CAREER: MINDWATCH: Multimodal Intelligent Noninvasive brain state Decoder for Wearable AdapTive Closed-loop arcHitectures

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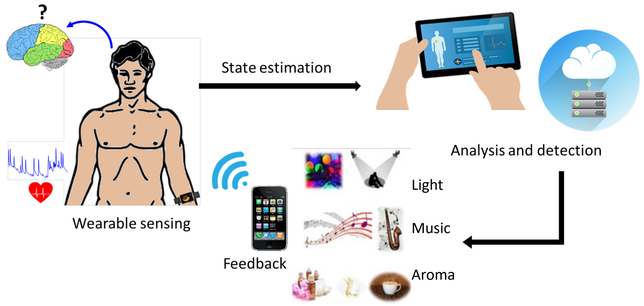
Challenges

- There is a rising **cost** of **healthcare** in the United States
- Wearable devices can be exploited for patient monitoring to recover rich information about internal physiological states for prognosis, diagnosis, and treatment

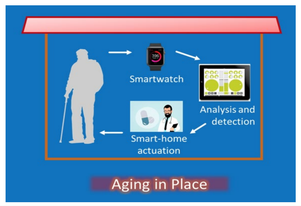


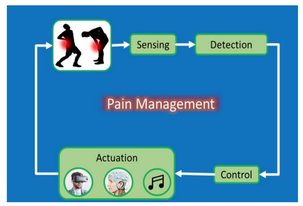
- To overcome the challenges with using wearable devices for health monitoring, the goals of this project include:
  1. Inferring discrete brain-related events in real-world settings
  2. Decoding multidimensional latent neurobehavioral states
  3. Robust adaptive supervised control design for regulating neurobehavioral states

Scientific Impact

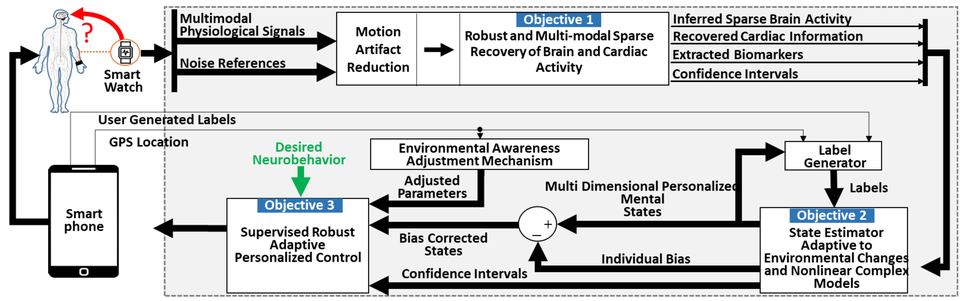
A transformative system-theoretic computational toolset for:

- Multimodal system identification and brain activity recovery
- Interpretable adaptive tracking of neurobehavioral states
- Personalized closed-loop control design for reliable actuation





Solution



Objective 1

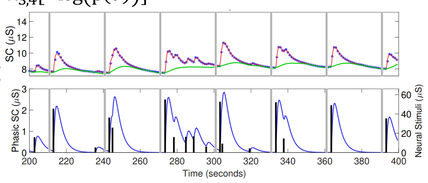
Brain activity inference from EDA with physiological Priors:

$$\min J_\lambda(\theta,u,\boldsymbol{q}) = \frac{1}{2}\|\boldsymbol{y} - A_\theta x_0 - B_\theta \boldsymbol{u} - \boldsymbol{C}\boldsymbol{q}\|_2^2 + \lambda_1 \|u\|_1 + \lambda_2 \|\boldsymbol{q}\|_2 + \lambda_{3,4}[-\log(\mathrm{p}(\theta))]$$

Physiological priors

$$\text{s.t.} \quad \boldsymbol{u} \geq 0, \boldsymbol{q} \geq 0, \quad C\theta \leq b$$

- Identification performance with AUC of 0.865 in ROC
- Successfully analyzed 109 participant recording with $R^2 > 0.96$

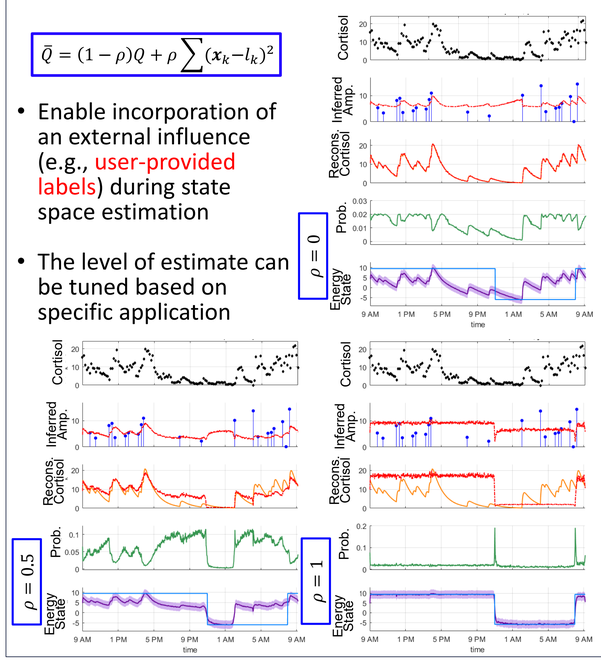


Objective 2

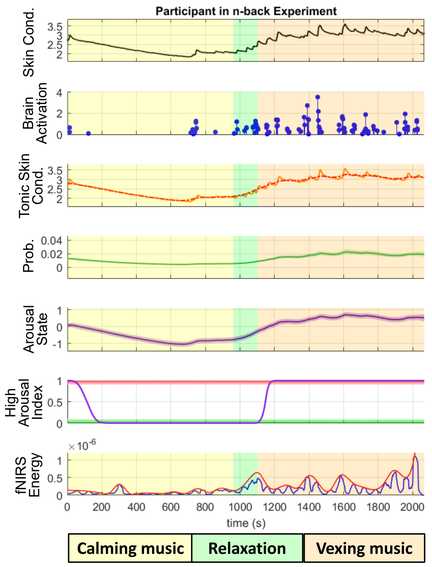
Fusion of state estimation & external Information:

$$\bar{Q} = (1-\rho)Q + \rho \sum (\boldsymbol{x}_k - l_k)^2$$

- Enable incorporation of an external influence (e.g., user-provided labels) during state space estimation
- The level of estimate can be tuned based on specific application



Arousal estimates from skin conductance match fNIRS (brain imaging) data:



Solution Continued

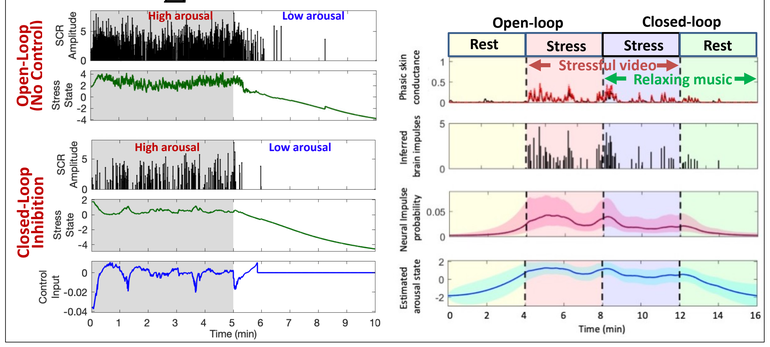
Objective 3

Supervised control architecture:

Supervised update of Q and R

$$\min \quad J_u = \sum (\acute{x}_k Q x_k + \acute{u}_k R u_k)^2$$

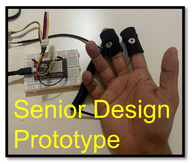
Closed-loop emotion modulation testbed for regulating brain arousal state using music



Societal and Quantified Impact

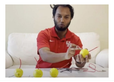
- 34% of US institutions intend to run classes primarily online.
- 42% of US students indicated staying engaged is a major problem in online learning
- 88% of US physicians want patients to monitor their health parameters at home
- 35% of US employers use medical wearable technology to facilitate wellness programs

Educational and Outreach Impact



- **2** journal articles published and **3** submitted
- **3** senior design teams designed wearables for emotion monitoring
- **14** published educational videos
- **3** Undergraduate Research Projects (Honors Thesis, REU, Summer Undergraduate Research Fellowship).
- PI gave several laymen talks about this research to general audience and broader community
- PI served as a panelist to guide Montgomery Community College students through their career paths

Computational Medicine Lab took part in the 2021 Girls Engineering the Future - Virtual Outreach



Computational Medicine Lab along with Engineers in Real Life co-hosted the outreach event Engineers Make a World of Difference.

2021 NSF Cyber-Physical Systems Principal Investigators' Meeting
June 2-4, 2021

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