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Perception-Comprehension-Action Cycle Enhancement based on Emotions in Human-Robot Interactions

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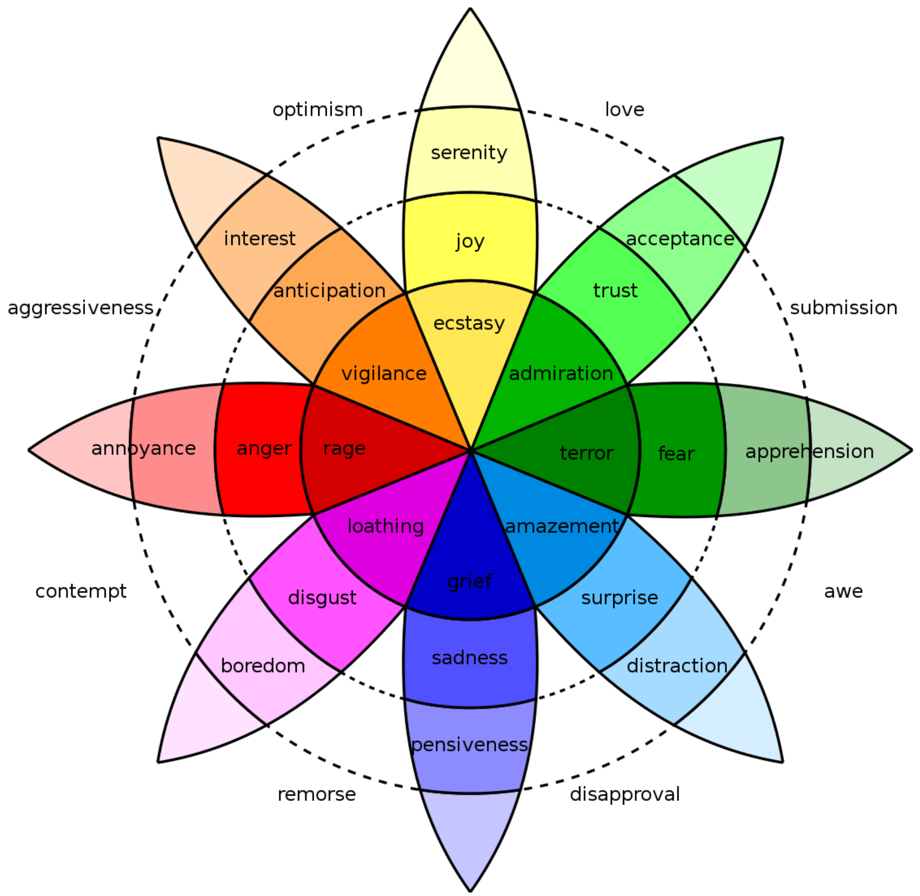
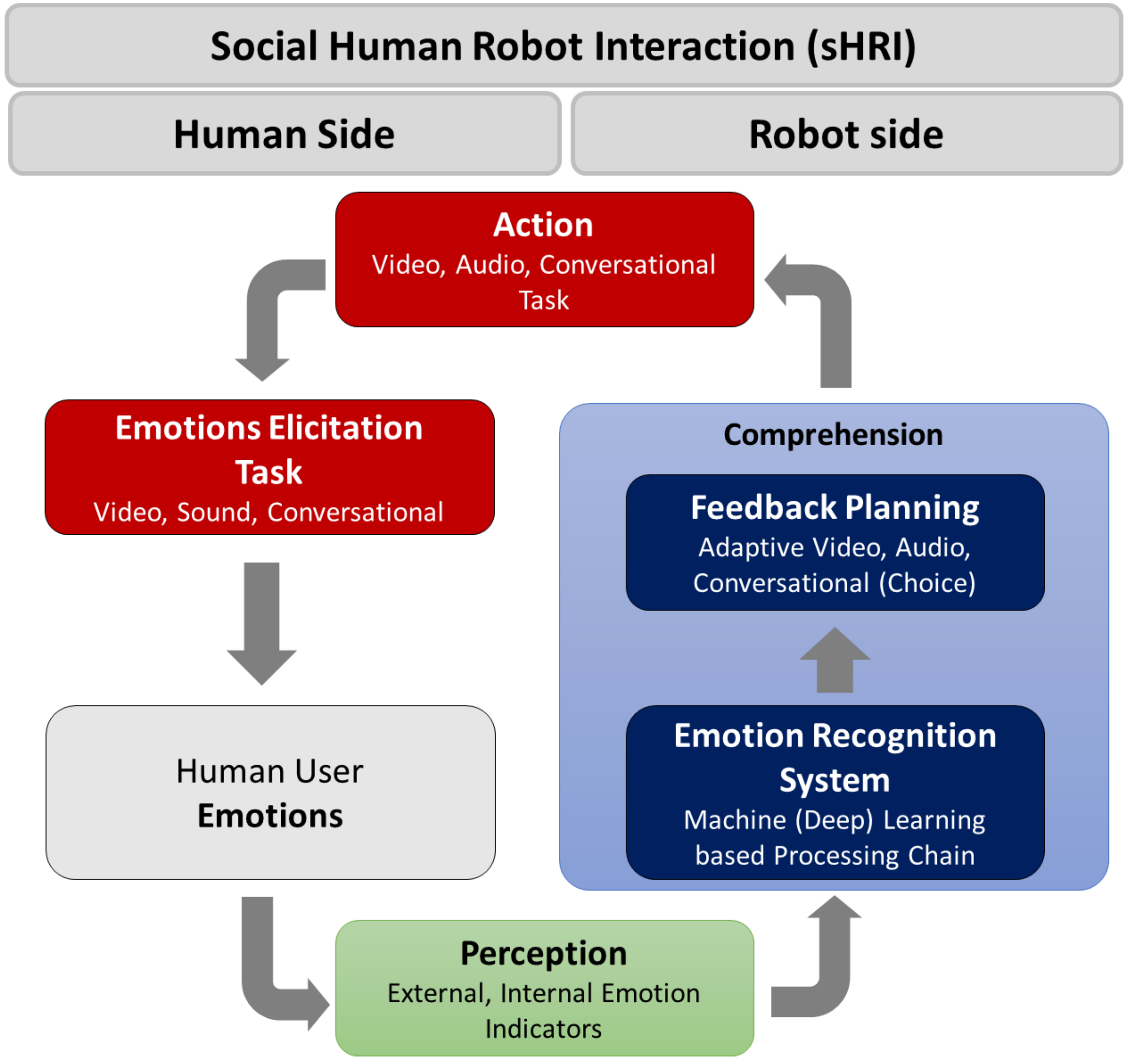
Outline

- ✓ **Introduction**
- ✓ **Motivations and Aims**
- ✓ **The Architecture**
- ✓ **Results**
  - ○ Dataset
  - ○ System Performance
- ✓ **Conclusions**



Plutchik, R. The nature of emotions: Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice. American scientist 2001 89.4: 344-350.

Introduction: Affective Loop



Perception-comprehension-action cycle in Human-Robot Interactions

Perception

- **External Indicators :** Natural Language Analysis, face and body motion
- **Internal Indicators:** Physiological Signals

Comprehension

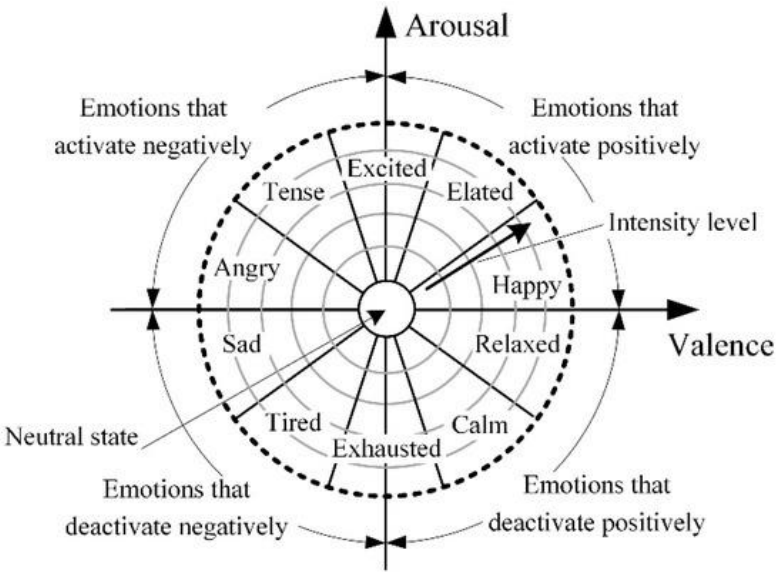
- Semantic-based approach
- **Machine (Deep) Learning approach**

Action

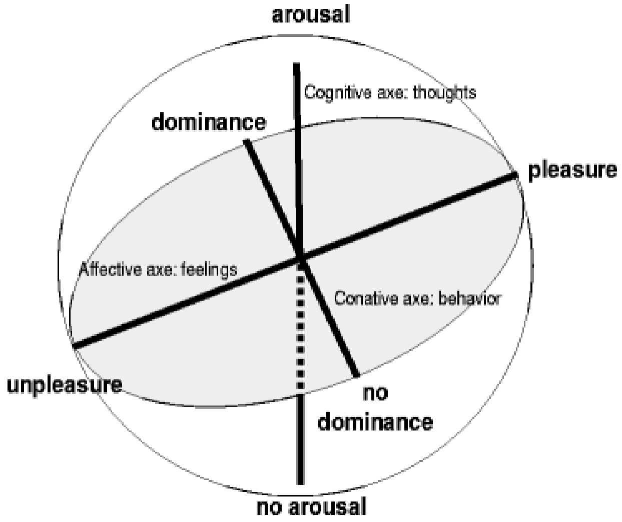
- Adaptive Conversational Task
- Senses Stimulation

Expansion of Personal Care Robots (PCRs) social sphere

Introduction: Emotions Classification



Circumplex model of Affect



Arousal Valence and Dominance model

Emotion Classification

Word –based description:

- Wheel of Emotions (Plutchick [1])
- Seven Primitive Emotions model (Ekman[2])

Quantitative description:

- **Circumplex Model:** 2D model based on Arousal and Valence Parameter [3]
- **Improved Circumplex Model:** 3D model based on Arousal, Valence and Dominance Parameter [3]

[1] Plutchik, R. The nature of emotions: Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice. American scientist 2001 89.4: 344-350.
[2] Ekman, P. An argument for basic emotions. Cognition & emotion 1992 6(3-4), 169-200.
[3] Braun, M., Schubert, J., Pfleging, B., and Alt, F. Improving driver emotions with affective strategies. Multimodal Technologies and Interaction 2019, 3(1), 21.

Introduction: State-of-the-Art

Ref.	Classified Emotions	Feature Extraction	Classifier	Accuracy (%)
Gannouni S. et al. 2020	Happy, pleased, relaxed, excited, neutral, calm, distressed, miserable, depressed	Power Spectrum Density (PSD), Sensitive lobes selection, and relevant electrodes selection	10 classifiers Not specified	A: 82.35 V: 79.95 D: 71.14 AVD: 65 (80% max)
Li G. et al. 2017	Excited, relaxed, negative	Wavelet Packet Transform (WPT), Relative power spectrum energy, variance, sample entropy of β band	RBF-SVM	A: 94.1 (max) V: 58.8 (max)
Mohammadpour M. et al. 2019	Fear, sad, frustrated, happy, pleasant, satisfied	Discrete Wavelet Transform (DWT), Statistical features of 4 EEG frequency bands: δ, θ, α, β.	ANN (best results) kNN SVM	AV: 55.58
Barjinder K. et al. 2018	Calm, anger, happiness	Non-stationary and non-linear features with the fractal dimension (FD)	RBF - SVM	AV: 60
Gupta V. et al. 2019	Two binary classifiers (singularly or together): HV/LV and HA/LA	Information Potential (IP) from the flexible analytic wavelet transform (FAWT)	RF	A: 79.95 V: ~80 AV: 71.43
Valenza G. et al. 2020	HA/LA	Time features: peak to peak mean, variance. Frequency features: Hjorth parameters, maximum power spectral frequency, Power Spectrum Density (PSD), and power sum	RF (best results) kNN SVM	A: 62.58

Acronyms: N.A.: RBF- radial basis function; SVM – Support Vector Machine; ANN: Artificial Neural Network; RF: Random Forest; kNN: k-Nearest Neighbour; H(L)V - High(Low) Valence; H(L)A - High Low Arousal

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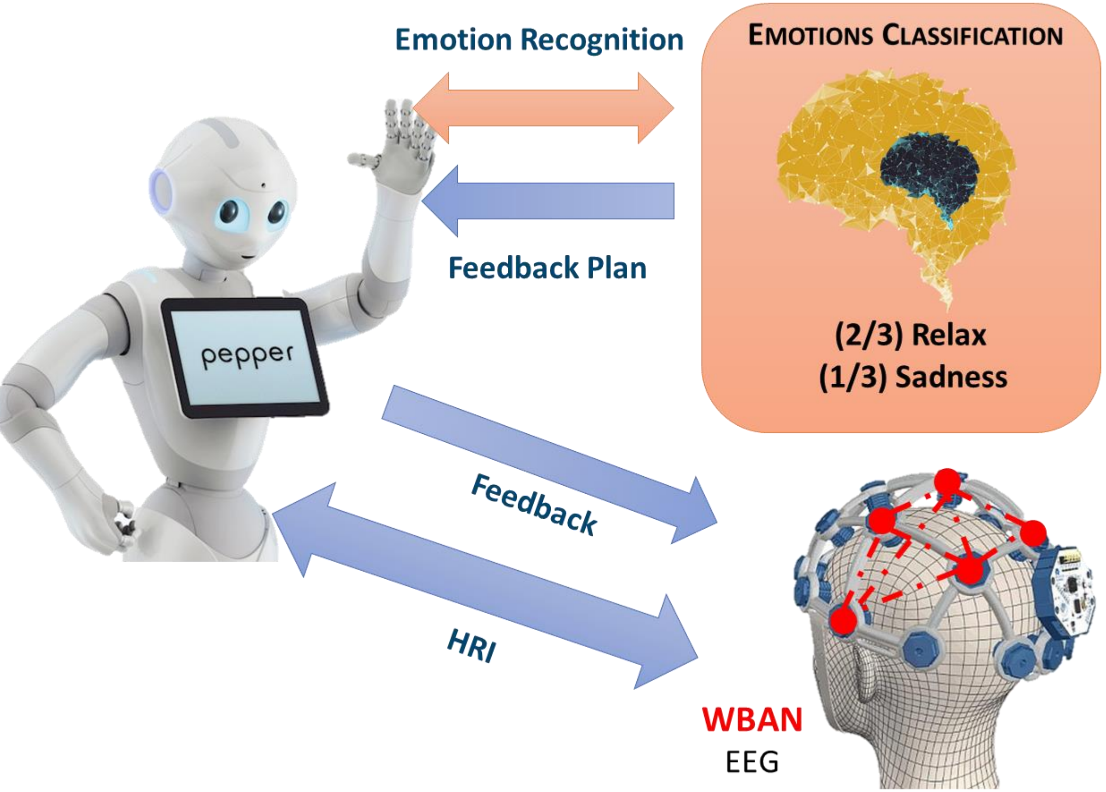
Valenza G. et al. 2020	HA/LA	Time features: p[illegible] Frequency features: Hjorth parameters, maximum power spectral frequency, Power Spectrum Density (PSD), and power sum	[illegible] (best results) kNN SVM	A: 62.58

The use of the **AVD model** permits to **increase** the number of **detectable emotions**

An increment in the **overall accuracy** is necessary to plan a proper feedback. **Must be maximized.**

Acronyms: N.A.: RBF- radial basis function; SVM – Support Vector Machine; ANN: Artificial Neural Network; RF: Random Forest; kNN: k-Nearest Neighbour; H(L)V - High(Low) Valence; H(L)A - High Low Arousal

Motivations and Aims



Proposed Architecture Workflow

The work proposes the **design** and **test** of an **EEG-based emotion recognition system** that ensures:

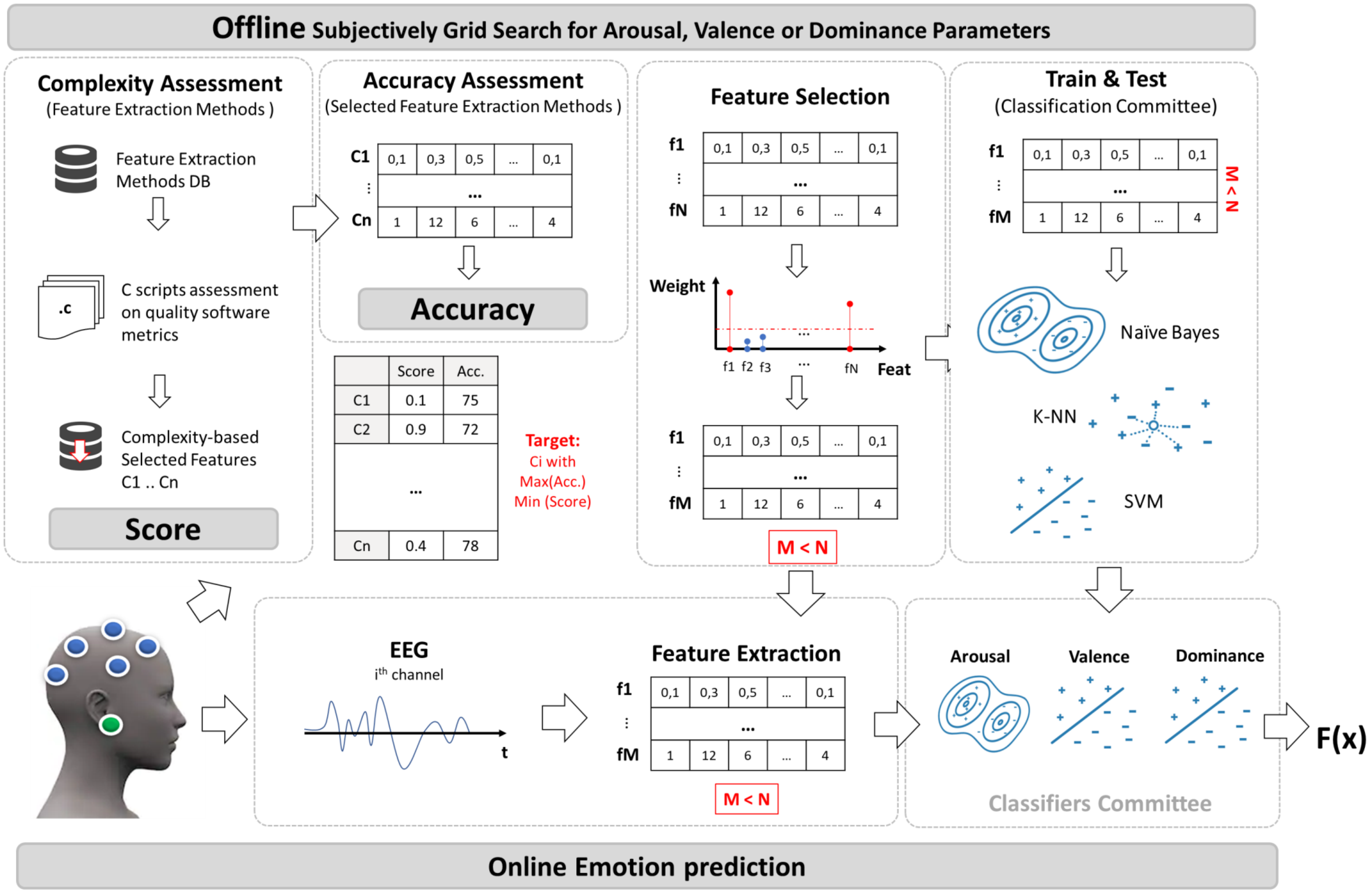
- **low-memory** usage and **low-complexity** operations
- Suitability for embedded electronics and congested PCR cores
- **High** emotion recognition **accuracy** (>70%)

METHOD

Using a **grid-search routine** based on a **multi-objective optimization** of the **features extraction** stage.

It consists of **assessing** - ***together*** - the **easiness of implementation**, memory usage, and **classification performance**

The Architecture



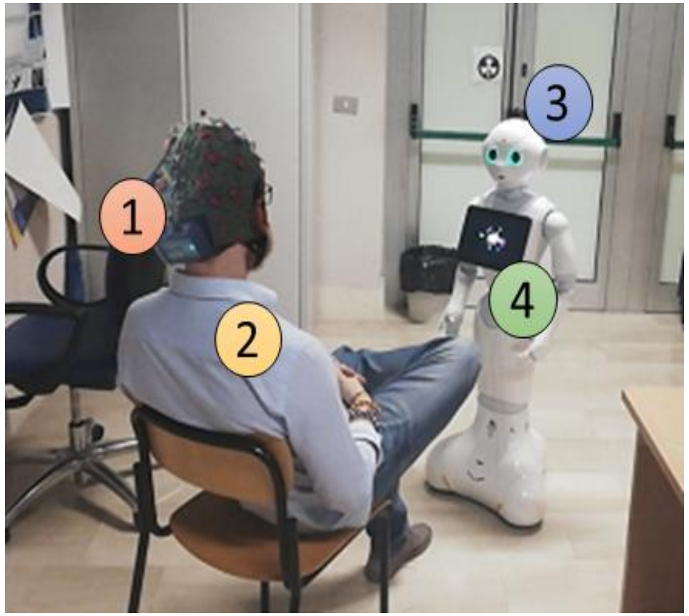
Results

Algorithm Design, Validation and Test:

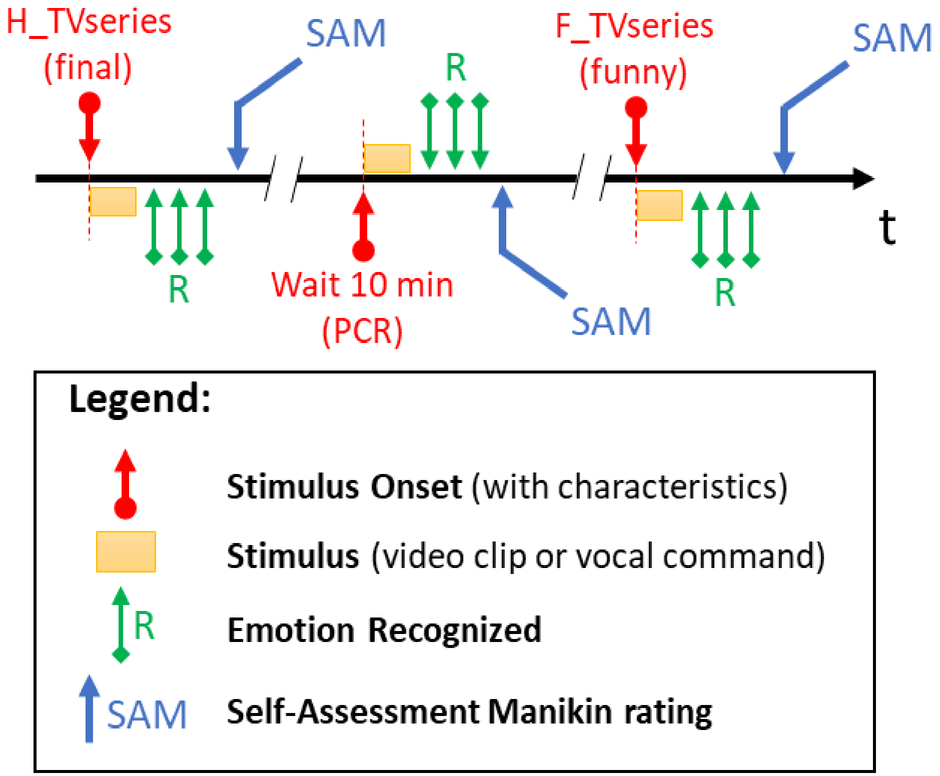
DEAP Dataset: https://www.eecs.qmul.ac.uk/mmv/datasets/deap/readme.html

32 Subjects (range: 19-37 years old) watching at 40 1-min long music videos.
Arousal Valence and Dominance evaluated via **self-assessment manikin** (SAM) rating scale

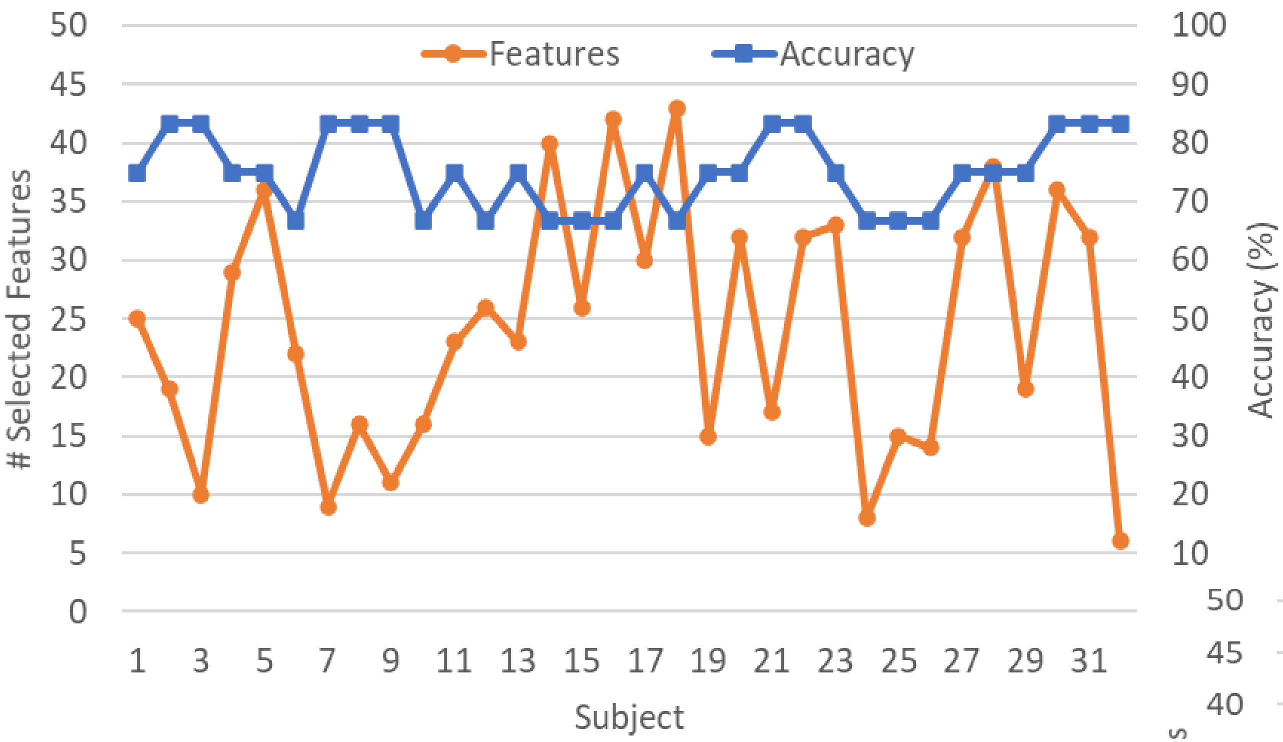
Real Life Scenario Application:



Experimental setup for the emotion recognition system application in a real-life scenario.

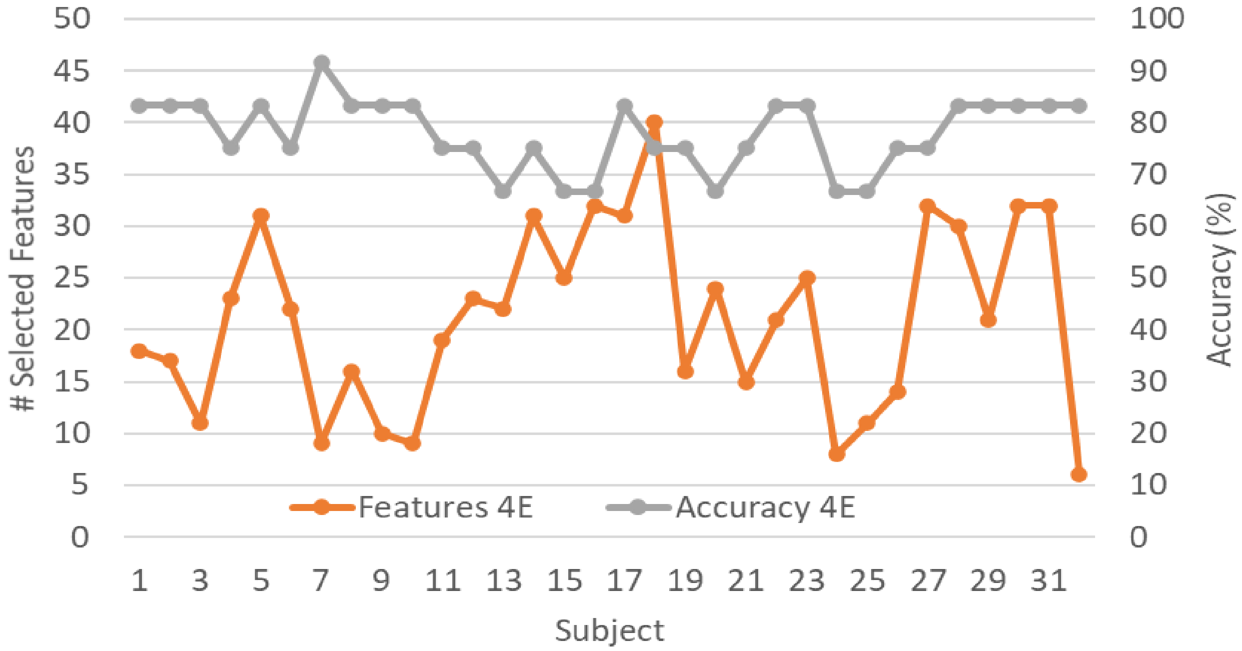


Results: Classification Performance



In the **8-emotion discrimination context** the proposed system showed an **overall accuracy** of **75 ± 6.7 %.**

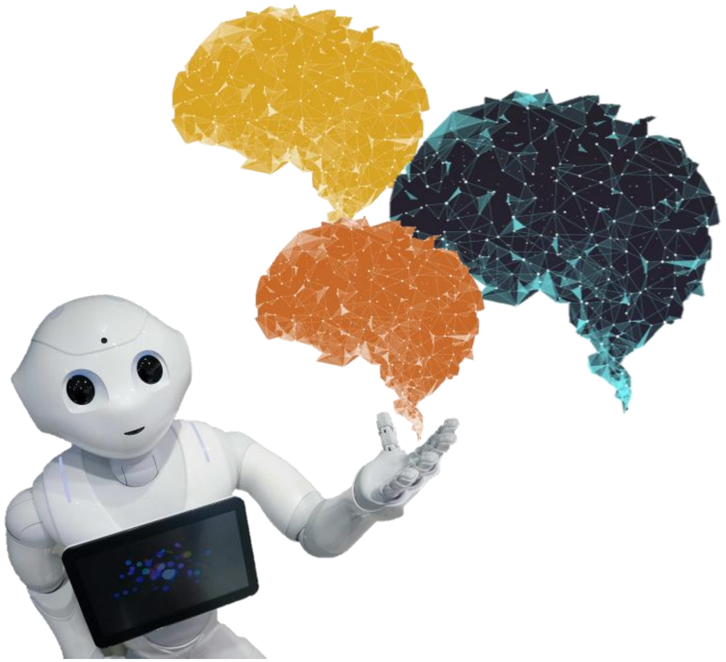
In the **4-emotion discrimination context** the proposed system showed an **overall accuracy** of **77.86 ± 6.89 %**



Conclusions

This work focused on the **design,** and **test** of a novel emotion recognition system for the perception-comprehension-action cycle improvement in HRIs.

The proposed system exploits **EEG signals** to find a **direct connection** between the **brain activity** and the **arousal-valence-dominance model** .



The system uses a **multi-objective optimization** of the features extraction stage, which consists of **assessing** - **together** - the **easiness of implementation** and **classification performance**.

The system performance have been validated on an online dataset (DEAP) and in a real-life scenario.

The system can reach an **overall accuracy** of **75%** on **8 emotions** discrimination and **~77%** on **4 emotions.**