

An assistive handwashing system with emotional intelligence

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Agenda

1 Problem Statement

- Motivation
- Objectives

2 Basic Concepts

- Affect Control Theory (ACT)
- The BayesACT Framework

3 System Design

4 Experimental Results

5 Discussion

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

- Using Emotional Intelligence in Assitive Systems
- 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

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

Affect Control Theory (ACT)

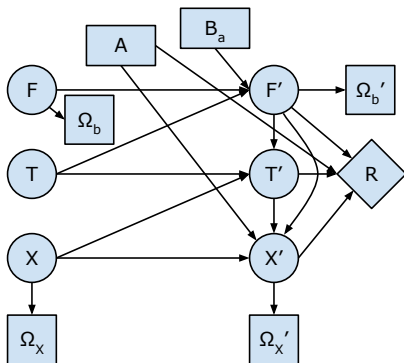
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The ACT Principle

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

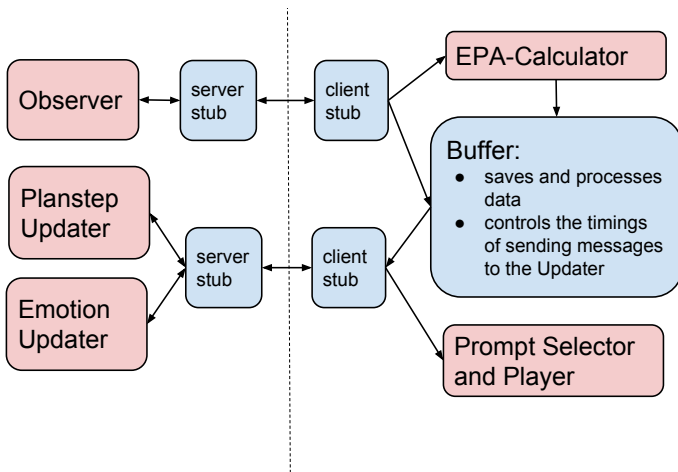
Concepts - BayesACT

- 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)

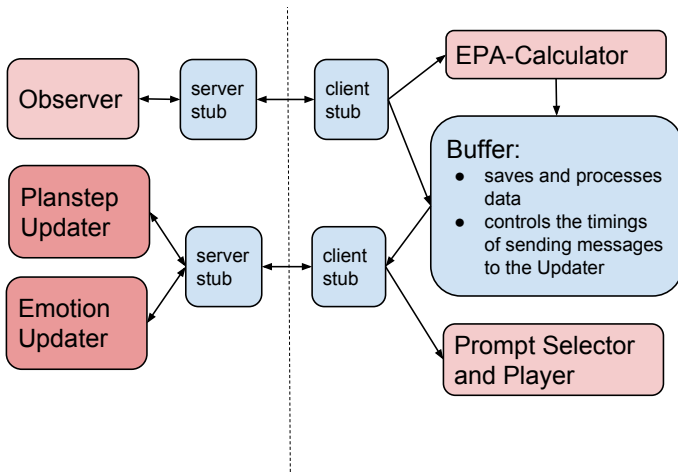


- States $S = \{X, F, T\}$, where $F = \{F_{ij}\}$, $T = \{T_{ij}\}$, $i \in \{a, b, c\}$, $j \in \{e, p, a\}$
- Note: F_c denotes the agent's belief of the client's identity
- Observations $\Omega = \{\Omega_X, \Omega_b\}$
- Actions $\{A, B_a\}$
- Calculate $\{A, B_a\}$ based on $\{X, F, T\}$

Design - Overview



Design - the Planstep and Emotion Updater



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 $\{A, B_a\}$

Design - the Planstep and Emotion Updater cont.

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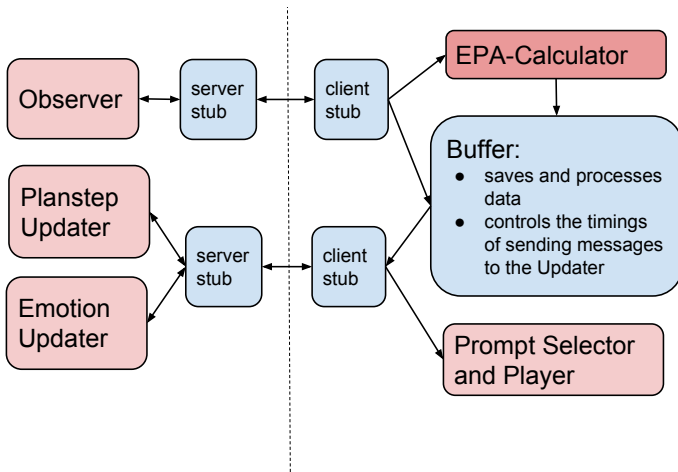
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- Compute X'_{ps} based on Ω_x , Ω_b and $\{X, F, T\}$

Design - the Planstep and Emotion Updater cont.

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Design - the EPA-Calculator



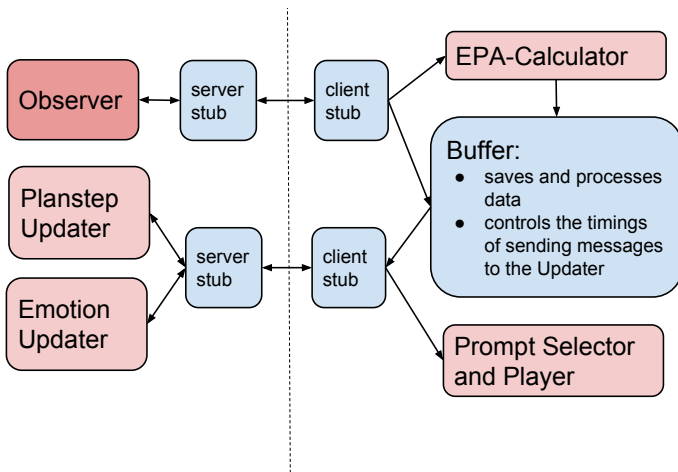
Design - the EPA-Calculator cont.

- 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

Design - the EPA-Calculator cont.

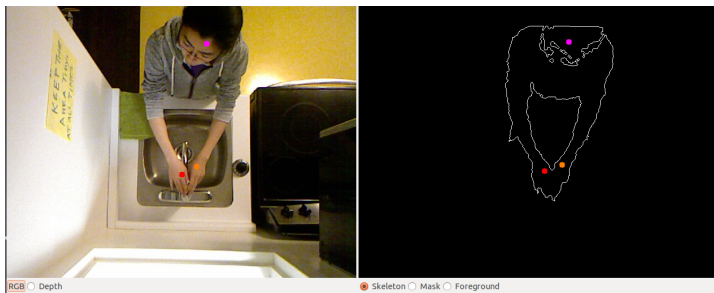
- Calculates affective meanings of user behaviours
- Feature Selection
 - analysis on facial expressions and speeches?
 - related research for this special application scenario hasn't been done yet
- Our approach
 - E stays neutral (value = 0); its value is ignored in the reasoning engine
 - P scaled 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



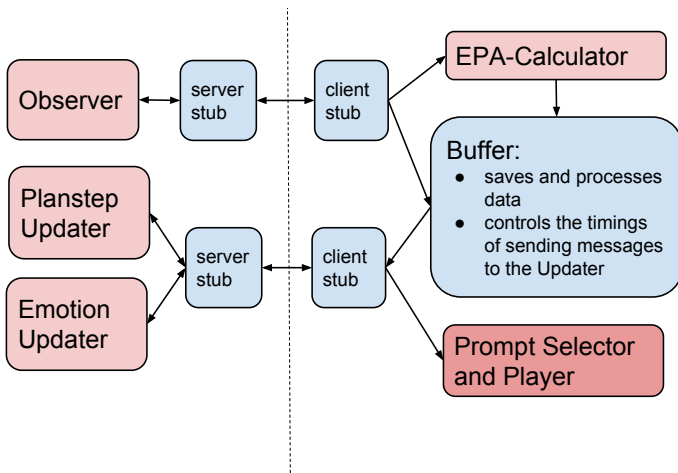
Design - the Observer cont.

- Step 1: Get the locations of the user's hands
 - bases on a body tracker implemented in a 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



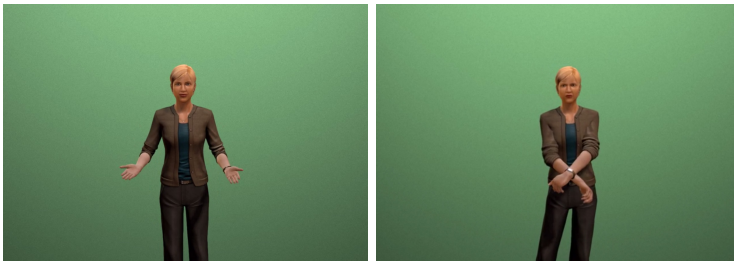
- Step 2: Map locations to user behaviours
 - if hands are close to an object, then there's high probability of performing the behaviour corresponded to the object
- Observation noise handled by the observation function in the reasoning engine

Design - the Prompt Selector and Player



Design - the Prompt Selector and Player cont.

- The prompt dataset
 - 30 audio-visual prompts generated in a 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

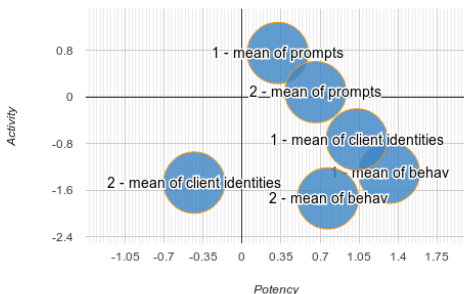
- washed hands while the system observed and assisted in real time
- acted more powerfully and more actively in the first test than in the second
- results shown in thesis

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

Experiments - Conclusion

- Functionality performance
 - In general, the system 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

This is the same as predicted by the Affect Control Theory.

Contribution

- designed, implemented and tested a prototypical hand-washing system that fulfills the objectives
- indicated a correlation between the EPA values of user behaviours, user identities, and system prompts

Future Work

- improve the EPA-Calculator
- improve the reasoning engine
- generate better prompt datasets
- 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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- 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 :

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

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

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

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

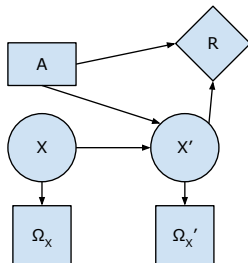
Update X'_{ps} based on Ω_x and $\{X_{ps}, X_{behav}, X_{aw}, F, T\}$

- *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.

```
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
27:       prompt correct then
28:       move on and aw high
29:     else
30:       unlikely: aw high and not moving
31:       forward
32:     end if
33:   else
34:     unlikely: aw high and moving forward
35:   end if
36: end if
```

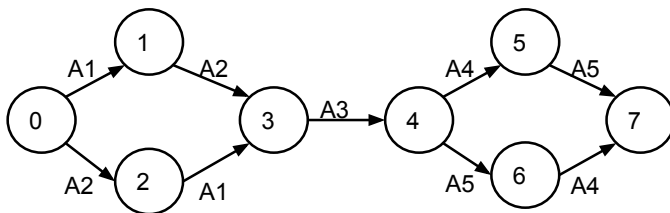
Partially Observable Markov Decision Process (POMDP)



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

Solution - Representing “Functional States”

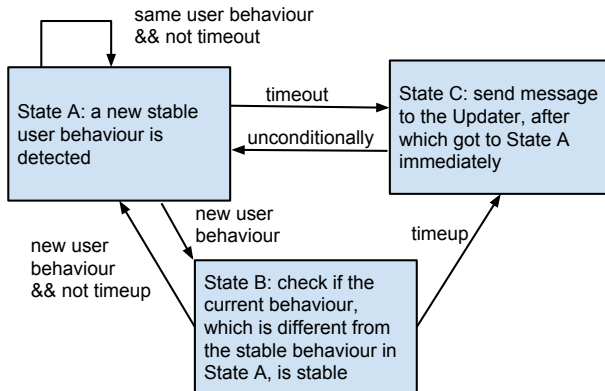
Planstep Definition and Update Diagram



- 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



- Smooths EPA values calculated 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 |