Active User Affect Recognition and Assistance

Wenhui Liao, Zhiwe Zhu, Markus Guhe*, Mike Schoelles*, Qiang Ji, and Wayne Gray*

Email: jiq@rpi.edu

Department of Electrical, Computer, and System Eng.
*Department of Cognitive Science
Rensselaer Polytechnic Institute

Research Goal

- Design an intelligent user assistance system
  - Improve user's performance, minimize human errors, and enhance HCI experience by mitigating the impact of negative affective states
  - Three functions
    - Real time and non-intrusive acquisition of user state measurements of different modalities
    - Recognize affective states
      - Fatigue, stress, confusion, boredom, anxiety, ….
    - Provide user assistance
      - No-assistance, warn, simplify, intervene, ….

Challenges

- Observations about user’s affective states are ambiguous, uncertain, dynamic, and are often from different modalities
- User affective states develop over time, and are person-dependent and context-dependent
- Measurements of user state need be non-intrusive and non-interference with user’s work
- Decisions about the user’s need and assistance must often be rendered *appropriately* and timely.

Related Work: User State Measurements

- Physiological measurements
  - EEG, EKG, EMG, Blood Pressure, Respiration, ..
- Visual measurements
- Behavioral measurements

Existing measurements tend to be intrusive or from a single source of modality.

The measurements are combined in a heuristic and ad hoc way.

Related Work: Affective State Recognition

- **Approaches**
  - Rule-based [Pantic02]
  - Discriminate analysis [Ark99]
  - Fuzzy rules [Elliott99, Hudlicka02]
  - Neural Network [Petrushin99]
  - HMM [Picard97, Cohen00]
  - Bayesian Networks [Ball00, Cohen02, Conati02, Ji04]
  - More ....

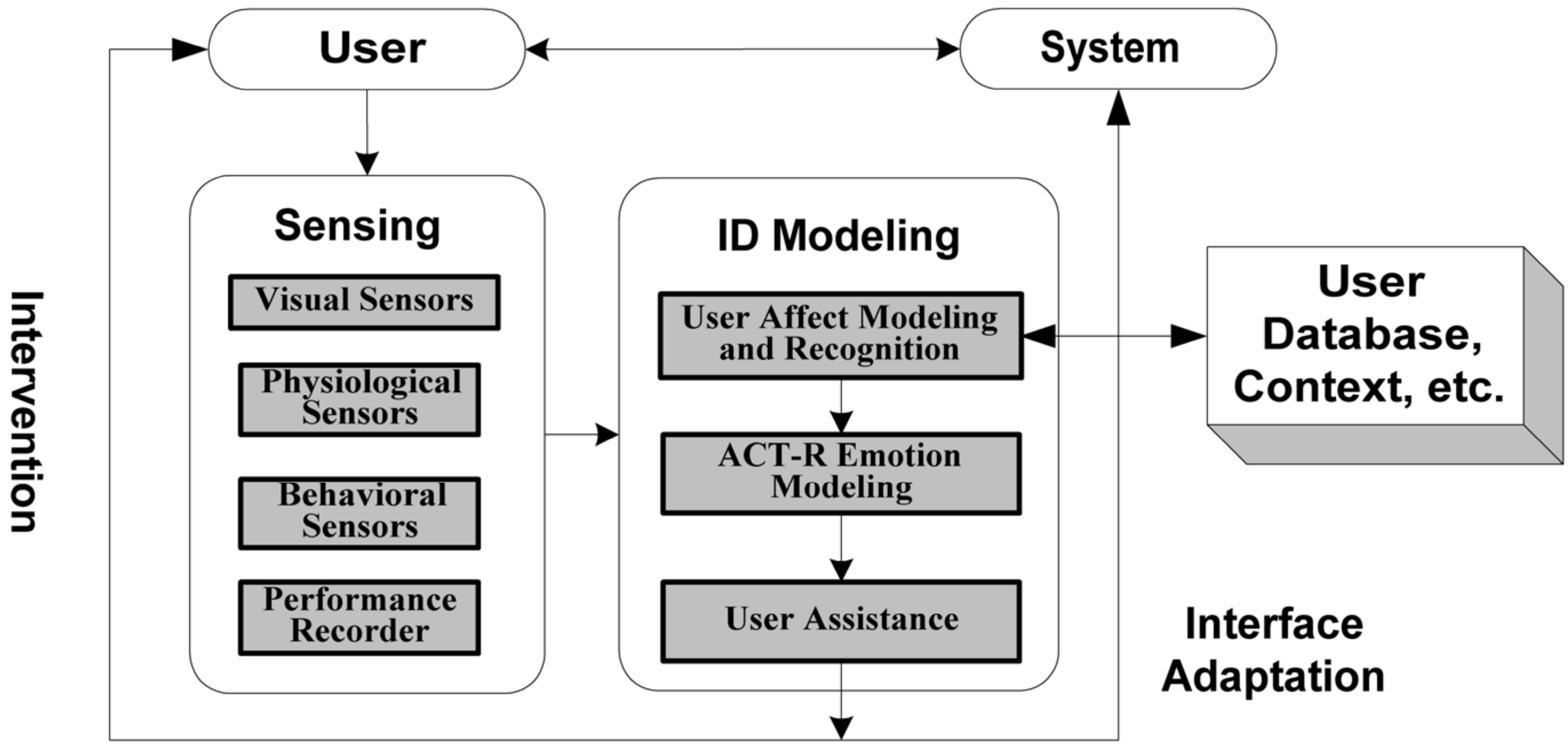
Related Work (Cont'd)

- **Limitations of the existing methods**
  - Lack the capability of representing dependencies and semantics between different emotion variables and tend to ignore prior and contextual information (rule-base, fuzzy rule, discriminate analysis, Neural Network, HMM)
  - Tend to ignore temporal relations (rule-based, discriminate analysis, fuzzy rule, Neural Network)
  - Perform passive affect inference
  - Focus on generic emotion recognition instead of task-specific emotions

Related Work: User Assistance

- **Probabilistic user assistance systems**
  - A Markov decision process framework is proposed to automatically provide the user with a sequence of tailored recommendations and instructions [Bohnenberger01].
  - Dynamic Decision Network to generate tailored interventions to improve student's learning with educational games [Conati02].
  - Decision-theoretic methods are proposed to identify the best interruption/assistance to help satisfy user's needs [Horvitz98,00,03].

Overview of Our Approach

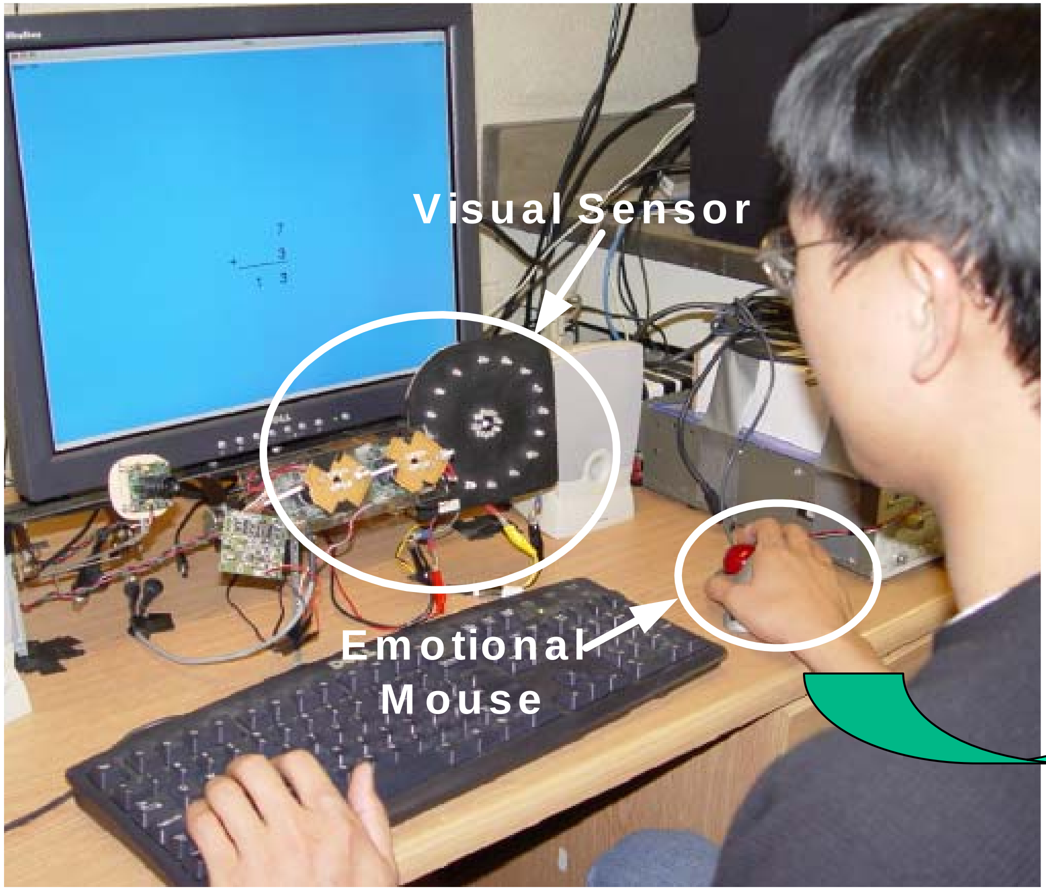


Multi-modal Sensing

We developed real-time and non-intrusive sensing systems to obtain user affect measurements of different modalities

- Visual
- Physiological
- Behavioral
- Performance

Multi-Sensory System Setup

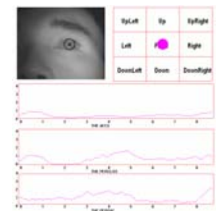


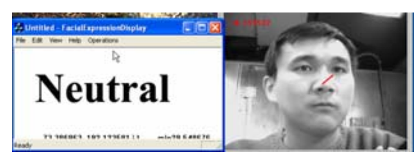
Visual Measurements

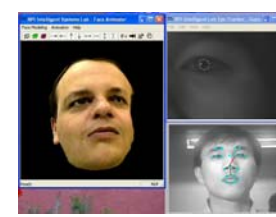
- Pupil related
  - Normalized Pupil Size Variation (PupDiff)
  - Percentage of Large Pupil Dilation (PerLPD)
- Eyelid related
  - Blinking Frequency (BF)
  - Average Eye Closure Speed (AECS)
  - PERCLOS
- Eye Gaze related
  - Percentage of Saccadic Eye Movement (PerSAC)
  - Gaze Distribution (GazeDis)
- Head: head movement variation, head tilt, …
- Facial Expressions: expression change, mouth movement, some basic expressions.

Vision System Demos

- Real time eye tracking
- Eye gaze tracking
- Eyelid movement tracking
- Head movement tracking
- Facial expression tracking







Physiological and Behavioral Measurements

- Behavior
  - Mouse movements
  - Button click frequency
  - **Finger pressure** when a user presses the button
- Physiological information
  - Heart rate – ECG, **PPG**
  - **Skin temperature**
  - Skin conductivity (**GSR**)

Emotional mouse

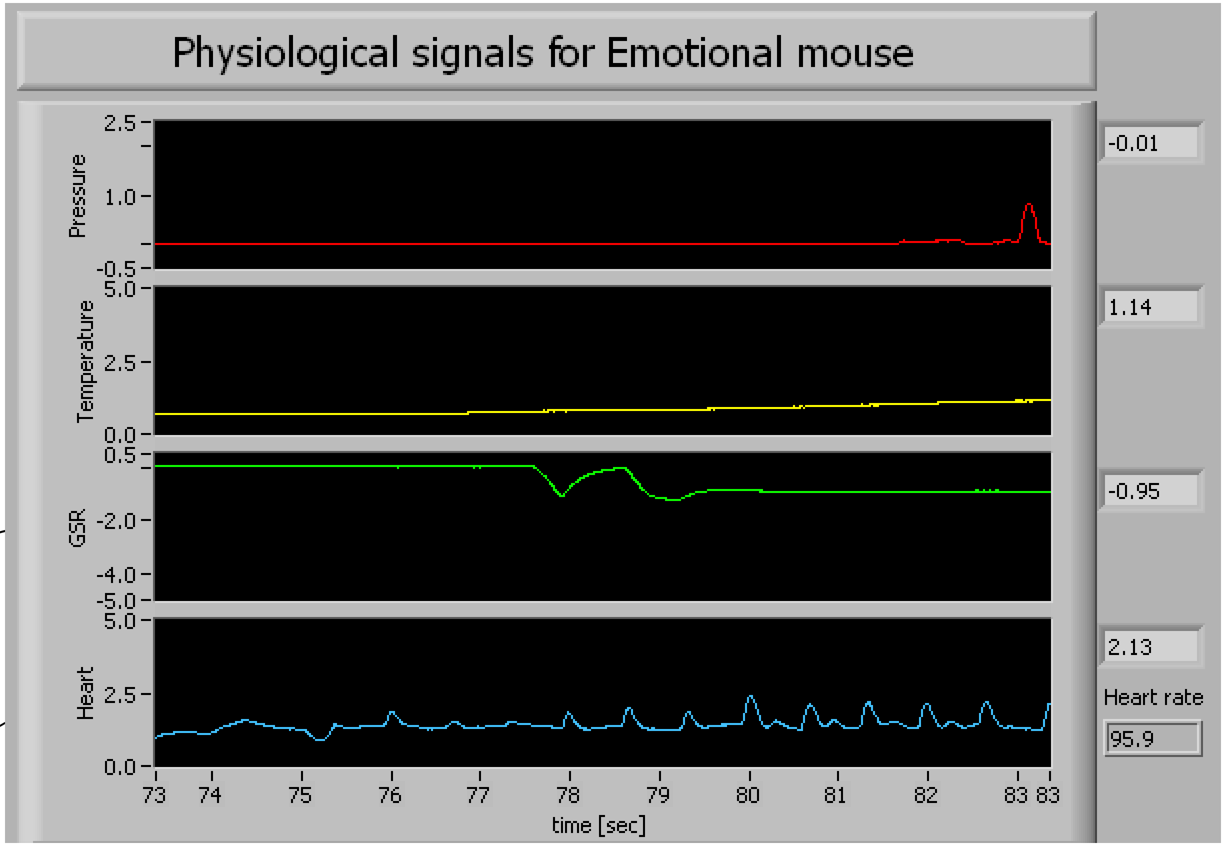
Physiological Signals

Pressure of index finger tip

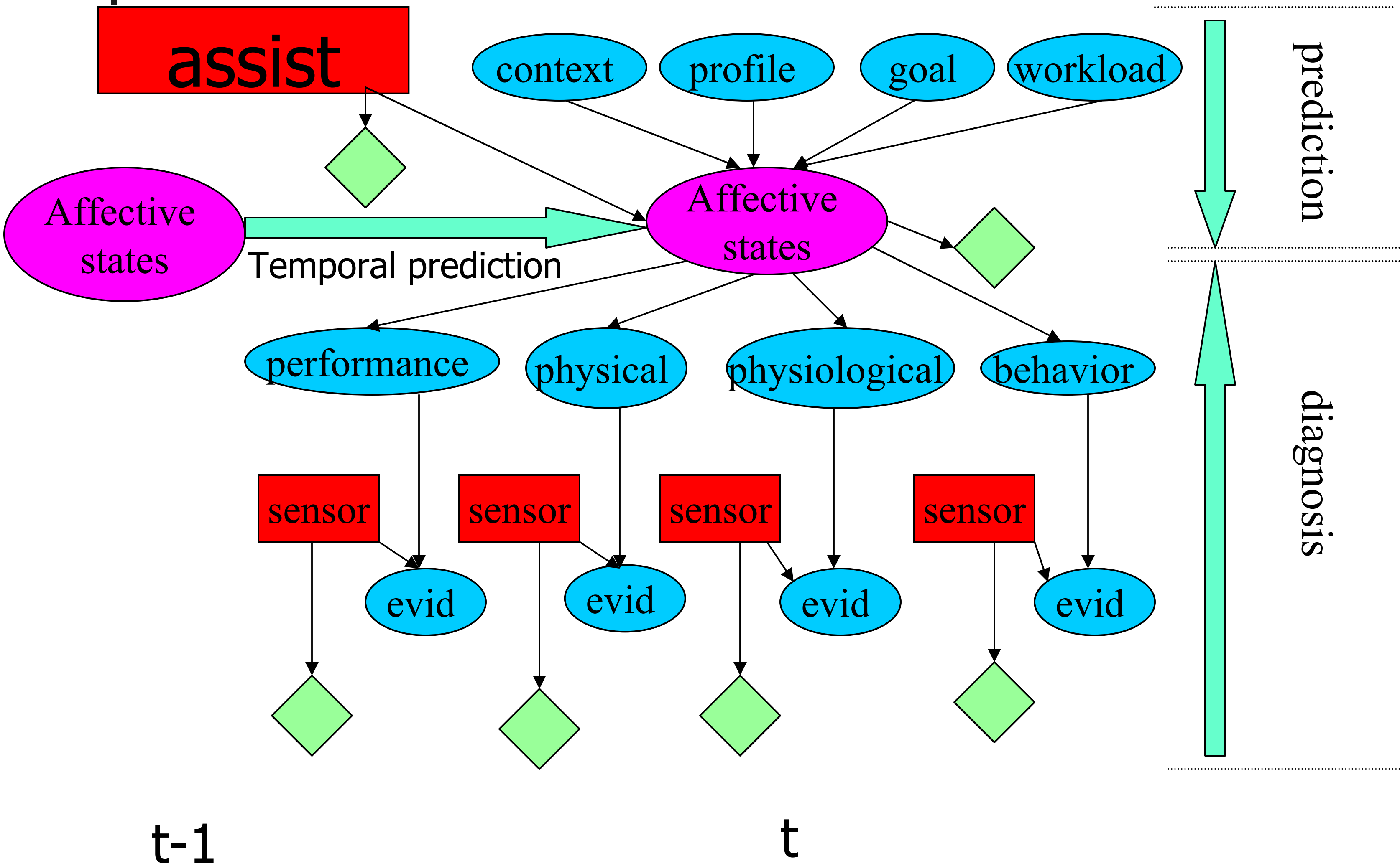
Temperature in user's palm

Galvanic skin resistance in user's palm

Heart rate from the little finger

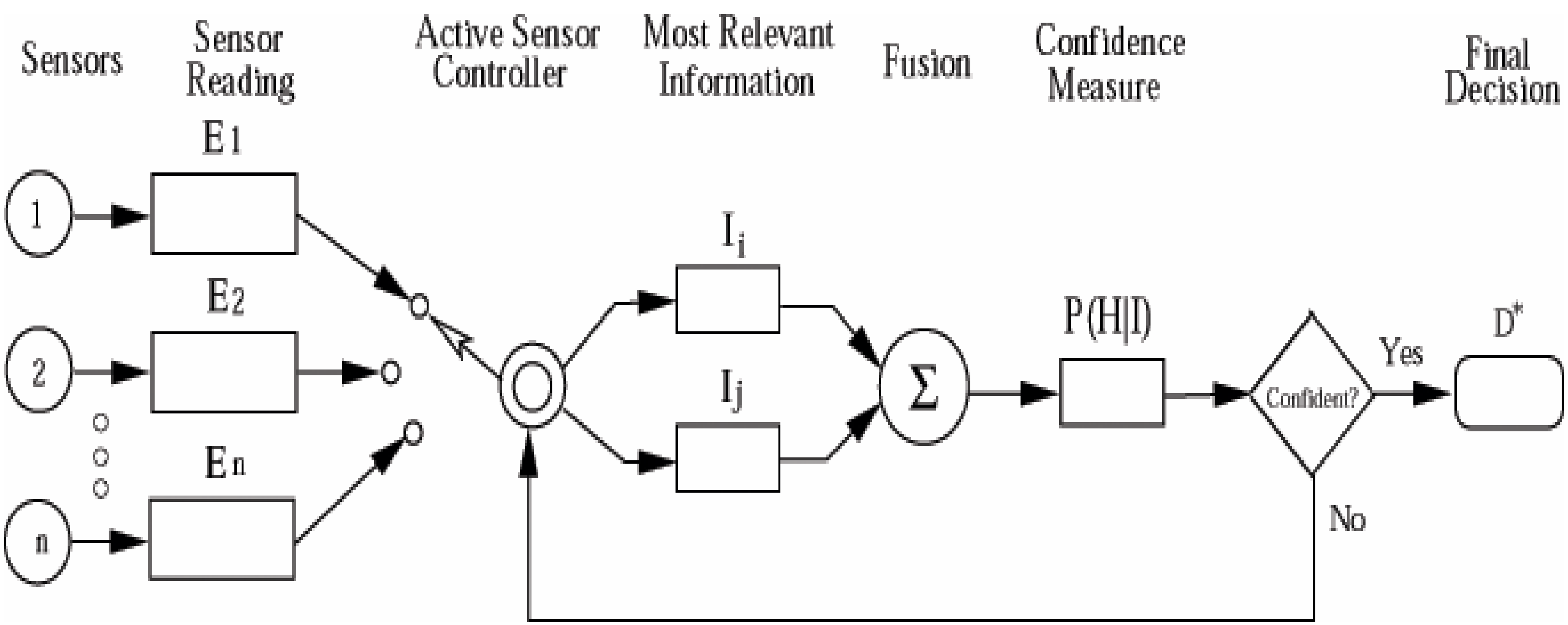


A Dynamic Influence Diagram for Affective State Modeling



Active Affect Recognition

- Due to time and resource constraints, it is not possible to use every sensing measurements.
- Identify the most likely affective state in a timely and efficient manner by selecting the most informative sensory measurements.



Active Sensor Selection

- Mutual information I(S;A) between a set of sensors S and affective state A
  - Associated with S is a set of evidence variables E_S
  - Mutual information characterizes uncertainty reduction potential

$$I(S;A) = \sum_{e_S}\sum_{a} p(e_s,a)\ln\frac{p(e_s,a)}{p(e_s)p(a)}$$

  - Let g(S) be the cost of operating sensors in S
- Optimal sensor subset is

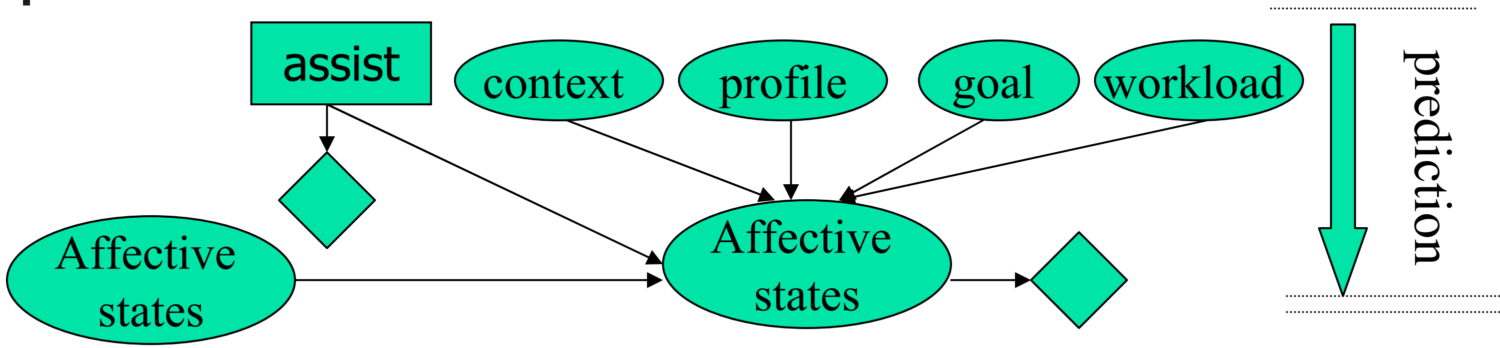
$$S^* = \arg\max_{S} \frac{I(S;A)}{g(S)}$$

Affective State Recognition

- Recognition
  - Given set {e} of evidences and the probability p_(a) of affective states, compute the posterior probability p(a)
- The posterior probability is a standard inference where U is joint event of …

$$P(A \mid \bigcup E = e)$$

Optimal User Assistance



$$d^* = \underset{d}{\operatorname{argmax}} \left\{ \sum_a p_d(a) g_v(a) - g_{v_d}(d) \right\}$$

- Decide the optimal assistance
  - *d*={no-assistance, warn, simplify, repeat, intervene ..}
  - *a* is affective state, the first item is the expected benefit and the second item is the cost of performing the assistance

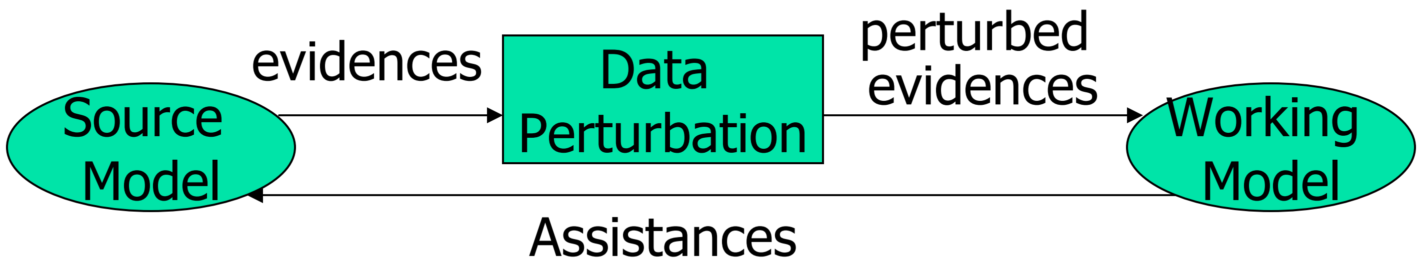
Utility of Assistance

- The utility of an assistance represents the optimal trade-off between its benefits and its cost
- The benefit is:
  - The potential to return user to a positive and productive state
- The cost includes
  - Computational cost
  - Potential of annoying the user
  - Physical cost
  - Cost of not providing or delaying the assistance

System Validation

- Validation criterion
  - How accurate are the estimated affective states?
  - How appropriate are the provided user assistances?
- Validation methods
  - Simulation with synthetic data
  - Real world data

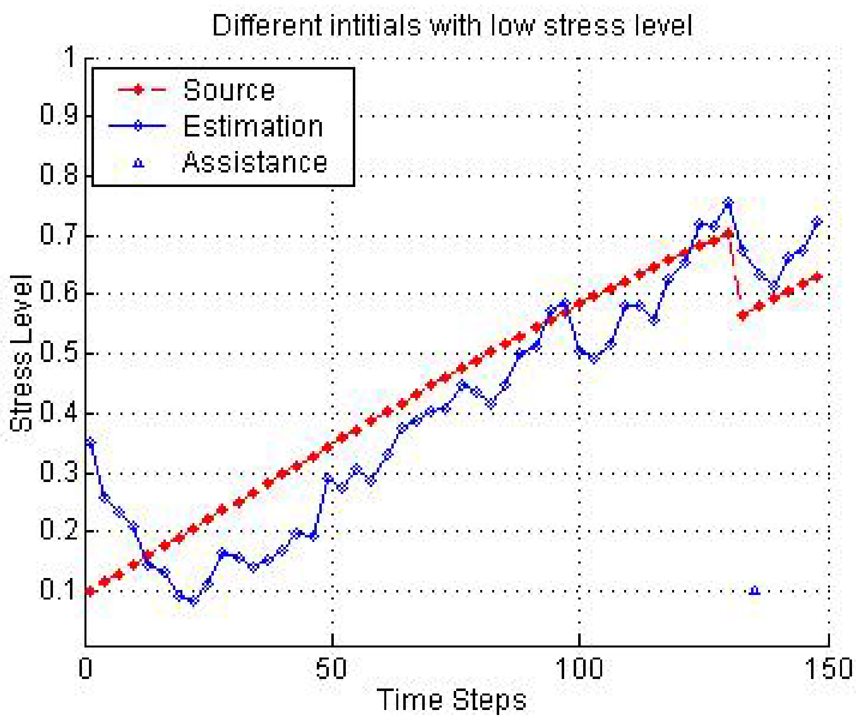
Simulation System

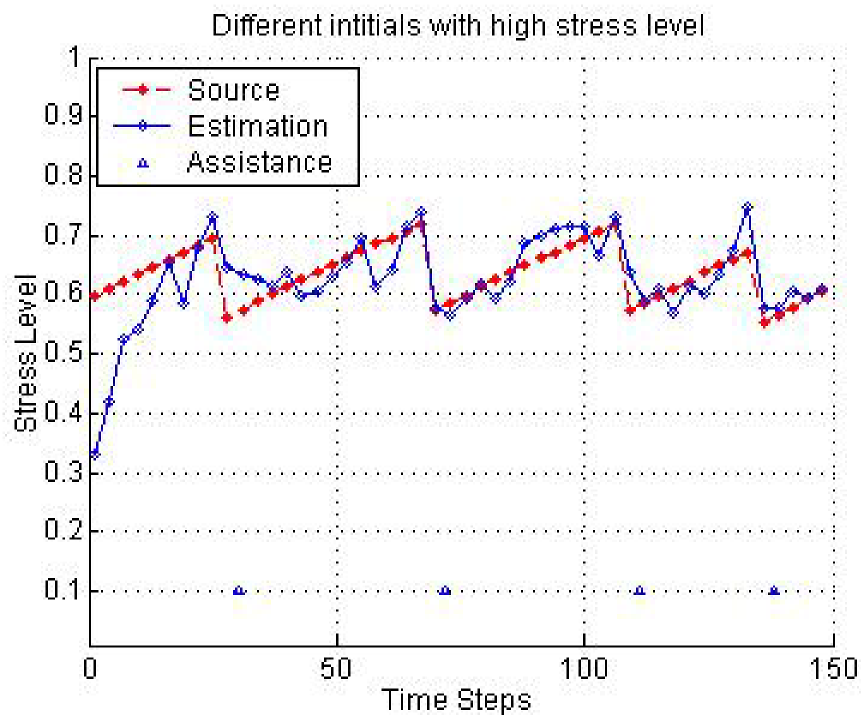


- Source model
  - Simulate the true affective states of the user
  - Produce the evidences reflecting the true affective states
- Working model
  - Maintain an estimate of the affective states by collecting evidences from the source model
  - Determine and provide assistance

Simulation Result

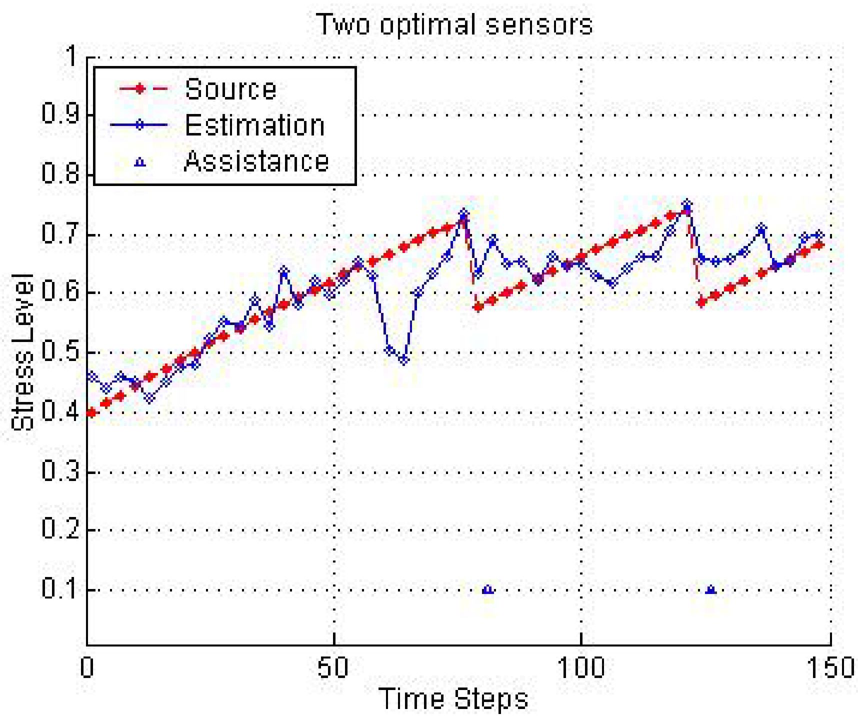
- Can recognize affective states and provide assistance well

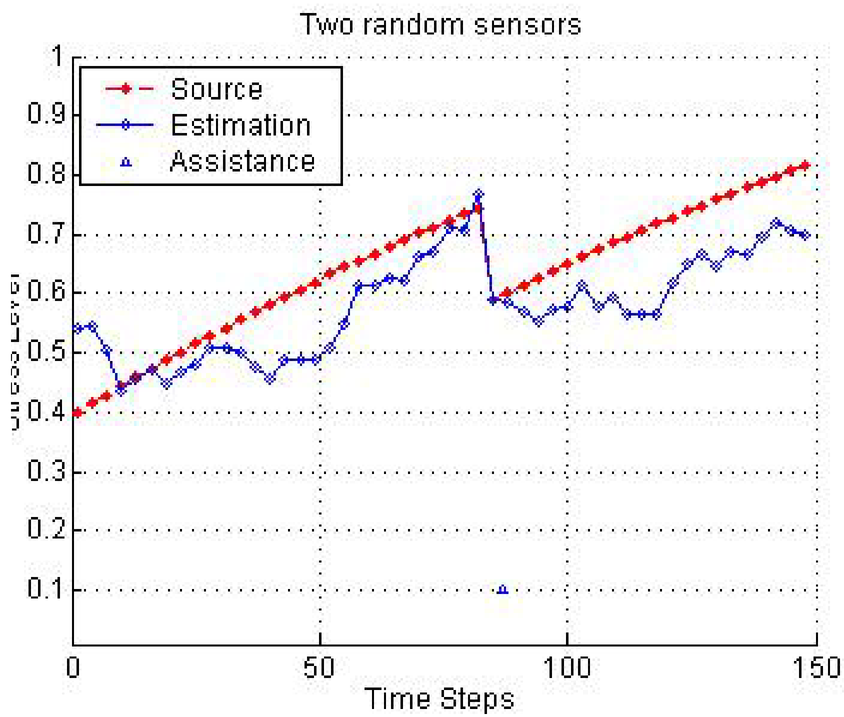




Simulation Result

- Active sensing strategy can provide better performance



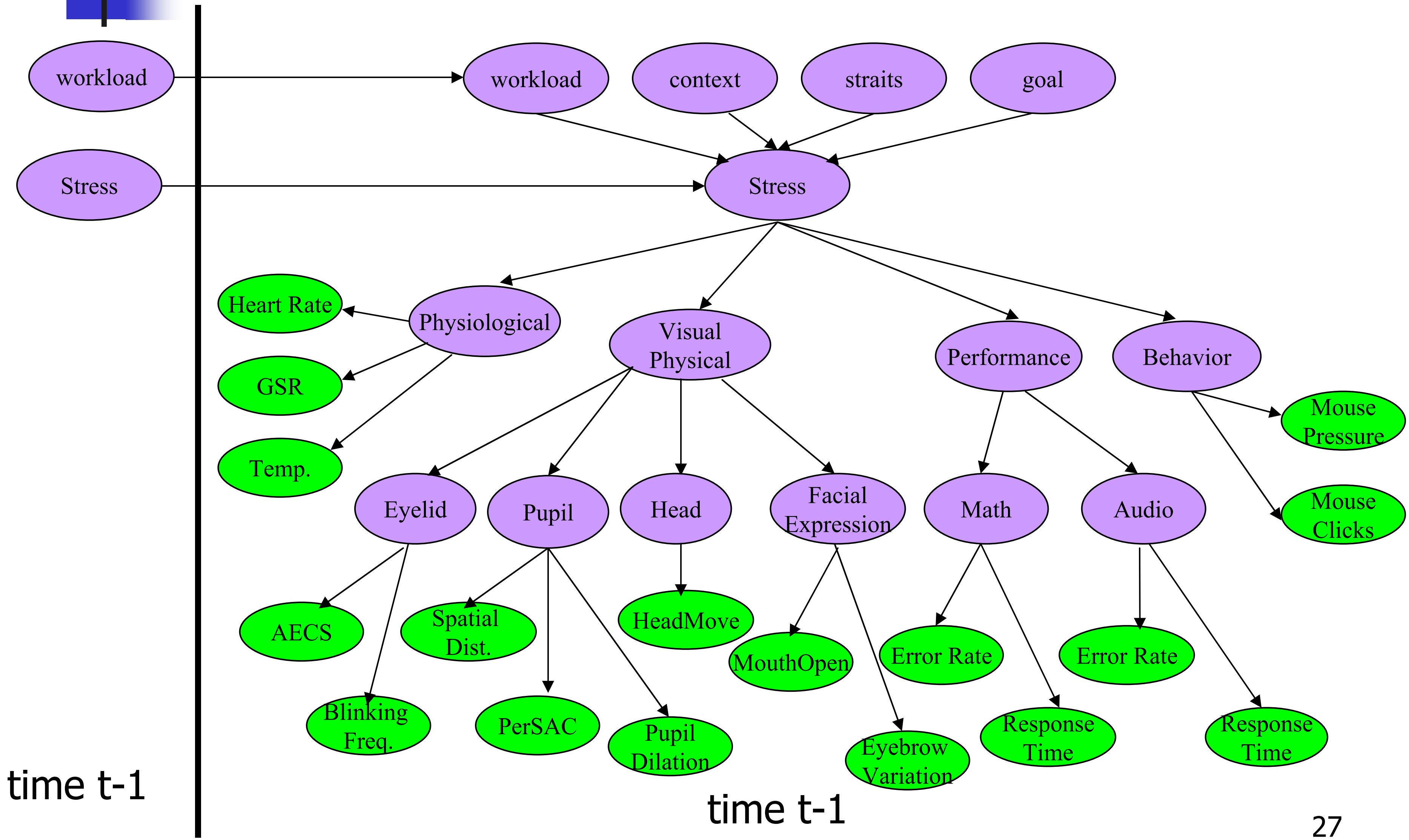


Real World Experiment

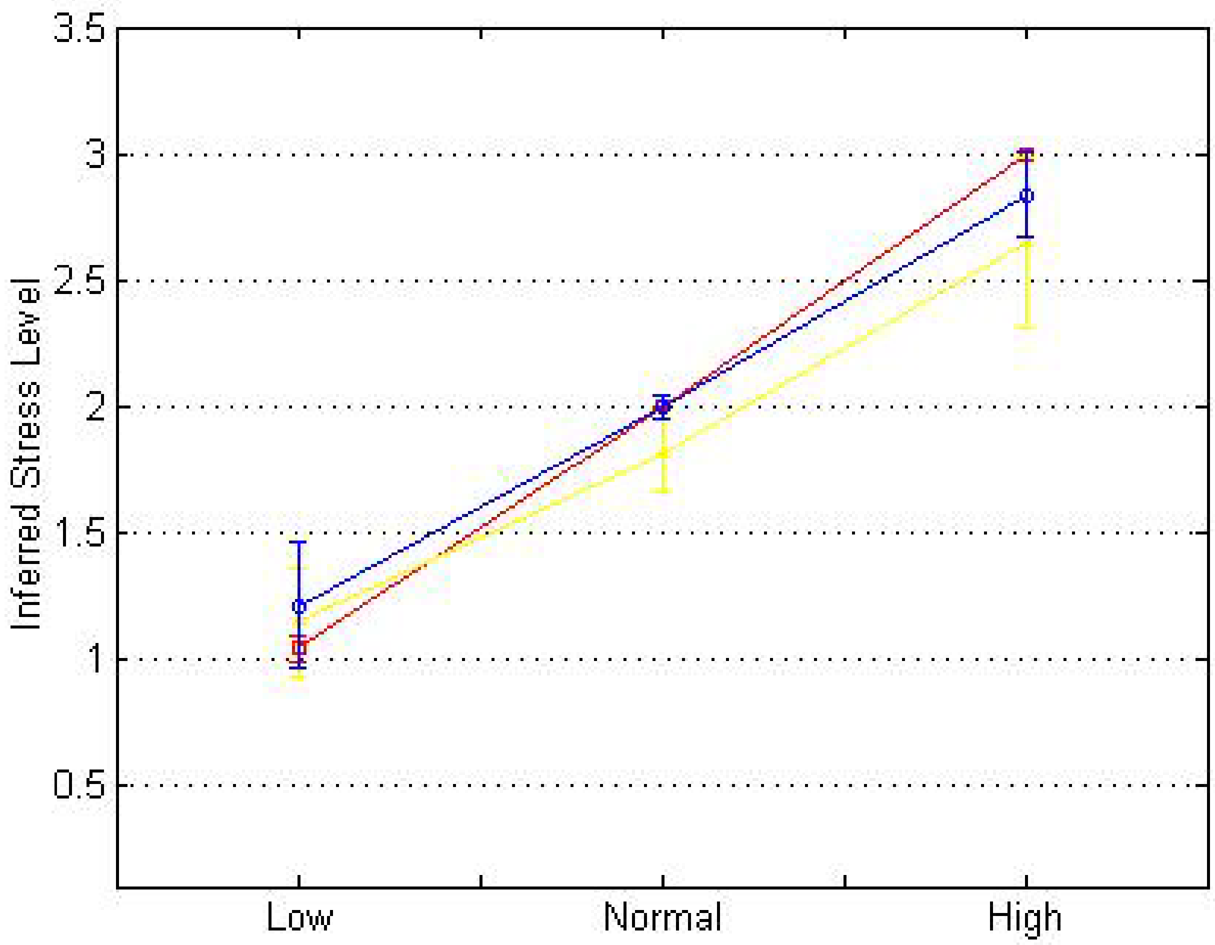
- Emotion to recognize: stress

- Experimental Tasks:
  - Audio task is about the alphabetic precedence of two consecutively presented letters
  - Math task is about the addition/subtraction arithmetic of two two-digit integers

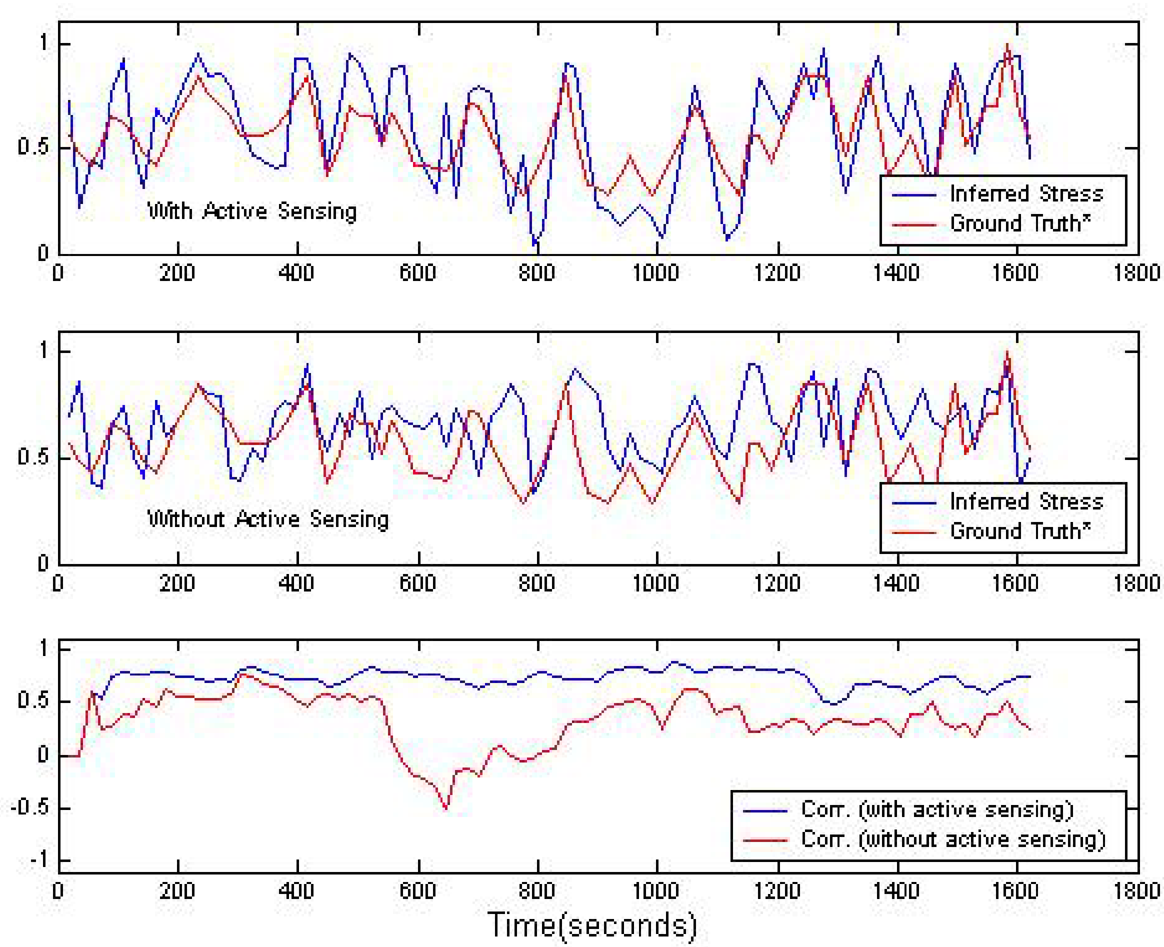
An ID for Stress Modeling



Composite Stress Index



Inferred Stress Level



Fatigue System Validation

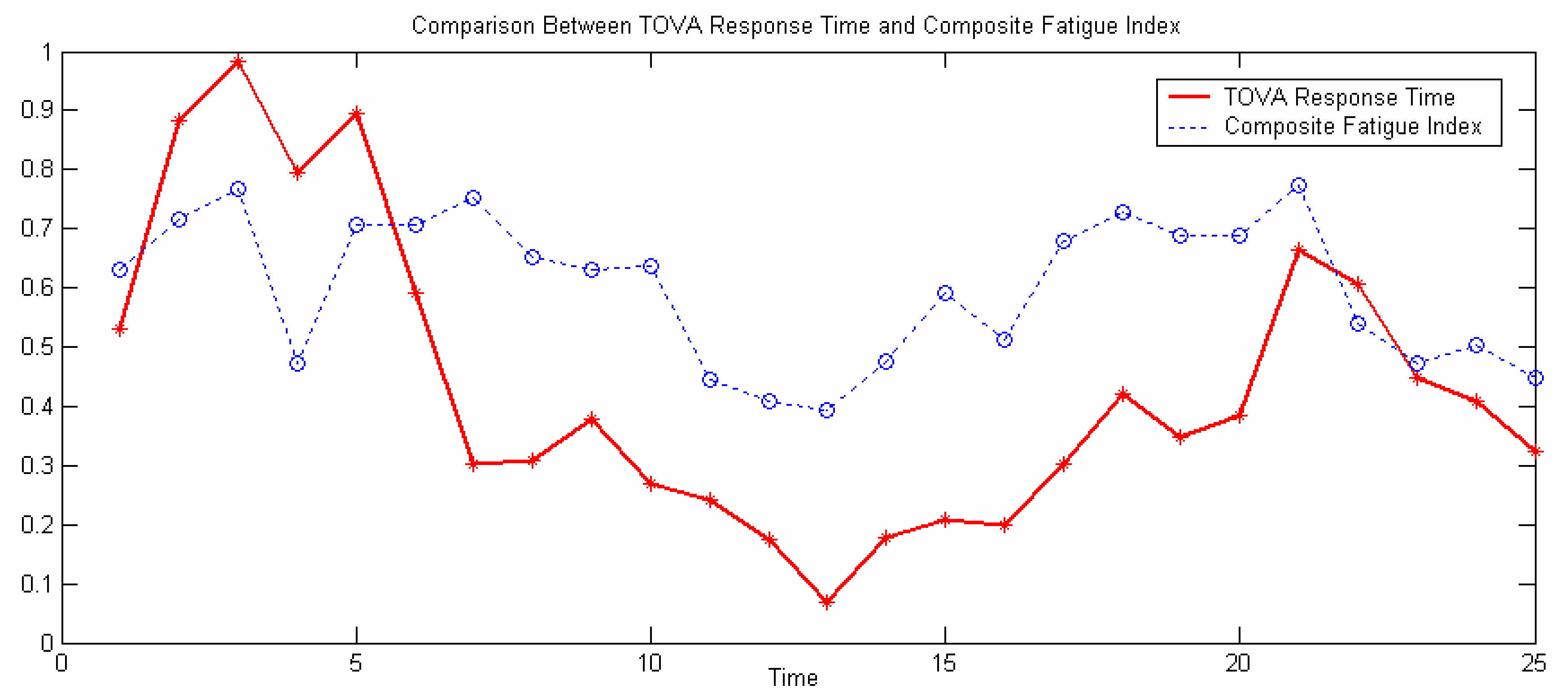
Human subjects study to validate our fatigue monitor:

The study is to correlate the output of our fatigue monitor with that of the TOVA (a vigilance test) and with that of EEG and EOG.

Experiment Setup

Validation Results

The composite fatigue score computed by our proposed fatigue modeling system highly correlates with the subject's response time, which is used as a metric to quantify the subject's performance.



Conclusions

- Developed an non-intrusive and real time sensing system for acquiring observations of different modalities.
- Presented an unified framework based on the dynamic influence diagram for simultaneously modeling both affective state recognition and user assistance.
- The empirical analysis on both synthetic and real-world data shows the promise of the proposed framework for affect recognition and user assistance

Conclusions (cont'd)

- Multi-modalities of data and their systematic integration is crucial for robust characterization of user state
- Facial expression $\neq$ emotion
- Emotion is person, context, dependent
- It is important to account for temporal changes
- A framework is needed to systematically represent the associated knowledge and to infer user state in a timely and efficient manner
- May not limit to the known/standard emotions