Siewiorek

WIC 2011 Technology Conference
Pittsburgh, PA
September 21, 2011
Outline

- Quality of Life Technology Center
- Overview of Virtual Coaches
- Context Recognition
- Virtual Coach Examples
- Rehabilitation
- Motivation
- Social
- Challenges
Vision

- Access User Capability and Automatically Accommodate
Quality of Life Technology
Engineering Research Center

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Intelligent systems that augment body and mind
... Technology to Enable Self-determination for
Older Adults and People with Disabilities

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QoLT Vision: Outcome

Intelligent systems that augment body and mind

Increase **employability and productivity** across the life span

Expand the range of environments in which people will be independently and safely mobile, increasing community participation

Expand the number of people and number of years that they can live independently at home

Enhance **QoL** and capacity of caregivers

**Relate**

human physiological, physical, and cognitive function
to the design of intelligent systems

**Create** technologies & systems that make measurable positive impact on quality of life

**Work closely**

with user groups throughout design, development, test, and deployment phases for adoption, evaluation, and privacy concerns

**Develop the QoLT curriculum,**

**motivate** students and

**inspire** under-represented groups to pursue QoLT careers

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QoLT ERC Research Model

intentions & information

Human-System Interaction

Mobility and Manipulation

Perception and Awareness

Person and Society

users, providers, payers

people & their environments

assistances & effect

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Quality of Life Technology
Integration Testbed
Turning Vision into Reality

McKIZ:
McKeesport Independence Zone (Blueroof)

10-acre 12-block area with
12~15 single family houses with:
church, convenience store, community center and other infrastructures

End user participation daily living situation: application of PASIM
(Person and Society Infusion Model)

Residential agreement on data collection

Pedestrian and vehicular traffic

Sensor saturation in home

Complete monitoring and wireless coverage in environment

Enthusiastic industry, local government and other stakeholder's support
Partner Universities
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Virtual Coach - Overview

Seated Activity

Anaerobic Exercise

Aerobic Exercise

Wheel Chair Propulsion

Mobile Sensors

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Quality of Life Technology
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- Overview of Virtual Coaches
- **Context Recognition**
- Virtual Coach Examples
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Context Recognition Through Real Time Machine Learning
eWatch

Sensors

Notification

Calendar
eWatch Sensors

- Temperature Sensor
- Accelerometer (bi-axial, on the plane parallel to the face of the watch)
- Microphone
- Light Sensor
Feature Space After Linear Discriminant Analysis (LDA) Transformation
Activity Recognition Accuracy at Body Locations

<table>
<thead>
<tr>
<th>Activity</th>
<th>wrist</th>
<th>pocket</th>
<th>bag</th>
<th>necklace</th>
<th>shirt</th>
<th>belt</th>
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<tbody>
<tr>
<td>descending</td>
<td></td>
<td></td>
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<tr>
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<tr>
<td>standing</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ascending</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Accuracy Classification
Recorded Over 100 Minutes

Activity

walking
ascending
standing
sitting
running
descending

Time in minutes

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Multiple Sensors Improve Activity Recognition

Sensor Placement

![Image of person with sensors on various body parts]

**Performance Comparison - Additional Sensors**

<table>
<thead>
<tr>
<th>Sensor Location</th>
<th>Classification Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>67%</td>
</tr>
<tr>
<td>HD, HL</td>
<td>73%</td>
</tr>
<tr>
<td>HD, HL, AR</td>
<td>76%</td>
</tr>
<tr>
<td>HD, HL, AR, AN</td>
<td>75%</td>
</tr>
<tr>
<td>HD, HL, AR, AN, WR</td>
<td>77%</td>
</tr>
</tbody>
</table>

HD = Hand  
HL = Holster  
AR = Arm  
AN = Ankle  
WR = Wrist

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Light Sensor

TV

Light bulb
Audio and Light Sensor Clustering
Real Time Assessment of Psychosocial Stress
Think about how you are feeling right now.

Sleepy?

Happy?
Modalities of Interaction

- **Input Modalities**
  - Buttons
  - Voice (Speech)
  - Tap
  - Gestures

- **Output Modalities**
  - Vibration
  - LCD Screen
  - LEDs
  - Beep
Cognitive Modelling of Interactions

- Prototyping and pilot testing interaction modality time consuming
- Cognitive modelling estimates how modalities affect user interactions
- Use a design storyboard to automatically generates detailed cognitive models of expert behavior from a sequence of demonstrated actions

An eWatch displaying the start screen of the interview application (left) and the bluetooth remote, smart-phone and headset of Mobile Audio Visual Interface System - MAVIS (right)
COGTOOL Modelling Results

- CogTool predictions are within 10% of measured results.
- Generally, the more novel the modality, the less accurate the predictions
  - Accelerometer gestures modelled as pen-based graffiti
  - Audio based interaction a recent addition to CogTool

Cognitive Model Predictions vs Averaged Interaction Times
Cell Phone Activity Recognition

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New Sensor Types Increase Range of Activity Recognition

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Quality of Life Technology
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Example Virtual Coaches
Propulsion Pattern Recognition
Objective

- To determine the propulsion pattern of a manual wheelchair user by utilizing an accelerometer
- Provide feedback to user including proper propulsion technique to minimize forces required to complete tasks and minimizing extremes of wrist and shoulder in order to reduce risk of elbow and shoulder injury
- To help understand the cause of upper limb injuries and pain by correlating acceleration data with force data via the SmartWheel
Experiment Setup

- Light, audio and acceleration data is collected
- The location is annotated using an application on the eWatch on wrist
- The eWatches are synchronized before data collection begins

eWatch on Wrist

eWatch on Frame
Propulsion Pattern, Self-Propulsion and Surface Classification for Manual Wheelchair

Surfaces: Dynamometer, Carpet - medium, low pile, Tile, asphalt

Semicircular

Single Looping over Propulsion

Double Looping over Propulsion

Arcing

Fig 2. Propulsion patterns. Four classic propulsive strokes are shown: (A) semicircular (SC); (B) SLOP; (C) DLOP; and (D) arcing (ARC). The dark bars to the right of each pattern represent the beginning of the propulsive stroke. The dark bars to the left of each pattern represent the end of the propulsive stroke and the beginning of recovery.

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## Results

<table>
<thead>
<tr>
<th>Propulsion Pattern</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Looping</td>
<td>92.1%</td>
</tr>
<tr>
<td>Semicircular</td>
<td>92.1%</td>
</tr>
<tr>
<td>Double Looping</td>
<td>97.4%</td>
</tr>
<tr>
<td>Arcing</td>
<td>74.1%</td>
</tr>
<tr>
<td>Average</td>
<td>90.1%</td>
</tr>
</tbody>
</table>

- Based on 142 samples over four different surfaces: medium pile carpet, deep pile carpet, tile, parking lot
- Arcing accuracy low because it is often misclassified as semicircular
Non-programming Based Specification

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></td>
<td></td>
<td></td>
<td></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>
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<tr>
<td>Pressure</td>
<td>0</td>
<td>60mm</td>
<td>200mm</td>
<td>0 sec</td>
</tr>
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</table>

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

- Tilt in Space
- Detect Incline of the chair
- Elevating Legrests
- Seat Elevation

**Tilt sensor**

- Next to IR sensor

**Pressure sensor x8**

- Locate on hotspots

- Used to detect and remove the “hotspot” – where user tend to give more pressure on

**IR sensor**

- Used to detect obstacles in front or back when users try to recline
Seating Coach Functional Prototype
Seating Coach User Feedback Modality Study

Ranking of Vibration Location on the Seat

<table>
<thead>
<tr>
<th></th>
<th>Armrest</th>
<th>Headrest</th>
<th>Backrest around Shoulder Blade</th>
<th>Backrest around Mid of Upper Trunk</th>
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<tbody>
<tr>
<td>1</td>
<td>60.0</td>
<td>6.7</td>
<td>26.7</td>
<td>6.7</td>
</tr>
<tr>
<td>2</td>
<td>13.3</td>
<td>6.7</td>
<td>26.7</td>
<td>53.3</td>
</tr>
<tr>
<td>3</td>
<td>26.7</td>
<td>6.7</td>
<td>33.3</td>
<td>26.7</td>
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<tr>
<td>4</td>
<td>0</td>
<td>80.0</td>
<td>13.3</td>
<td>13.3</td>
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Ranking of Speaking Property

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Cartoon</th>
<th>Monotonic</th>
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<tbody>
<tr>
<td>1</td>
<td>33.3</td>
<td>33.3</td>
<td>26.7</td>
<td>6.7</td>
</tr>
<tr>
<td>2</td>
<td>20.0</td>
<td>33.3</td>
<td>26.7</td>
<td>20.7</td>
</tr>
<tr>
<td>3</td>
<td>33.3</td>
<td>20.0</td>
<td>20.0</td>
<td>26.7</td>
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<tr>
<td>4</td>
<td>13.3</td>
<td>13.3</td>
<td>26.7</td>
<td>46.7</td>
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</tbody>
</table>

Ranking of Animation Property

<table>
<thead>
<tr>
<th></th>
<th>Female face</th>
<th>Male face*</th>
<th>Cartoon</th>
<th>PSFs task</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>6.7</td>
<td>33.3</td>
<td>53.3</td>
</tr>
<tr>
<td>2</td>
<td>20.0</td>
<td>6.7</td>
<td>46.7</td>
<td>33.3</td>
</tr>
<tr>
<td>3</td>
<td>53.3</td>
<td>20.0</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>4</td>
<td>26.7</td>
<td>66.7</td>
<td>13.3</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Health Kiosk

- Touch Screen
- Loudspeakers
- Headphones
- Hand Dynamometer
- Blood Pressure Monitor
- Pulse Oximeter
- RFID reader
- Seated Scale
- Cabinet with Computer & Printer
HealthNode

Add Residents/Clinicians
Link Resident/Clinicians
Add Tests/Devices
Schedule Tests
Behavioral Surveys
Physical Tests
View History
Messaging

Resident

Clinician

Administrator

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Health Kiosk Resident Main Page

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

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Health Kiosk User Evaluation
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Rehabilitation and Compliance
Ideal Balance Treatment Cycle

Symptoms of Imbalance

Balance Clinic

Patient Assessment → Exercise Prescription

Home

Patient “Dosage” → Patient Response

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Quality of Life Technology
Actual Treatment Cycle

Therapists cannot know what patients are actually doing at home
• “Dosage”
• Compliance
Gaze Stabilization Exercise

Improves Vestibulo-Ocular Reflex (VOR)

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
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
HeadCoach Prototype
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Augmented Feedback using Personal Robotics for Neuro Rehabilitation
**Motivation**

Restore arm functionality

**Stroke**

#1 cause of disability in US

Per Year: 776K Total: 6.6M

Cost $65.5 B per year

35% After Hospital Care
System Architecture

Myomo Arm

Reader

Virtual Controller

Game App

Log Replayer

Therapist App
Rehabilitation and Motivation

Curt
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
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Social Buddy
Social Calendar

It's time for you to take some medicine! Press 1 for more detail.

12:00 P.M.
Meeting with John

2:00 P.M.
Balancing Exercise

5:00 P.M.
Family Reunion

- Alice started
  Aerobics exercise
- David is back home
- Ben is Away now
Buddy as Channel

<table>
<thead>
<tr>
<th>Ch.1: John</th>
<th>Ch.2: Susan</th>
<th>Ch.3: David</th>
<th>Ch.4: Sarah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Away</td>
<td>Busy</td>
<td>Available</td>
<td>Busy</td>
</tr>
</tbody>
</table>

- John changed his status to “Away” – 7:00 A.M.
- David is back home – 7:10 A.M.
- Susan and Sarah started group exercise: yoga – 9:00 A.M.
Bingo/Card Game

She came here with her children, one of my granddaughters is going to get married.

Alice, tell me about your daughter's visit last weekend.

Congratulations! Alice.

Bingo!
Group Exercise
Mutual Help

1. John  ch. 9  Need help with income tax form
2. Susan  ch.11  Need help with social security card
3. Jack  ch.84  I need help with reading a book
4. Jessica  ch.45  I need help in reminding about my medication
5. Alice  ch.34  I am looking for someone who can teach me some simple yoga
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Challenges

- Use low cost sensors and machine learning to determine user context and respond proactively anticipating user needs

- User engagement
  - Feedback without nagging
  - Error recovery

- Autonomic Virtual Coach
  - System responsible for it’s own management and evolution
  - Assess changes in user ability
  - Request synthesis functionality to coach to adapt to change
  - Automatic download of new capability