Physiological signal processing for human-centric applications

Prof. Naeem Ramzan

Naeem.Ramzan@uws.ac.uk

Director of Affective and Human Computing for Smart Environment
(www.ahcse.uws.ac.uk)

Programme Leader of MSc Advanced Computing, MSc Big Data, MSc IoT
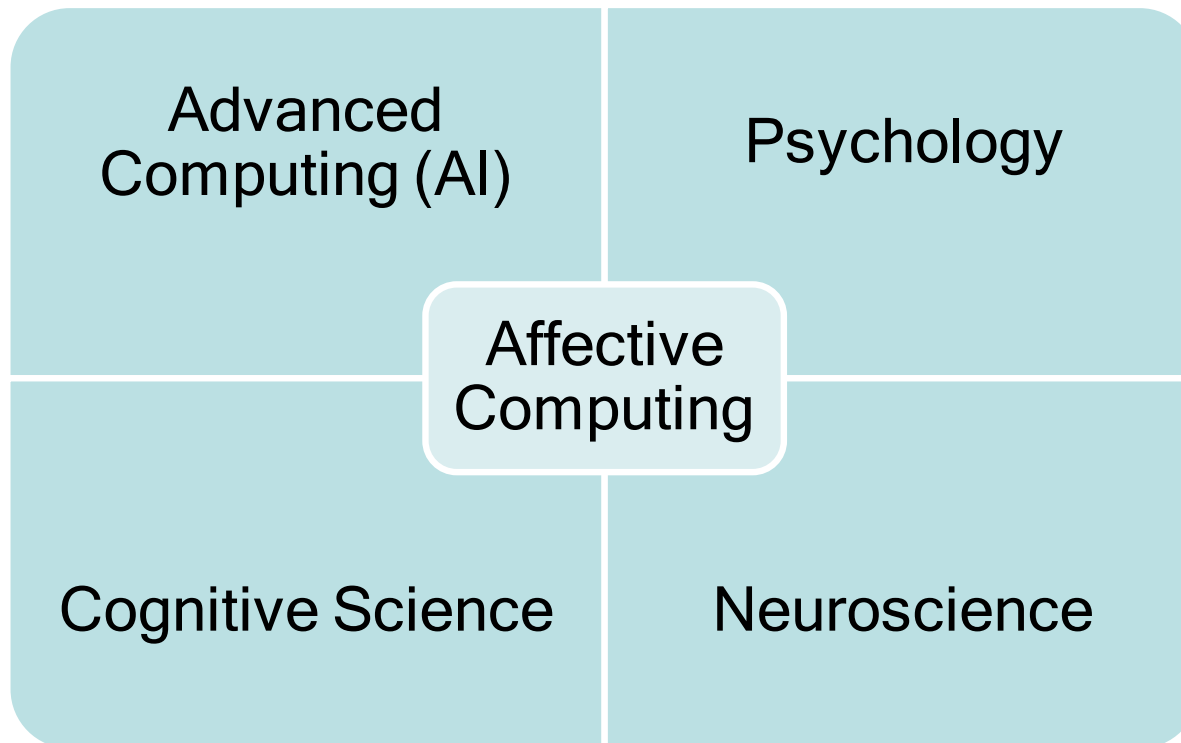
Technologies for Brain Health and Dementia Prevention Workshop

13-14 June 2022

Definition

- Affective Computing (Emotional AI) is an emerging technology that enables the systems and devices to identify, interpret and **stimulate human affects**.

| Advanced Computing (AI)	Psychology
Cognitive Science	Neuroscience

Affective Computing

Affect detection and recognition

- Conventional Method (surveys, focus group, interviews)
- Recent advances
  - Facial expression
  - Speech/vocal expression
  - Gesture expression
  - Biosignal analysis
    - Physiological sensors
    - Wearable sensors
  - Brian/Heart signal analysis
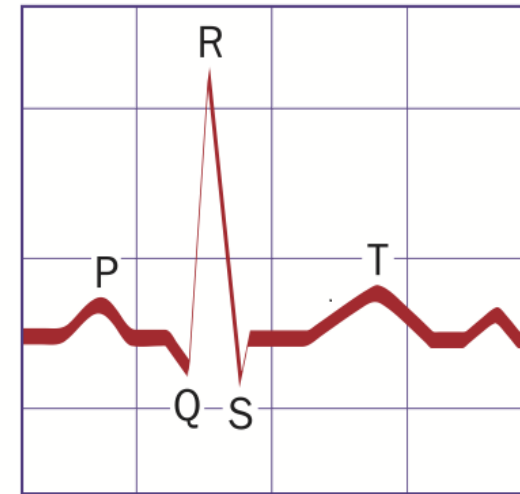 - Skin Galvanic response

Applications

- **Emotion Recognition using Kinect for Facial and Corporal Expression**
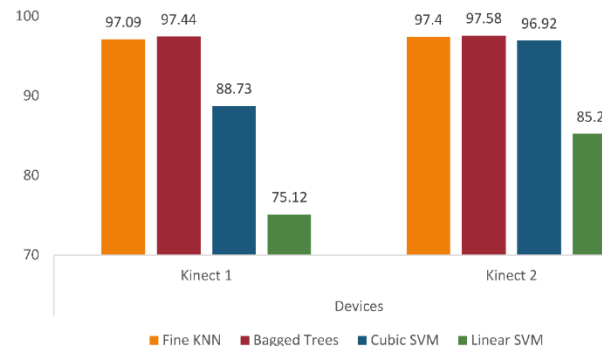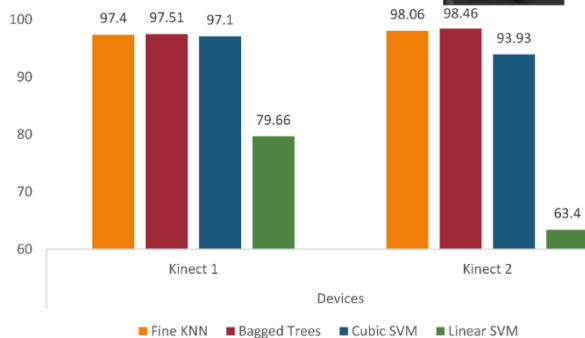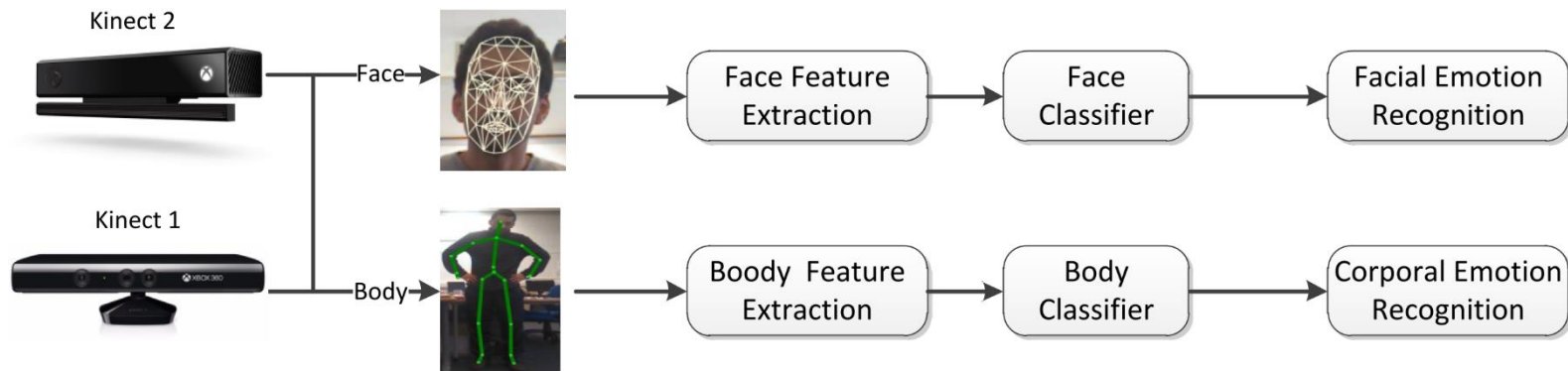
Physiological signals

- ECG: Recording of electrical activity of the heart over a period of time.

    – *Usually identified by five peaks and valleys represented by the letters P, Q, R, S, T*

ECG

- EMG: Recording of electrical activity produced by muscles.

RAW EMG Signal
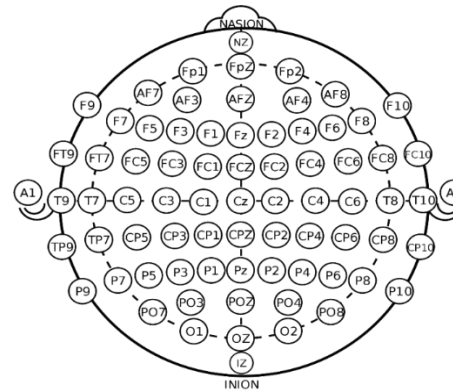
Rectified EMG Signal

Rectified & Integrated EMG Signal

EMG

Physiological signals

Electroencephalography (EEG)

- Recording of electrical activity in the scalp.
- Different frequency bands are usually studied:
  - Delta (δ): 0-4Hz
  - Theta (θ): 4-8 Hz
  - Alpha (α): 8-12 Hz
  - Beta (β): 12-30 Hz
  - Gamma (γ): 30+ Hz

Physiological signals (pre-processing)

- ECG signal pre-processing
    - Baseline wander reduction
- EMG signal pre-processing
    - 3% of lowest/highest peaks cut
    - 3rd order Butterworth FIR lowpass filter (0.4Hz cutoff)
    - Normalisation in range [0 , 1]
- EEG: Bandpass filter (0.4-65 Hz) and PREP pre-processing pipeline

Physiological signals (Feature Extraction)

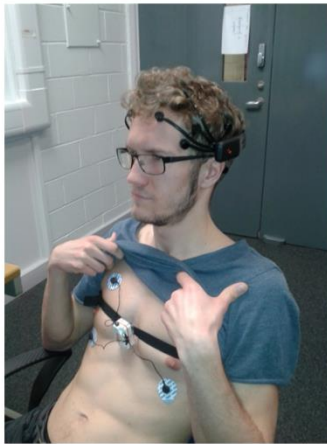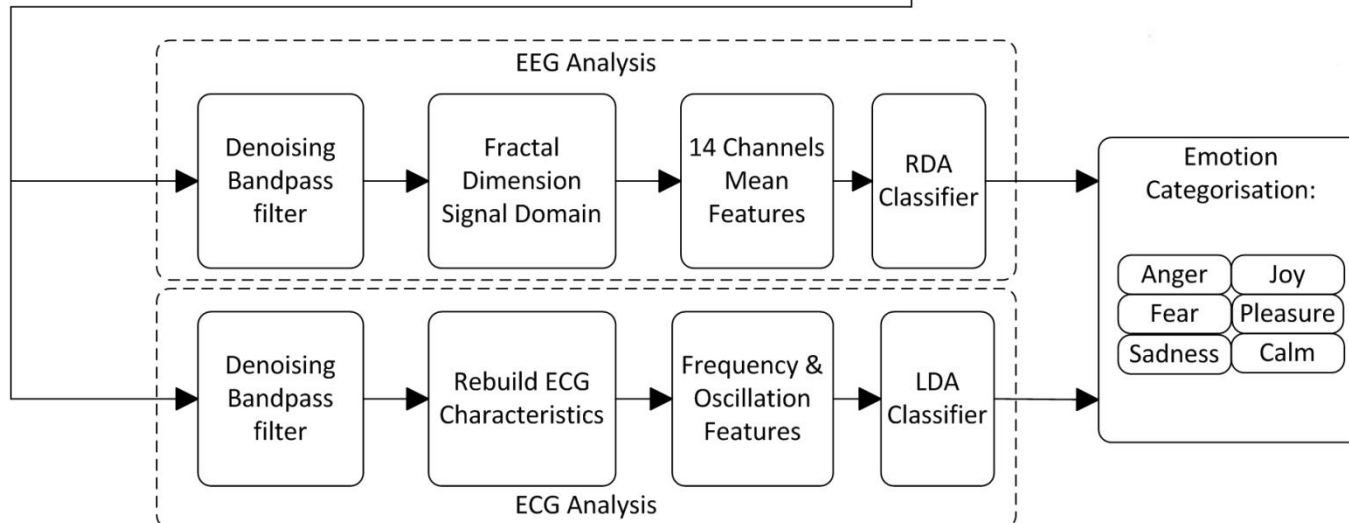| ECG	Maxima, minima, mean, media, standard deviation and range from the raw signal and the derivative of PQ, QS and ST complexes. Number of intervals with latency >50 ms from HRV. PSD from HRV between the intervals [0 , 0.2], [0.2 , 0.4], [0.4 , 0.6] and [0.6 , 0.8]. Maxima, minima, mean, median, standard deviation and range from HRV histogram. (84 features)
EMG	Maxima, minima, median, mean, standard deviation, and number of times per time unit that the signal reached both the minima and the maxima, extracted from the a) raw signal, b) first derivative, and c) second derivative. (21 features)
EEG	Average PSD of EEG: The logarithm of the Power Spectral Density (PSD) of the theta, alpha, low alpha, beta, and gamma bands. Band-based Spectral EEG features: Spectral Bandwidth, Spectral Crest Factor, Spectral Flatness, Spectral Roll-off, Ratio f50 vs f90 MFCC of EEG: Mel Frequency Cepstral Coefficients (MFCCs) from the 0.5-40 Hz. 4-40 Hz. 0.5-30 Hz. and 4-30 Hz bands.

Applications

- **Emotion Recognition using Brain and Heart Signals**

Stimulus

Subject

EEG Analysis

Denoising Bandpass filter → Fractal Dimension Signal Domain → 14 Channels Mean Features → RDA Classifier

ECG Analysis

Denoising Bandpass filter → Rebuild ECG Characteristics → Frequency & Oscillation Features → LDA Classifier

Emotion Categorisation:

Anger	Joy
Fear	Pleasure
Sadness	Calm

"DREAMER: A Database for Emotion Recognition Through EEG and ECG Signals from Wireless Low-cost Off-the-Shelf Devices", IEEE Journal of Biomedical and Health Informatics, 2017.

Applications
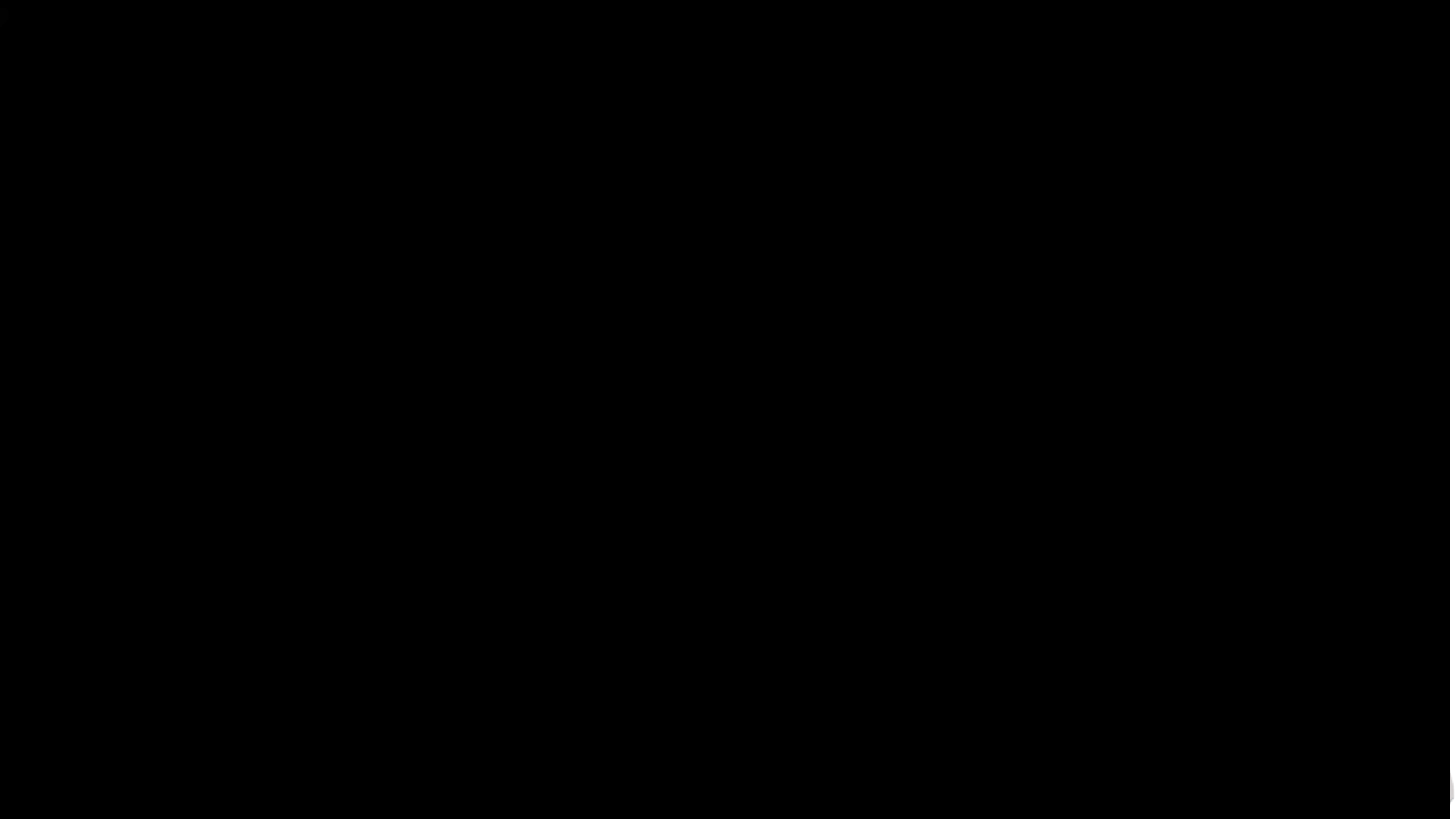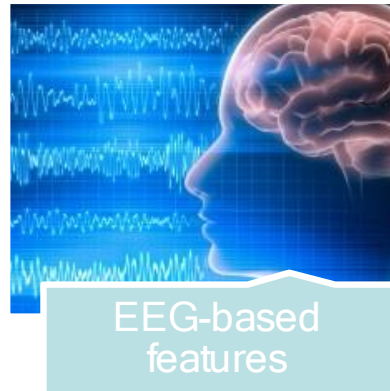
- **Emotional Gym**

Applications

- **EEG-based subject identification**

  - We are studying the effect of emotions in the performance of EEG-based biometrics

User identification request

EEG-based features

Machine learning

Subject identification

"On the influence of affect in EEG-based subject identification", IEEE Transactions on Affective Computing, Nov. 2018.
"BED: A New Data Set for EEG-Based Biometrics", IEEE Internet of Things Journal, 2021.
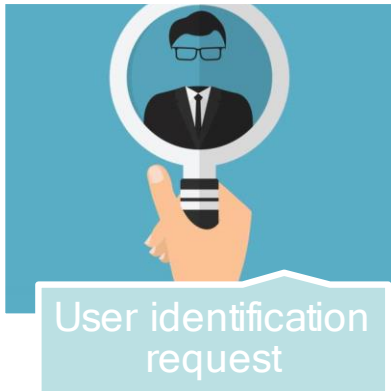
Applications

- **Dementia episode detection**

  - We plan on using machine learning techniques in order to detect episodes of disorientation or confusion in patients with dementia

  - Main idea: Implement in a robotic assistant that would be used in care homes

""You Feel Like You Kind of Walk Between the Two Worlds": A Participatory Study Exploring How Technology Can Support Emotion Regulation for Autistic People", Journal of Autism and Developmental Disorders, 2022.

Applications

Market Dynamics

- Main Drivers
    - Growing demand for wearable devices
    - Increased focus of R&D institutions on software technologies
    - Increased usage of computing technologies in various sectors
    - Various applications for technology oriented customers
- Main Restraints
    - Security-related issues and misuse of data
    - Complexity of technology
    - Privacy apprehensions

THANK YOU

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