On Applying Ambient Intelligence to Assist People with Profound Intellectual and Multiple Disabilities

Michał Kosiedowski
Poznań Supercomputing and Networking Center, Poland

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

Jožef Stefan Institute

INSENSION

www.insension.eu

Personalized intelligent platform enabling interaction with digital services to individuals with profound and multiple learning disabilities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

PARTNERS:

PSNC

Pädagogische Hochschule HEIDELBERG University of Education

Jožef Stefan Institute

CTIC centro tecnológico

stowarzyszenie na tak

HARPO

The goal

Design and develop an ICT platform that <u>enables</u> persons with profound intellectual and multiple disabilities (PIMD) to use digital applications and services that:

- **can enhance the quality of their life**
- **increase their ability to self-determination**
- **and enrich their life.**

INSENSION

People with profound intellectual and mutliple disabilities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

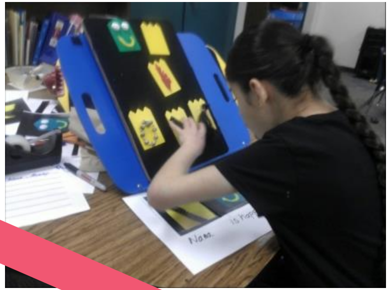
PSNC Pädagogische Hochschule HEIDELBERG University of Education Jožef Stefan Institute CTIC centro tecnológico stowarzyszenie na tak HARPO

People with PIMD

- **profound intellectual disability (IQ < 20) combined with other disabilities:** severe forms of motor disabilities, sensory disabilities (hearing or visual impairment), severe forms of epilepsy (on heavy medicamentations, frequent epileptic seizures up to grand mal)
- **communication:**
  - (usually) no verbal language
  - often on a pre-symbolic level
  - use of unconventional behavior signals
- **long-term high need for therapy, care, support (WHOLE LIFE!)**

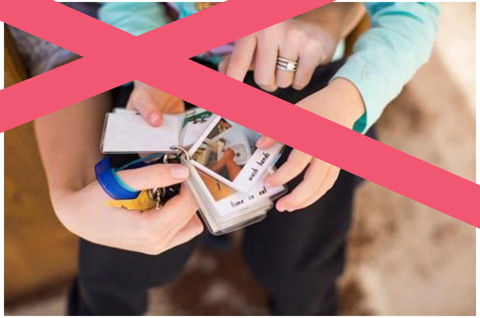
→ **difficult social participation!**

Non-symbolic interaction (1)



Request an it

Receive the item



AUGMENTATIVE AND ALTERNATIVE COMMUNICATION

Non-symbolic interaction (2)

- Reactions to the happenings around through:
  - gestures
  - facial expressions
  - vocalizations
  - gaze

- These signals are highly individual!

Non-symbolic interaction (3)

ACCEPT
(I WANT IT)

DEMAND

?

COMMENT

DISAPPROVE
(I DON’T WANT IT)

PROTEST

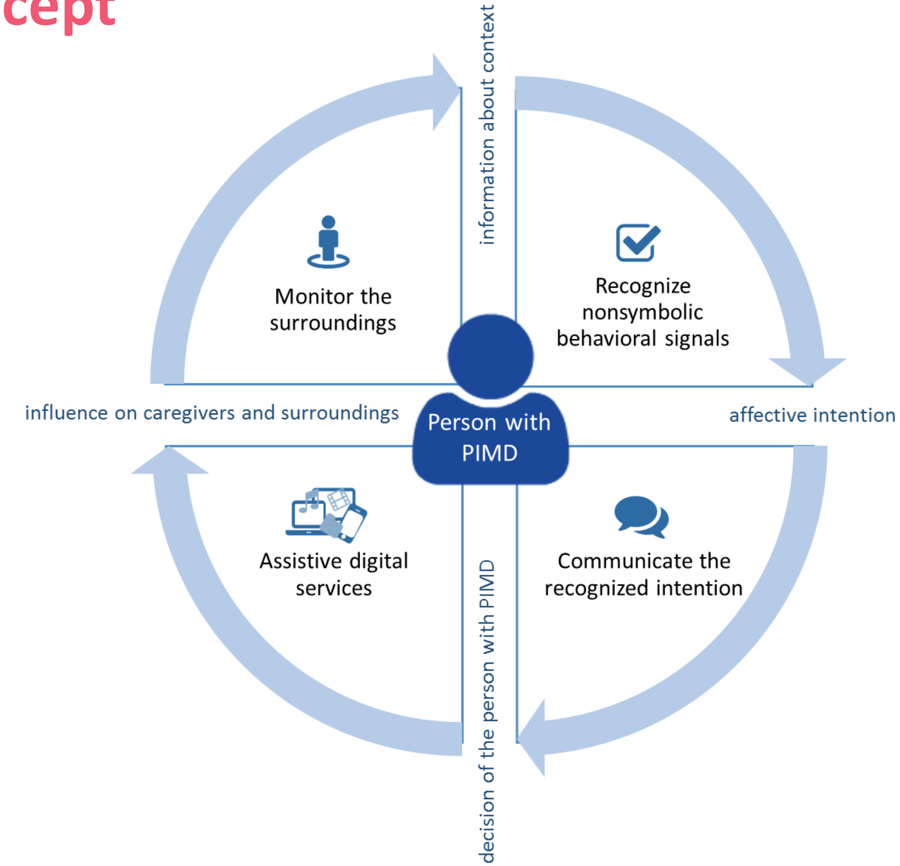
Physiological affective response

- *„heart rate and skin temperature can give information about the emotions of persons with severe and profound ID"* [Vos et al. 2012]
- *„frequent consistent physiological reactions"* to stimuli [Lima et al. 2013]
- *„a shallow, fast breathing pattern, used less thoracic breathing, had a higher skin conductance and had less RSA when experiencing positive emotions then when experiencing negative emotions"* [Vos et al. 2010]

The INSENSION Platform

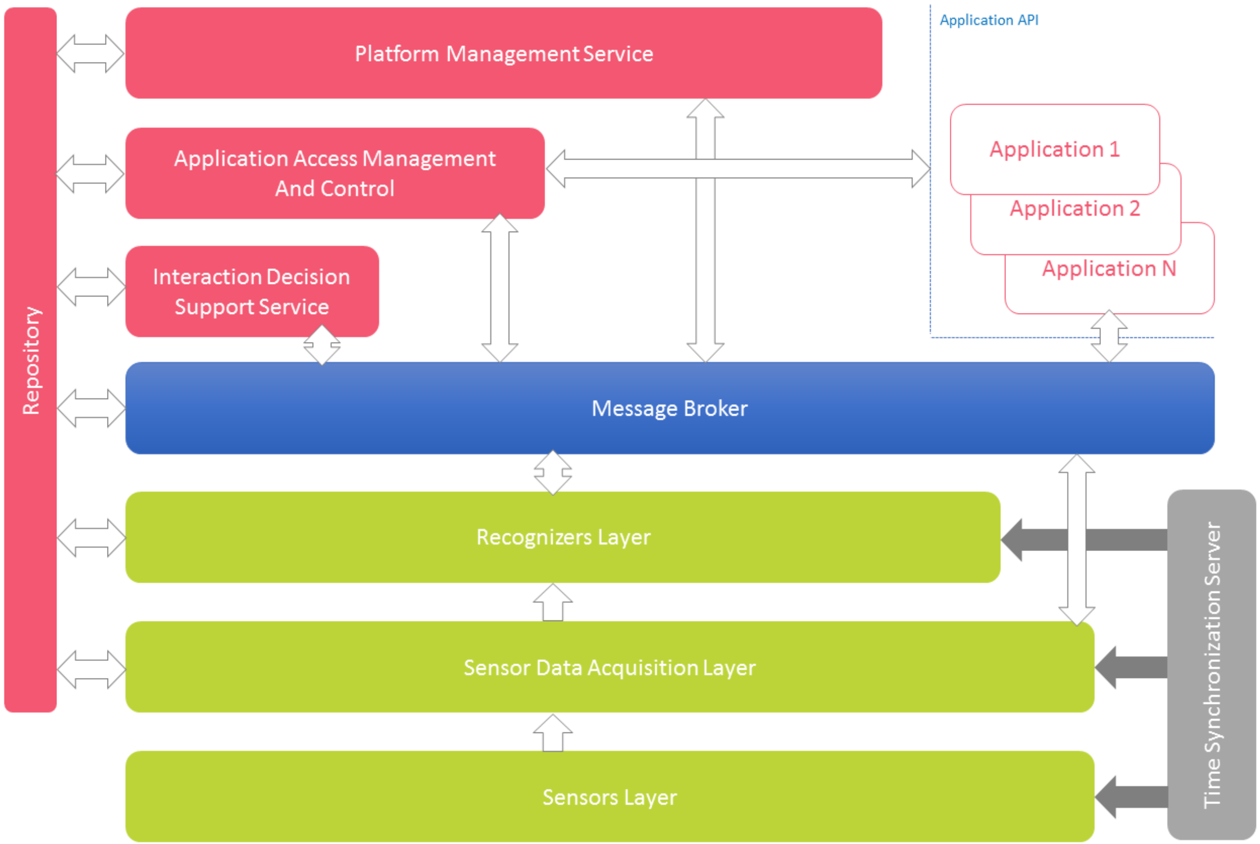
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

General concept



System architecture

Event-driven



INSENSION

AI components

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

PSNC

Pädagogische Hochschule HEIDELBERG University of Education

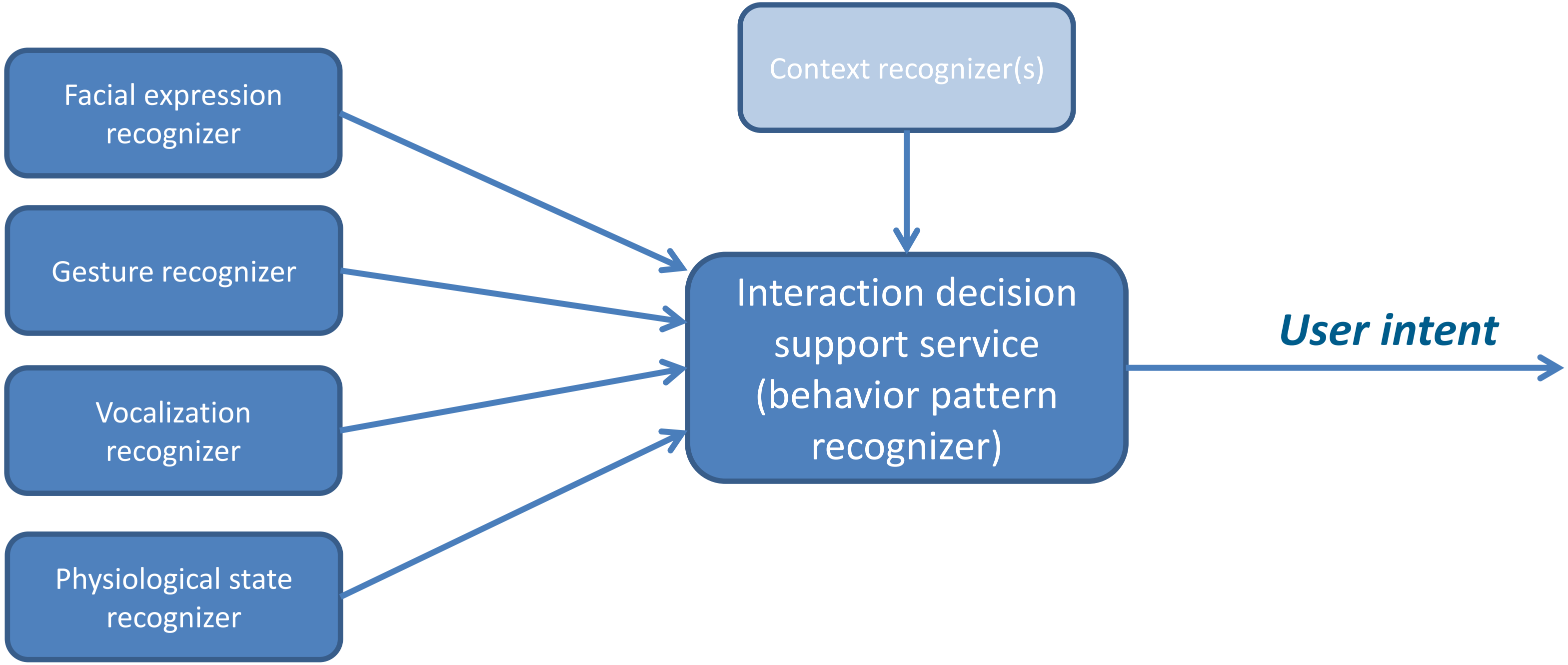
Jožef Stefan Institute

CTIC

na tak

HARPO

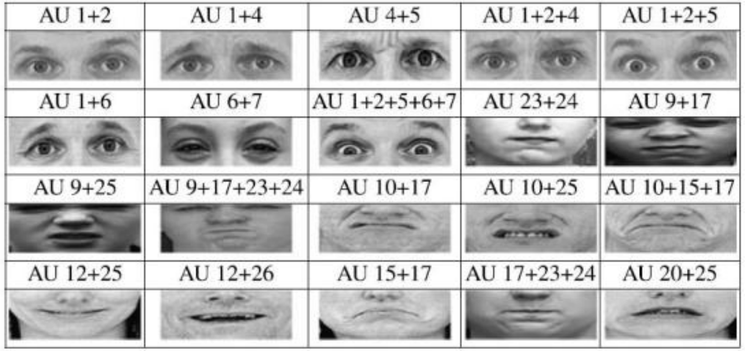
AI workflow in INSENSION



INSENSION

Facial expression recognition

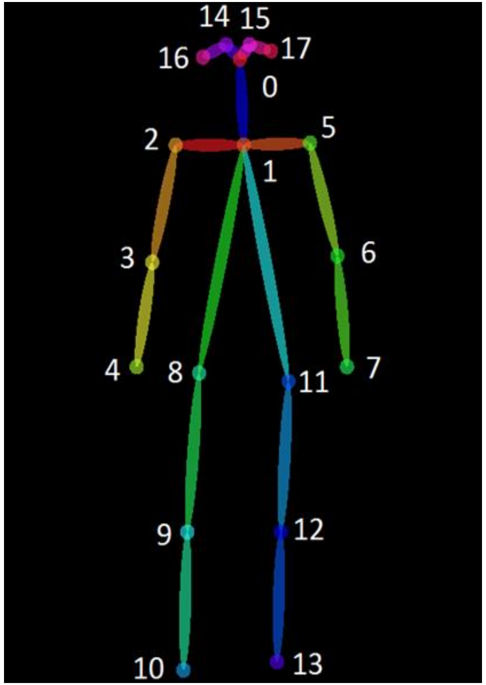
- We identify facial changes as facial action units (AUs) and facial expressions can be defined as the combination of these AUs
- Methodology
  - Extracting facial landmarks.
  - Characterizing the AUs using (relative) distances/positions between landmarks.
  - Collecting the database.
  - Implementing the algorithm for recognizing each facial expression
- We use public facial expression databases:
  - THE BOSPHORUS DATABASE (150 subjects, 4666 samples, 25 AUs)
  - The Cohn-Kanade AU-Coded Database (210 subjects, 593 samples, 30 AUs)
  - The ChildrenFacialExpression Database (12 subjects, 208 videos)



OpenPose

Gesture recognition

- Methodology:
  - Extracting body keypoints
  - Characterizing poses/movements using (relative) distances, angles, positions between keypoints
  - Collecting the database
  - Implementing the algorithm for recognizing each gesture

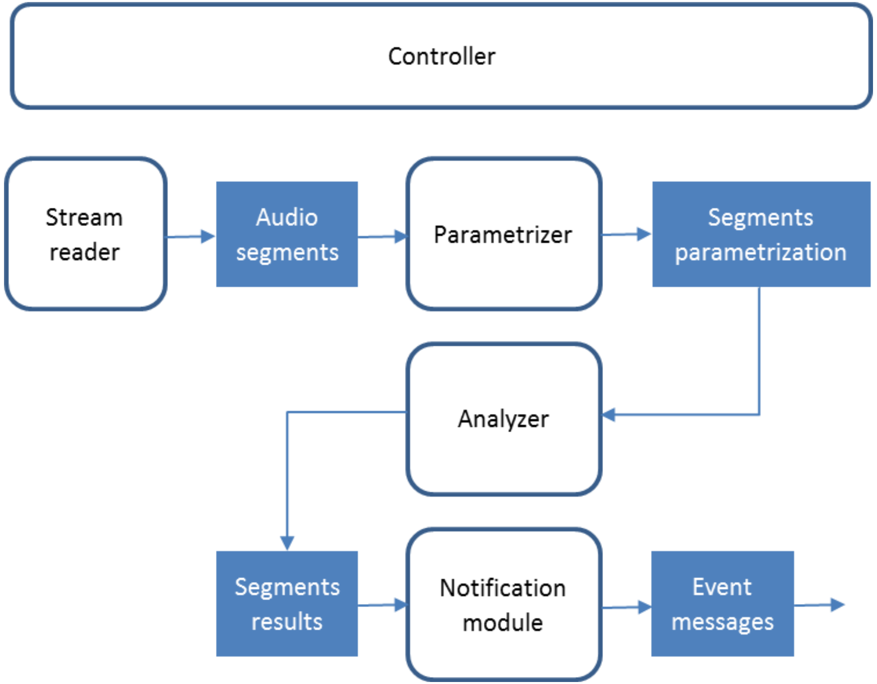


OpenPose

Vocalization recognition

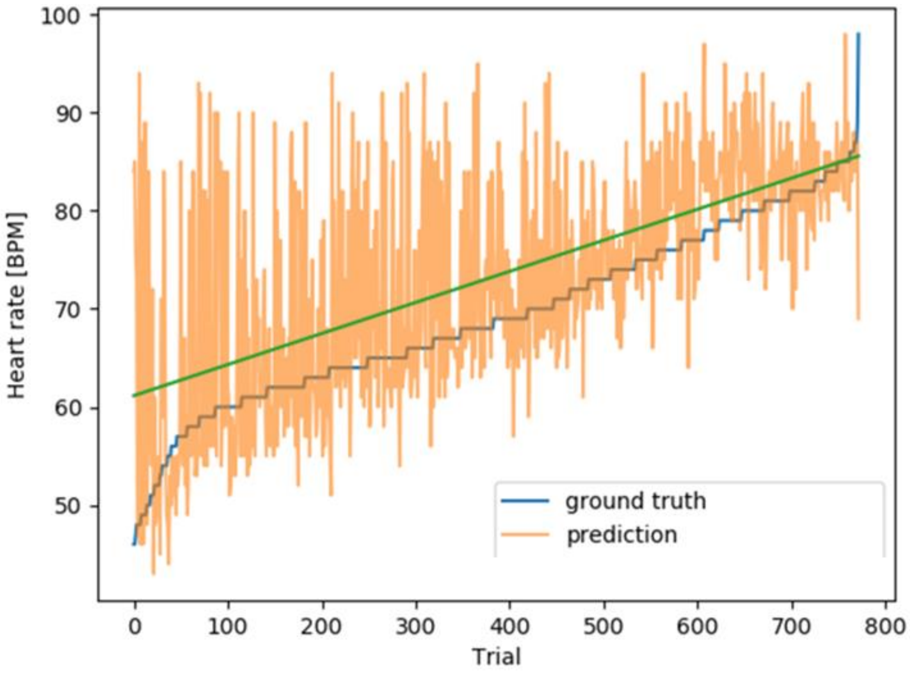
- A separate model constructed for each vocalization type

- Model training
  - Signal parametrization = mel-frequency cepstral coefficients (MFCC)
  - Training
    - Phase 1. Unsupervised audio frame clustering (Gaussian Mixture Model)
    - Phase 2. Reestimation (Baum-Welch-based, several iterations)
- Detection algorithm
  - Signal parametrization (MFCC)
  - Event detection using statistical process modeling (HMM)



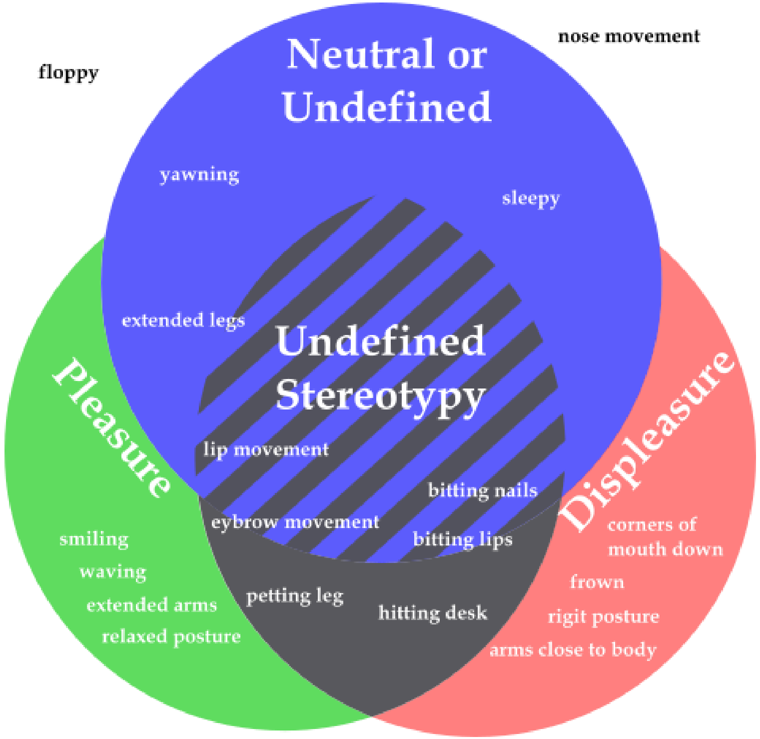
Video-based recognition of physiological state

- Two main approaches for PPG reconstruction using RGB cameras reported in literature:
  - analysis of changes in skin-color
  - analysis of small head movements induced by pumping of blood into head
- Our approach: deep neural network
  - Step 1: plane orthogonal to skin (POS) algorithm -> rough PPG reconstruction
  - Step 2: long short-term memory (LSTM) network -> improved reconstruction



Behavior pattern recognition

- The goal is to understand the inner state of the user (person with PIMD):
  - behavioral state: *pleasure, displeasure, neutral*
  - communication attempt: *demand, protest, comment*
- Several approaches to decision making tested:
  - Standard ML classification = sliding window -> recognized outputs as features -> behavior state / communication attempt as class
  - Unique non-symbolic communication signals model = each behavior state / communication attempt defined with unique combinations of non-symbolic communication signals (see figure)
  - Valence derived inner state model = each non-symbolic communication signal is assigned a "valence" – propensity for appearing during pleasure vs. displeasure and demand vs. protest; these valences are then added up
  - Decision support system based on expert knowledge



Summary

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.

Summary

- AI is a key technology for constructing a sort of a prosthesis of verbal communication for a person who is biologically unable to use verbal communication
- Primary challenge: building database of samples (especially concerning vocalizations)
- Facial expression and gesture recognition: no difference between people with PIMD and without disability -> components work very well for facial expressions and gestures known to the relevant components (accuracy > 90%)
- Sound recognition: experimenting with convolutional neural networks
  - early experiments show accuracy can be at 98% if the training set is around 50 samples
- Decision making: improvements to the expert system required

Thank you for your attention!

Find us on Facebook and on www.insension.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 780819.