

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

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<https://www.albany.edu/~dz973423/projects/nsf-career-2020/index.html>

Vision:

Rigorously describe and **optimize operation of** cost-constrained complex cyber-physical-human systems

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/alterd** by **human behavior**

Accurate and Scalable Estimation and Control for CPHS is hard!

Scientific Impact:

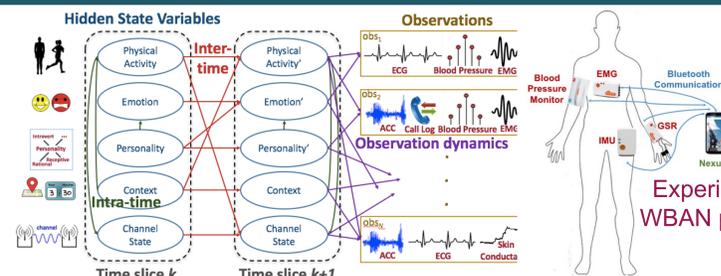
- **Stochastic dynamic models** and **representation of interactions** for complex CPS
- **Dynamic fine-grained state estimation strategies** for complex CPS
- **Fundamental limits** of dynamic fine-grained state estimation for complex CPS
- Formally integrate **impact of humans-in-the-loop**
- **Control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

Solution:

Instance-wise Feature Acquisition in Multiclass Settings

- For large number of states, **training complexity is high**
- **Dynamically assess smaller-scale** problems on **case-by-case** basis
- Experiments show **at least 5% training time reduction**

Publications: [Under review-2025, extended version-2025 (under submission)]



Graphical representation of CPHS stochastic system model

Instance-wise Experts Selection

- **Instance-wise classifier subset selection improves performance** If additional features don't boost accuracy
- Experiments show **56% accuracy boost** with **88% fewer features** and **80% fewer experts** on average

Publications: [ICASSP-2025, ICASSP-2024, TAI-2024 (under review)]

Impact on Society:

- **Societal impact**
 - Help engineers optimize CPS/CPHS operation
 - Enable scientists to objectively study human behaviors
 - Means to self-monitor and improve 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:

- Student training in CPHS theory and practice
 - **Schenectady High School visit** (~75 students) – smart lightning sensor
 - PhD students trained on machine learning for enhancing CPHS operation
 - Dr. Sachini Ekanayake, **ML and Systems Rising Star 2024**
- Feature selection/acquisition tutorial at SIAM SDM 2024

Broader Impact:

- **Unveil important factors related to CPHS operation**
 - Key variables that affect CPHS operation
 - Fundamental limits of estimation
 - Inherent trade-offs in optimization of CPHS
- **Estimation and control methods for CPHS**
- **CPHS Education/Outreach**