An Automated System to Assist Elderly Persons with Memory Deficiencies

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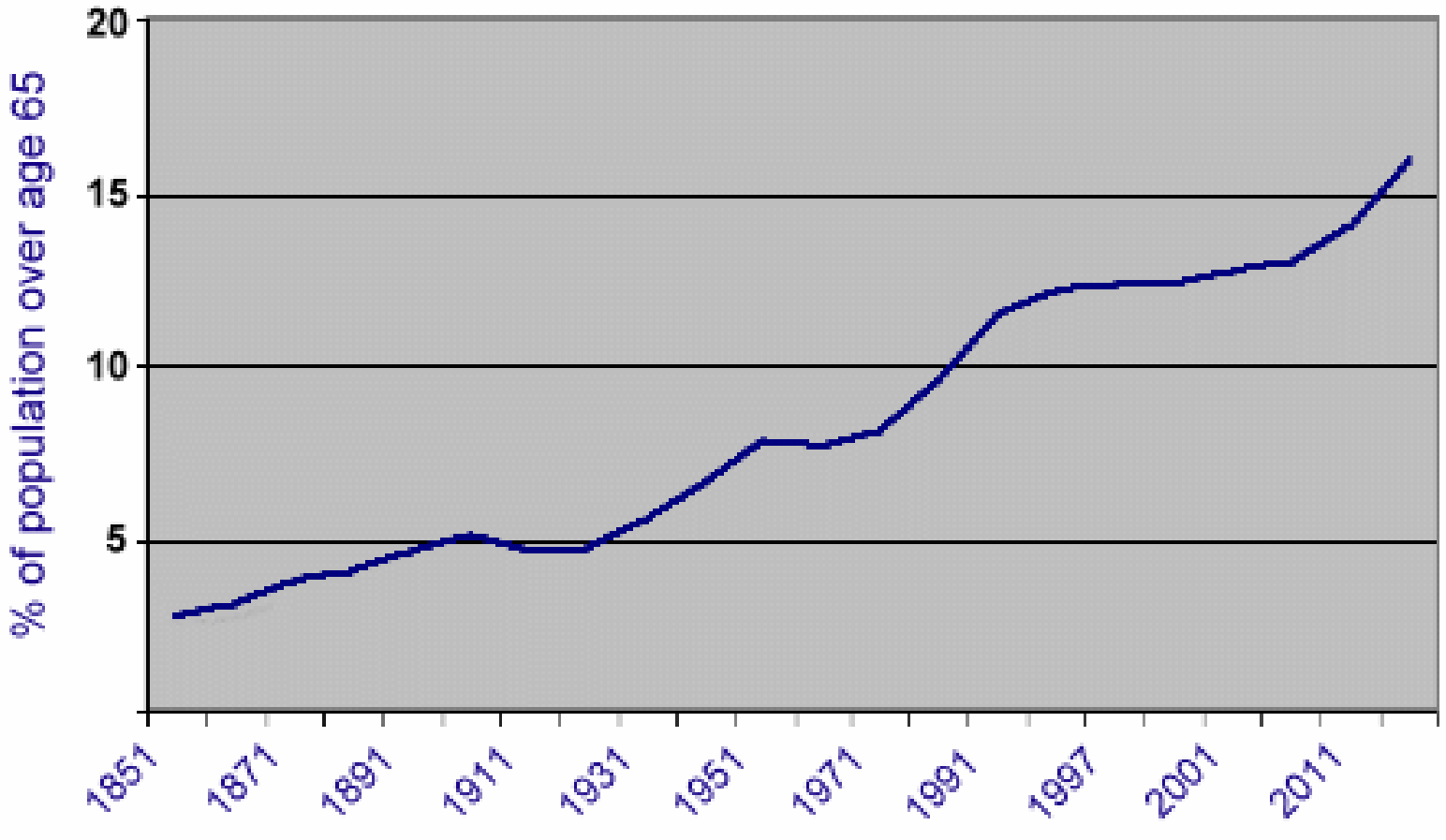
Aging Canadian Population



Institute for Research and Innovation in Sustainability

Aging Population

- Older population suffers from
  - Dementia (e.g., Alzheimer's disease)
  - Deterioration of intellectual faculties
  - Memory deficiencies
- This results in
  - Lack of autonomy
  - Inability to carry out simple daily tasks
    - Washing, toileting, eating, dressing, taking medication, etc.

Elder care

- In home caregiver
  - Time consuming (if family member)
  - Expensive (if hired professional)
- Long-term care facility
  - Unfamiliar environment for patient
- Monitoring devices
  - E.g., help button, bracelet
  - Often obtrusive
  - Inadequate for emergencies or advanced dementia

Intelligent Assistive Technology

- Technology
  - To assist in activities of daily living
  - Non-obtrusive, yet pervasive
  - Adaptable

- Benefits:
  - Relieve caregiver burden
  - Cost effective
  - Facilitates aging at home
  - Improved autonomy
  - Feeling of independence

Outline

- COACH: an automated prompting system to help elderly persons wash their hands
- Reasoning under uncertainty for assistive technology
- Video clips
- Preliminary study
- Future work

COACH project

- Collaborators: Alex Mihailidis, Jennifer Boger, Jesse Hoey, Craig Boutilier, Geoff Fernie and Szymon Wartak

System Overview

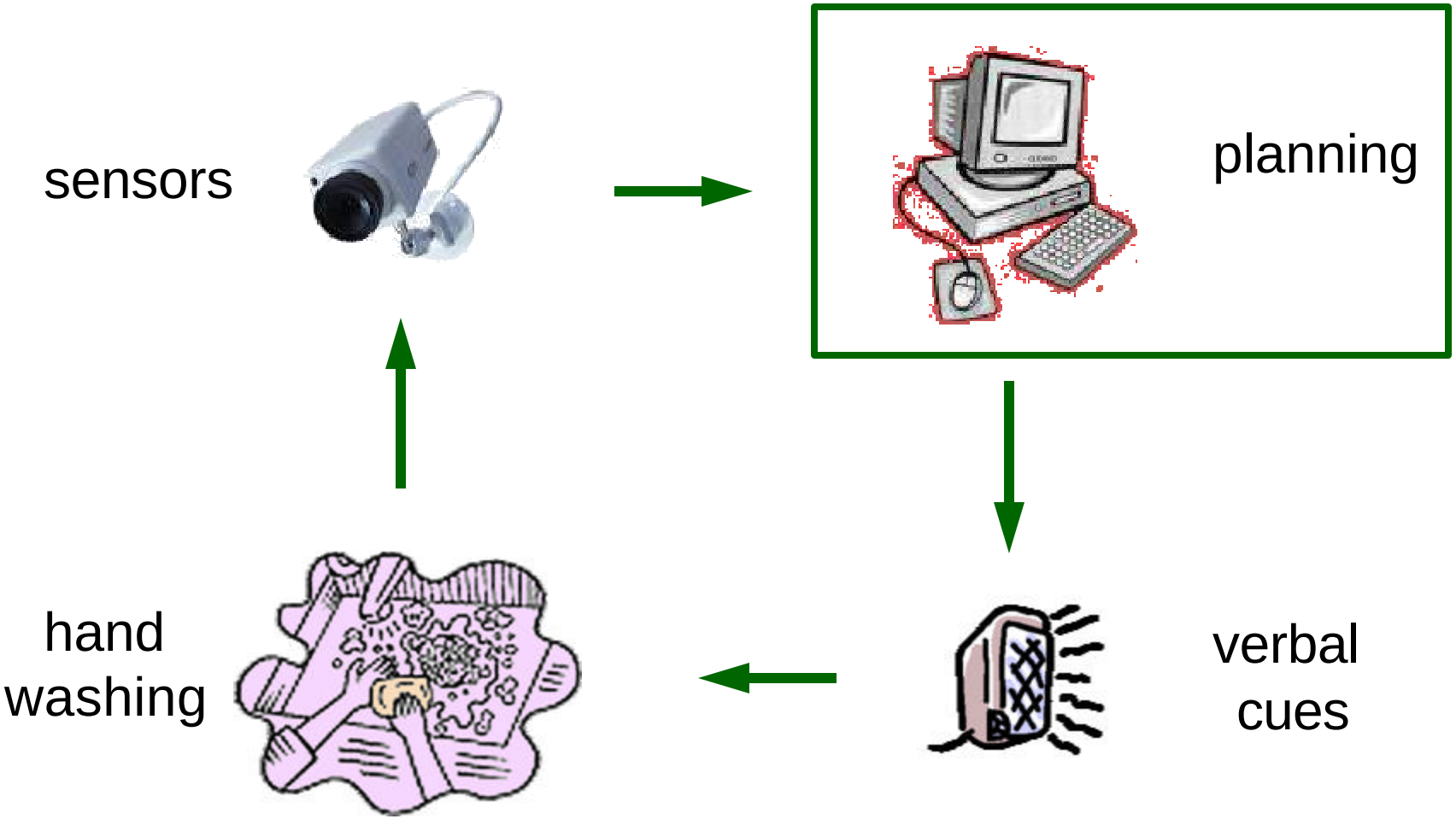
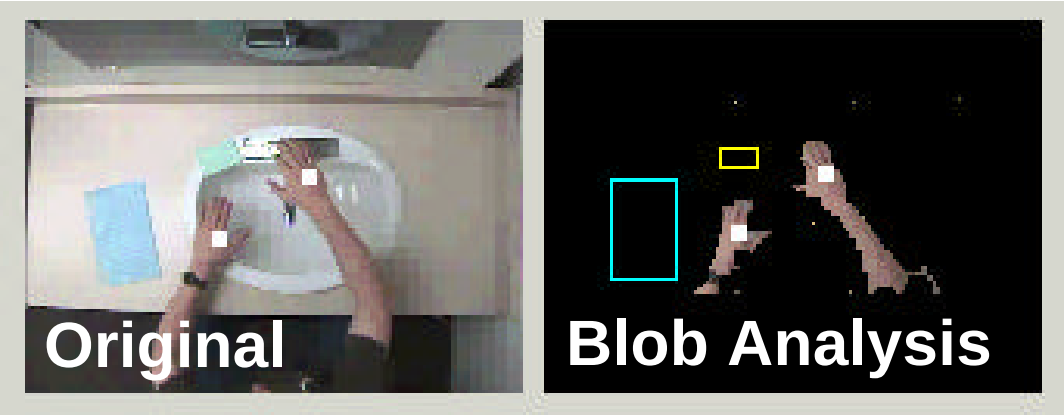
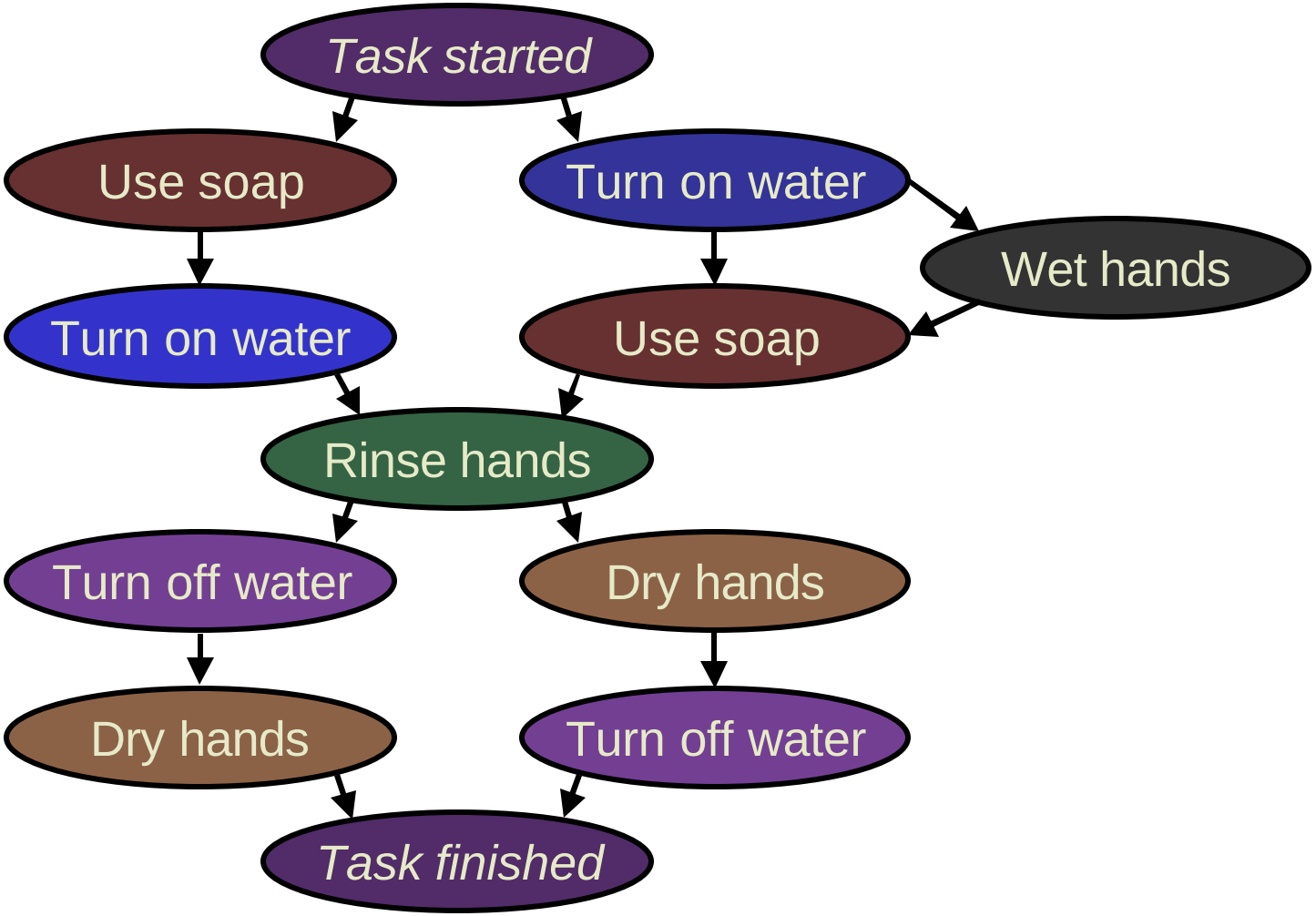


Image analysis

- Off the shelf software
  - Skin tracking
  - Background subtraction



Steps of Handwashing



Prompting Strategy

- Sequential decision problem
  - Sequence of prompts
- Noisy sensors & imprecise actuators
  - Noisy image processing, uncertain prompt effects
- Partially unknown environment
  - Unknown user habits, preferences and abilities
- Tradeoff between complex concurrent goals
  - Rapid task completion vs greater autonomy
- Approach: Partially Observable Markov Decision Processes (POMDPs)

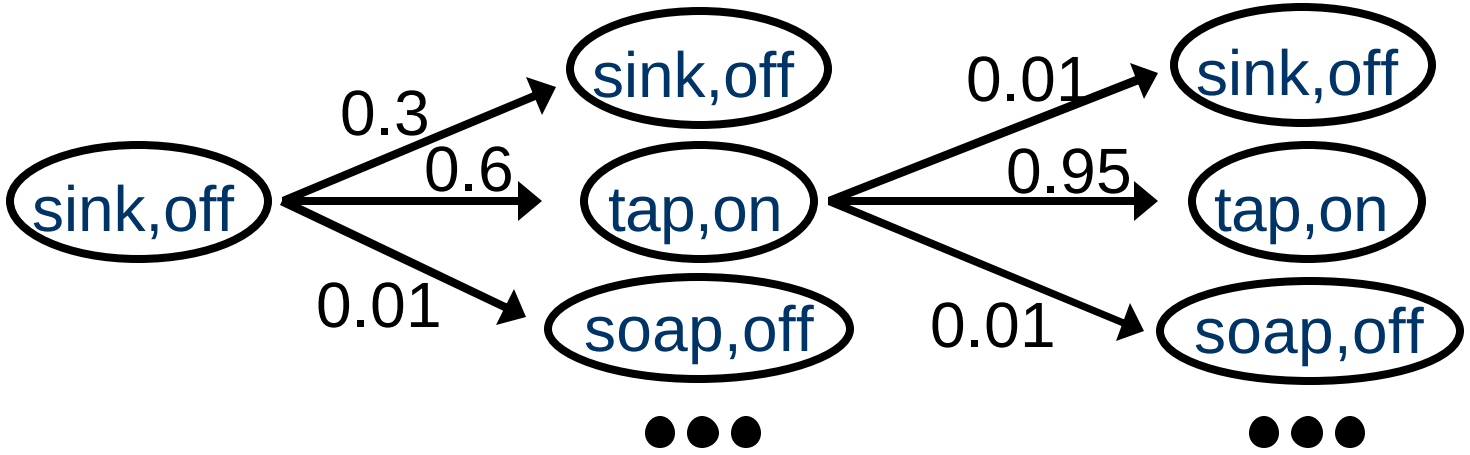
POMDP components

- State set **S** = dom(HL) x dom(WF) x dom(D) x …
  - Hand Location ∈ {tap,water,soap,towel,sink,away,…}
  - Water Flow ∈ {on, off},
  - Dementia ∈ {high, low}, etc.
- Observation set **Z** = dom(C) x dom(FS)
  - Camera ∈ {handsAtTap, handsAtTowel, …}
  - Faucet sensor ∈ {waterOn, waterOff}
- Action set **A**
  - DoNothing, CallCaregiver, Prompt ∈ {turnOnWater, rinseHands, useSoap, …}

POMDP components

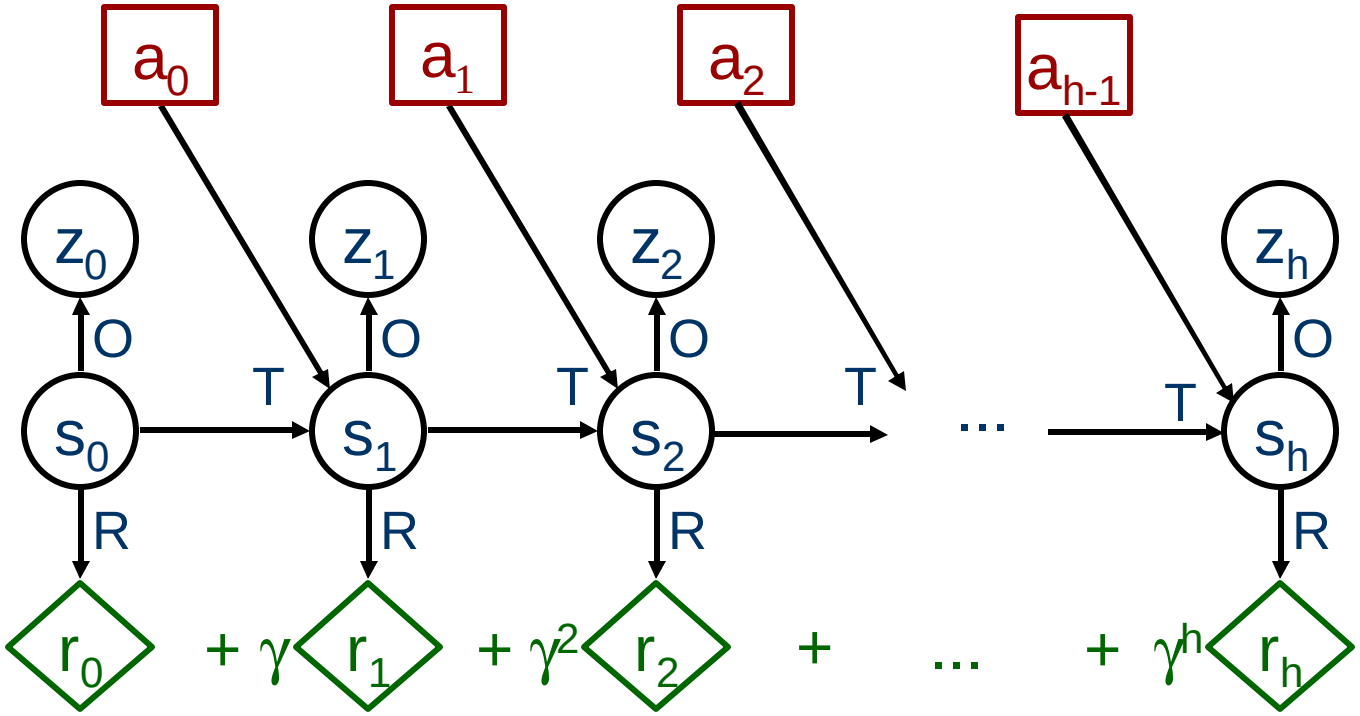
- Transition function
  T(s,a,s') = Pr(s'|s,a)

Observation function
O(s',z) = Pr(z|s')



- Reward function **R(s,a)**
  - Task completed → +100
  - Call caregiver → -30
  - Each prompt → -1, -2 or -3

Graphical Representation



Solution: policy π maximizes expected total rewards

Policies

- Policy π : B → A
  - Mapping from belief states to actions

- Belief state b
  - probability distribution over states
  - summarizes all past actions and observations

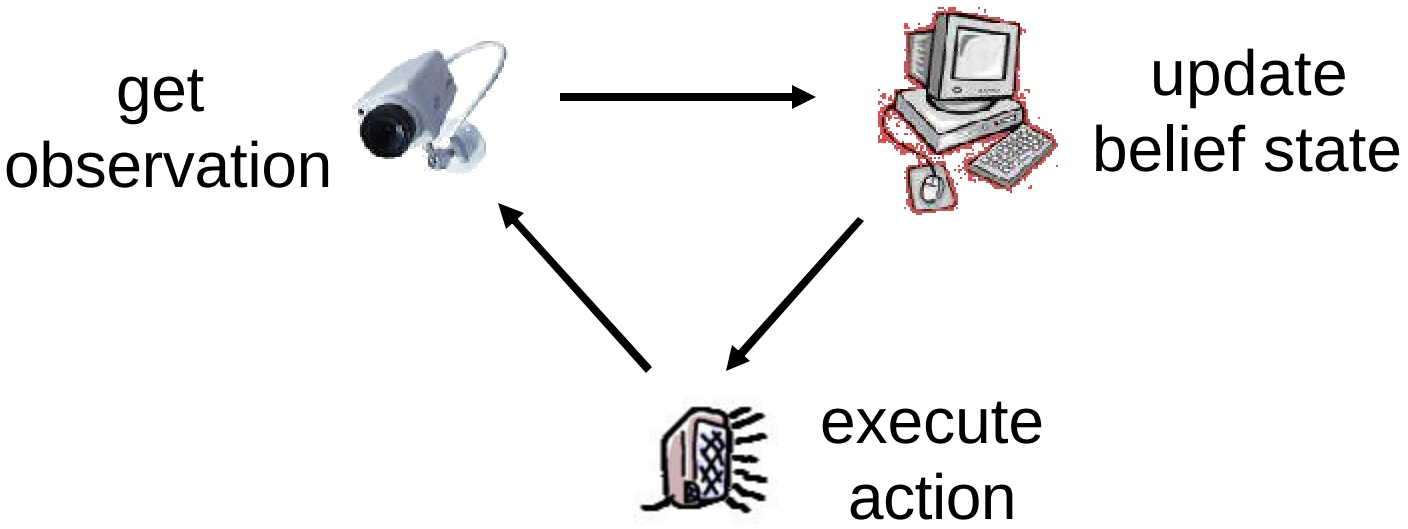
    $b_t = <\ldots, a_{t-3}, z_{t-2}, a_{t-2}, z_{t-1}, a_{t-1}, z_t>$
  - Belief update using Bayes theorem:

    $b_t(s') = k \Sigma_{s \in S} b_{t-1}(s) \Pr(s'|s,a_{t-1}) \Pr(z_t|a_{t-1},s')$

Policies

- Offline policy optimization
  - Symbolic point-based value iteration
    - A form of dynamic programming

- Online policy execution (real-time)



Preliminary Study

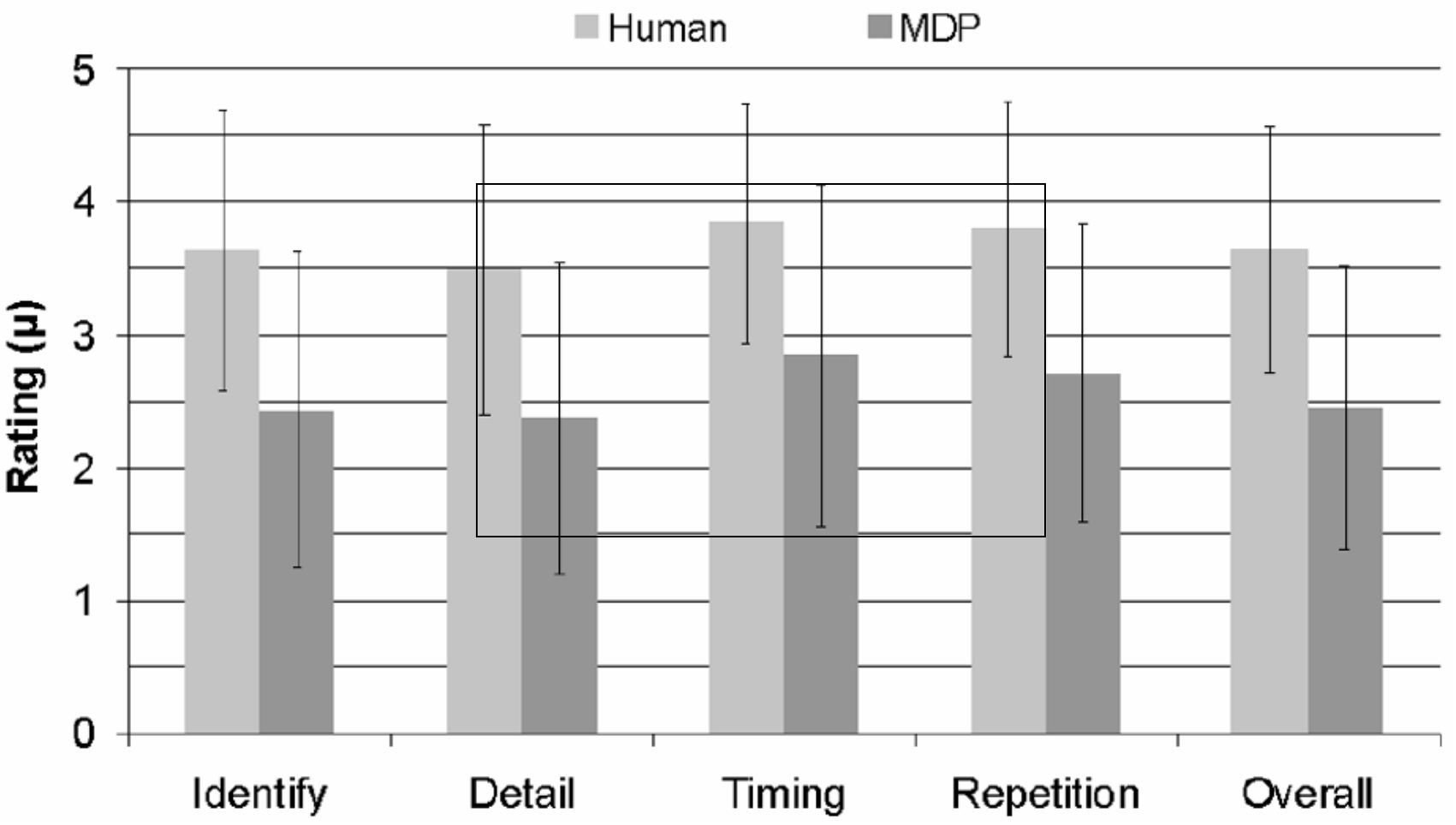
- Evaluation
  - Planning module only
  - Reduced model (fully observable MDP)

- Set up
  - Patient: actor
  - Prompts:
    - Decided by caregiver or MDP
    - Always given by the same person
  - Evaluation: by professional caregivers

Video Clip #1

Video Clip #2

Efficacy Study



Overall Evaluation

- 150 Ratings (by professional caregivers)
  - MDP better than caregiver (11)
  - MDP and caregiver equally good (17)
  - Caregiver better than MDP (122)
- Overall:
  - MDP not as good as caregiver
  - However, MDP policy is credible
  - Is it good enough to be installed in a home?

Conclusion

- COACH system:
  - Automated task monitoring
  - Automated prompting system
  - Non-obtrusive
  - Technology that adapts to people

- Take home message:
  - Intelligent assistive technology possible
  - We can robustly handle uncertainty

Future Research Directions

- Short term
  - Clinical trials this month
  - Agitation monitoring
  - Natural language processing
- Vision: smart assistive house
  - Monitor people's activities
  - Assist in simple daily tasks
    - Toileting, eating, taking medication

My research interests

- General themes:
  - Reasoning under uncertainty
  - Machine learning

- Health informatics related interests
  - Ubiquitous systems
  - Adaptive systems
  - User modelling
  - Preference elicitation
  - Data analysis