KEH-Gait: Towards a Mobile Healthcare User Authentication System by Kinetic Energy Harvesting

Never Stand Still | Faculty of Engineering | Computer Science and Engineering

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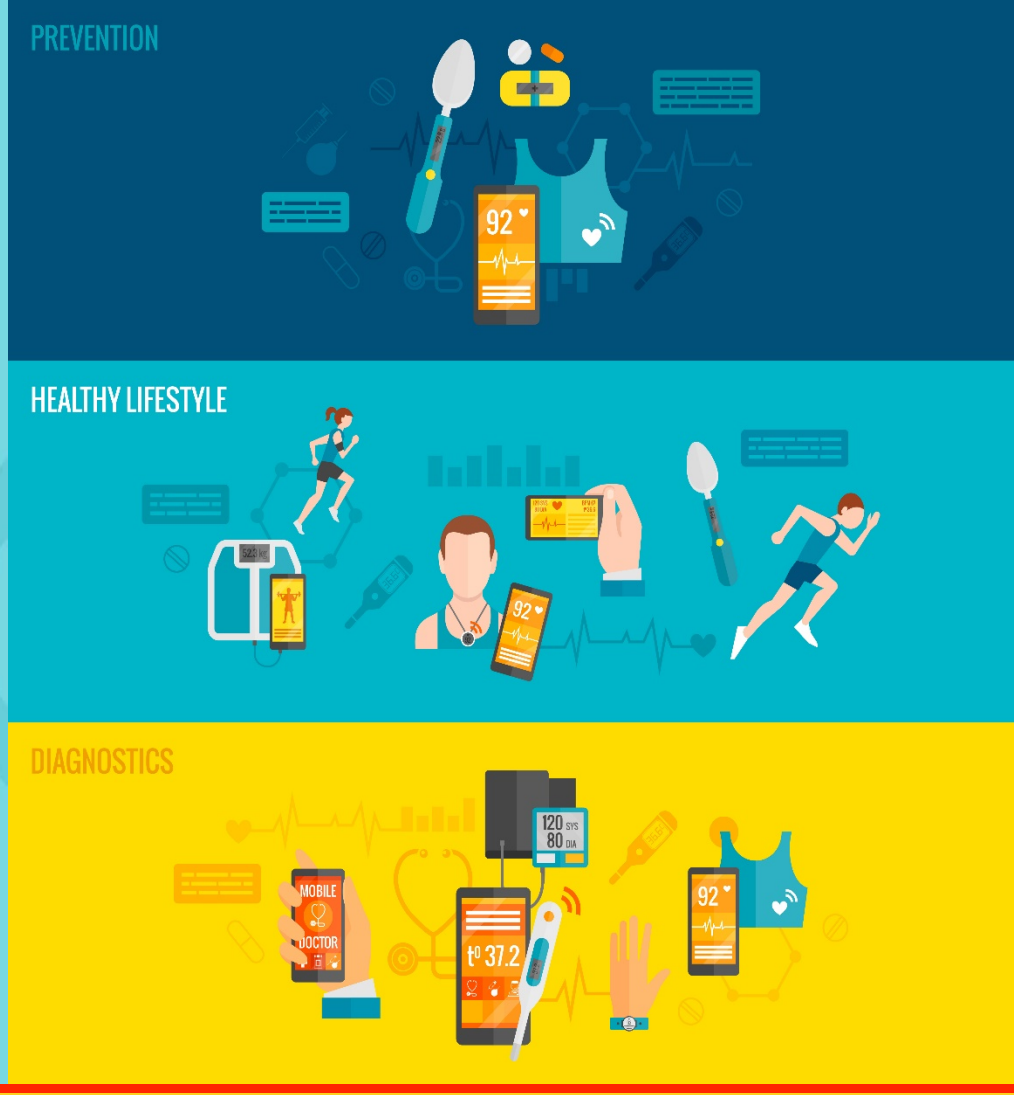
PREVENTION
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HEALTHY LIFESTYLE
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DIAGNOSTICS
120 SYS
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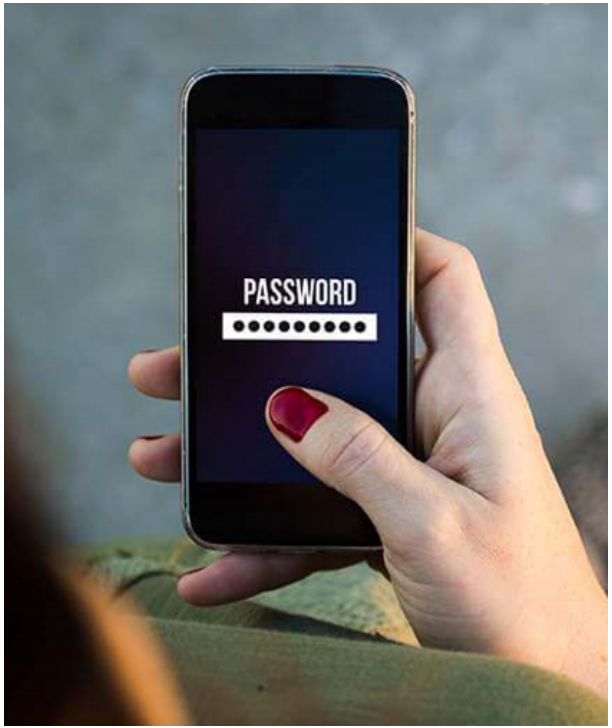
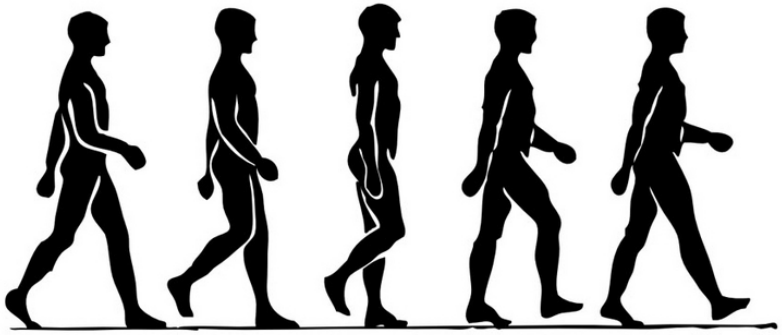
Privacy & User Authentication

- User Authentication:
  - Confirm the identity of the user.
- Sensitive data:
  - Medical records
  - Bank account
  - Personal location information
  - and so on …



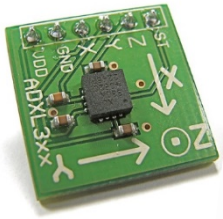
Gait Recognition using Wearable Sensors



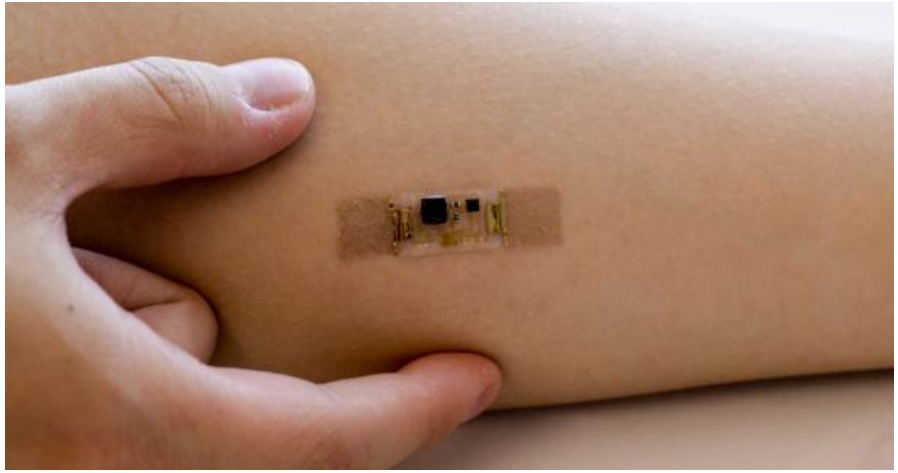
- Gait recognition:
  - Identifying an individual by his/her unique *walking pattern*.
- Using wearable sensors, *accelerometer*, to capture gait patterns.

Challenge: Power Constraint

- Limited Battery Life
  - Small form factor
  - High Energy Consumption:
    - Powering motion sensors
    - Powering micro-controller (MCU)
    - Powering wireless communication unit

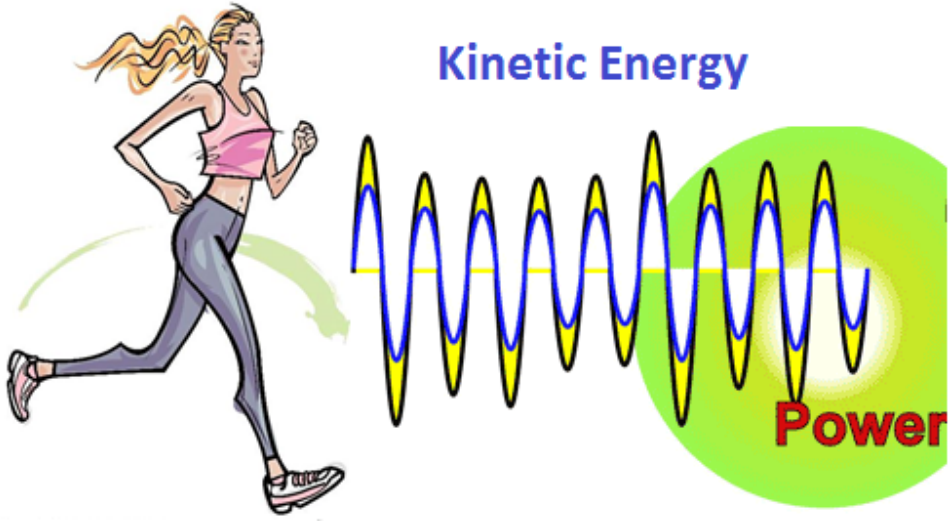


Bluetooth® SMART



Kinetic Energy Harvesting (KEH)

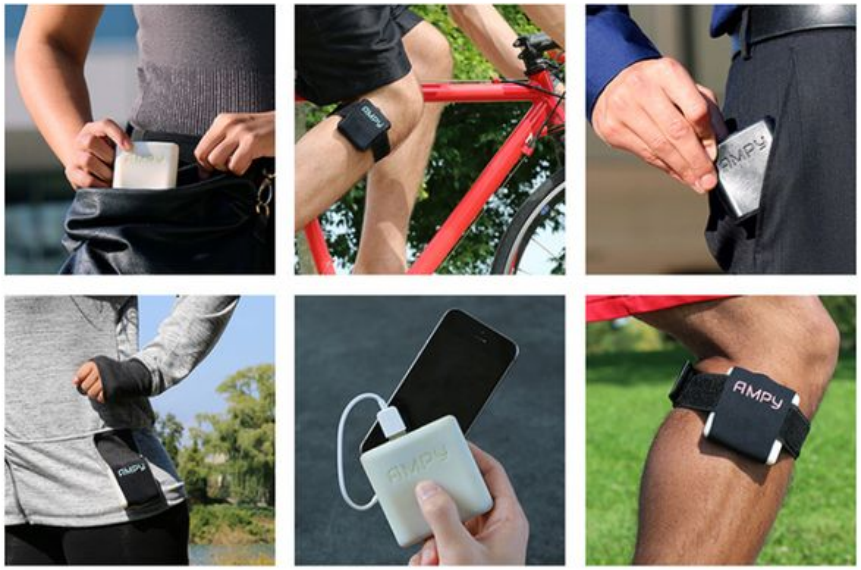
- A new vison: Kinetic Energy Harvesting-powered wearable system.
  - Powering wearable devices using ambient kinetic motions.



Kinetic Energy Harvesting (cont.)

- Practical products:

World's first wearable motion-charger



	AMPY	Smartphone	Smartwatch	Fitness Tracker
WALK	10,000 steps daily average	3 HOURS	24 HOURS	72 HOURS
CYCLE	1 hour			
RUN	30 minutes			

Kinetic Energy Harvesting (cont.)

- Practical products:

  Shoe sole based energy harvester

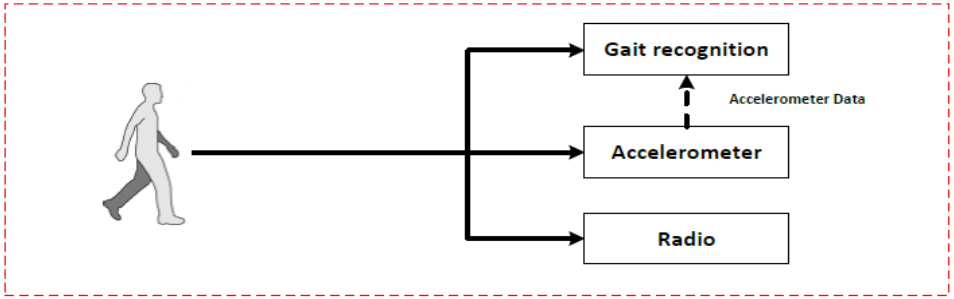
Motivations

- Accelerometer-based gait recognition is energy consuming
  - Continuous data sampling -> *High energy consumption*
  - Especially for resource-constrained wearable devices
- Kinetic energy harvesting is promising in powering wearable devices.

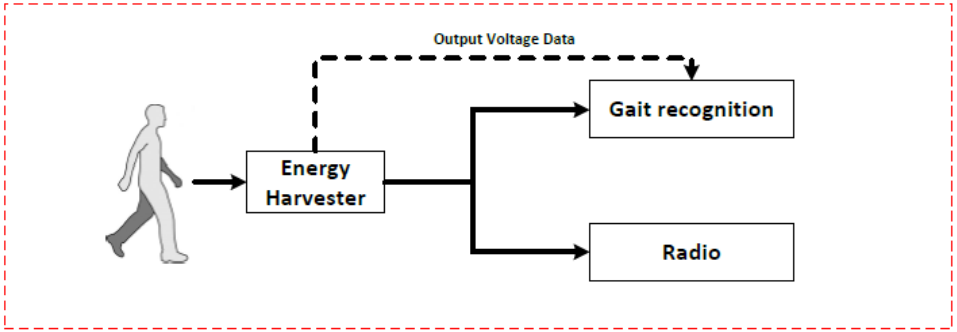
- Our Idea:
  - Gait recognition using the voltage signal generated by the KEH!
- Intuition:
  - If humans have unique walking patterns, then the corresponding patterns of the harvested power from KEH should also be unique.

System Overview

Traditional accelerometer-based gait recognition system:

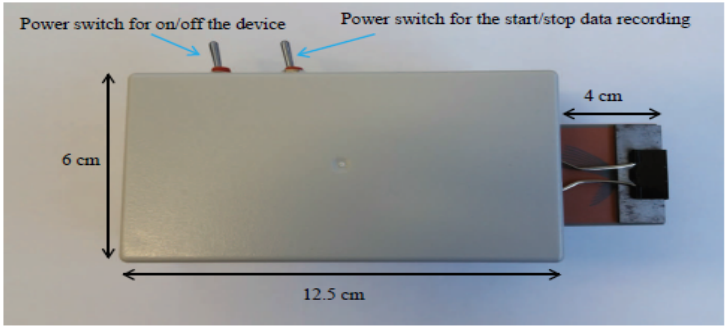


Proposed KEH-based gait recognition system (KEH-Gait):

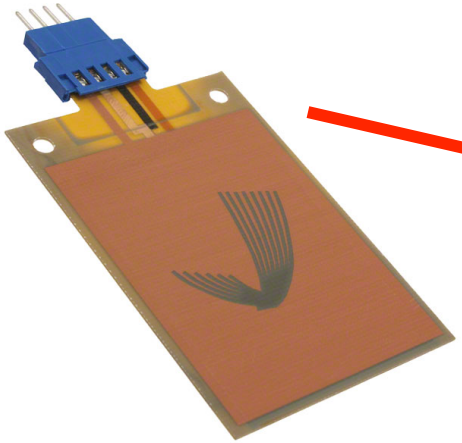


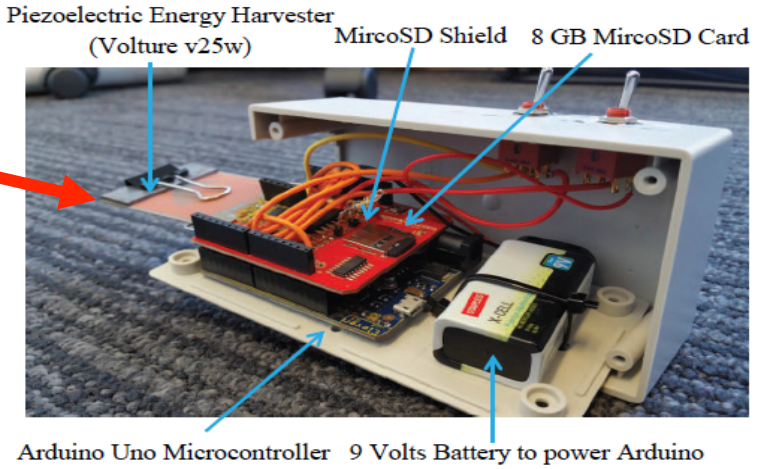
Prototypes Design

- Prototype One:
  - Piezoelectric Energy Harvester (PEH)



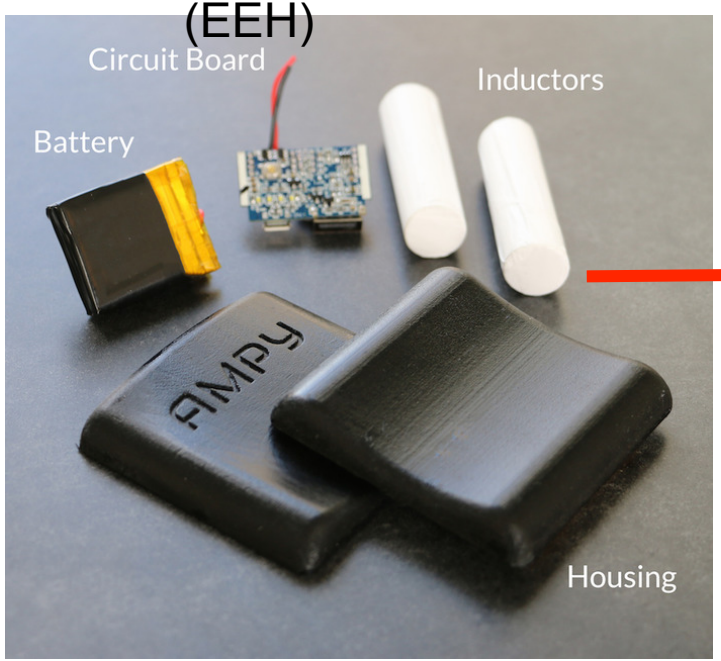
(a)

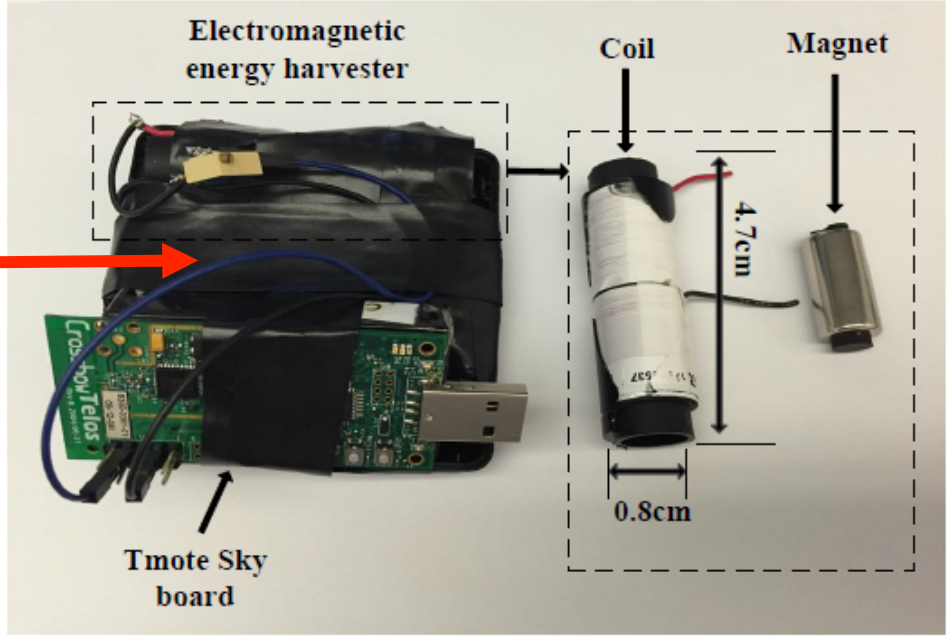




Prototype Design (cont.)

- Prototype Two:
  - Electromagnetic Energy Harvester (EEH)





Data Collection

- Two Datasets
  - 20 subjects (14 males, 6 females)
  - Both Indoor and Outdoor
  - PEH-dataset
  - EEH-dataset

(a) Indoor experiment

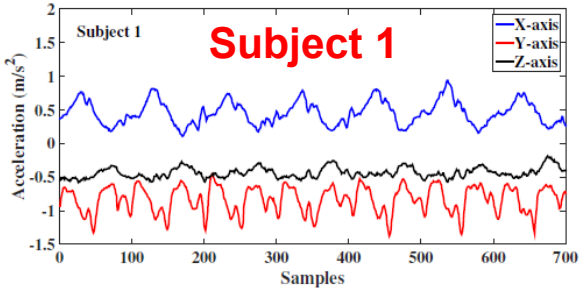
(b) Outdoor experiment

(c) Holding PEH device

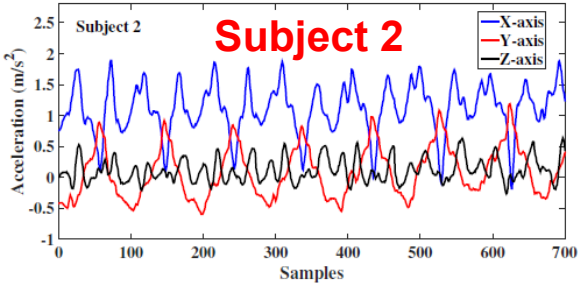
(d) Holding EEH device

Signals

Accelerometer signal

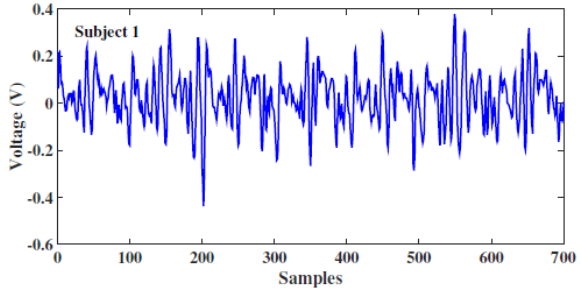


(a) Acceleration signal of subject 1

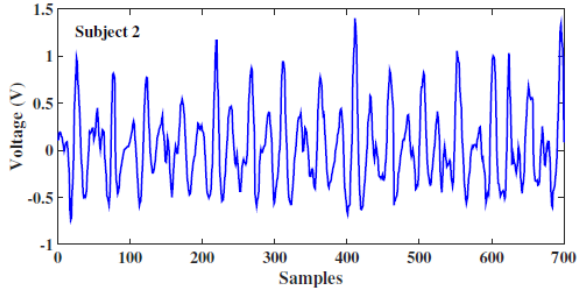


(b) Acceleration signal of subject 2

PEH signal

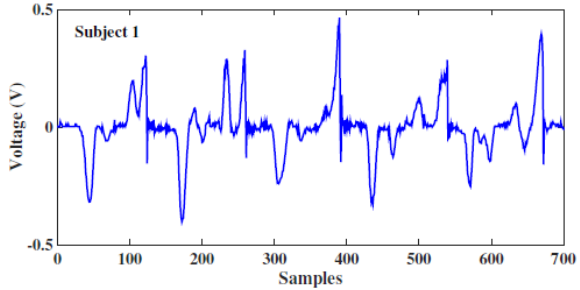


(c) Output voltage of subject 1 from a PEH device

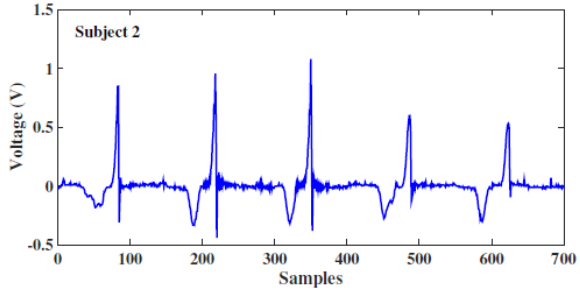


(d) Output voltage of subject 2 from a PEH device

EEH signal

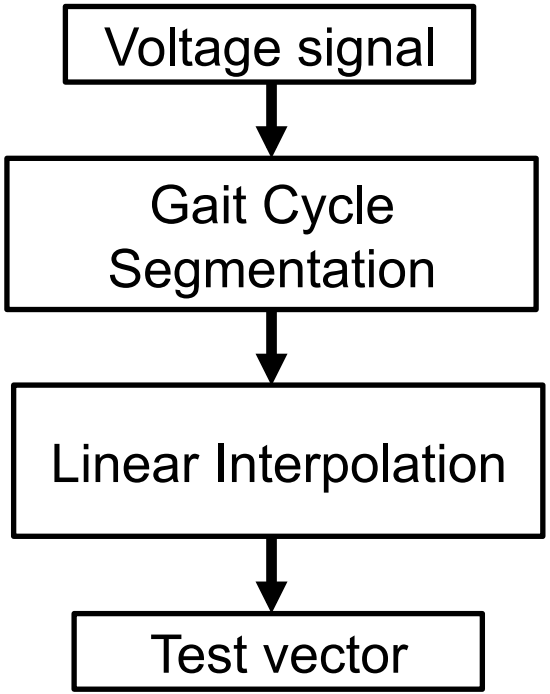


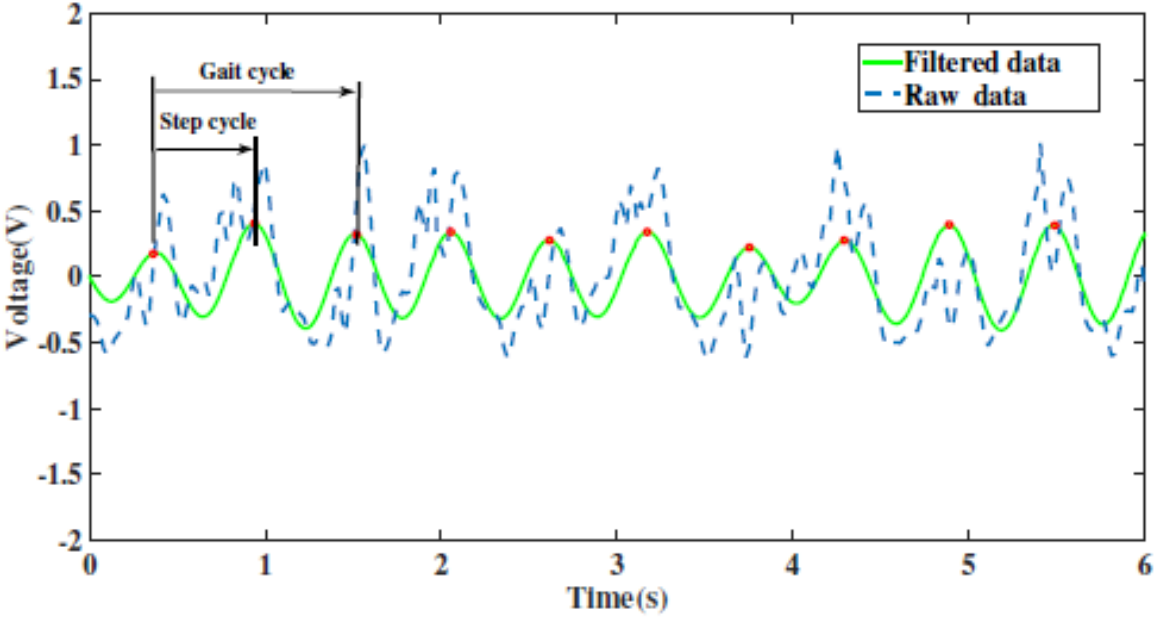
(e) Output voltage of subject 1 from an EEH device



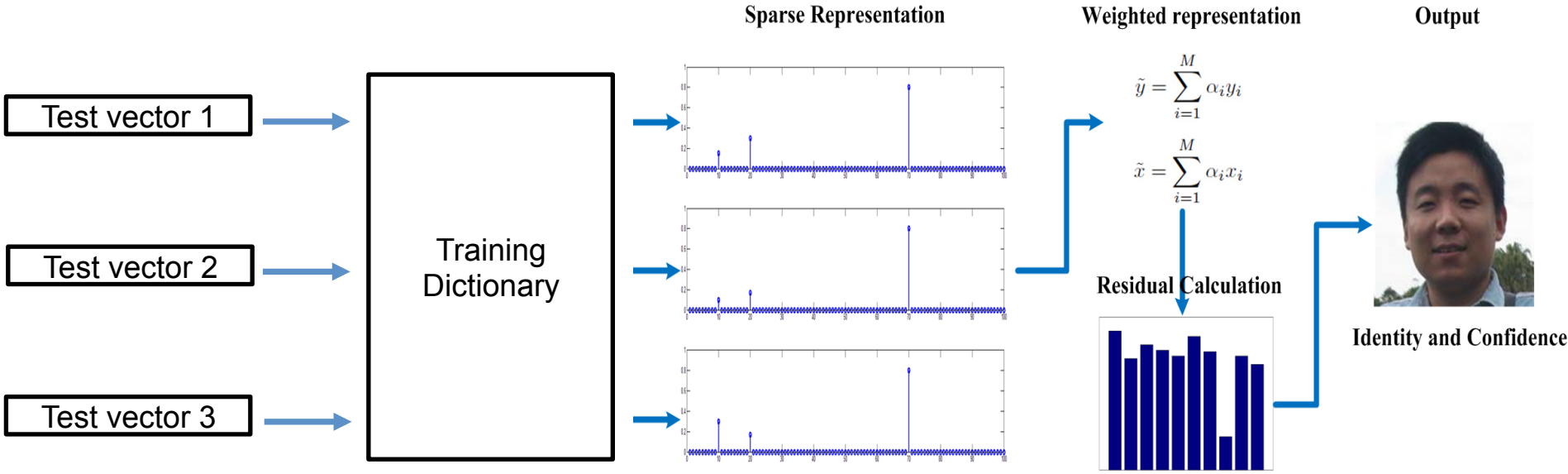
(f) Output voltage of subject 1 from an EEH device

Signal Processing





Multi-Step Sparse Representation Classification (MSSRC)



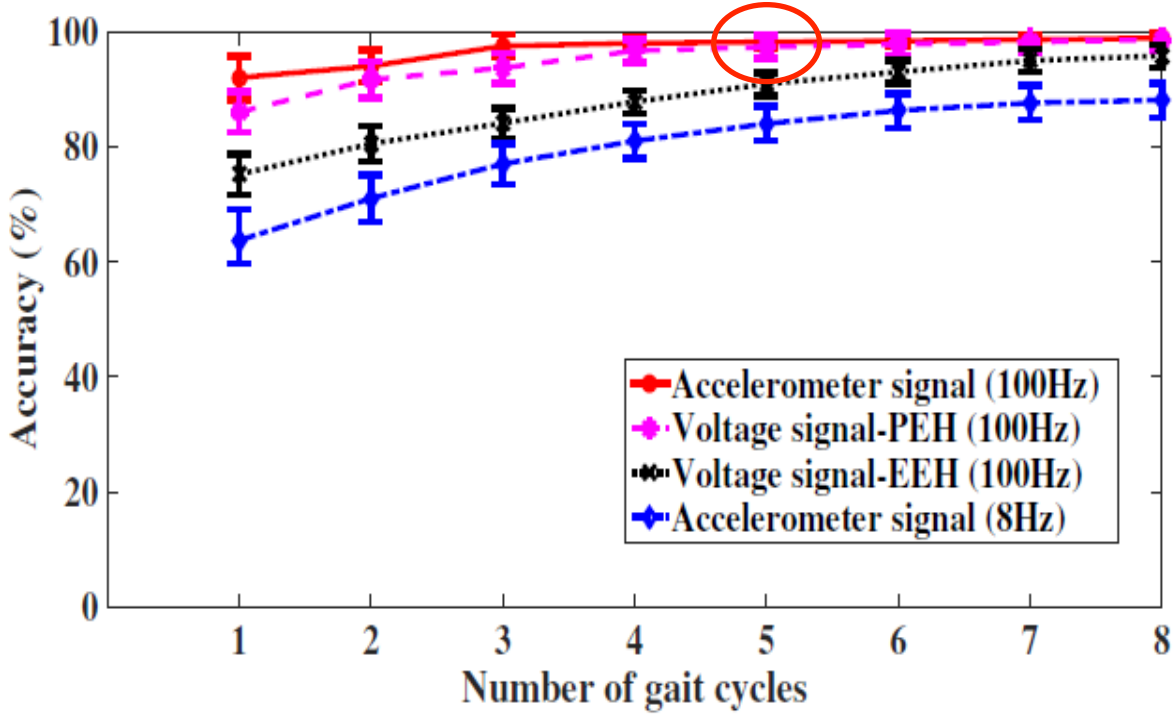
MVSRC exploits the sparsity of multiple steps and apply a weighted model to improve accuracy.

System evaluation

- Goals of evaluation:
  1. KEH-Gait *v.s.* Accelerometer-based system.
  2. Performance of two different energy harvesters:
     - Piezoelectric-based (PEH-based)
     - Electromagnetic-based (EEH-based)
  3. System robustness.
     - Against time variation.
     - Against different environments.

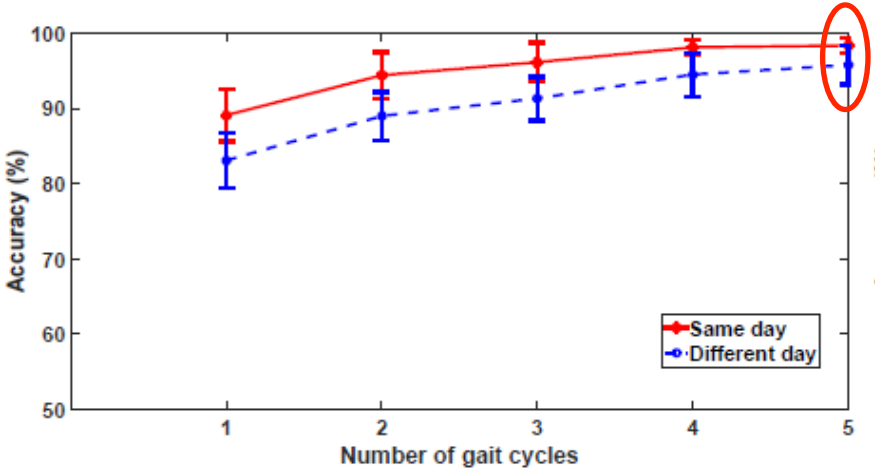
Evaluation results

- KEH-Gait *v.s.* Accelerometer-based system

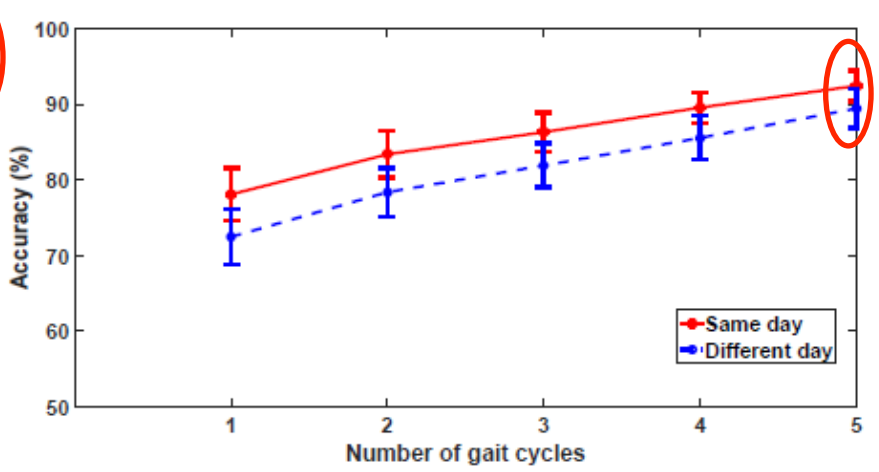


Evaluation results (cont.)

- Robustness to Gait variations:
  - Variations over time (one week)



(a) PEH dataset

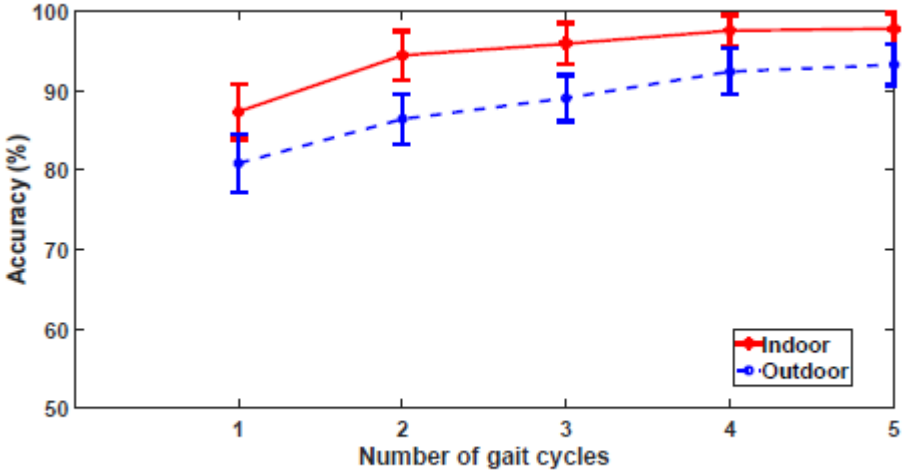


(b) EEH dataset

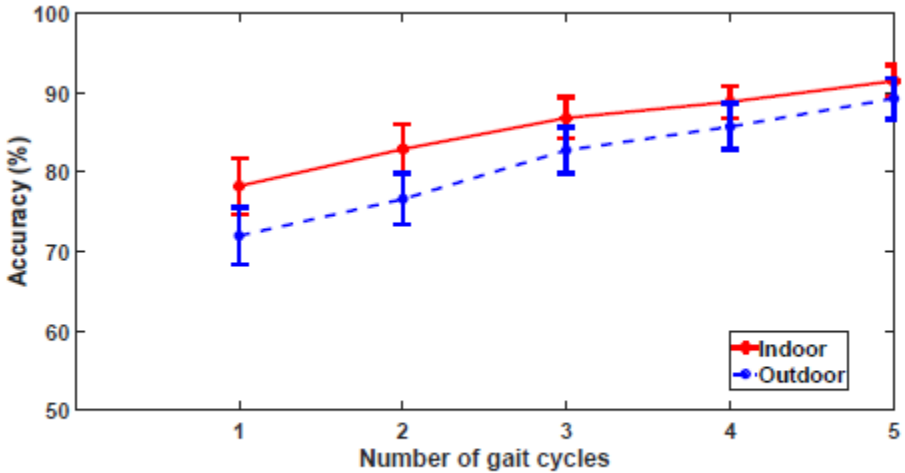
Accuracy of authentication in different days is approximately 5% lower than that of the same day authentication.

Evaluation results (cont.)

- Robustness to Gait variations:
  - Different environments:



(c) PEH dataset

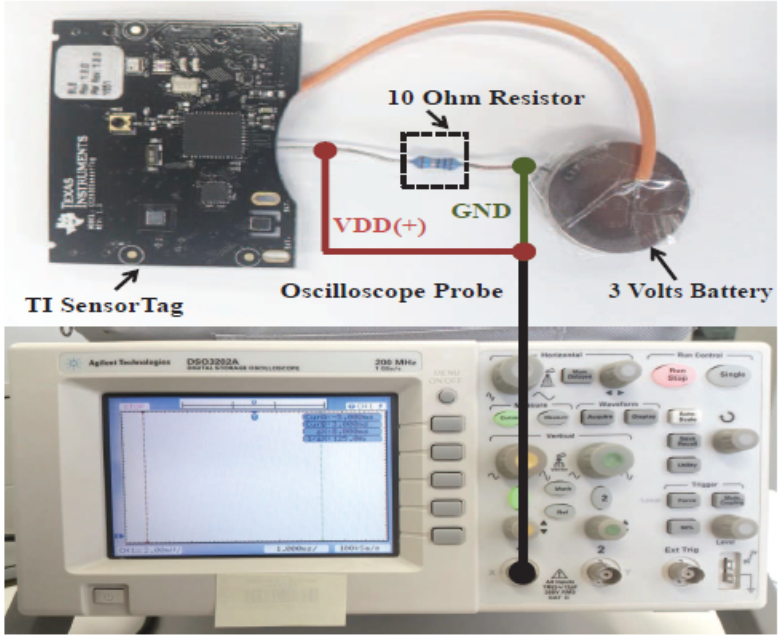


(d) EEH dataset

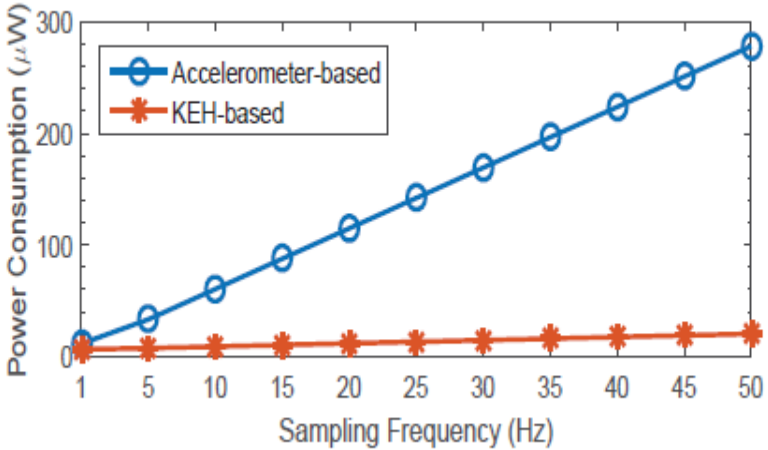
Our system achieves lower accuracy in outdoor environment, due to different road conditions.

Energy Consumption Analysis

- Measurement Setup



- Measurement Results



Our system can reduce energy consumption by 75.88%. (extend battery lifetime by 4 times)

Conclusions

- A novel KEH-based gait recognition system which uses only the KEH voltage as the source signal to achieve user authentication.
- Two different KEH prototypes, one based on piezoelectric energy harvester (PEH) and the other on electromagnetic energy harvester (EEH).
- We demonstrate that KEH-Gait reduces the power consumption of conventional accelerometer-based system by 78%.

Thanks for your attention.

Questions?

For further questions, feel free to contact:
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