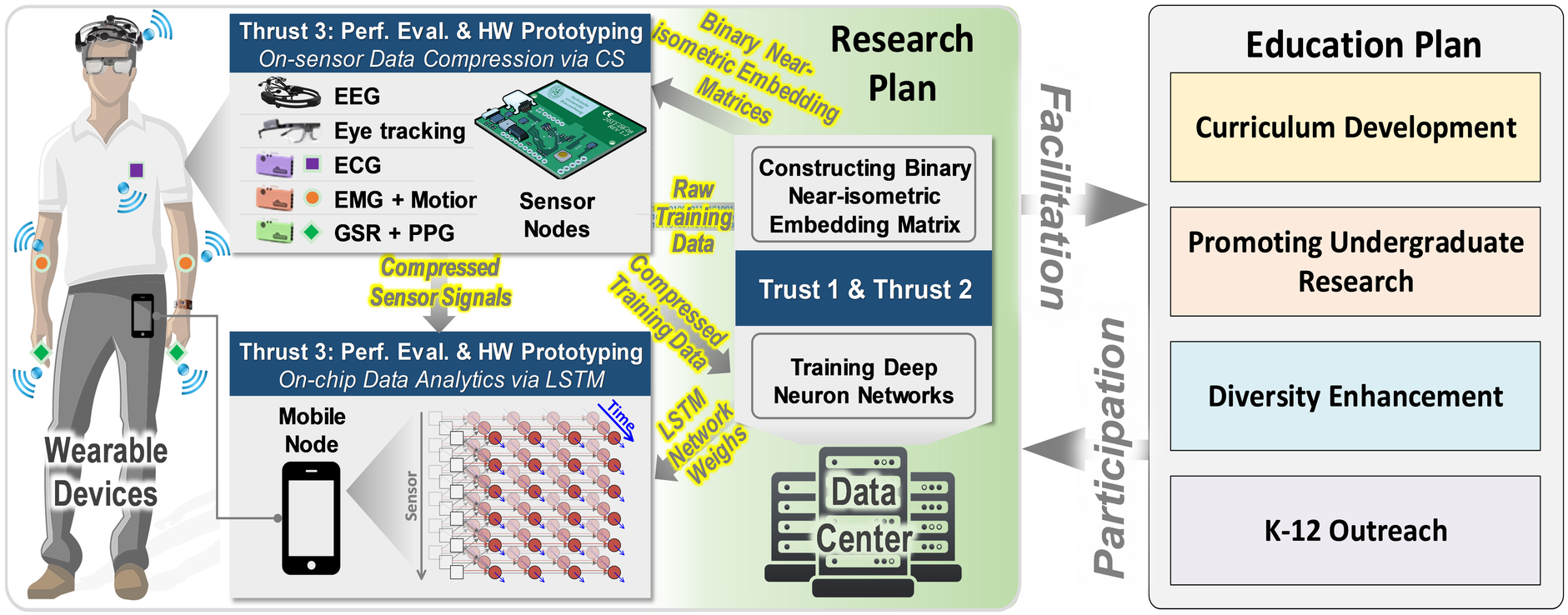
2017 NSF CYBER-PHYSICAL SYSTEMS PRINCIPAL INVESTIGATORS' MEETING

# CAREER: Building Energy-Efficient IoT frameworks—A Data-Driven and Hardware-Friendly Approach Tailored for Wearable Applications

Award #: IIS-1652038 | Award Date: February 15, 2017 | PI: Fengbo Ren, Arizona Sate University

**The research goal of this CAREER program** is to develop a data-driven and hardware-friendly IoT framework to fundamentally addresses the unmet energy efficiency need of wearable applications by seamlessly integrating compressive sensing (CS) and data analytics in compressed domains using deep learning methods.




## Challenge:

- As the IoT era unfolds, mobile and wearable devices are becoming mainstream application drivers. Due to the limited battery capacity that can fit into small form factors, the energy efficiency of sensing and computing is becoming an increasingly critical concern for these devices. Their short battery life often limits the precision or accuracy of decision making in practical applications.
- As most wearable sensors are used to sample signals at a low frequency (<1KHz), the energy efficiency of such systems is dominated by the energy consumption of radio frequency (RF) transceivers for wireless communication rather than analog-to-digital converters (ADCs).
- A generic solution for on-sensor data compression is the key to reducing data size for transmission and saving energy on sensors. This solution must be simple and hardware-friendly in nature such that its hardware mapping on sensors is viable and cost-effective.

## Solution:

- **Thrust 1: Constructing Binary Near-Isometry Embedding Matrices for On-Sensor Data Compression.** The specific objective of this thrust is to formulate optimization problems and develop efficient solvers to construct binary embedding matrices that best fulfill the RIP with minimum rank (row dimension). Combining rank minimization with binary constraints is the key to enabling data size reduction and the cost-effective hardware implementation of CS on resource-constrained sensor devices.
- **Thrust 2: Training Deep Neuron Networks for On-Chip Data Analytics.** The specific objective of this thrust is to establish a generic framework to decode information directly from compressive samples by leveraging deep learning methods. The feedforward structure and high data concurrency of DNN models are favorable features for exploiting pipelining and parallelism in hardware implementations.
- **Thrust 3: Performance Evaluation and Hardware Prototyping.** The specific objectives of this thrust are to evaluate the numerical performance of the proposed frameworks in Trust 1 and 2 over a variety of physiological signals and to implement the online portions of the proposed frameworks in hardware to assess the system performance.

## Scientific Impact:

- Advance the theory development of data-driven compressive sensing by filling the current knowledge gap on how to design near-isometry embedding matrices with binary constraints that are essential for cost-effective hardware mapping.
- Uncover the intrinsic connections between CS and deep learning by establishing a viable data analytics solution for decoding information directly from compressively sampled signals.
- Provide a transformative IoT framework that significantly reduces the data size for transmission from sensors to cloud while improving the overall quality of information delivery and bringing signal intelligence closer to users.
- Allow future IoT devices to precisely sense and transfer the information of interest specified by users in an energy-efficient manner rather than just recording imprecise data in raw forms as in existing approaches.

## Broader Impact:

- Directly impact a variety of IoT applications by allowing compressive sensors to be deployed in energy-constrained environments to perform precise information acquisition over a significantly increased time span impossible with existing technologies. Such applications include smart environmental sensing for monitoring the airborne quality, radiation, water quality, hazardous chemicals, and many other environment indicators.
- The on-sensor data compression solution provided by this research can extend sensor battery life and help reduce the cost of sensor replacement in the wild or outdoors for long-term monitoring. With the on-chip data analytics solution, the proposed framework will enable important progress in transforming the existing healthcare model from episodic examination for disease diagnosis and treatment to continuous monitoring for disease prediction and prevention. This will make our healthcare systems more effective and economical and improve the overall quality of living for billions of individuals.
- The PI is undertaking an ambitious education program that tightly integrates consistent efforts in curriculum development, promoting undergraduate research, diversity enhancement, and K-12 outreach to actively engage and impact a diverse population of K-12, undergraduate, and graduate students to take away the PI's research and create more values for the community in the long term.