CAREER: Towards Optimized Operation of Cost–Constrained Complex Cyber–Physical–Human Systems

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Vision:

Systematically describe cost–constrained complex cyber–physical–human systems and **optimize their operation**

Cyber–Physical–Human Systems (CPHS) Challenges:

- Sensing, processing & transmitting data **under resource constraints** (e.g., energy, time)
- Fuse **heterogeneous data** (in terms of fidelity, informativeness and cost) to satisfy application requirements
- **State–dependent communication** and prone to **sensing errors**
- Dynamics and cyber variables are **intertwined with/altered** by **human behavior**

 Accurate and Scalable Estimation and Control for CPHS is hard!

Scientific Impact:

- More **realistic stochastic dynamic models** and **representation of interactions** for complex CPS
- **Dynamic** fine–grained state **estimation strategies** for complex CPS
- **Fundamental limits** of dynamic fine–grained state estimation for complex CPS
- Formally integrate **impact of humans–in–the–loop**
- **Control strategies** for optimizing CPS operation with **complex dynamics** and **heterogeneous capabilities**

Solution:

- Instance-wise Feature Acquisition in Multi-view Settings
  - Different sensors (e.g., IMU,ECG) produce **multiple distinct data**
  - Prediction of class of data instance (e.g., physical activity) can be improved by **acquiring the most ``useful'' features** extracted from such data
  - Improvement both in **accuracy** and **energy efficiency**
  - ``Easy'' data instances are classified using very few features/views
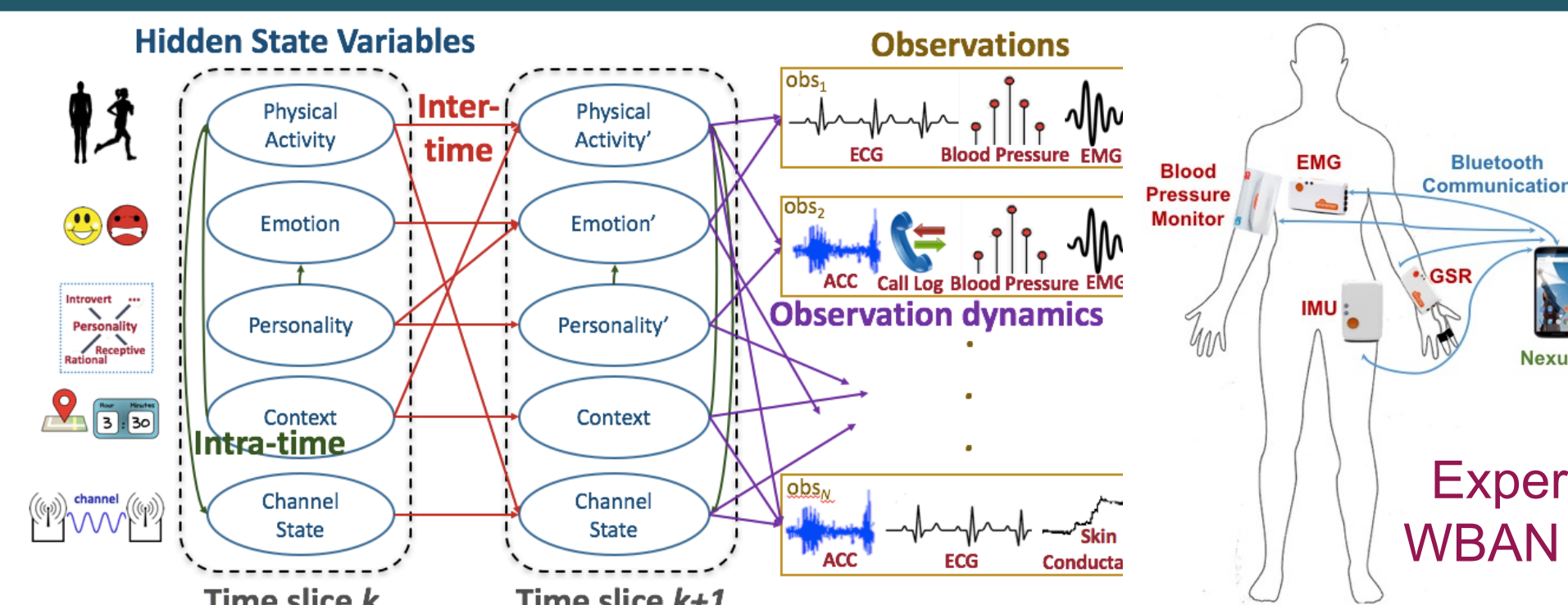
Graphical representation of CPHS stochastic system model

- Instance-wise Classifier/Ensemble Selection
  - If acquiring additional features does not improve accuracy, **instance-wise selection** of **one or more classifiers improves performance** w/o additional cost
  - ``Difficult'' data instances are classified using this mechanism
- Instance-wise Feature Acquisition is interpretable

Impact on Society:

- Societal impact
  - Help engineers optimize CPS/CPHS operation
  - Enable scientists to objectively study human behaviors
  - Provide individuals with means to self–monitor and improve their behavior
- Who will care/benefit from project outcomes?
  - CPS/CPHS engineers and system designers
  - Scientists in medicine, education, and psychology
  - General public

Education and Outreach:

- Training of undergraduate/graduate students in both theory and practice of CPHS
  - Freshmen worked on K-12 hands-on projects (e.g., touch sensor, muscle sensor) and presentation materials that illustrate basic sensing principles
  - PhD students trained on machine learning for enhancing CPHS operation

Broader Impact:

- Unveil important factors related to CPHS operation
  - Identify key variables that affect CPHS operation
  - Uncover fundamental limits of estimation process
  - Understand inherent trade–offs in optimization of CPHS processes
- Estimation and control methods for CPHS
- CPHS Education/Outreach