# Visual Data Analytics and IoT in Smart Construction Management

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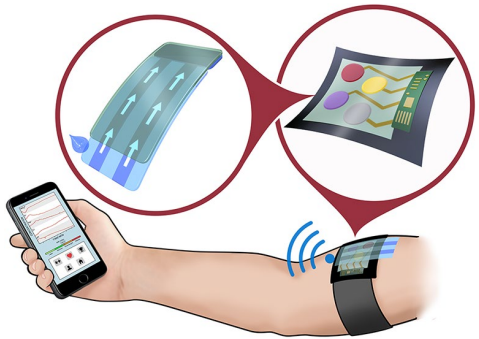
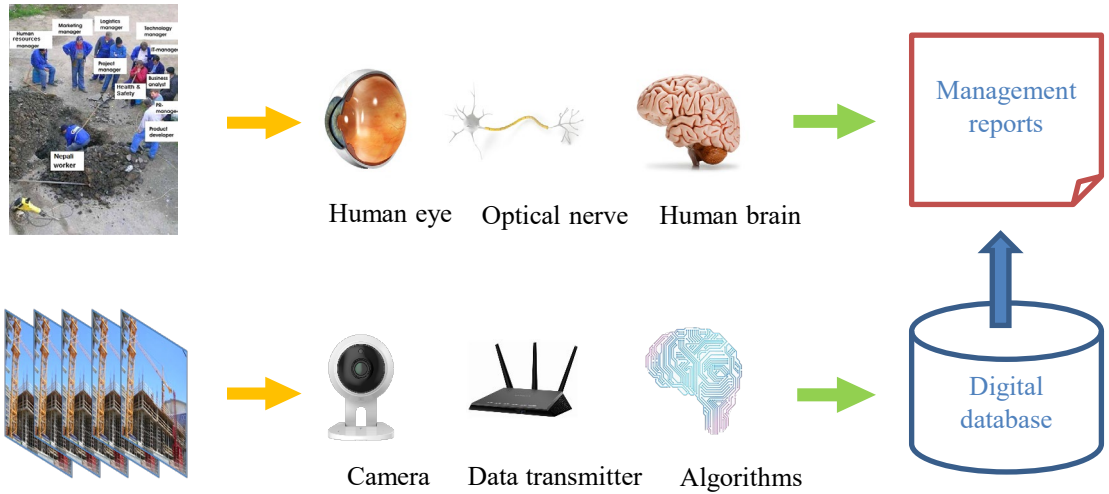
# Outline

- Video-based and sensor based smart site management
- Sweat based vital signs measurement to detect physical fatigue
- Smart cushion based measurement to detect mental fatigue
- In-ear device to measure EEG and ECG

# VIDEO-BASED AND SENSOR BASED SMART SITE MANAGEMENT



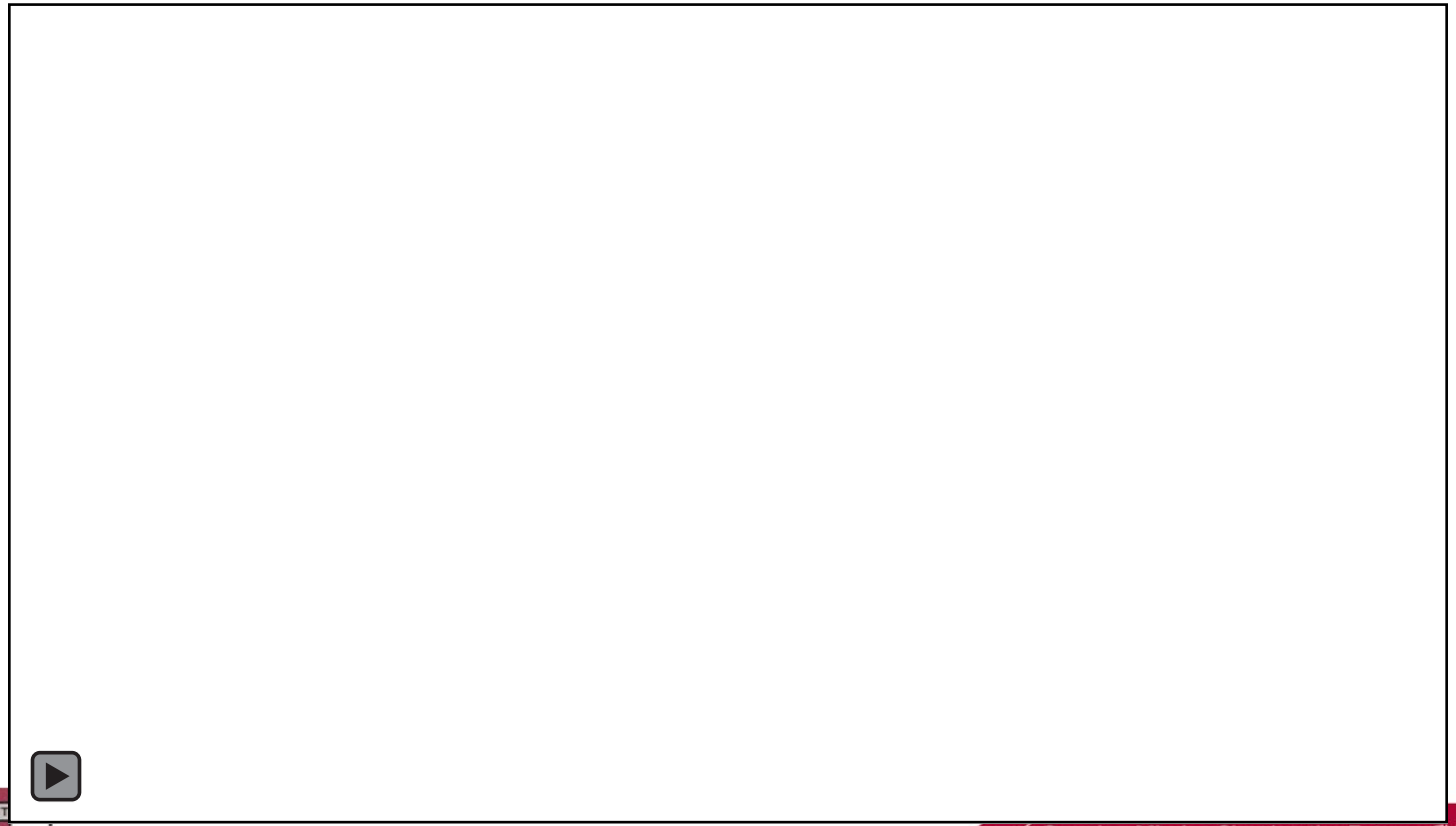
It is likely that construction managers will be replaced by computer vision and AI （项目经理很可能被计算机视觉和人工智能所取代）



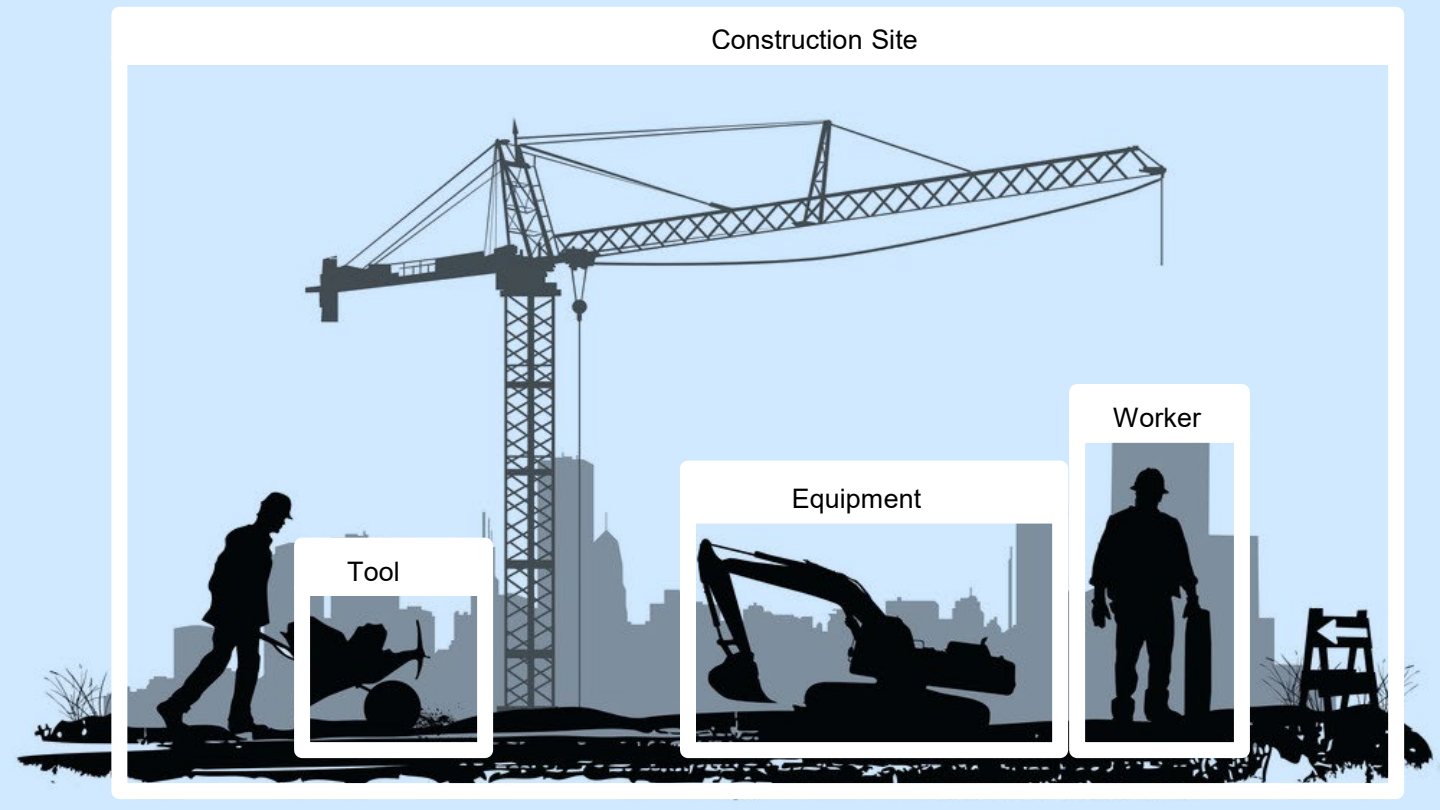
# Computer vision and deep learning


MILL END LOFTS

# Site supervision using CV and AI



# Monitoring tools when there is no lighting

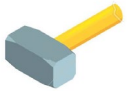

Construction Site
Tool
Equipment
Worker

Angle Grinder

Circular Saw

Coping Saw

Drill



Hammer

Jig Saw

Wrench

Orbit Sander

Screwdriver

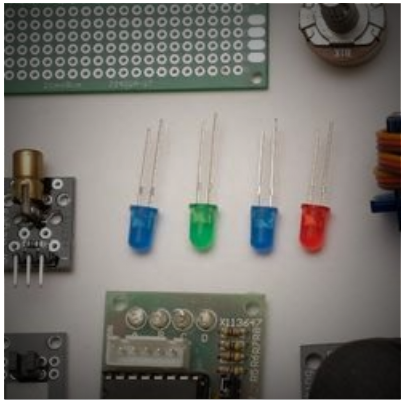
Tape Measure

Torpedo Level

Trowel

By X.Y.

# Hardware



1

Micro-Electro-Mechanical System Inertial Measurement Unit

- 3-axis accelerometer
- 3-axis gyroscope
- 3-axis magnetometer
- Thermometer

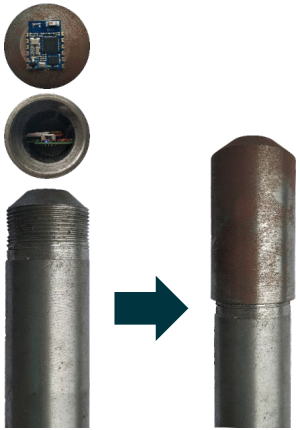
2

Bluetooth Low Energy 4.2

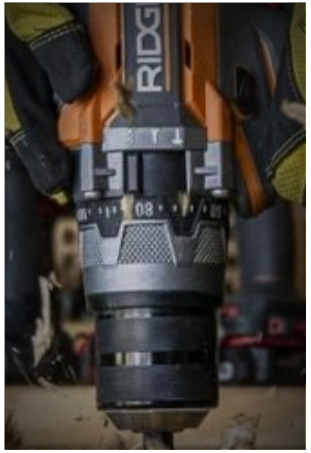
- Communication 4.2 Mbits / s
- Distance 50 m

By X.Y.

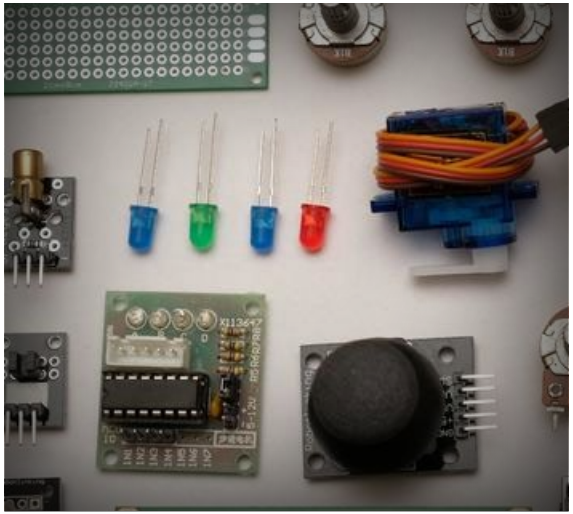
# IMU based tracking system






RIDG

# Hardware



## 1 MEMS-IMU

Micro-Electro-Mechanical System Inertial Measurement Unit

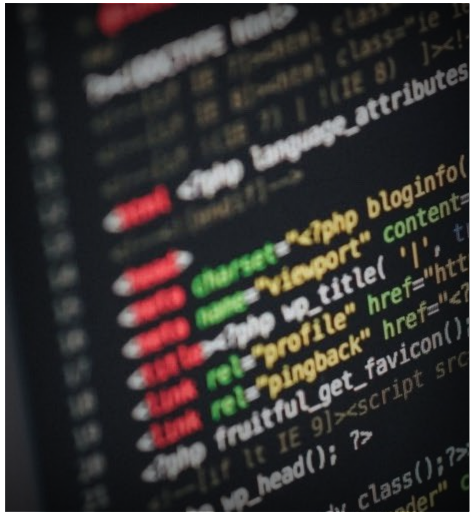
- 3-axis accelerometer
- 3-axis gyroscope
- 3-axis magnetometer
- Thermometer

## 2 BLE

Bluetooth Low Energy 4.2

- Communication 4.2 Mbits / s
- Distance 50 m

# Software



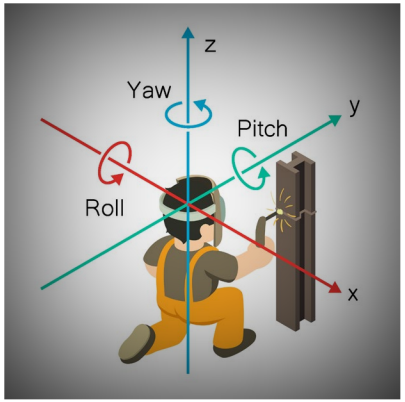
## 1 Core Programming

Python + Blender
- Communication: pyserial
- GUI: tkinter, PyQt5
- Visualization: matplotlib, qtgraph

## 2 API

Application Interface
- Connect
- Read
- Adjust
- Save

# Data Processing – Data Fusion for Orientation (AHRS)



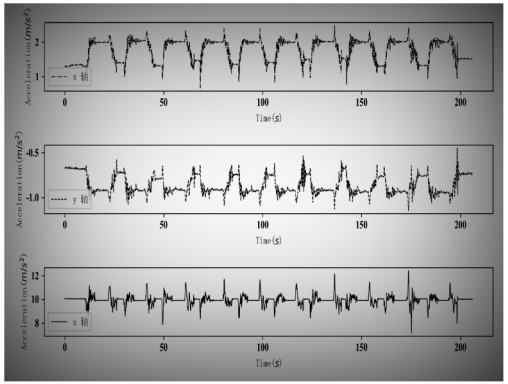

$$\phi = \tan^{-1}\frac{a_y}{a_z}$$

$$\theta = \tan^{-1}\frac{-a_x}{\sqrt{a_x^2 + a_y^2}}$$

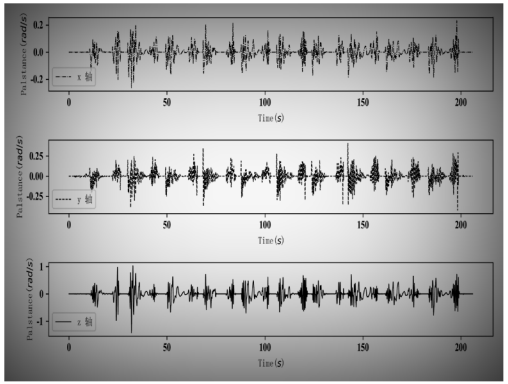
$$\psi = \tan^{-1}\frac{-m_x^N}{m_y^N} \pm \Delta\psi$$

$$= \tan^{-1}\frac{-\cos\phi m_y^B + \sin\phi m_z^B}{\cos\theta m_z^B + \sin\phi\sin\theta m_y^B + \cos\phi\sin\theta m_z^B} \pm \Delta\psi$$

# Collected data from an internal vibrator

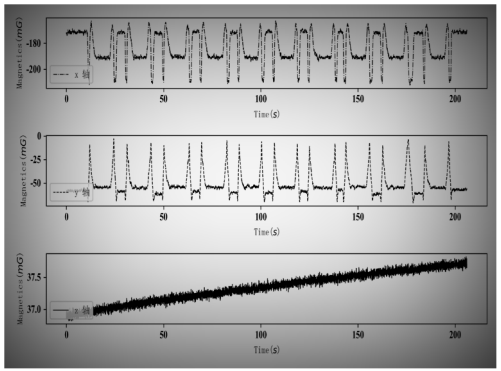



Acceleration

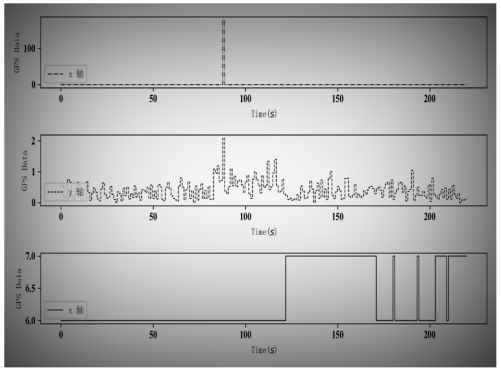



Angular velocity

# Collected data from an internal vibrator

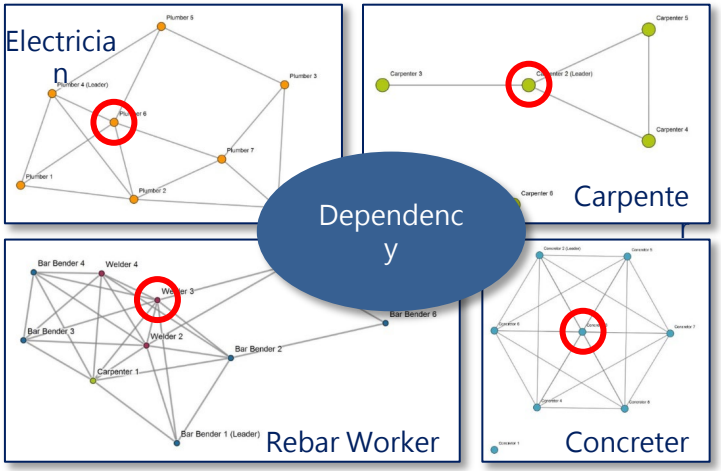



Magnetic field

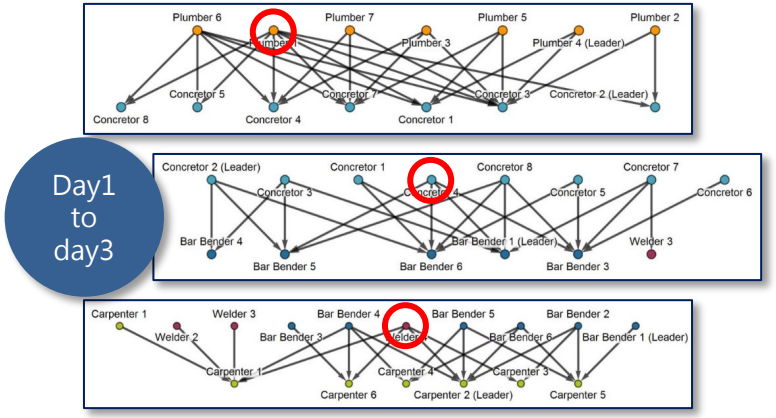



GPS (latitude, longitude, height)

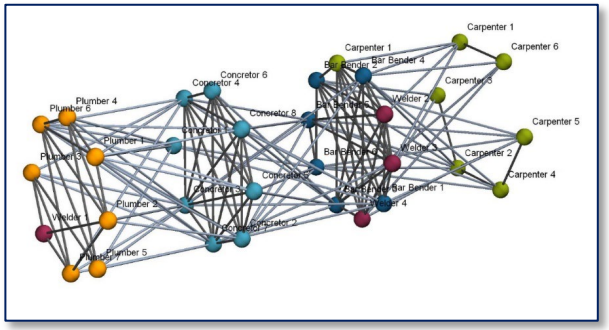
## Dependence network



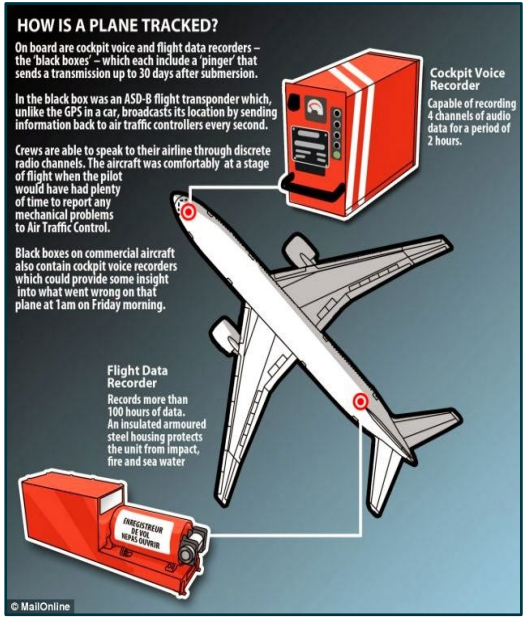
## Sequential inter-dependency netweork

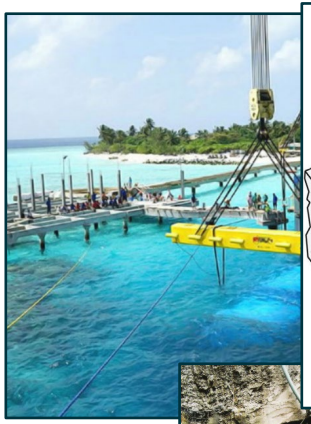


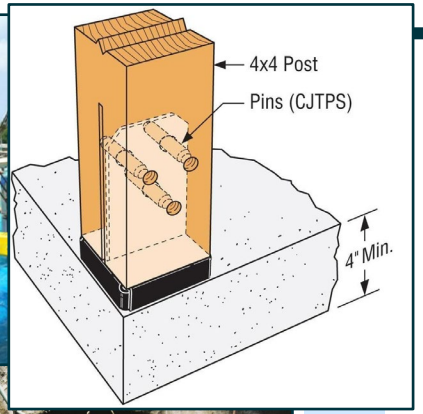
## Traceability chain

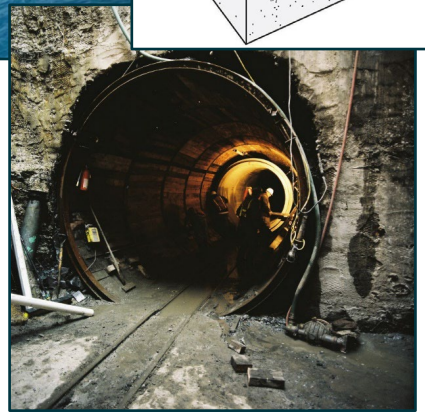



It is possible to develop a traceability chain using the dependency network. This allows to trace "who should be responsible for it, if something goes wrong"



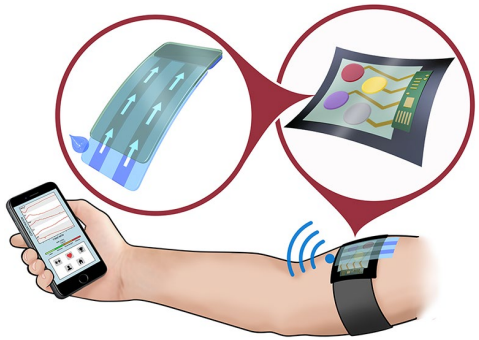




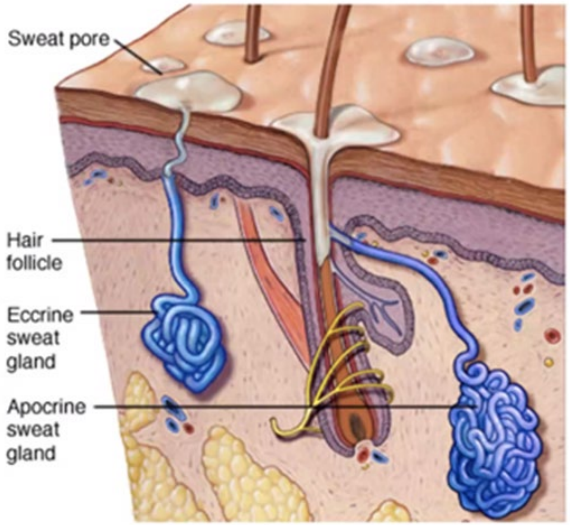



This technology is potentially useful in situations where portions of work are invisible.

# SWEAT BASED VITAL SIGNS MEASUREMENT TO DETECT PHYSICAL FATIGUE



# Sweat Biosensors for assessing Physical and Mental Fatigue




Structure of sweat gland

Physical Fatigue  Mental Fatigue

**Chemical Biomarkers**

Seshadri et al. (2019)

**Blood or Saliva**

Strong Intrusive

Calibration Test

**Sweat**

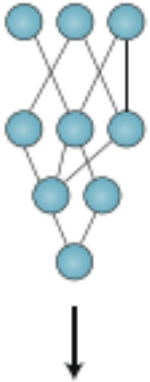
**Sweat Biosensor**

Rich distribution & abundant biochemical contents (sodium, chlorine, potassium, lactate, calcium. Glucose, ammonia, ethanol, urea, cortisol etc.)

- Non-invasiveness
- Simplicity
- Low-cost

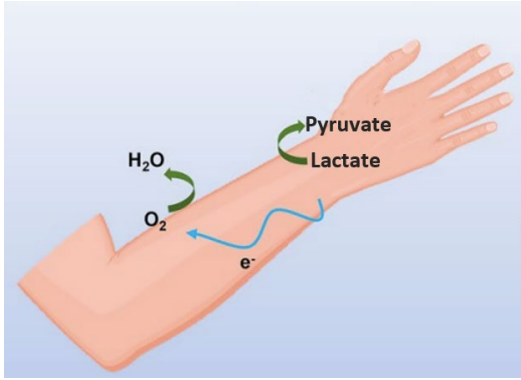
# Structure and mechanism

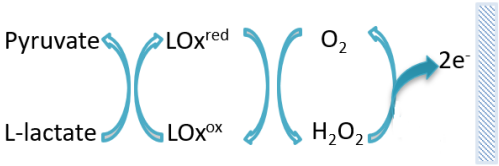
Sweat sensors | Data Storage | Data Analysis | Fatigue Alerting

Predictive algorithms

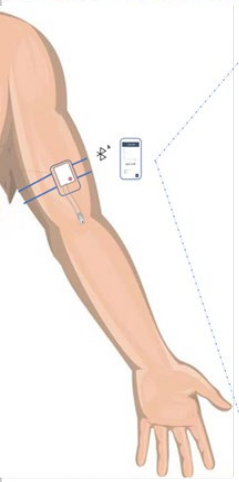
| Fatigue Level |
| --- |
| Low |
| Medium |
| High |
| Very High |

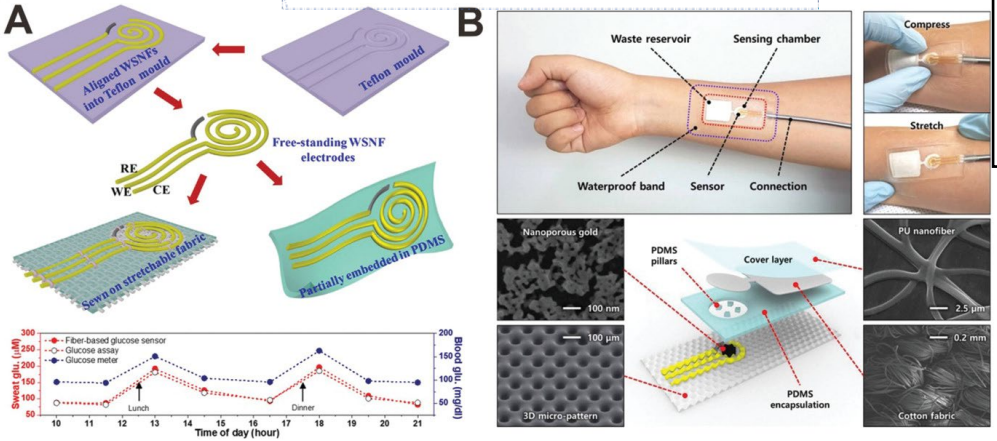


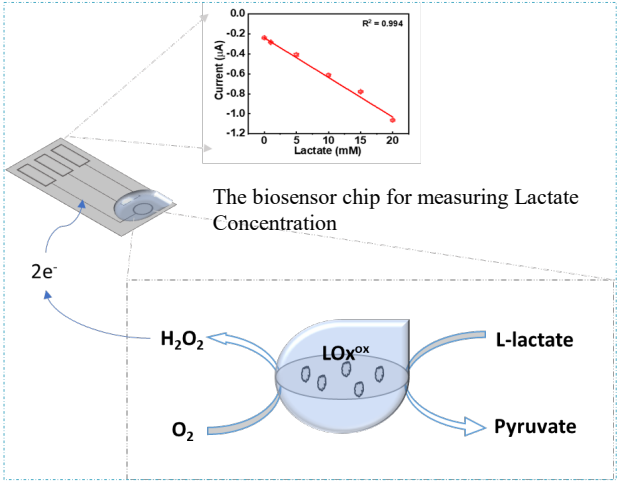

**Biochemical signals** → **electronic signals**

# Working Model



# Detection and measurement




The biosensor chip for measuring Lactate Concentration

$$\text{L-lactate} + O2 \xrightarrow{L-lactate\ Oxidase} \text{Pyruvate} + H_2O_2\,,$$

$$H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-\,,$$

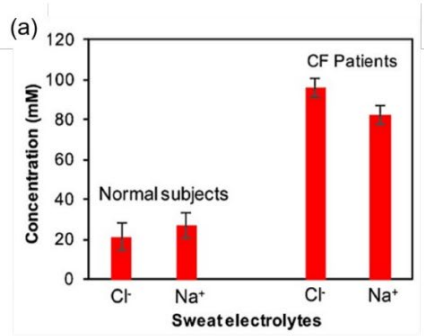
Primary mechanism

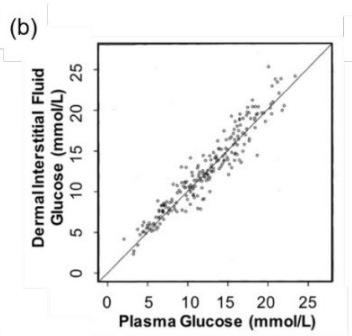
## Advantages

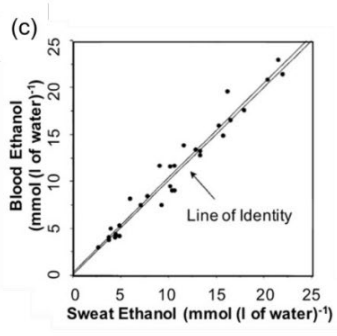
- ✓ Continuous monitoring.
- ✓ Right Treatment at the right time
- ✓ Easy to wear and takeoff.

## Application:-

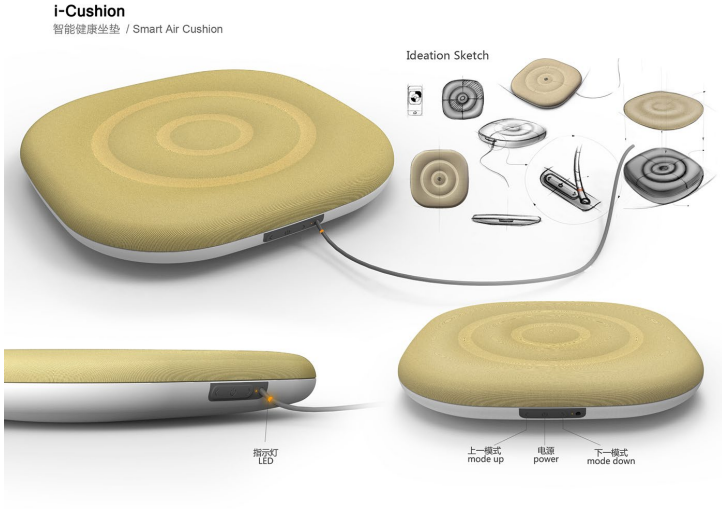
- ✓ Combat casualty care.
- ✓ Medical monitoring.
- ✓ Sports/ Performance monitoring.
- ✓ Space experiments.
- ✓ Mission critical/ hazardous application.
- ✓ Fire- fighting.



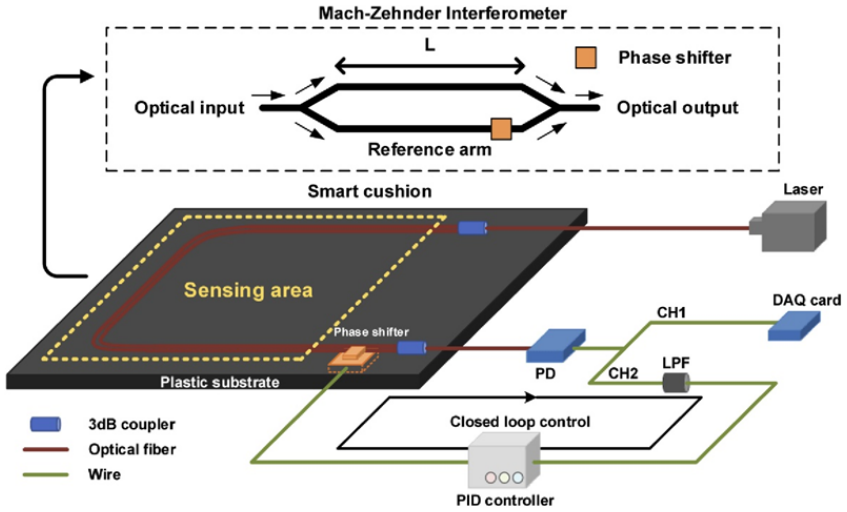



# SMART CUSHION BASED MEASUREMENT TO DETECT MENTAL FATIGUE

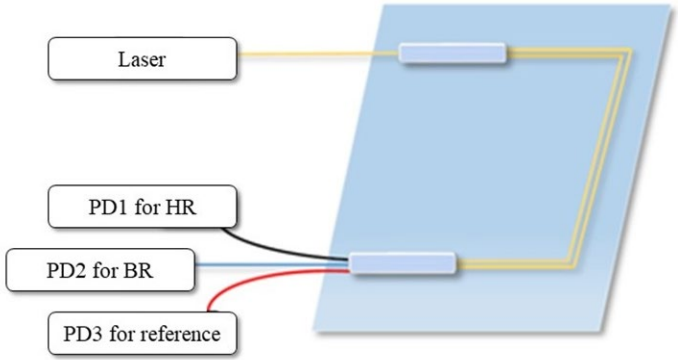


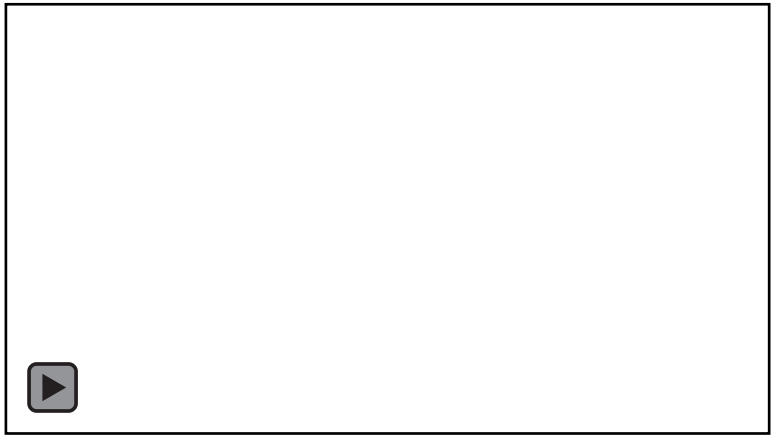
# Structure and mechanism

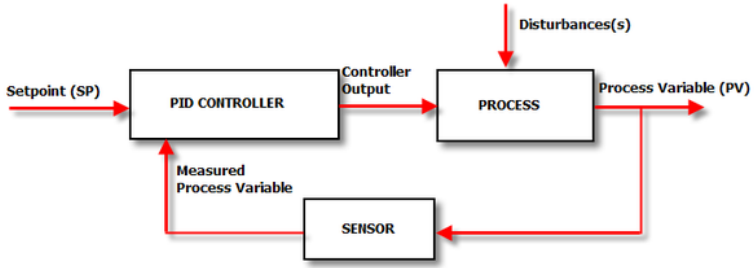
- The monitoring system consists of the Mach-Zehnder interferometer (MZI)-based BCG monitor.
- The optical fiber MZI contains two 3 dB couplers.
- The arms of MZI, including the sensing arm and reference arm, are fixed in the parallel form which is used to maintain the interferometer system in quadrature by a PID controller.



# Working Model



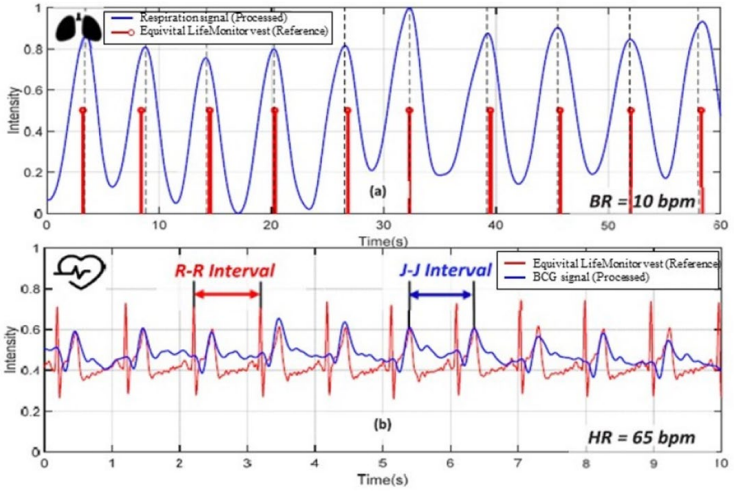






A proportional-derivative (PD) controller can be used **to make a simple system track some reference point**.

A PID controller is **an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables**.

# Accuracy and reliability evaluation




- While the smart cushion will be used to extract HR and BR signals of the operator, its measurement accuracy will be evaluated against the measures from an Equivital EQ02 LifeMonitor vest.

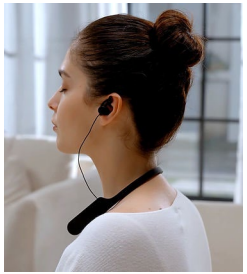
- The Equivital LifeMonitor vest is chosen as a ground truth because studies have found it to be a reliable and valid instrument for monitoring HR and BR signals.

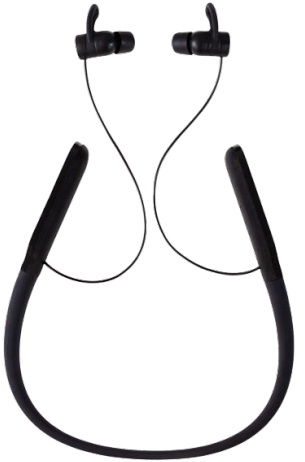
# Application of Smart cushion

- The system finds various applications in different fields especially in the areas of construction industry, where workers operate heavy machinery (like oil and sea ores) which requires continuous monitoring

- The second most critical aspect is for construction workers drivers transporting materials on the site with uneven surfaces which could deteriorate workers health and requires constant monitoring to avoid hazards and accidents

# IN-EAR DEVICE TO MEASURE EEG AND ECG





# Mental fatigue assessment method

Mental fatigue can be reflected in the changes of individual subjective evaluation, behavioral performance, and physiological performance.

(1) Self-report-based methods

- Questionnaires or interviews using the Fatigue Severity Scale (FSS)

(2) Contact and non-contact based monitoring sensors

- Electrodermal activity (EDA) sensors
- Cameras
- Ultra-wideband (UWB)
- Acoustic-based sensors

✗ subjective

✗ cause work interruption

✗ impractical for simultaneous monitoring of multiple workers

✗ hinder individual movements

✗ easily distorted by noise and movements

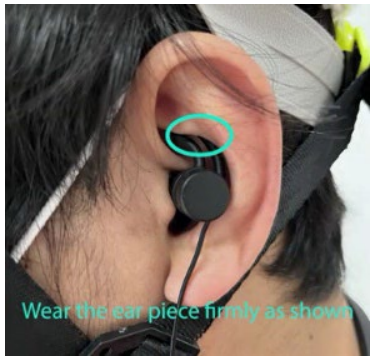
✗ privacy issues

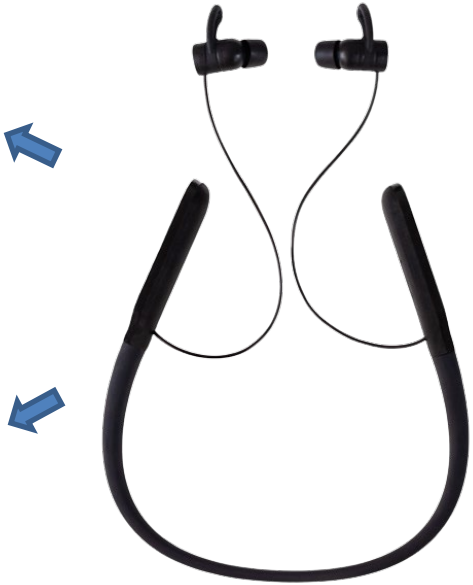
✗ not real time

# Structure and mechanism

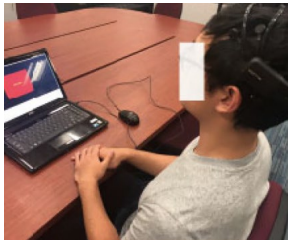
*The in-ear device fitting for construction workers*

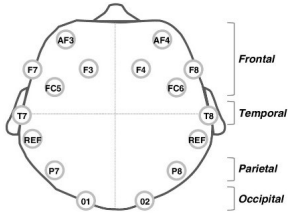





# Proposed method



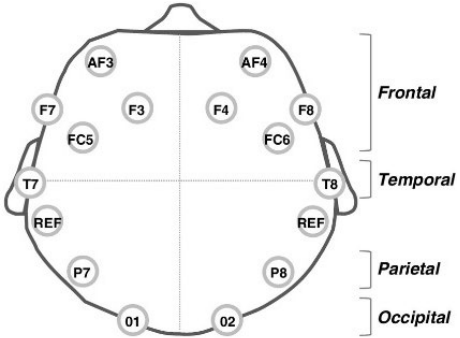



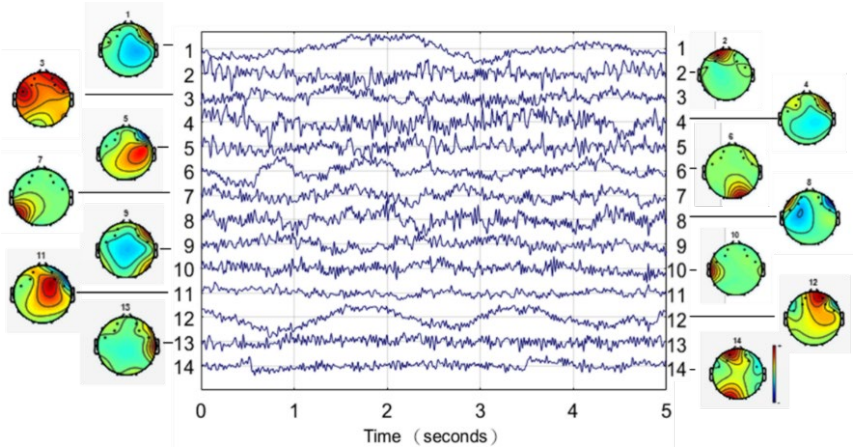

(3) Scalp-based EEG

- Wearable, non-invasive monitoring devices
- No privacy issues involved
- Objective monitoring approach

# Data collection, analysis and correlation

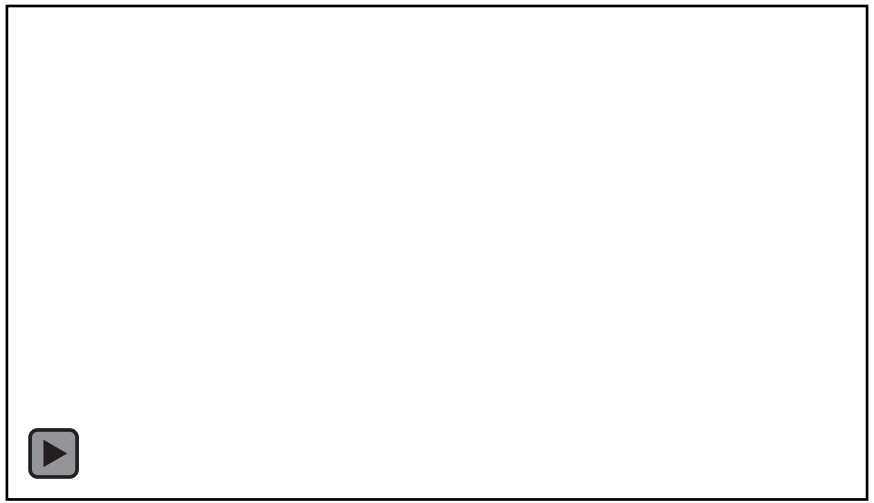
- Various **machine learning** algorithms have been applied in EEG decoding.
- **Deep learning** algorithms used in EEG signal decoding are applied from the four categories: convolutional neural network (CNN), deep belief networks (DBN), auto-encoder (AE) and recurrent neural network (RNN).



# Working Model

| Ear-EEG type | Applications | Selected features |
|---|---|---|
| In-ear EEG/ECG | Auditory attention | Event-related potential |
| | Sleep monitoring | Multi-scale fuzzy entropy |
| | High and low cognitive tasks | Common spatial pattern |
| | Sleep monitoring | Power spectral density |
| | Attention State Classification | Power spectral density and temporal features |
| | Sleep staging assessment | Power spectral density and temporal features |
| | Eye-state identification | Filtered time-series |



**Contact Prof LI Heng**

# Thank you!

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