

Decision-Theoretic User Modeling



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Need for software customization

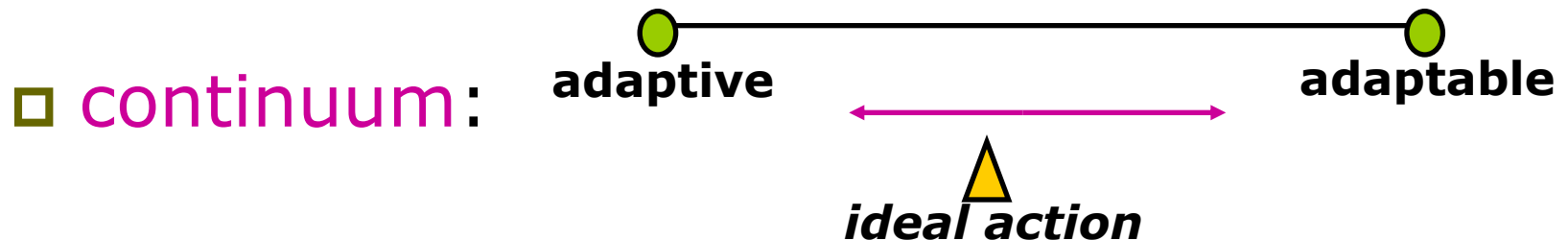
- increased software complexity
- examples
 - functionality: hide unused ones
 - presentation: ease of accessibility
 - navigation: thumbnails of slides
- most affected users
 - cognitive, sensory, motor impairments
 - elderly
 - children
 - novices

Approaches to customization

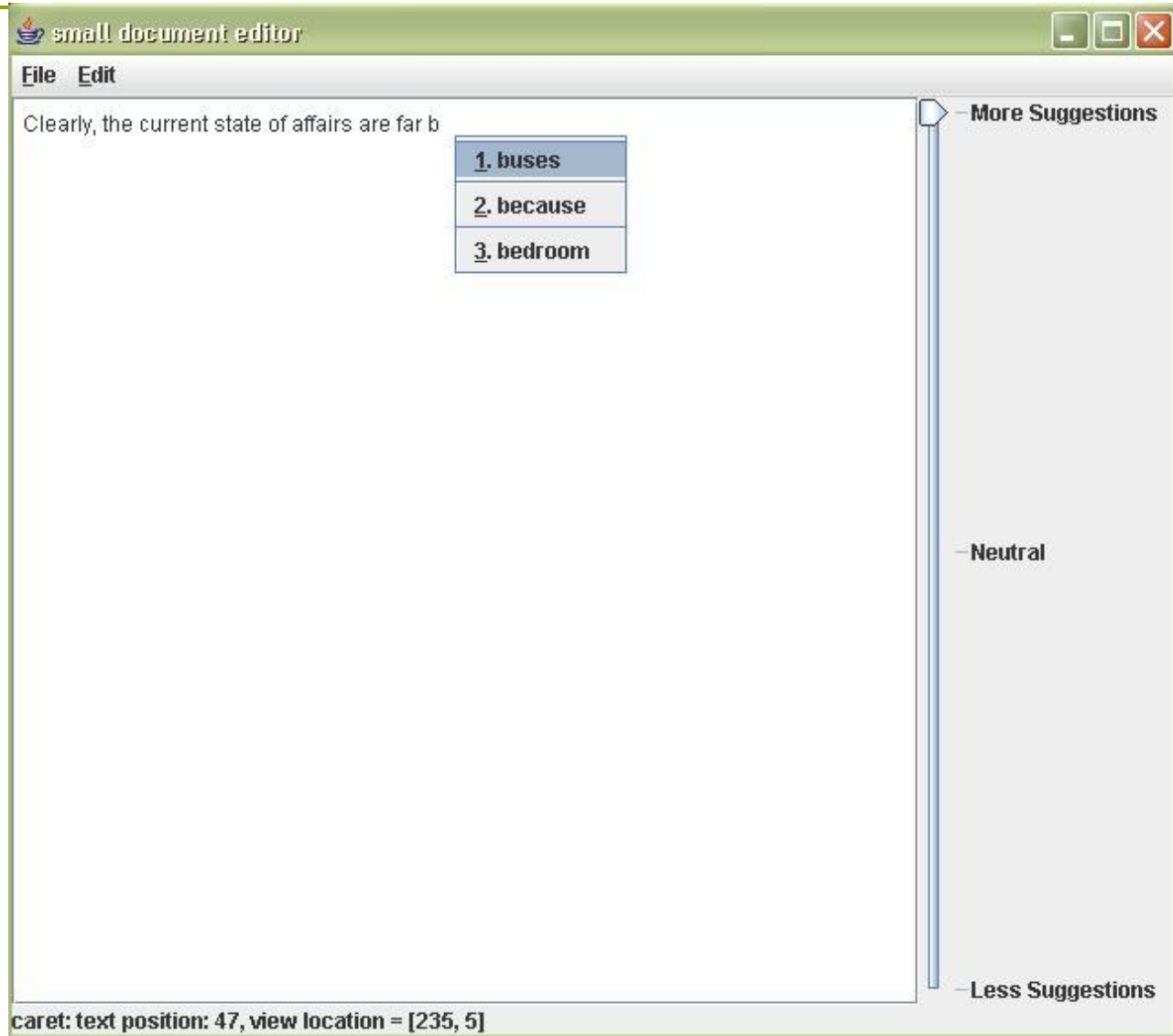
- adaptable – more user effort
- adaptive – when, what, which, how?
- hybrid – DBN (system accuracy),
 - doesn't learn about user

Approaches to customization

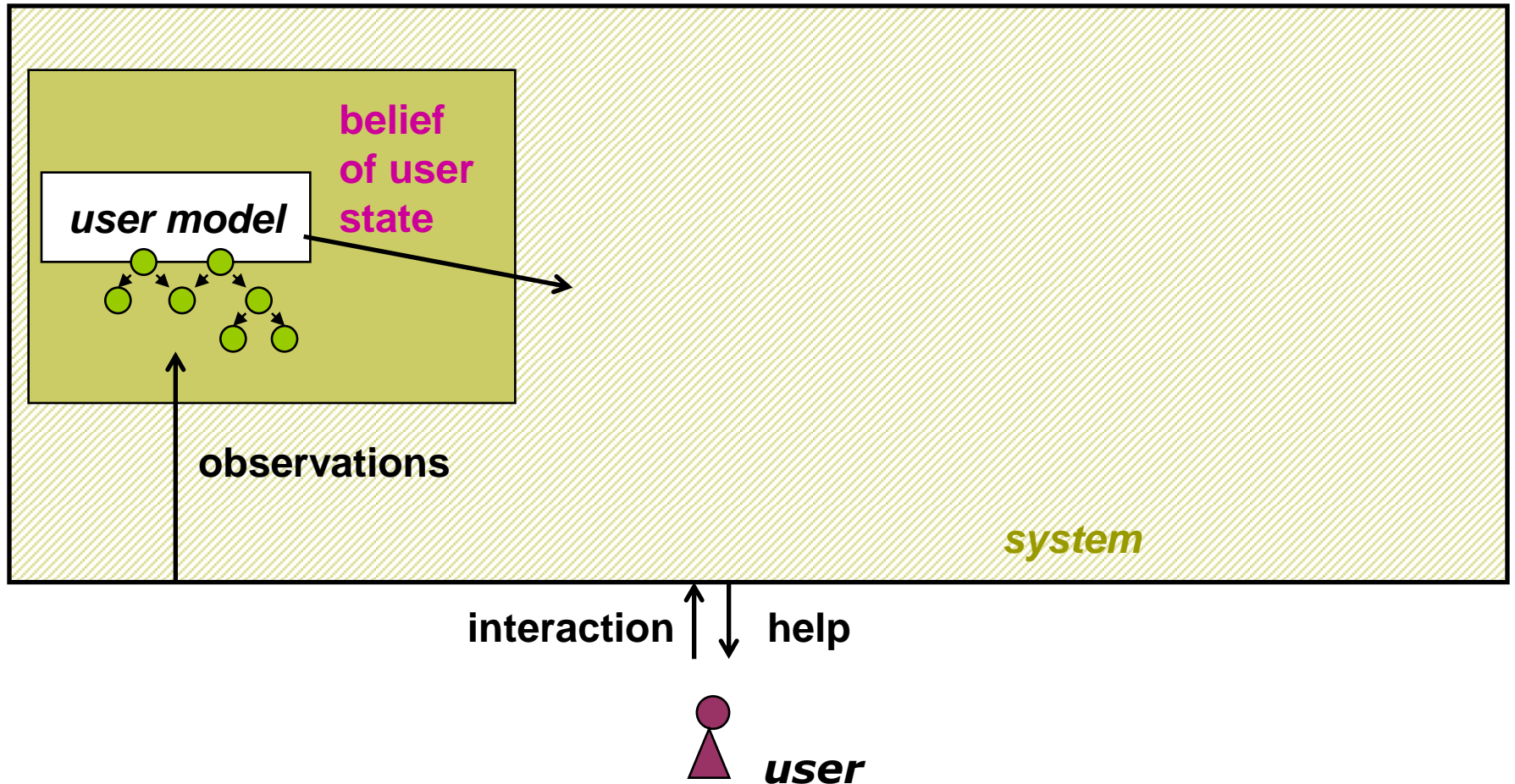
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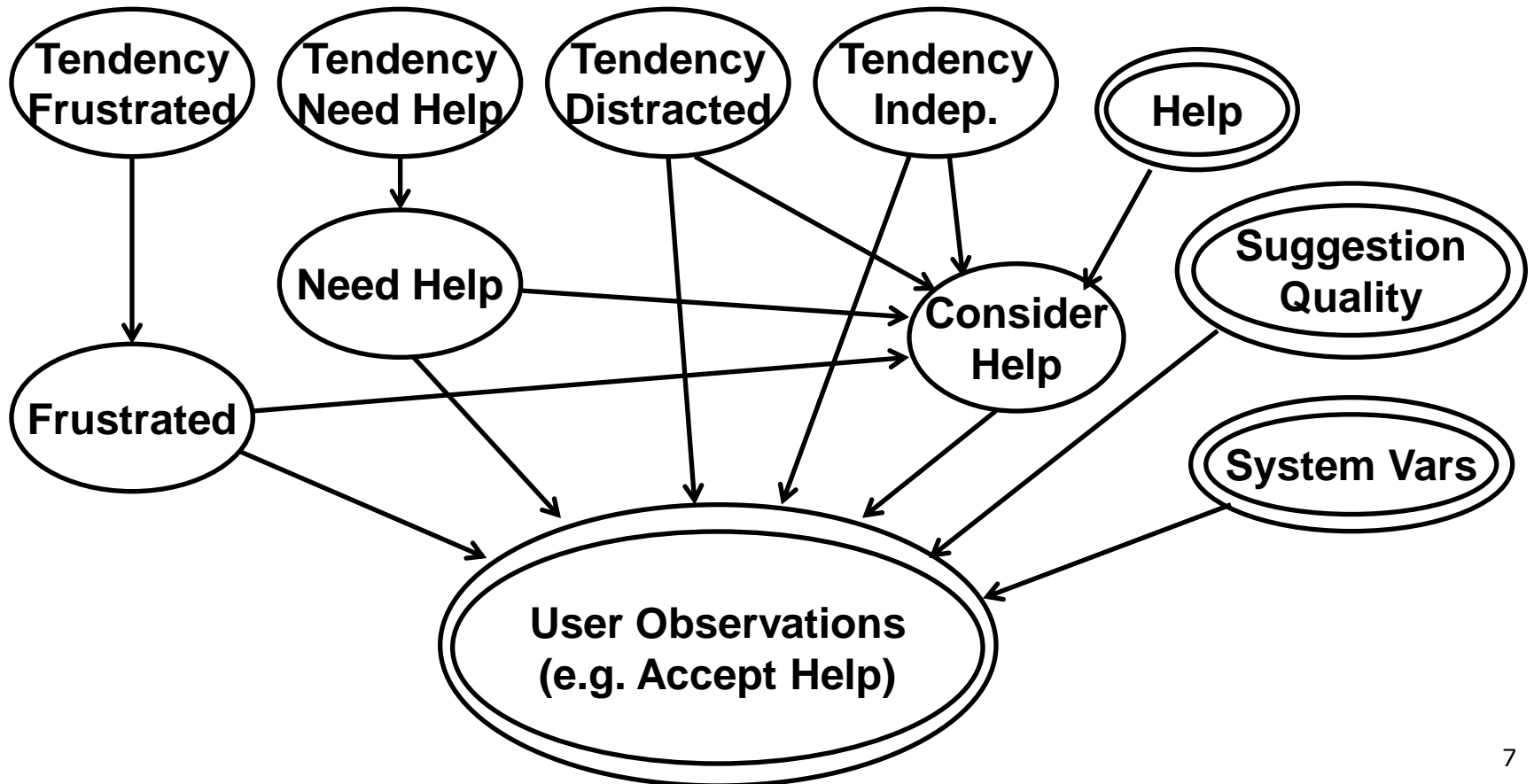
Word prediction prototype



Belief distribution of user state



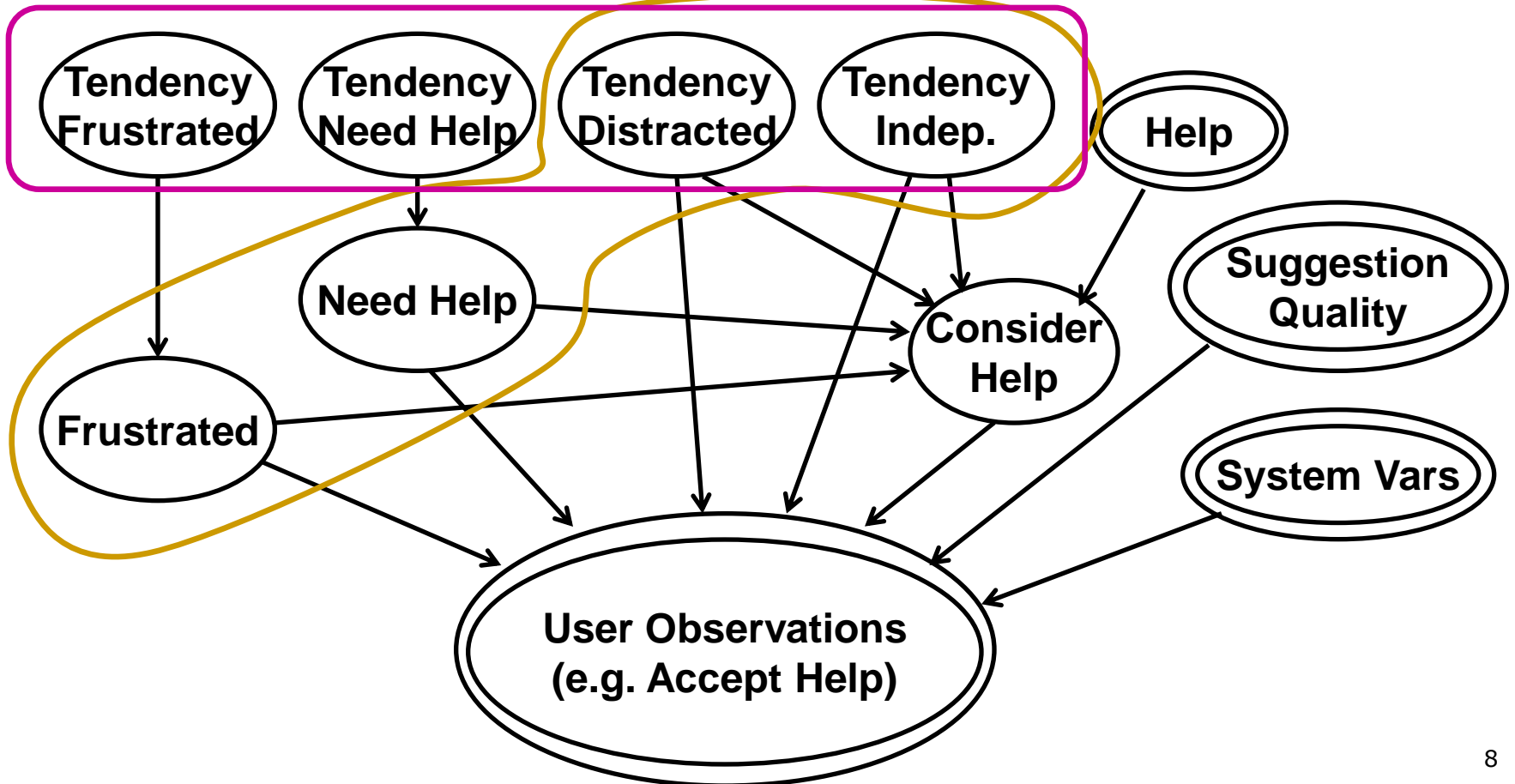
Generic user model



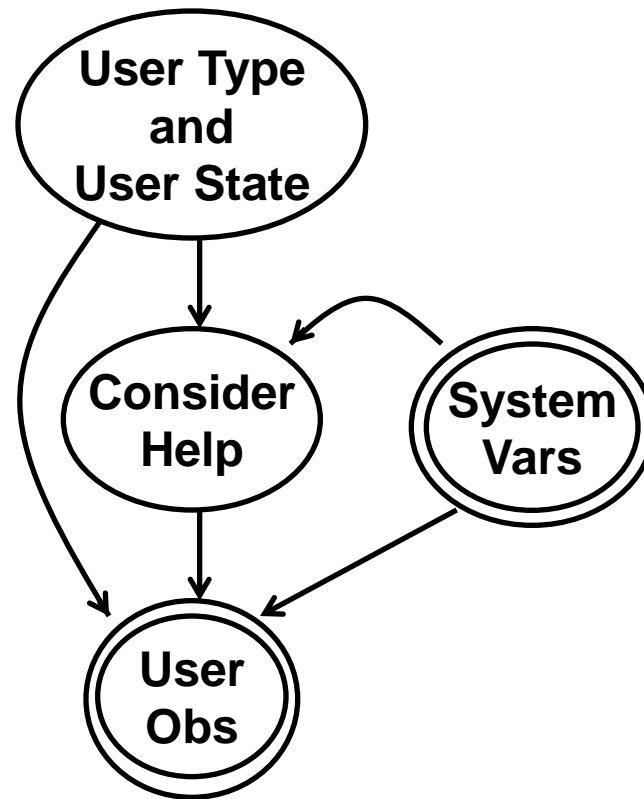
Generic user model

user type (36)

user states (81)



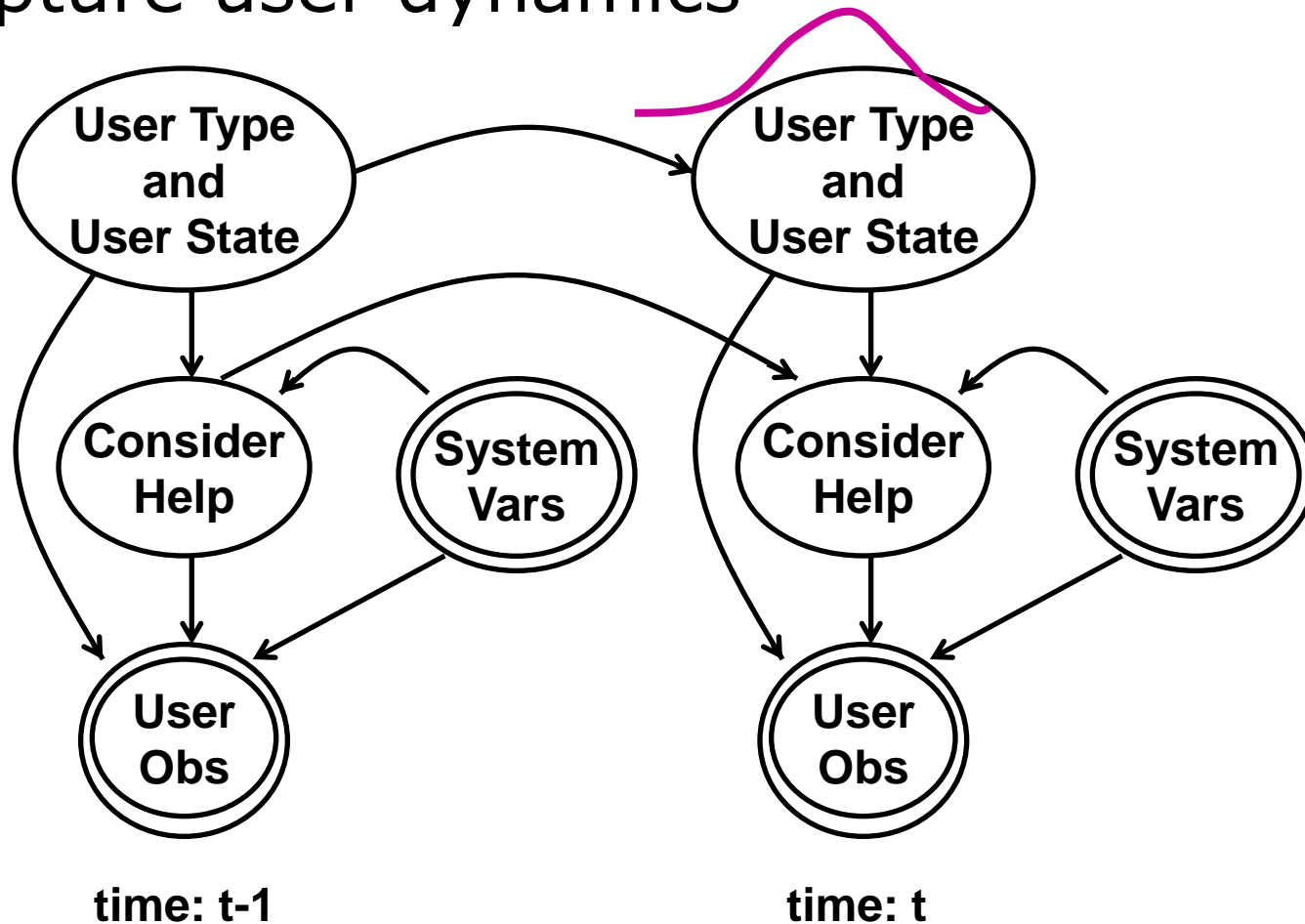
Dynamic Bayesian network (DBN)



time: t

Dynamic Bayesian network (DBN)

- capture user dynamics



Tasks of interest

□ $\Pr(\text{BEL}_t | \text{Ev}_{1:t})$

■ $\sum_{\text{TF}_t, \text{TN}_t, \text{CONS}_t} \Pr(X_t | \text{Ev}_{1:t})$

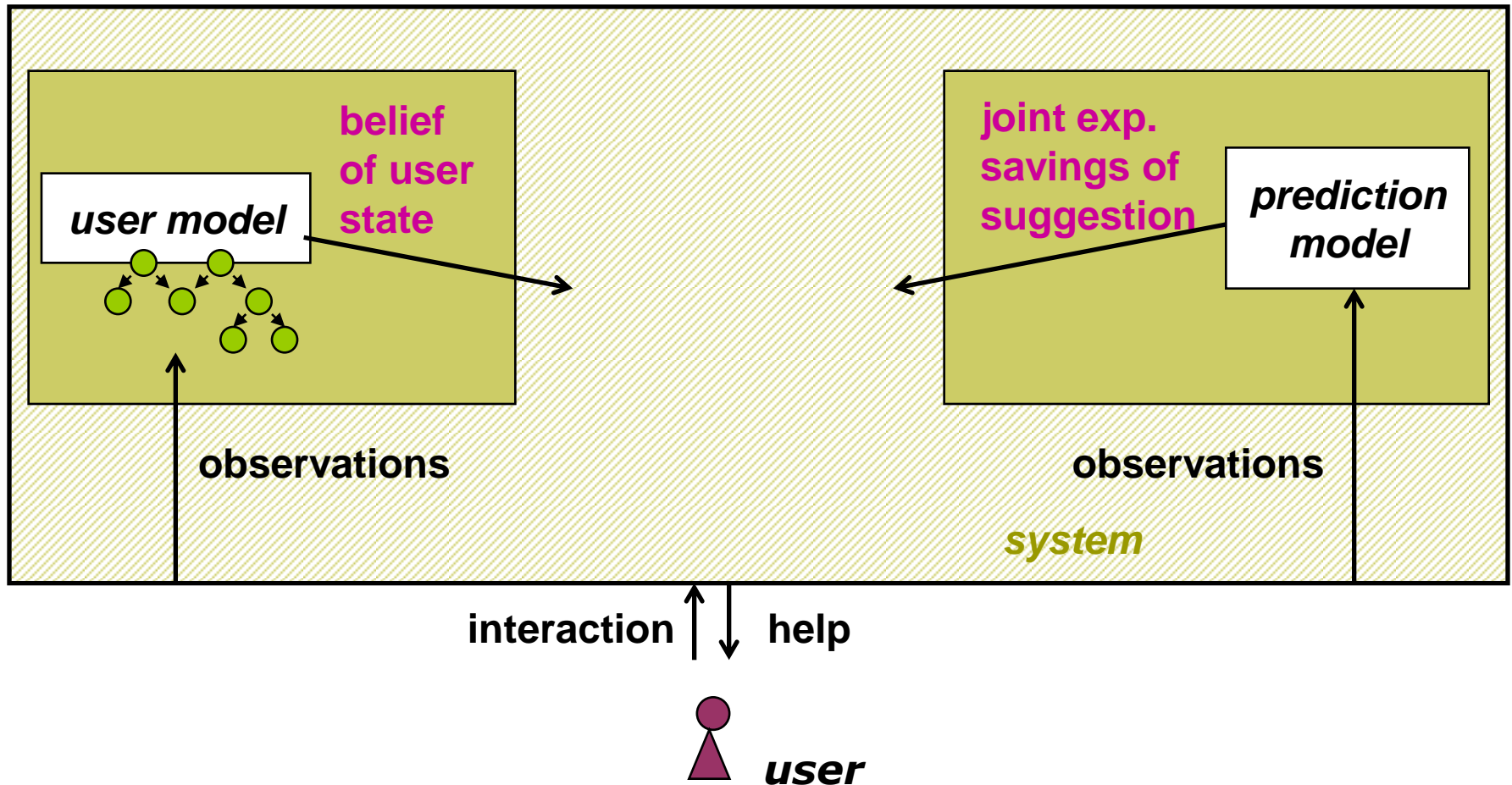
■ $\sum_{\text{TF}_t, \text{TN}_t, \text{CONS}_t} \Pr(\text{Ev}_t | X_t) \Pr(X_t | \text{Ev}_{1:t-1})$

□ $\Pr(\text{OBS}_{t+1} = \text{acc}, \text{HELP}_{t+1}, \text{QUAL}_{t+1}, \text{SYS}_{t+1} | \text{Ev}_{1:t})$

■ $\Pr(\text{Ev}_{t+1} | \text{Ev}_{1:t}) = \sum_{X_t} \Pr(\text{Ev}_{t+1} | X_{t+1}) \Pr(X_{t+1} | \text{Ev}_{1:t})$

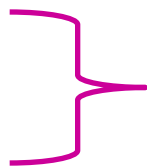
□ $X = \text{clique with } \{\text{BEL}, \text{TF}, \text{TN}, \text{CONS}\}$

Joint expected savings of suggestions



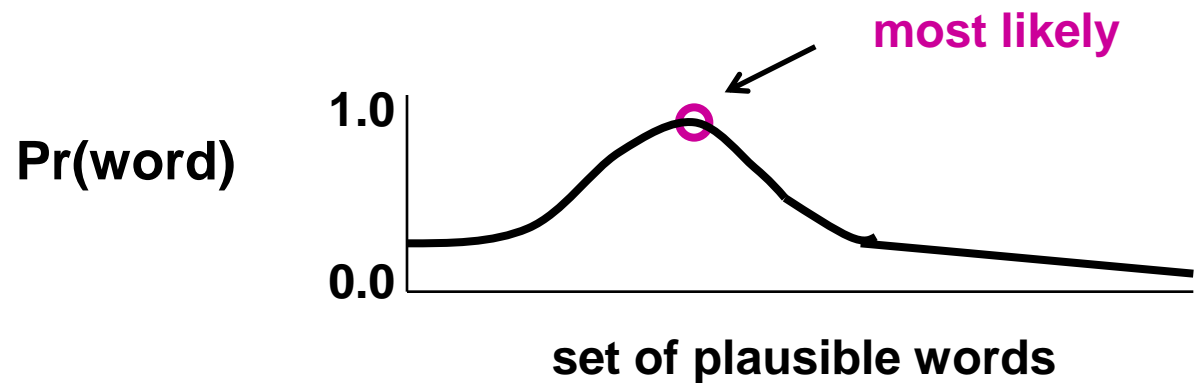
Joint expected savings (JES)

- e.g., $\Pr(\text{word}_{\text{offer}} | \text{"the"}, \text{"nu"})$
- most likely (word bigram):
 - number
 - numbers
 - nuclear
- joint expected savings (ours):
 - number
 - nuclear
 - nurses



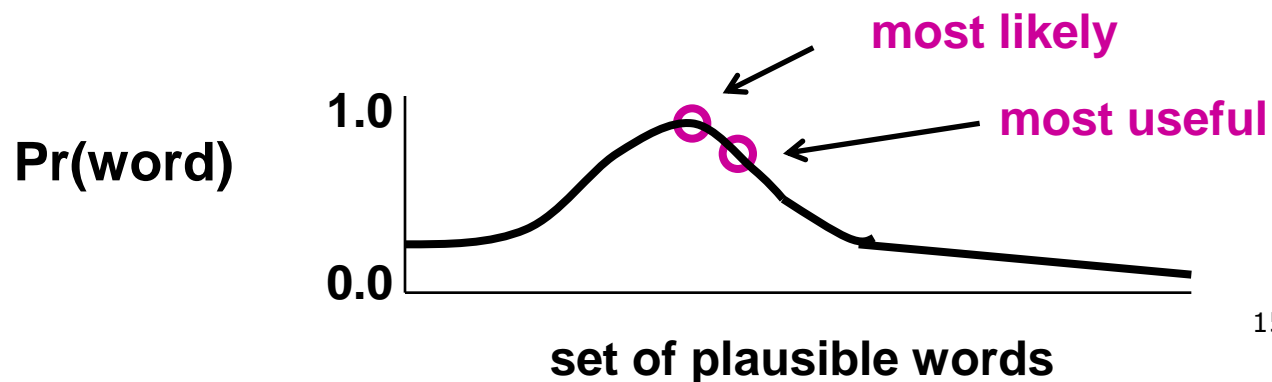
Joint expected savings (JES)

- prediction (bigram) model: $p_1 \dots p_K$
 - most likely



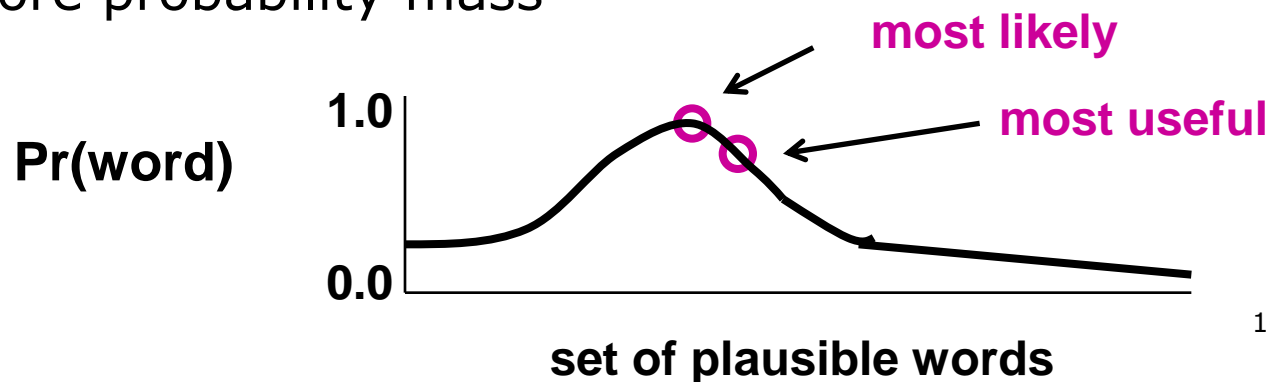
Joint expected savings (JES)

- prediction (bigram) model: $p_1 \dots p_K$
 - most likely
- utility model: $U(c_{\text{offer}} | c_{\text{trueword}})$
 - most useful

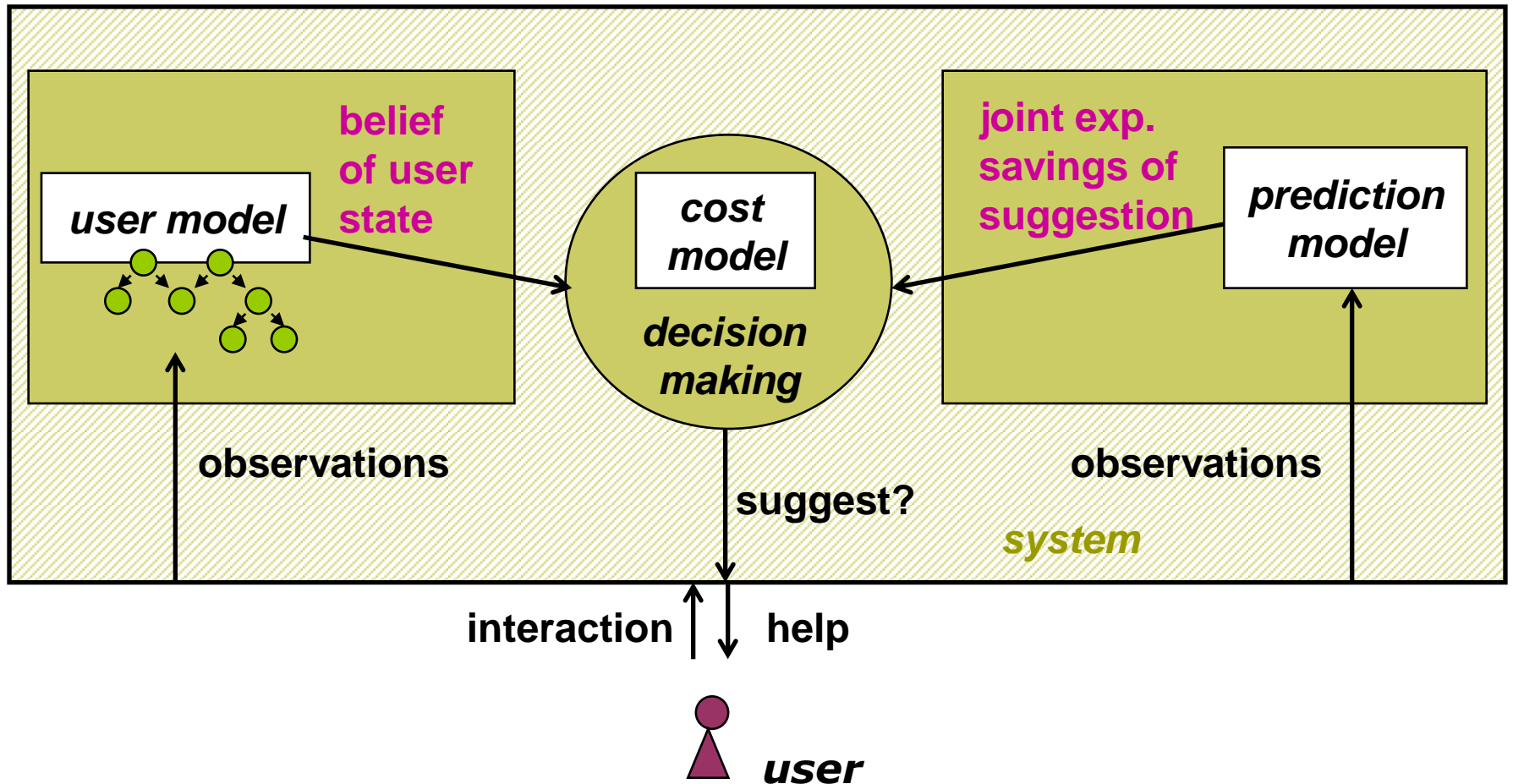


Joint expected savings (JES)

- prediction (bigram) model: $p_1 \dots p_K$
 - most likely
- utility model: $U(c_{\text{offer}} | c_{\text{trueword}})$
 - most useful
- expected character savings: $ES(c_k) = \sum^K U(c_k | c_i) p_i$
 - most useful + accurate
- joint E.S.: $JES(c_1, \dots, c_J) = \sum_{i=1}^K \operatorname{argmax}_{c_j} U(c_j | c_i) p_i$
 - covers more probability mass

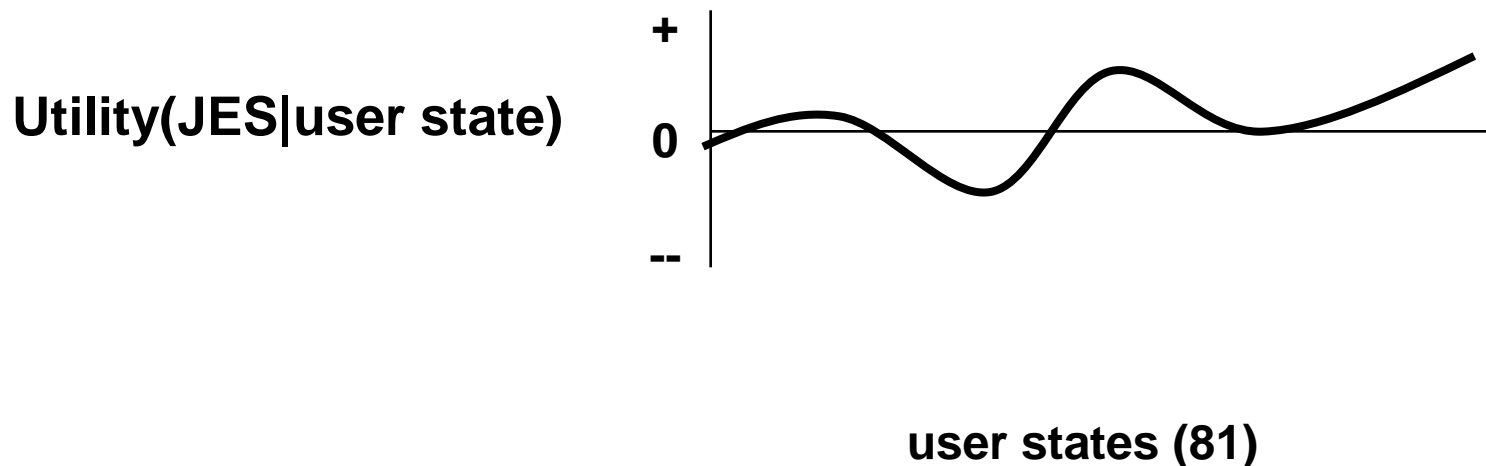


Decision making component



Bayesian action selection

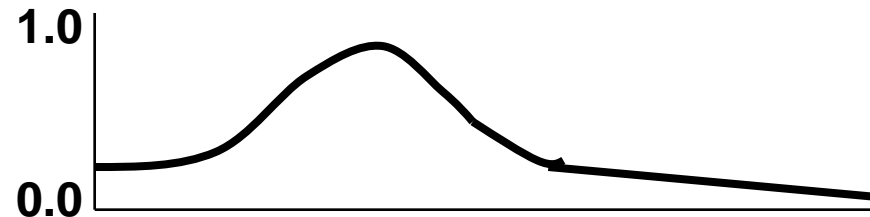
- cost model – generalized additive utility



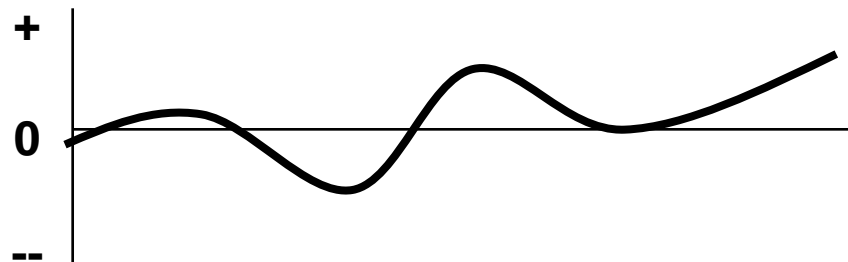
Bayesian action selection

- cost model – generalized additive utility
- action with maximum expected utility (MEU)
- EU:

Pr(user state)



Utility(JES|user state)

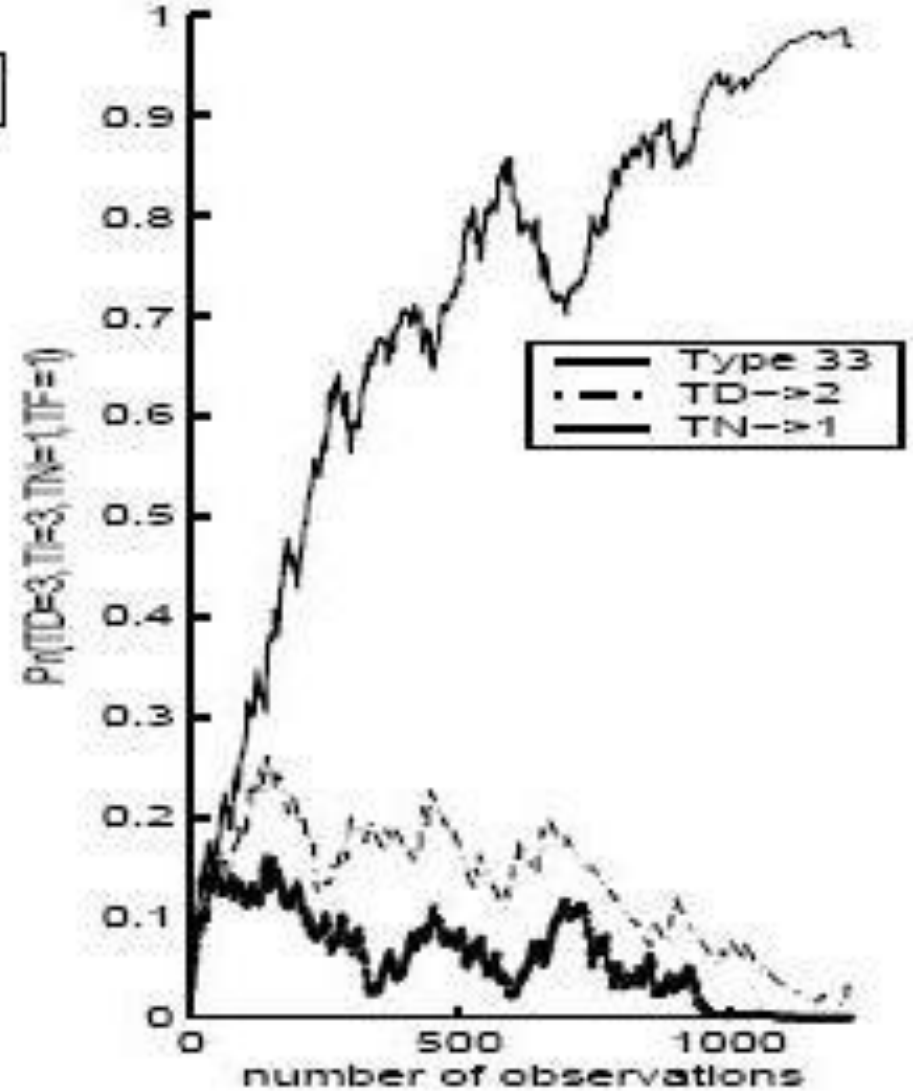
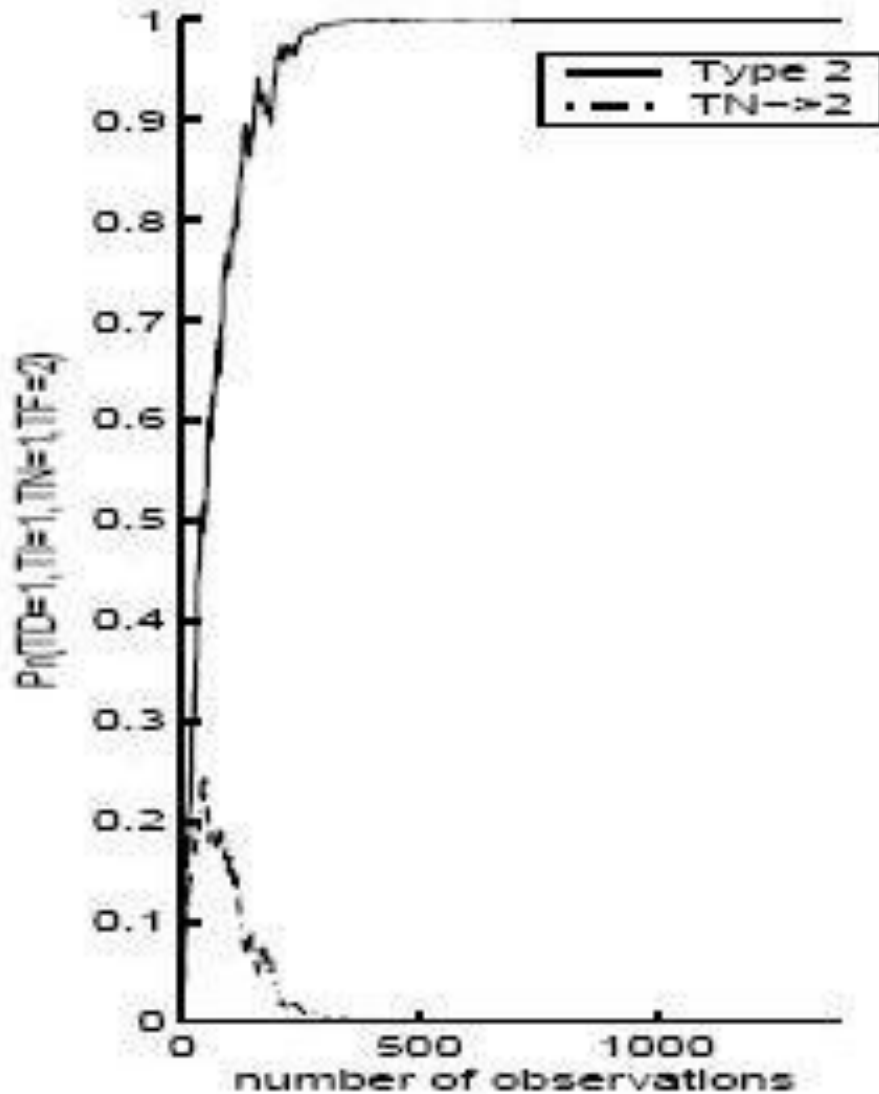


user states (81)

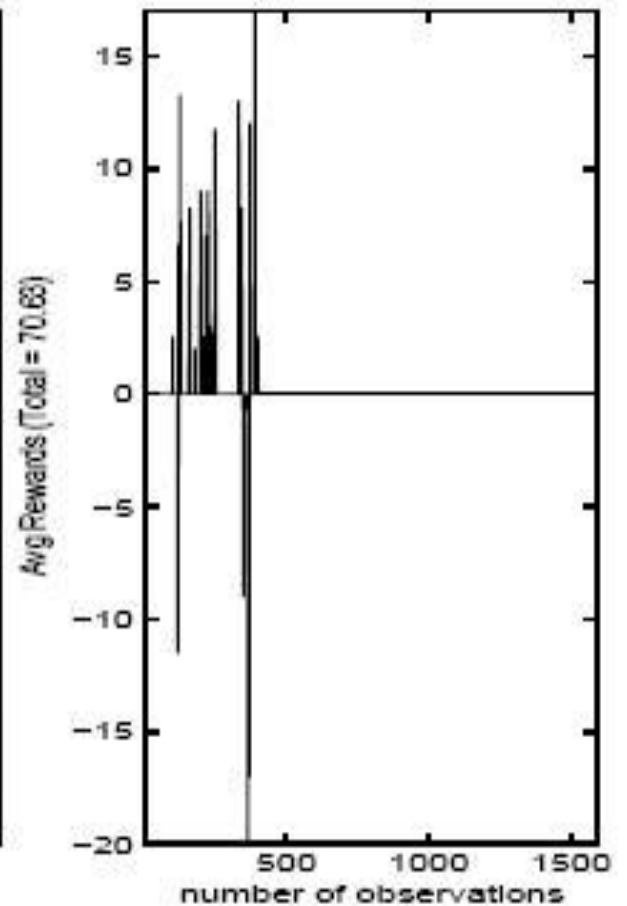
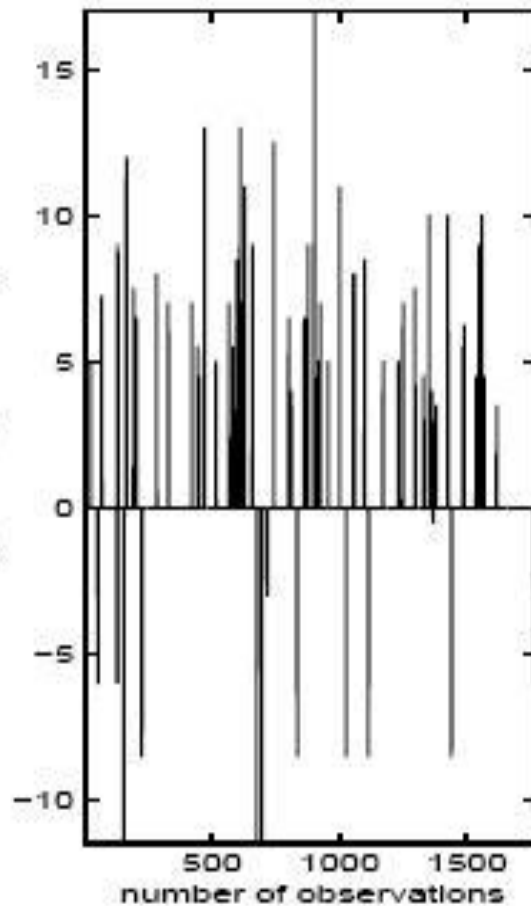
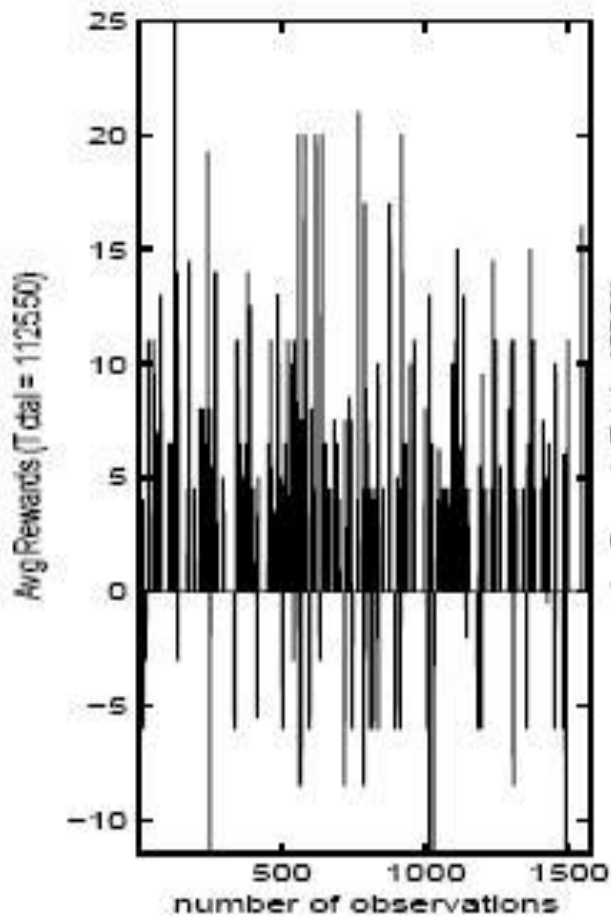
Simulations

- user model
 - converge to user type?
- prediction model
 - value of utility definition?
- cost model
 - effect of personalization?
- text 300 words, 100 runs

User model – convergence



Cost model – personalization



Cost model – policy comparison

- average reward per time step for {Frustrable, Needy, Distractible, Independent}

User Type	ALWAYS	MEU	THRESHOLD	NEVER
{_F, ¬N, ¬D, ¬I}	1.64	0.93	0.91	0
{¬F, ¬N, ¬D, ¬I}	0.46	0.62	0.65	0
{_F, ¬N, ¬D, ¬I}	-0.64	0.39	0.31	0
{¬F, ¬N, ¬D, ¬I}	-10.89	-1.89	-2.93	0
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More realistic model

- learn user model parameters
 - user states \sim behavioural observations
 - control lab setting with 45 participants
- topology of users
- evaluate *usability* of new model
 - 4 policies: ALWAYS, NEVER, THRESHOLD, MEU
 - 4 participants in pilot study
 - text 70 words

Preliminary usability results

- typing speed 4-8 words/min (hi Needy, low Indep)

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- subjective: ALWAYS >> adaptive >> NEVER
- typing effort: NEVER >> adaptive >> ALWAYS

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- subjective: MEU >> THRESH, quality
- num accept, per correct help: THRESH >> MEU
- 20% partial accepts

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users perceive *utility* of suggestions

Summary of contributions

- HCI as decision making problem
- generic model of user preferences
- learn user features online
- individual costs/rewards
- Bayesian action selection

Future work

