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.
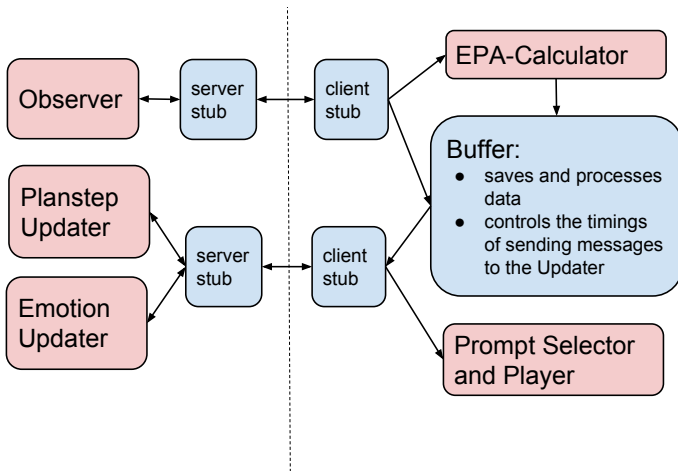
Concepts - BayesACT

- A Bayesian version of the ACT theory
- Extends the ACT with POMDP model
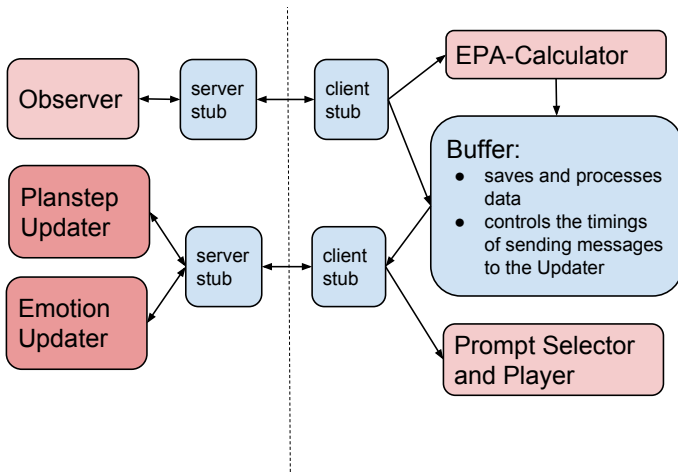- Uses a "turn-taking" model and represents state variables for Agent, Behaviour and Client (ABC)
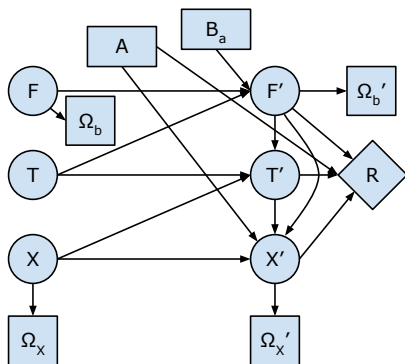
- States $S = \{X, F, T\}$, where $F = \{F_{ij}\}, T = \{T_{ij}\}, i \in \{a, b, c\}, j \in \{e, p, a\}$
- Note: F_c denotes the agent's belief of the client's identity
- Observations $\Omega = \{\Omega_X, \Omega_b\}$
- Actions $\{A, B_a\}$
- Calculate $\{A, B_a\}$ based on $\{X, F, T\}$

Design - Overview

Design - the Planstep and Emotion Updater cont.

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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- Note: the "confidence" of Ω_b can be specified by γ, which is the variance of a normal (Gaussian) distribution.

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- Compute X'_{ps} based on Ω_x, Ω_b and $\{X, F, T\}$

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Design - the EPA-Calculator
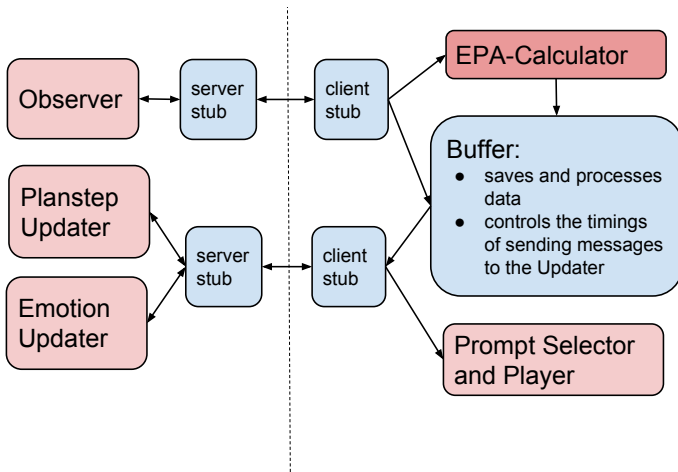
Design - the EPA-Calculator cont.

- Calculates affective meanings of user behaviours

- Feature Selection
  - analysis on facial expressions and speeches?
  - related research for this special application scenario hasn't been done yet

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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

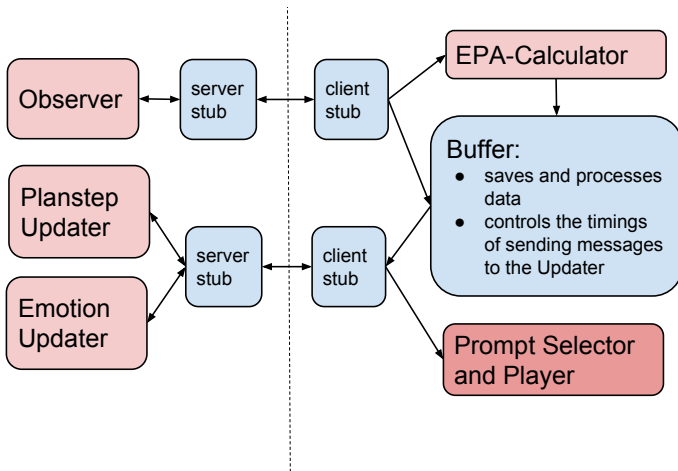- "Confidence" of Ω_b can be specified in the reasoning engine
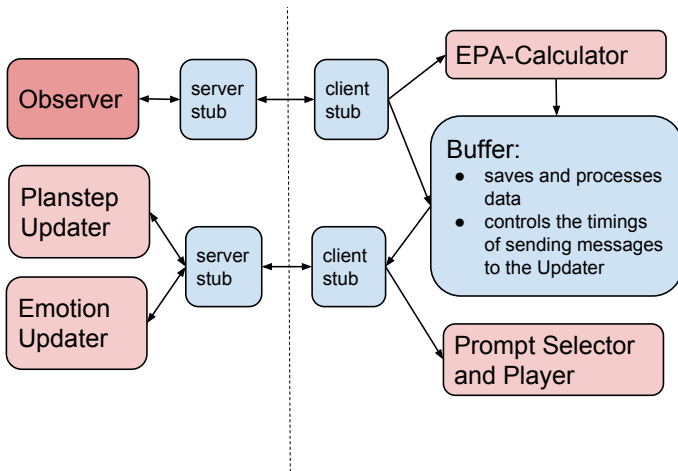
Design - the Observer cont.

- 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 cont.
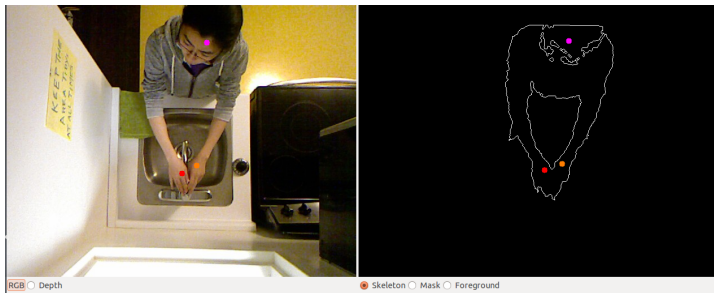
- Step 2: Map locations to user behaviours
  - if hands are close to an object, then there's high probability of performing the behaviour corresponded to the object

- Observation noise handled by the observation function in the reasoning engine

Design - the Prompt Selector and Player cont.

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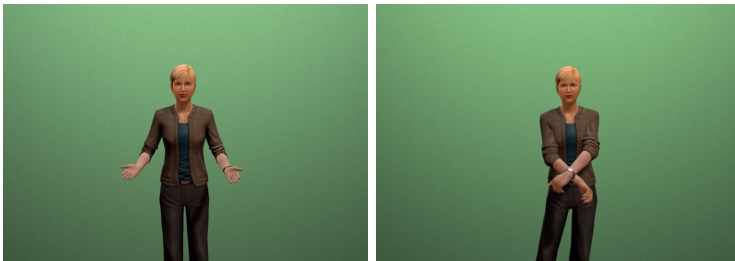
- A proper prompt is selected as the final prompt if it:
  - has the same propositional labels as the desired prompt
  - has the closest emotional (EPA) values as the desired prompt

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

- washed hands while the system observed and assisted in real time
- acted more powerfully and more actively in the first test than the second
- link to video of test #2
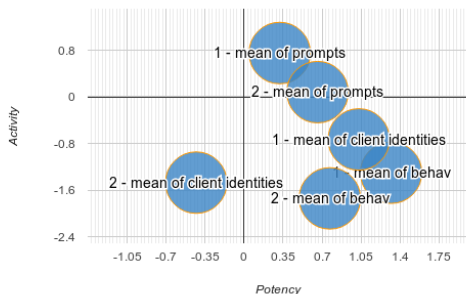- results shown in thesis

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

Experiments - Conclusion

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

Comparison of P and A values in the two tests

Generally, user behaviours with higher P and higher A values 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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- James Tung and Peter van Beek
- Stephen Czarnuch, Aarti Malhotra and Celia Yu
- Families and friends, especially Chengbo Li, Xiao Yang, Enxun Wei and Luyi Lin

Thank you!

- Questions?
- Comments?

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

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

```
 1: if Deflection(F, T) is high then
 2:    threshold = high
 3: else
 4:    threshold = low
 5: end if
 6: if aw high then
 7:    if prompted then
 8:        if random_prob() < threshold then
 9:            aw = low and not moving forward
10:        else if prompt wrong then
11:            aw = low and not moving forward
12:        else if likely then
13:            moving forward
14:        else if random_prob() < threshold
           then
15:            aw = low and not moving forward
16:        end if
17:    else
18:        if random_prob() < threshold then
19:            aw = low and not moving forward
20:        else
21:            aw stays high and moving forward
22:        end if
23:    end if
24: else
25:    if prompted then
26:        if random_prob() > threshold and
           prompt correct then
27:            move on and aw high
28:        else
29:            unlikely: aw high and not moving
               forward
30:        end if
31:    else
32:        unlikely: aw high and moving forward
33:    end if
34: end if
```

Partially Observable Markov Decision Process (POMDP)
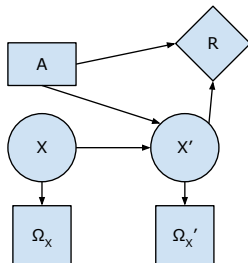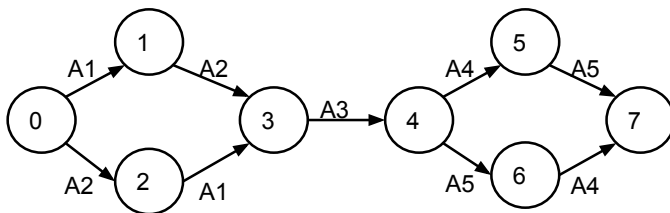

- A timeslice of a POMDP process
- Variables: $\{ X, A, \mathbf{\Omega_X} \}$
- $Pr : X \to \Delta(\mathbf{\Omega_X})$,
  $Pr : X \times A \to \Delta(\mathbf{X})$
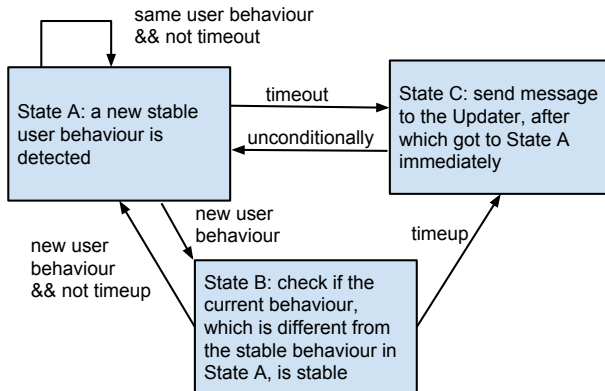- Reward Function: $R(A, X')$

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

same user behaviour && not timeout

State A: a new stable user behaviour is detected

timeout

State C: send message to the Updater, after which got to State A immediately

unconditionally

new user behaviour && not timeup

new user behaviour

State B: check if the current behaviour, which is different from the stable behaviour in State A, is stable

timeup

- 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