An assistive handwashing system with emotional intelligence

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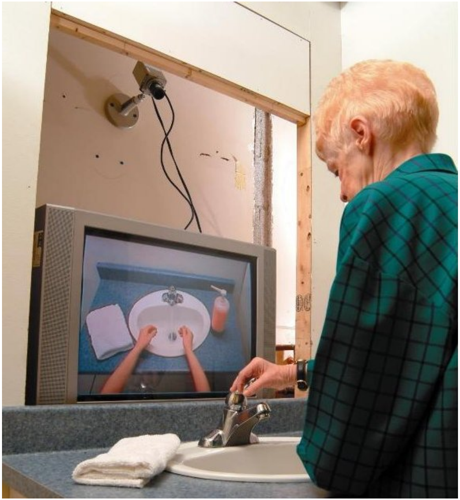
Agenda

Problem Statement - Motivation

The COACH system



- An assistive system helping people with dementia (e.g. Alzheimer's Disease) completing daily activities
- Works well for some persons, but not as well for others
- Only considers functional states of users

Problem Statement - Objectives

To augment the COACH system with an emotional reasoning engine so that the augmented system:

- is designed in a portable and extensible way
- runs in real-time from the perspective of the user group
- provides a level of functional assistance
- produces the prompts according to the emotional state of a user

Using Emotional Intelligence in Assitive Systems is the future direction.

Concepts - ACT

Affect Control Theory (ACT)

- represents emotions as EPA vectors, where E stands for "evaluation", P stands for "potency", and A stands for "activity"
- describes social events by an Actor-Behaviour-Object grammar
- "fundamentals" of identities and behaviours; shared between people within a same culture
- "transient impressions": emotional feelings caused by a specific event

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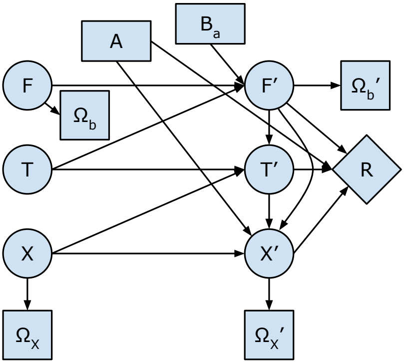
The ACT Principle

Actors work to experience transient impressions that are consistent with their fundamental sentiments.

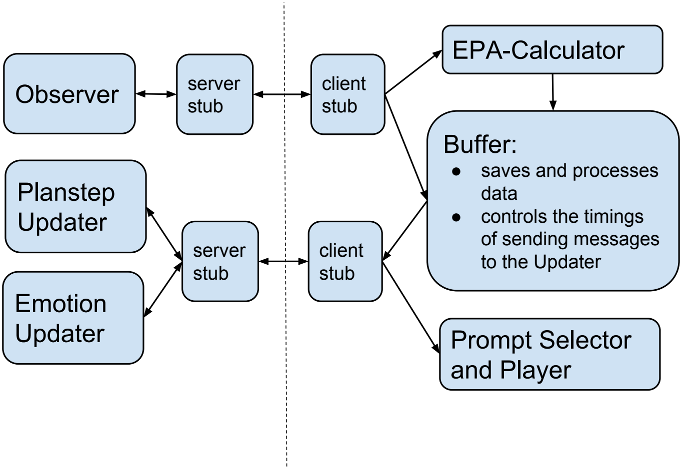
Concepts - BayesACT

- A Bayesian version of the ACT theory
- Extends the ACT with POMDP model
- Uses a "turn-taking" model and represents state variables for Agent, Behaviour and Client (ABC)



- States $S = \{X, F, T\}$, where $F = \{F_{ij}\}$, $T = \{T_{ij}\}$, $i \in \{a, b, c\}$, $j \in \{e, p, a\}$
- Note: F_c denotes the agent's belief of the client's identity
- Observations $\Omega = \{\Omega_X, \Omega_b\}$
- Actions $\{A, B_a\}$
- Calculate $\{A, B_a\}$ based on $\{X, F, T\}$

Design - Overview



Design - the Planstep and Emotion Updater

Use the BayesACT framework in the handwashing scenario

- Recall: BayesACT includes states $S = \{X, F, T\}$, observations $\Omega = \{\Omega_x, \Omega_b\}$, and agent actions $\{A, B_a\}$

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Design - the EPA-Calculator

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- Feature Selection
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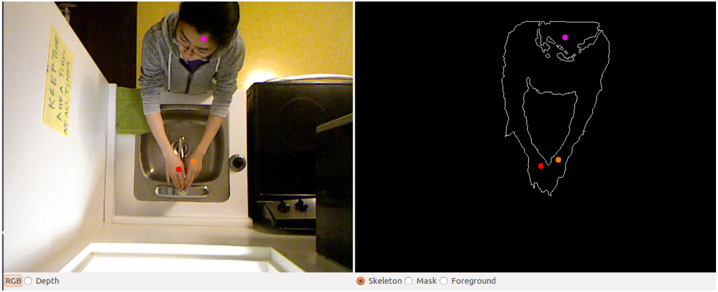
- Our approach
  - E stays neutral (value $= 0$); its value is ignored in the reasoning engine
  - P scaled from the expansiveness of the user's two hands
  - A scaled from the moving speeds of the user's hands
  - Used piecewise linear interpolation method
- "Confidence" of Ω_b can be specified in the reasoning engine

Design - the Observer

- Step 1: Get the locations of the user's hands
  - bases on a body tracker implemented in previous work
  - obtains locations of body parts from depth images taken from an overhead perspective
  - was trained using partially labeled, unbalanced data, and is configurable and re-trainable



Design - the Observer

- Step 2: Map locations to user behaviours
  - if hands are close to an object, then there's high probability of performing the behaviour corresponded to the object
- Observation noise handled by the observation function in the reasoning engine

Design - the Prompt Selector and Player

- The prompt dataset
  - 30 audio-visual prompts generated in previous study
  - created using the USC Virtual Human Toolkit
  - EPA values of videos evaluated by human raters


- A proper prompt is selected as the final prompt if it:
  - has the same propositional labels as the desired prompt
  - has the closest emotional (EPA) values as the desired prompt

Experiments - Latency of the system

Average latency of the system

- 46.80ms for obtaining user behaviours
- 1.65s for calculating and updating functional and emotional beliefs
- 1.70s in total

The system runs in real-time from the perspective of its user group

Experiments - Two laboratory tests

Two laboratory tests

- link to test #1
- link to test #2

Another 15 tests were also run. Results are in the Appendix.

Experiments - Conclusion

- Functionality performance
  - sometimes false positively recognizes an user behaviour
  - is able to produce propositionally useful system prompts in general
- Emotionality performance

No.	mean of behav.	init of client identities	mean of client identities	mean of prompt
#1	$[0, 1.32, -1.3]$	$[1.61, 0.84, -0.87]$	$[2.8, 1.03, -0.73]$	$[1.62, 0.32, 0.75]$
#2	$[0, 0.77, -1.74]$	$[-0.64, -0.43, -1.81]$	$[1.13, -0.43, -1.47]$	$[1.53, 0.66, 0.08]$

Generally, user behaviours with higher P and higher A values may lead to

- client identities with higher P and higher A values
- system prompts with lower P and higher A values
- as predicted by the Affect Control Theory

Discussion

Contribution

- Designed and implemented a prototypical hand-washing system that satisfies the objectives
- Tests also indicated a correlation between the EPA values of user behaviours, user identities, and system prompts

Future Work

- Improve the EPA-Calculator
- Improve the prompt generation process
- Improve the Planstep- and Emotion- Updater
- Conduct clinical trials for the system

Acknowledgement

This work is based on previous works of:

- Hoey, J., Schroder, T., & Alhothali, A. (2013, September). Bayesian affect control theory. In Affective Computing and Intelligent Interaction (ACII), 2013 Humaine Association Conference on (pp. 166-172). IEEE.
- Czarnuch, S., & Mihailidis, A. (2014 (in review)). Depth image hand tracking from an overhead perspective using partially labeled, unbalanced data: Development and real-world testing. IEEE Journal of Biomedical and Health Informatics.
- Malhotra, A., Yu, C., Schroder, T., & Hoey, J. (2014 (in review)). An exploratory study into the use of an emotionally aware cognitive assistant.

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The end

Thank you!

- Questions?
- Comments?

Concepts - BayesACT cont.

Model formulation

- The deflection $\phi(F, T)$ between F and T:

$$\phi(f, t) \propto e^{-(f'-t')\Sigma^{-1}(f-t)} \tag{1}$$

- The probability of a post-action fundamental sentiment f':

$$Pr(f'|f, t, x, b_a, \phi) \propto e^{-\phi(f',t')-\xi(f',f,b_a,x)} \tag{2}$$

  where t' can be computed from $\{f', t, x\}$ by empirically derived prediction equations of ACT.
- $Pr(x'|x, f', t', a)$: how the application progresses
- $Pr(\omega_b|f)$ and $Pr(\omega_x|x)$: observation functions for the client behaviour sentiment and system state

Update X'_{ps} based on Ω_x and $\{X_{ps}, X_{behav}, X_{aw}, F, T\}$

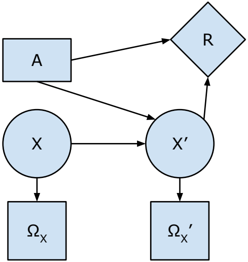
- $SampleXVar()$ and $evalSampleXVar()$
- Pseudocode of $SampleXVar()$ (on next page)
- $Pr : X_{behav} \rightarrow \Delta(\Omega_x)$ used in $evalSampleXVar()$

Update X'_{ps} based on Ω_x and $\{X_{ps}, X_{behav}, X_{aw}, F, T\}$ cont.

```
if Deflection(F, T) is high then
    threshold = high
else
    threshold = low
end if
if aw high then
    if prompted then
        if random_prob() < threshold then
            aw = low and not moving forward
        else if prompt wrong then
            aw = low and not moving forward
        else if likely then
            moving forward
        else if random_prob() < threshold then
            aw = low and not moving forward
        end if
    else
        if random_prob() < threshold then
            aw = low and not moving forward
        else
            aw stays high and moving forward
        end if
    end if
else
    if prompted then
        if random_prob() > threshold and prompt correct then
            move on and aw high
        else
            unlikely: aw high and not moving forward
        end if
    else
        unlikely: aw high and moving forward
    end if
end if
```

Concepts - POMDP

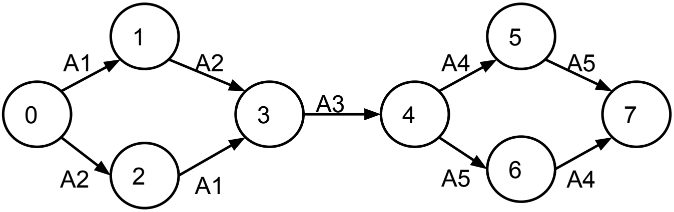
Partially Observable Markov Decision Process (POMDP)



- A timeslice of a POMDP process
- Variables: $\{\ X,\ A,\ \mathbf{\Omega_X}\ \}$
- $Pr : X \to \Delta(\mathbf{\Omega_X})$,
  $Pr : X \times A \to \Delta(\mathbf{X})$
- Reward Function: $R(A, X')$

Solution - Representing "Functional States"

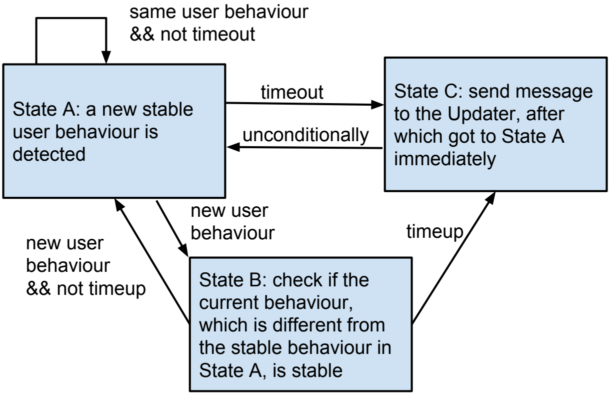
Planstep Definition and Update Diagram



- Eight plansteps: (0) "off/dirty/dry", (1) "on/dirty/dry", (2) "off/soapy/dry", (3) "on/soapy/dry", (4) "on/clean/wet", (5) "off/clean/wet", (6) "on/clean/dry", (7) "off/clean/dry"
- Five behaviours: A1 to A5 are "turn on water", "put on soap", "rinse hands", "turn off water", and "use towel", respectively.

Solution - The Buffer

- Between the Observer, the EPA-Calc, and the Reasoning Engine
- Controls timings of sending messages



- Smoothes EPA values calucated by the Calculator

Experiments - Parameter values used in laboratory experiments

Param.	**Value**	**Defined in which component**
n	10	EPA-Calc
distance	$\{-\infty, 0, 8, 40, 128, 160, +\infty\}$	EPA-Calc
potency	$\{-4.3, -4.3, 0, 1, 2, 4.3, 4.3\}$	EPA-Calc
difference	$\{-\infty, 0, 3.5, 17.5, 35, 70, +\infty\}$	EPA-Calc
activity	$\{-4.3, -4.3, -2, -1, 0, 4.3, 4.3\}$	EPA-Calc
alpha	0	Buffer
timeout	300	Buffer
timeup	1	Buffer
β_a^0	0.001	Updater
β_c^0	2.0	Updater
γ	$(100000, 1.0, 0.5)$	Updater
N	2000	Updater
f_a^0	$[1.5, 0.51, 0.45]$	Updater
f_c^0	Different in each test	Updater