Self-powered ultrasonic wearable sensing prototype

Autonomous University of Yucatan – Perkins School for the Blind – Massachusetts Institute of Technology

Concluding Remarks

Project Description

An ultrasonic sensing device for interactive human-machine interface (HMI) is addressed in a wearable embedded prototype. The highly sensitive system is based on a low-power microcontroller, which processes the ultrasonic data and provides a vibration level to the user according to the distance of an object. The electronic glove redesign and the integration of an energy harvester circuit are also proposed in this project to extend the battery life toward a self-powered operation. In particular, a dynamic power management strategy (DPMS) is programmed into an ultra-low-power microcontroller, combined with a thermoelectric generator energy harvesting (TEG-EH) circuit, to achieve a proof-of-concept wearable embedded system.

MIT/Perkins-UADY Collaborative Activities

The Robotics and Industry 4.0 laboratory was the host for the redesign of a wearable structure for a blind glove device. The motivation consists into integrate thermal electric generators (TEGs) and electronic devices in a novel prototype.

Objectives:

- Redesign the wearable structure of the previous electronic glove to guide blind persons in a smaller glove/electronic system with ultra-low-power components and harvester circuits.
- Extend the battery life of a low-power ultrasonic wearable sensing system.

Activities:

All the teams, integrated by one or two students of UADY and one MIT student, must implement the following activities.

- 3D Modelling, design, and printing with SolidWorks or similar, the structure of the ultrasonic embedded systems.
- Program ultra-low-power microcontrollers.
- Implement a dynamic power management strategy (DPMS) in the microcontroller.
- Battery life estimation and ultrasonic mems characterization

Requirements:

- Req1. 3D model design with less possible PLA/TPU.
- Req2. Harvesting Structure 3D model design. Components:
    - Battery Lipo 3.7v
    - Harvester circuit
    - Two or more TEGs.
- Req3. Redesign of the electronic glove for blind persons. Components: MCU MSP430FR5994 (Necessary Code Composer Studio), ultrasonic sensor TDK microsystems model CH201 (Recommendation: https://www.mouser.com/catalog/specsheets/TDK_10012020_DS-000379-CH201-v1.1.pdf).
- Req4. Power consumption analysis and battery estimation.
- Req4. Cost analysis

Teams

Team1:
- Julio Heredia Lozano – UADY
- Alejandro Castillo Ancona – Winter school program
- Shruthi Shekar - MIT.

Team2:
- Ignacio Isaac Medina – UADY
- Evelyn Chablé – UADY
- Bilal Daqqah - MIT

Team3:
- Agustín Hernández Benitez – UADY
- Diana Sofia Hernández Hernández – Winter school program
- Ian Rosado - MIT

Team4:
- Jorge Flores Tun – UADY
- Nour Al Maalouf - MIT

Team5:
- Alfonso Alcocer Rivera – UADY
- Penelope Herrero-Marques - MIT

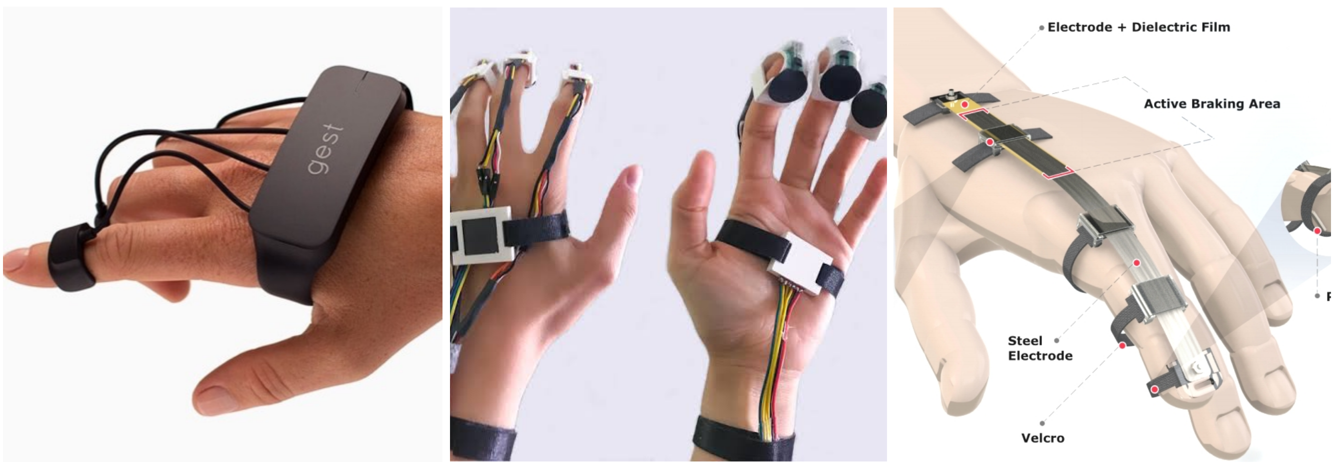

Fig. 1. State of art electronic gloves

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Design results

The presented results correspond to the selection of the best design characteristics of all the teams.

Design Considerations:

- Mobility, Comfortability, Hand-Positioning:
  - Ensuring the hand position is normal, not out of the ordinary.
- Identifying and alerting about Obstacles while walking:
  - Stairs/steps, potholes, rough terrain, preventing falls
- Use as **less material** as possible
  - Material selections for hot climate
- Power management strategy for low-power consumption
  - Dynamic strategy varying the sleep period according to the measurements.

Components:

The components were considered for their low-power consumption and small size for their integration in the prototype.

- TDK CH201 ultrasonic sensors
- MSP430FR5994 MCU
- Nano-vibration Motor
- Battery LiPo 3.7V 200mAh

Power consumption:

The power consumption was achieved with an emulator circuit of Texas instrument. The CCS energy-trace tool was used to estimate the battery life estimation and power consumption.

Unit	Component	Current consumption
1	MSP430FR5994	120 uA (Active mode)
3	TDK CH201 ultrasonic sensor	223 uA
1	Vibration motor	1 mA

Battery life estimation:

Total Consumption	1.8 mA
Power Consumption	6 mW
Estimation battery life	36 hr

Cost estimation:

The cost was estimated for the design of one prototype. This could be less for the manufacturing of several devices.

Electronics	
Components	Cost
TDK CH201 ultrasonic sensor	17 USD
MSP430FR5994	14 USD
Vibration Motor	1 USD
Battery LiPo	4 USD
TEG cell	4 USD
Bq25570	12 USD
Subtotal	52 USD
Structure	
Wrist Velcro	2 USD
Fingers Velcro	2 USD
Wires	4 USD
PCB manufacturing	5 USD
Subtotal	13 USD
TOTAL	**65 USD**

Power generation**:**

An energy harvested circuit (Bq25570) was used to collect the energy from TEG devices. This activity was validated in the laboratory. An open voltage up to 0.47 mV was achieved from the TEG devices.

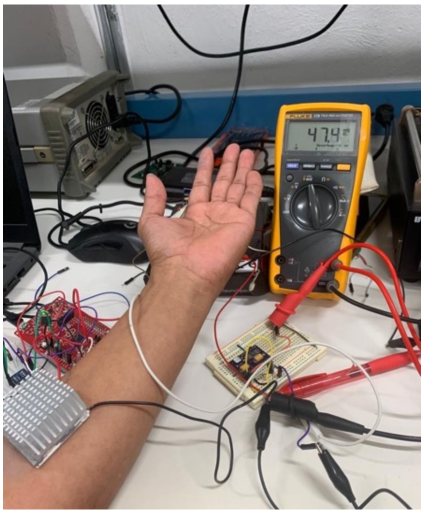

Fig. 2. Power generation with TEG devices.

3D CAD Designs

Design implemented with Fusion Studio 360.

Fig. 3. Design option 1: ultrasonic sensors in the fingers.

The design of Fig. 3 considers the ultrasonic sensors attached to the fingers and a small PCB, i.e., 3×3 cm, in the wrist. Another interesting approach is illustrated in Fig. 4, in which the ultrasonic sensor was attached to the same electronic PCB that is fixed with a watch exoskeleton.

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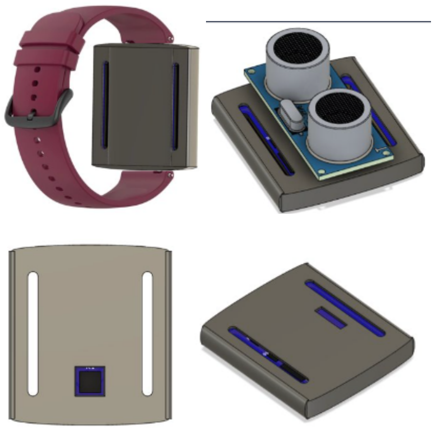

Fig. 4. Design option 2: system integrated in a watch exoskeleton.

Fig. 5 shows the 3D design separating the vibration motor in a ring structure and the electronics, including the battery in a bracelet.

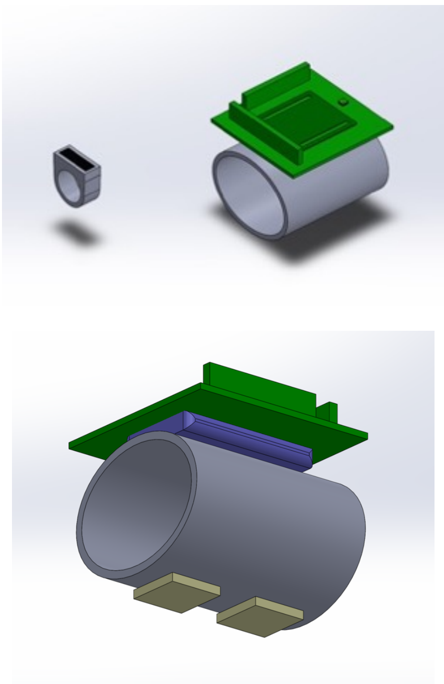

Fig. 5. Design option 3: vibrating motor located in a ring structure.

The motor location on the underside of the ring finger provides more sensitive vibrations than other parts of the hand. Another important consideration was the modulation of the signal to generate lower vibrations to conserve power. Finally, Fig. 6 illustrates a design with the electronics located in the wrist and the vibration motor in one finger.

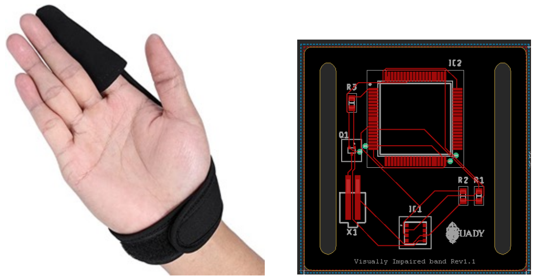

Fig. 6. Design option 4: Textile electronic glove attached in one finger and the wrist.

Final Discussion

The short collaborative work between MIT and UADY students was a very successful experience. At the end of the session, the student teams provided interesting results for the redesign of a self-powered ultrasonic wearable device. All the teams were able to follow the design requirements, achieving the 3D CAD design, the TEG-based power generation, power consumption analysis, and the cost analysis in one single-day session.

The interdisciplinary collaboration of the computer science, bioengineering, mechanical, and mechatronics students was essential for the development of this new wearable sensing prototype to guide blind persons. Although very simple prototype ideas were developed, the cost and power consumption analysis results look very promising. After the activity, the participants manifested that having more time for the development, verification, and validation of a prototype would have resulted in a better learning experience with more significant results.

We all agree that a workshop of 20hrs (short summer or winter school) would be the best option for this kind of collaboration.

LINK: All teams presentations.