Wearable Systems:
Integrated sensing, computation and feedback in wearable devices, from e-tattoos to near-zero computation to digital therapy

Roozbeh Jafari, Texas A&M University

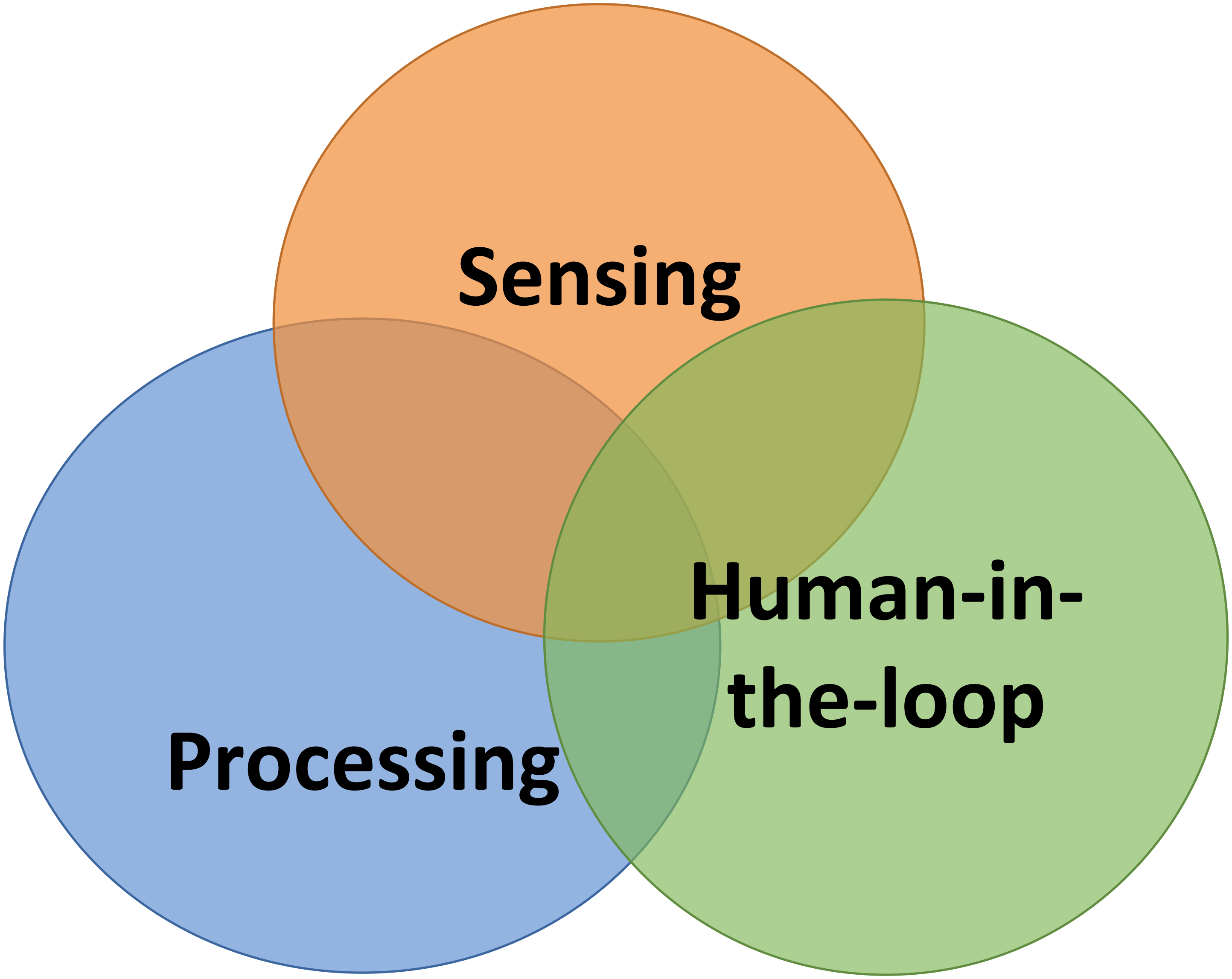
Hassan Ghasemzadeh, Washington State University

Tinoosh Mohsenin, University of Maryland, Baltimore County

Wearable Systems

- Hold the promise to transform **health** and **wellness** through automation of cost effective, objective, continuous, and real-time health monitoring and interventions.
- Much effort has been done in developing systems in **controlled** settings.
- Challenges
  - How to design these systems to provide **actionable information** while operating in **uncontrolled environments**?
  - Usability, reliability, power-efficiency, feedback, human-in-the-loop design, privacy/security

Topics



Sensing

- Designing sensors with consideration of **usability**
  - Sensors need to provide **intimate contact** with the user
  - Wear it and forget about it
  - Human factors
  - Battery lifetimes (e.g., can it last for a month?)
  - Needs to be comfortable, non-invasive
  - Should provide real value for decision making
  - Small form factor as a result of low power systems
- **Direct** measurement vs. **indirect** inferences/proxies
  - Sensors may not sense direct measurements; but they can provide inferences or proxies and computer systems research techniques should convert these sensing observations to actionable information.
  - Exact measurement: e.g., biochemical sensors that measure exact macronutrients (e.g., fat, protein, carb) and micronutrients (e.g., vitamin)
  - Proxies: e.g., understanding diet from behavior
  - Context-awareness

Processing for monitoring

- **Machine learning** for wearable systems
- **Personalization** of machine learning models
  - Diversity in devices and sensor, as well as deployment -> ML/DL models are often not aware of this and it is hard to estimate the impact ahead of time.
  - Translation between various sensing modalities to create actionable information and translate to sensing modalities with diagnostic value
- Machine learning at different **levels of abstraction**
  - From low-level events to high-level health outcomes
  - Detecting trends
- Degree of **confidence** about inferences
  - Impacts user's adoption of the technology
- Challenges associated with experimental work
  - Lack of high quality data (unlike vision research)

Processing for feedback

- Providing **actionable** information from sensor data
- How to develop **intervention** strategies?
- **Learning-based** interventions
  - Reinforcement learning
  - Requires a lot of training data
  - Can adversely impact usability and technology adoption due to exploration of the intervention impact
- Integration of **domain knowledge** into a new design
  - e.g., health behavior change should be gradual rather than sudden

Human-in-the-loop

- Human-in-the-loop is critical for both monitoring and intervention
- **Gathering labels/annotations** about sensor data while being mindful of the user (annotator)
  - Taking user-specific characteristics into account while gathering labels
  - Cognitive factors
  - Context-awareness in active learning
- **Label disparity**
  - Labels could be fuzzy / noisy / inaccurate
  - Spatial label disparity (different users have different interpretations about similar events)
  - Temporal label disparity (same user have different perceptions of the same event)
- **Just-in-time** learning with human-in-the-loop

Other Issues

- Adaptive resource management
- Sensor design
  - Biocompatibility/safety/side effects (physiological, physical), acceptance
- Repeatability of sensing platforms
  - Focus on robust testbed design/development, need for robust simulation platforms
- Deep learning
  - Why and when do we need DL?