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POMDP Practitioners Workshop, May 12th, 2010
Motivation

Prevalence of Alzheimer’s and related dementias in Canada

- 2008: 480,600 (1.5% of population)
- 2038: 1,125,000 (2.8% of population)

Prevalence of Alzheimer’s and related dementias worldwide

- 2008: 35.6 million
- 2050: 115 million

The economic burden of dementia in Canada

- 2008: $15-billion
- 2018: $37-billion
- 2028: $75-billion
- 2038: $153-billion

Sources: Alzheimer Society of Canada, World Alzheimer Report
Motivation

Excess demand for LTC beds in Canada

- 2008: 15,392 beds
- 2038: 157,461 beds

Hours of informal care provided for people with dementia in Canada

- 2008: 231 million hours
- 2038: 756 million hours

Source: Alzheimer’s Society of Canada
Motivation

Care is shifting toward home/patient/community

Technology
- can connect providers with recipients,
- can increase range/scope of care provision,
- but currently developed for specific applications:
- difficult to modify to suit individual user needs.

Economic and Social impact of Healthcare Informatics:
- Users/Customizability
- Sensors/Generalizability
- Decisions/Adaptivity
Talk Overview

- Assistance: what is involved?
  - User-centered design: what clients want
  - Computer vision: a general purpose virtual sensor
  - Generic, customizable task controllers

- Examples
  - COACH: Handwashing assistant (the “Talking Sink”)
  - ePAD: Art Therapy Tools
  - SNAP: Customizable situated prompting

- Future Work
Assistance Model

(a) 
\[
\begin{align*}
S & \rightarrow \Theta \\
\Theta & \rightarrow \Theta \\
S' & \rightarrow \Theta \\
O & \rightarrow O' \\
O' & \rightarrow O \\
& \rightarrow t
\end{align*}
\]

(b) 
\[
\begin{align*}
Y & \rightarrow Y' \\
B & \rightarrow B' \\
T & \rightarrow T' \\
K & \rightarrow K' \\
V & \rightarrow V'
\end{align*}
\]
System Model

- Sensors
- Actor
- Client
- Environment layer

- Input mapping
- Customisation interface
- Output mapping
- Customisation layer

- POMDP
- Policy generation
- Policy
- AI layer

- Belief monitor
- Temporal abstraction

- Measurements
- Observations
- Signals
- Actions

- Belief
Solutions

- 200K states × 198 observations × 26 actions
- Optimal solution **intractable**
- **Approximations** used:
  - Point-based (**Perseus** - Vlassis & Spaan, 2005)
  - Structured solution (**SPUDD** - Hoey & St. Aubin, 1999)
  - Bound size of solution (Poupart, 2005)
  - Disregard observations (Hoey & Poupart, 2005)
  - State aggregation (St. Aubin & Hoey, 2000)
- 75 iterations on Intel Xeon 3GHz - 4GB RAM: 53 Hours
Example I: COACH Handwashing System

An intelligent cognitive device that tracks a user through handwashing, providing cues when necessary.

The COACH
Cognitive Orthosis for Assisting Activities in the Home
Handwashing: Integrated System

- **Camera**: Video input to tracking module.
- **Tracking**:
  - Grab frame
  - Update tracker
- **Belief Monitor**:
  - Discretise observations
  - Check belief change
  - New, stable belief detected?
- **Policy**
- **Prompting**:
  - Summon human caregiver
- **Action**
Handwashing Input Mappings: Hand Tracking

Tracking through occlusions and changes in shape

- Objects modeled as **flocks of features**
- Simple **color features**, Gaussian distributions
- **Bayesian sequential** estimation
- Monte Carlo approximation (**particle filter**)
- **Three interacting** filters: 2 hands + towel
Handwashing Behaviors: Hand Locations
Handwashing Task: Plansteps

- **Dirty**: a
- **Soapy**: b, e
- **Soapy, Dry**: d
- **Clean, Wet**: g
- **Clean, Dry**: j, h, k
- **Dirty, Dry**: b, e
- **Water On**: d, g, j
- **Water Off**: b, e, d, g, j, k

**Behavior**: Rinse
## Handwashing: Abilities

<table>
<thead>
<tr>
<th>Factor:</th>
<th>Models:</th>
<th>Dynamics:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>need for assistance</td>
<td>changes quickly</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>response to assistance</td>
<td>changes from day to day</td>
</tr>
<tr>
<td>Dementia Level</td>
<td>likelihood user will be aware and responsive</td>
<td>does not change ...learn?</td>
</tr>
</tbody>
</table>
Handwashing: Actions

- **do nothing**: system waits
- **call caregiver**: system calls for **single step** assistance
- **prompts**:
  - 3 levels of specificity:
    - **low**: basic prompt with few details
      - "Use the soap"
    - **medium**: include person’s name, more details
      - "John, use the soap in the pink bottle"
    - **high**: medium prompt with video demonstration
Handwashing: Rewards

Tradeoff multiple, competing objectives

- get hands clean
- user independence
- caregiver burden
User Trial Example

Example: Subject 4, Trial 34
Learning Dementia Level

The graph shows the probability of different dementia levels (P(DL > LOW)) over a sequence of events. Each line represents a different subject (S1, S3, S4, S5, S6, S8) and their corresponding MMSE scores. The x-axis represents the sequence of events, while the y-axis shows the probability from 0 to 1. The MMSE scores are represented on the y-axis for each subject, with S5 at 20, S3 at 15, S6 at 10, and S8 at 5. The figure illustrates how different subjects progress through the dementia levels over time.
Example II: Art Therapy

Benefits:

- Leisure promotes well-being
- Leisure decreases Dementia Risk
- Cognitive activities slow down progress of AD
- Visual artwork has additional benefits
Art Therapy

Two kinds:
- Art in Therapy
- Art as Therapy

Goal is client:
- control
- engagement
- creativity

Clients do art and then:
- feel empowered
- show increased ability to engage with surroundings
Art Therapists Need

Art Therapists:
▶ work in long term care facilities,
▶ promote user independence,
▶ but have limited resources

Can technology:
▶ extend therapists’ reach
▶ to larger groups,
▶ and possibly into the home?

Project goal:
▷ tools for art therapists
▷ to promote independent engagement
    with creative activities
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Project goal:
▶ tools for art therapists
▶ to promote independent engagement with creative activities
▶ stimulate creativity
Engaging Platform for Art Development
User Centered Design

Four phases:

▶ Online survey (Jan 09)

▶ Focus group with creative arts therapists (May 09)

▶ One-on-one interviews, rapid prototyping (Nov 09)

▶ Efficacy trials with older adults (Spring 10)
User Requirements Analysis

Major findings:

- **Enthusiasm** for idea
- **Limit** device to a therapist inertial tool
- **Adaptivity** to changing users
- **Multi-touch** better than single touch
- **Large** better than small
- **Customizability** by therapists
Art Therapy: Device Overview

- database
- behavior/gesture mappings
- specific
- action mappings
- generic

therapist
Art Therapist Interface
Art Therapist Interface
Client Application
Art Therapy: Customization

- **Engagement (ability):** level of attention of a user in a task
  - face/head orientation
  - gaze direction
  - temporal on-screen actions

- **Involvement (behaviour):** categories defined by the level of engagement they demonstrate
  - interactive
  - active
  - intermittent
  - inactive

- **Interactivity (actions):** system actions place requirements on users
  - attention grabbing
  - high
  - medium
  - low
Art Therapy: Observations

Face detection (Viola Jones)
Art Therapy: POMDP Customisation

(adapted model)

(passivity level)

(percentage of prompting)

(activity level)

(eye-contact level)

(non-adapted model)
Example III: SyNdetic Assistance Processes (SNAP)

Syndetic Interaction Unit (IU) analysis
(Wherton and Monk, York)
# SyNdetic Assistance Processes (SNAP)

Syndetic Interaction Unit (IU) analysis
(Wherton and Monk, York)

<table>
<thead>
<tr>
<th>IU</th>
<th>Current Goals</th>
<th>Current Environment</th>
<th>Recognition/Recall/Affordance</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Final</td>
<td>cup empty on tray</td>
<td>Rn cup on tray RI step</td>
<td>No Action</td>
</tr>
<tr>
<td>2</td>
<td>Final cup TB+water</td>
<td>cup empty on tray</td>
<td>Af cup tray WS</td>
<td>Move cup tray → WS</td>
</tr>
<tr>
<td>3</td>
<td>Final cup TB+water cup TB</td>
<td>cup empty on WS box closed</td>
<td>RI box cont. TB Af box closed</td>
<td>Alter box to open</td>
</tr>
<tr>
<td>4</td>
<td>Final cup TB+water cup TB</td>
<td>cup empty on WS box open</td>
<td>Af TB in box cup</td>
<td>Move TB box → cup</td>
</tr>
<tr>
<td>5</td>
<td>Final cup TB+water</td>
<td>box open</td>
<td>Af box open</td>
<td>Alter box to closed</td>
</tr>
</tbody>
</table>
SyNdetic Assistance Processes (SNAP)

Cognitive Ability
RI: Recall
Rn: Recognition
Af: Affordance

user action (behavior)

environment state
SyNdetic Assistance Processes (SNAP)

Sensors (Ambient Kitchen, Culture Lab, Newcastle):

- accelerometers
- temperature sensors
- switches
- RFID tags

Image of a kitchen with labeled sensors.
Related Ongoing Work

- Stroke Rehabilitation
- Speech and Dialogue for Assistive Technology
- Wheelchair control
- Handwashing for Autistic Spectrum Disorder (ASD)
- Emergency Response and Health Monitoring
- Toothbrushing
- Music Therapy
- Decision theoretic information sharing in healthcare
- Customizable smart homes
Thanks to...

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School of Informatics

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