Construction Management and Project Engineering

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Lec 06. Wearable Applications in Construction Safety and Health

Outline

- Available and Emerging Sensing Technologies
- Applications in Construction Safety and Health
- Challenges and Opportunities of Wearable Applications
- Short Guest Talk: Nipun Nath, Visual sensing for Construction Safety
- Quick Data Collection for Activity Recognition

Motivation

- Limited resource for safety regulation enforcement (e.g., PPE, OSHA regulation)
- Behavior-based Safety (BBS): Intervene and modify unsafe behaviors via observation and feedback
  - Field observation is expensive
  - Hard to train field observers due to the nature of a construction projects

Available and Emerging Sensing Technologies

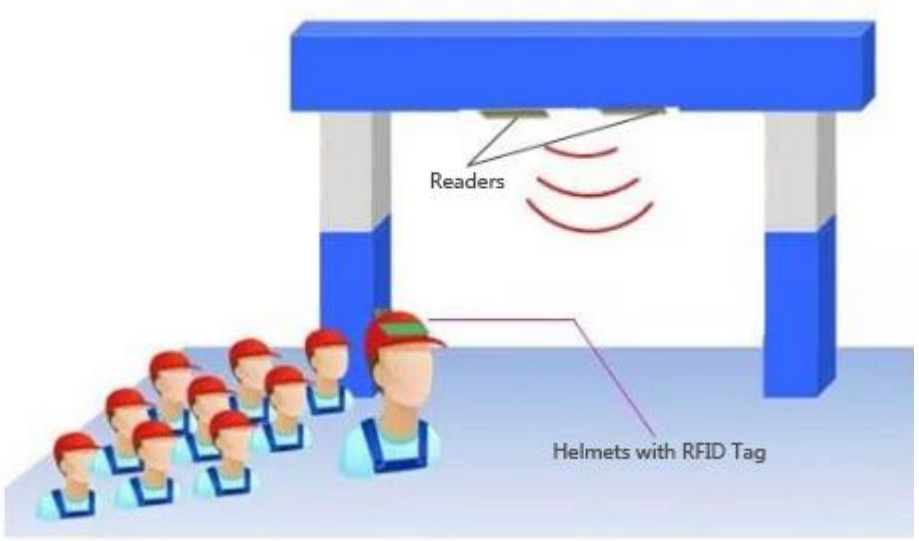
- Location Tracking & Proximity Sensing
- Kinematic & Physiological Sensing
- Visual Sensing

Location Tracking

- Locating and tracking resources is critical for monitoring safety
- Measure the metrics of the radio signals from several reference points.
  Use the measurements of:
  - Time of arrival
  - Angle of arrival
  - Time difference of arrival
  - Received signal strength
- Spatial resolution could be:
  - On/off site or in/out building
  - Floor or zone level
  - Exact coordinate

Most effective tracking technologies

- Attendance Management
  - RFID
  - Barcode
  - GPS



Challenges of Tracking Locations in Construction Sites

- Semi-indoor
- Dynamic Environment
  - Hard to do fingerprinting
  - Need to install/uninstall beacons (receivers) frequently
- Need to cover multiple stories
- Workers' resistance: need to wear a tag

Location Tracking

- Global Positioning System
- Ultra-wide band
- Radio-frequency identification (RFID)
- Bluetooth
- Ultrasound
- Wi-Fi + motion sensor

Proximity sensing

- For collision avoidance
- Relatively easier to deploy compared to location tracking, but need to be highly responsive and accurate
- Using:
  - Ultrasonic-based sensors
  - Radio frequency
  - Radar
  - GPS

Kinematic & Physiological Sensing

- Kinematic movement: Inertial measurement units (IMU)
  - Accelerometer, Gyroscope, Magnetometer

- Cardiac activity:
  - Electrocardiography (ECG)
  - Photoplethysmography (PPG): Volumetric change of blood flow

Kinematic & Physiological Sensing

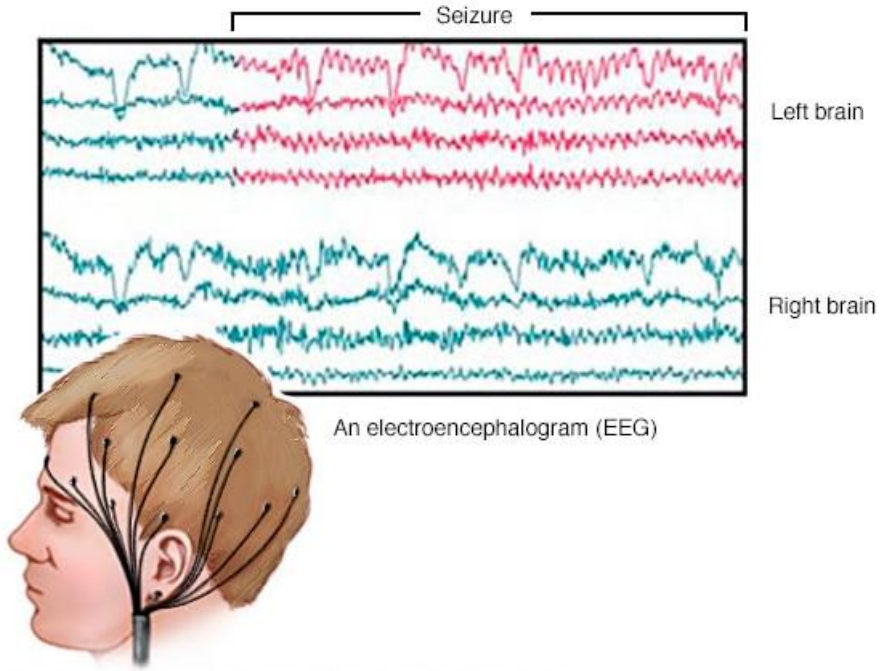
- Skin response:
  - Electrodermal activity (EDA): autonomic changes in the electronic properties of skin in response to sweat secretion; useful index of the sympathetic neural activities
    - ✓ Since the sympathetic nervous system is affected by the hypothalamus and limbic system—brain regions related to emotion—EDA can indicate individuals' affective phenomena and stress.
    - ✓ not contaminated by parasympathetic nervous activities
- Skin temperature: losely associated with workers' physical demands

Kinematic & Physiological Sensing

- Muscle engagement
  - Electromyography (EMG) sensors: Electrical potentials created by skeletal-muscle cells (converted into muscle loads)
- Eye movements :
  - relates to human perception of visual stimuli
  - Eye trackers: measures eye fixation and eye saccades

Kinematic & Physiological Sensing

- Brain activity
  - Electroencephalography (EEG): electrical activity of the brain recorded via electrodes placed on the scalp



An electroencephalogram (EEG)

Challenges of Kinematic & Physiological Sensing

- Signal artifacts and noise in field measurements
  - Any unwanted signals impacting the sensor's accuracy and function
  - Extrinsic Artifacts: Sensor orientation, device power–line interference, motion artifacts, and electrode-movement artifacts
  - Intrinsic Artifacts: signal noise generated from the body itself. E.g., skin, respiration, pulse, muscle, motion, and ocular artifacts
  - Construction activities creates a high level of signal artifacts: noisy environments, high levels of physical activity

Applications from Location Tracking/Proximity

- Tracking Hazard Zone Access

- Avoiding Collision

Applications from Kinematic/Physiological Sensing

- Preventing Musculoskeletal disorders
- Preventing Fall accidents
- Monitoring Physical workload and fatigue
- Evaluating Hazard-recognition abilities
- Monitoring workers' mental status

Applications from Visual Sensing

- Monitoring PPE compliance
- Preventing Musculoskeletal disorders

Challenges of Wearable Applications for Construction Safety (1)

- Variable standards in assessing personal safety and health risks
  - Ground-truth measurement systems are hard to implement on a jobsite (e.g., optical motion capture system) or does not exist at all.
  - Some ground-truth tests depend on qualitative data (e.g., physical fatigue assessment)
  - At-risk thresholds for personal safety and health is defined in a prescriptive manner (e.g., EXCESSIVE fatigue).

Challenges of Wearable Applications for Construction Safety (2)

- User resistance in technology adoption
  - Perceive usefulness, perceived privacy risk, and social influence
  - Form factor (size and shape of wearable devices).

- Uncertainty about the return on investment (ROI)
  - Hard to quantify the benefit
  - Maintenance cost is unknown

Future Directions

- Conducting sensor fusion for wearable applications
  - Using multiple sensor data to address signal artifact issues and enhance the accuracy
- Developing a business case
  - Overcoming user resistance and document ROI
- Engaging in risk assessment and post-injury compensability assessment
  - Reliable source to assess risk exposure at the personal level
  - Information on whether a reported injury is compensable or not

Assignments

- Please construct a case study on data sensing applications in construction safety and provide a presentation on Apr 14th.

1. Please choose one of the following topics:
    1. State-of-the-art review on localization in construction
    2. Kinematic sensor applications
    3. EDA sensor applications
    4. EEG/fNIRS study
    5. Eye-tracking study
2. Make sure to compile at least 2~3 recent studies (published after 2020).
3. Provide a review on how to process raw data, which features are extracted, how the test was designed.

- Each team should consist of 2 team members, and is given 10 min.