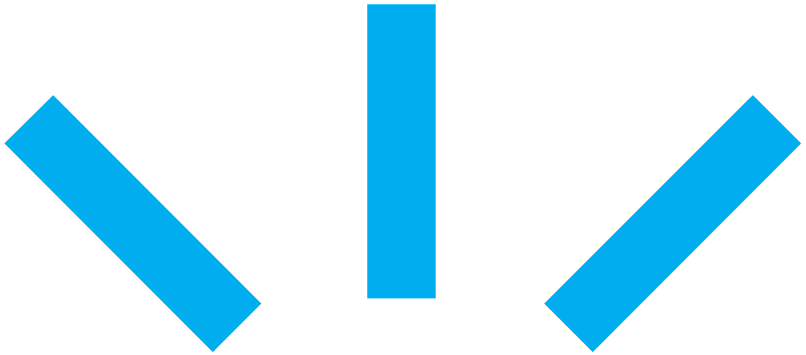

Multimodal signal analysis in medical applications

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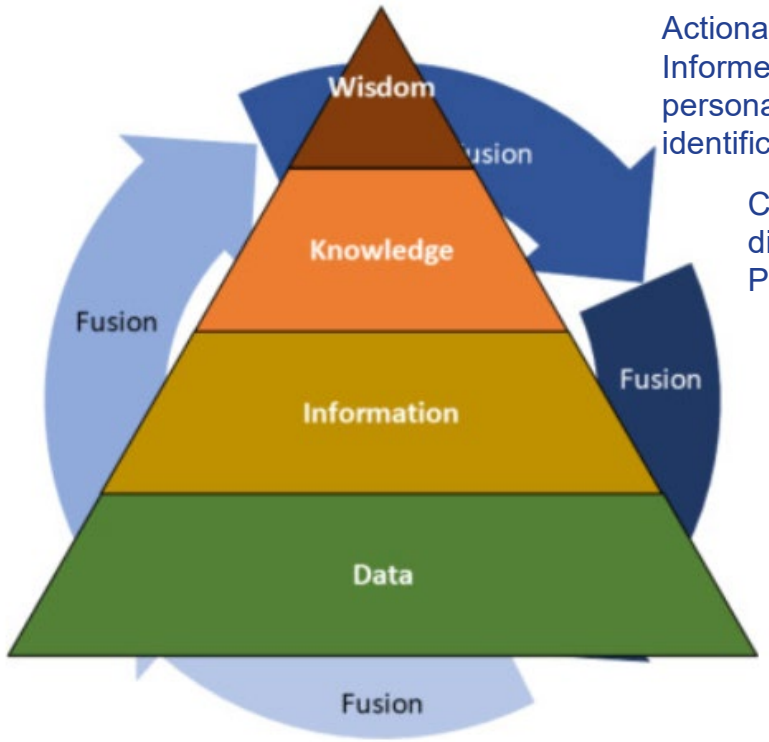
Multimodality in healthcare systems

- Multimodality in healthcare systems refers to the utilization of different data types with different representational modes
- As medical and health data become increasingly diverse, integrating multiple modalities can offer several advantages:

- Enhanced Accuracy: Combining information from various sources allows for more accurate information extraction and inference
- Reduced Bias: Multimodal approaches help mitigate bias by considering multiple perspectives
- Holistic Representation: By integrating multimodal data, healthcare systems create a holistic representation of physical, medical, or societal processes. This comprehensive view enables better decision-making, diagnosis, and treatment planning

Various data modalities in healthcare

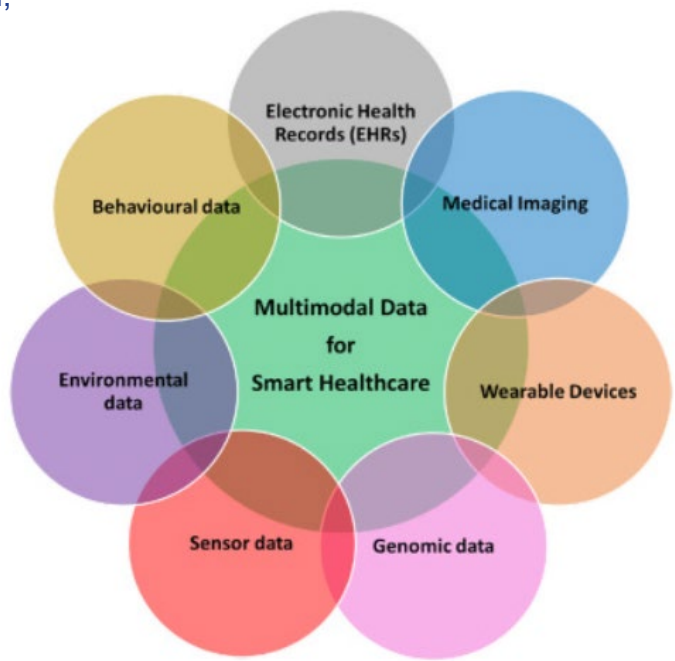


Actionable insights ->
Informed decision making, prediction of future outcomes, personalized treatment plans, predictions of disease progression, identification of risk factors

Connections between patients, diseases, medical treatments ->
Patterns, trends, correlations

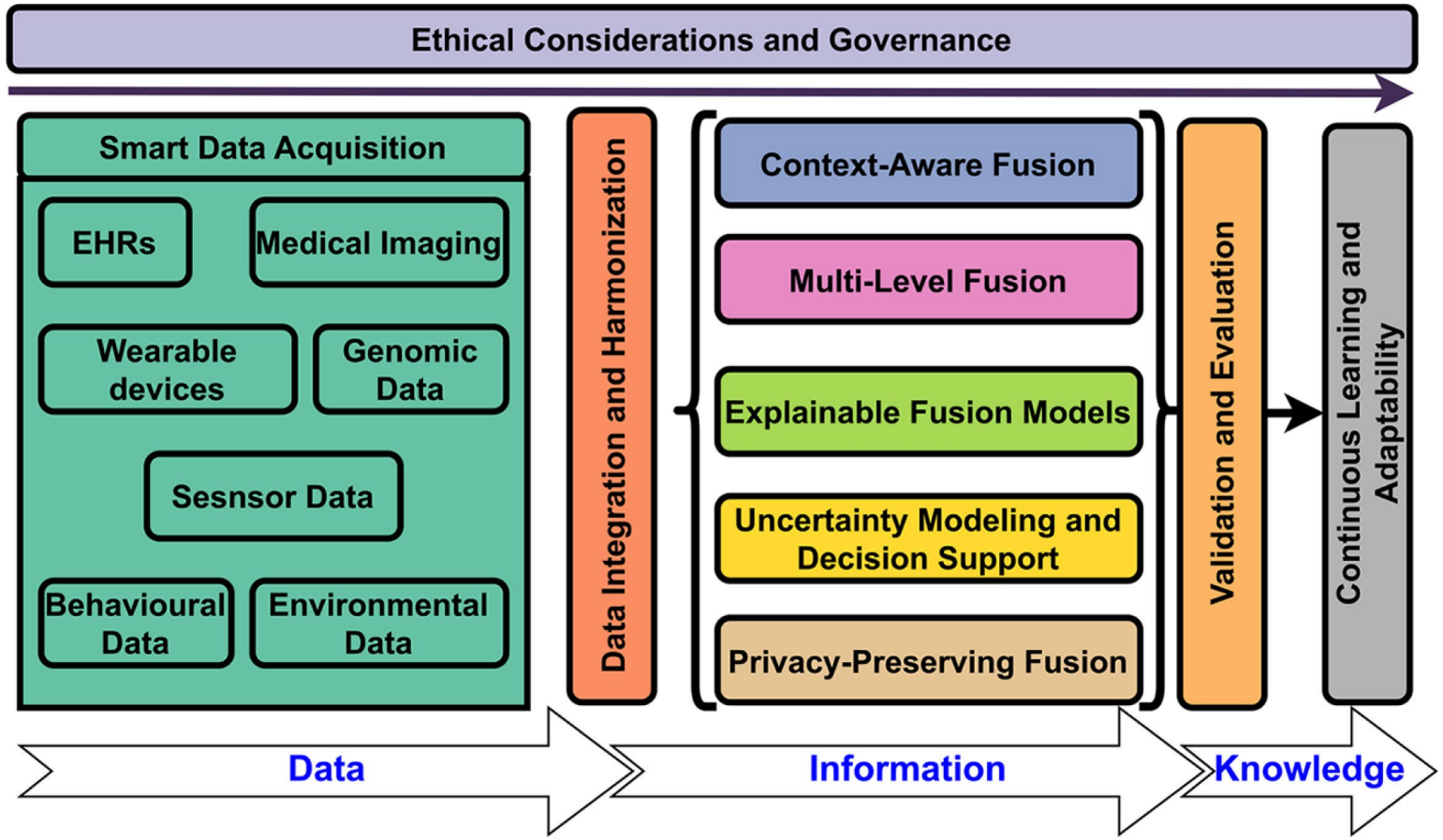
Processing, organization ->
Meaningful and contextualized information

Sources of raw data



https://doi.org/10.1016/j.inffus.2023.102040

Generic framework of multimodal analysis and fusion



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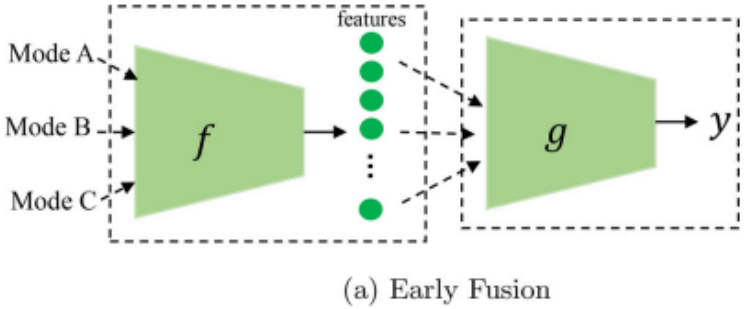
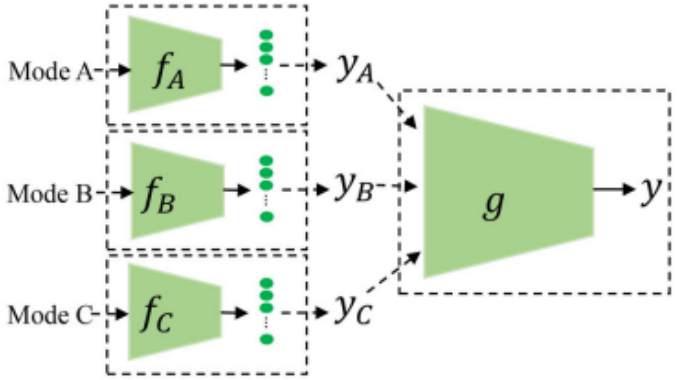
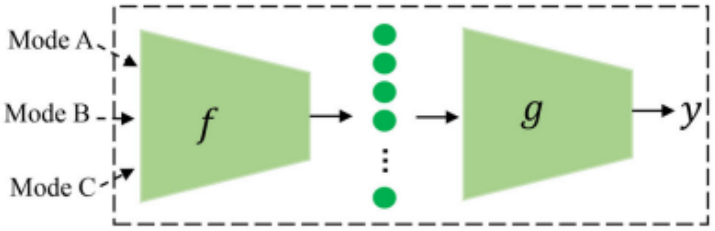


(a) Early Fusion



(b) Late Fusion



(c) Intermediate Fusion

Figure 1. Illustration of different levels of fusion.

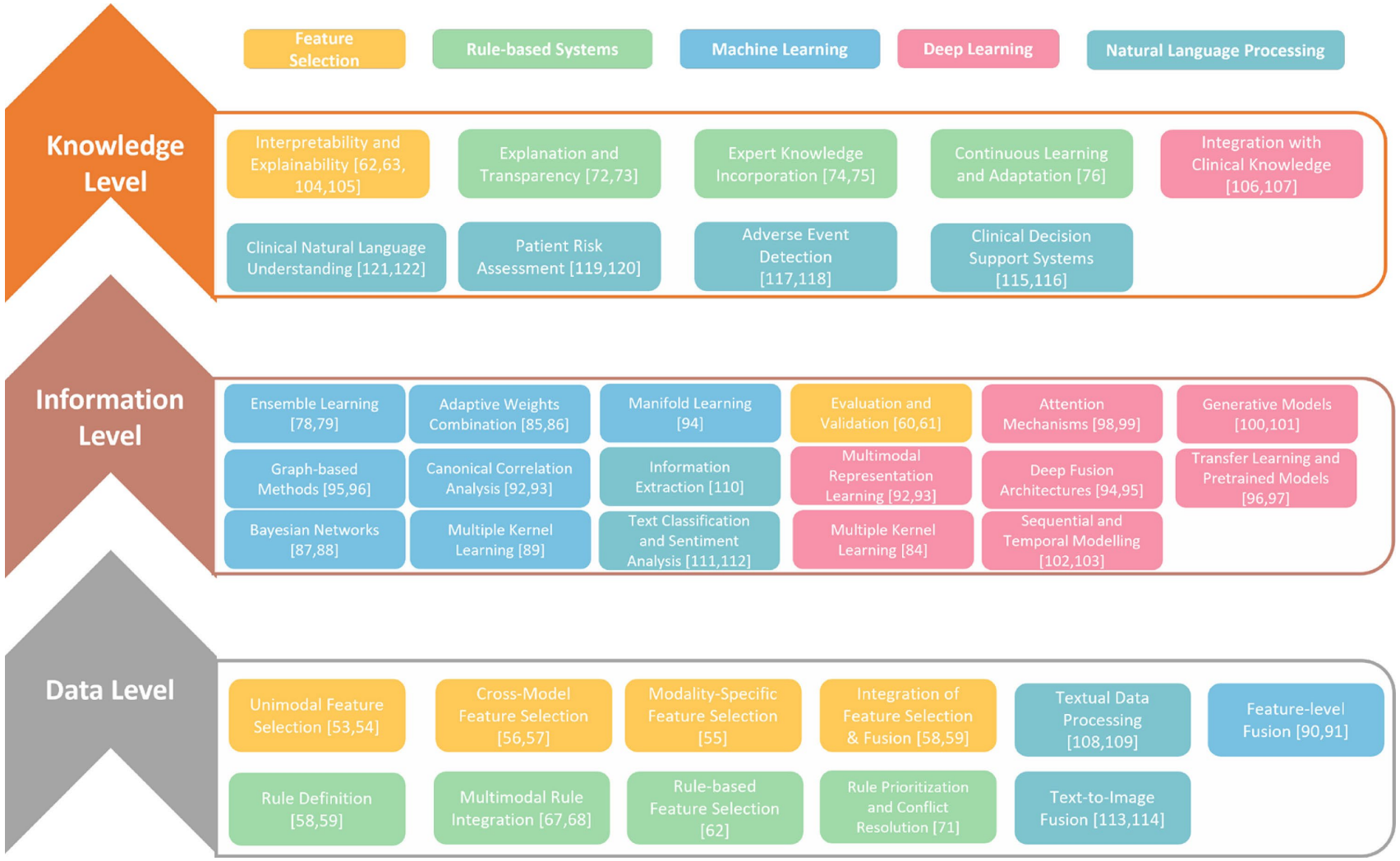
Multimodal fusion

- The process of integrating information from various input modalities and combining them into a complete command

- One type of grouping of available methods:
  - Decomposition-based methods: tensor analysis, factor analysis, generalized PCA etc, regularization
  - Neural networks esp. deep learning
  - Hybrid models: integrating domain knowledge (theoretical models) and data

https://doi.org/10.1080/24725854.2021.1987593

Another grouping of multimodal fusion techniques



https://doi.org/10.1016/j.inffus.2023.102040

Examples of applications

Table 1. Examples of multimodal tasks.

Modalities	Article	Overview
Images, time series, and tabular	[11]	Prediction of Alzheimer's disease based on magnetic resonance imaging and positron emission tomography (images) that are performed multiple times on one patient within specified periods of time (time series). Patient demographics and genetic data are also taken into account (tabular).
Audio, video, and event streams	[12]	Behavioral analysis and emotion and stress prediction. Analyzed data consist of 45-min recordings of students during the final exam period. They are recorded with the use of cameras (video), thermal physiological measurements of the heart, breathing rates (event streams), and lapel microphones (audio).
Text and images	[13]	Question answering based on images containing some textual data.
Images, text, and graphs	[14,15,16]	Outfit/movie recommender systems. Movies are recommended based on plot (text), poster (image), liked and disliked movies, and cast (graphs). Outfits are chosen based on product features in images and text descriptions.

https://doi.org/10.3390/s23052381

Internet of Medical Things: wearable devices for collecting health data

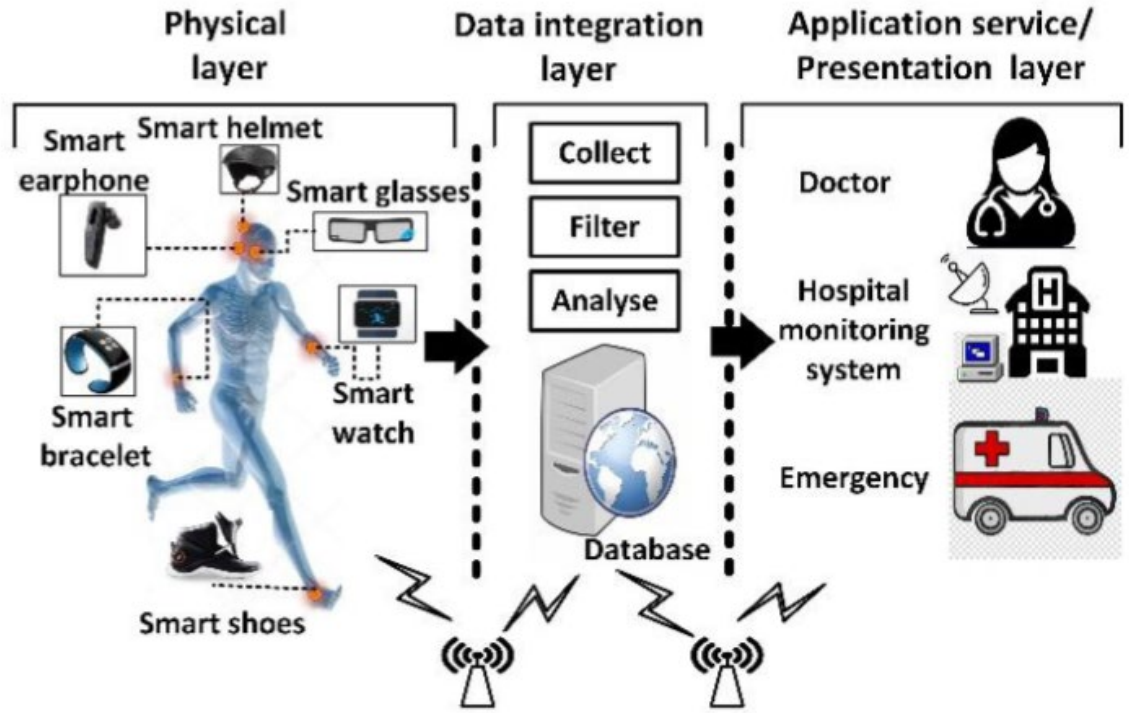


Figure 2. General architecture of IOMT systems.

http://dx.doi.org/10.21014/acta_imeko.v10i2.1080

Multimodal analysis of physiology during movement: motion sensors, ECG, respiration

KINETICS AND KINEMATICS

RESPIRATORY FUNCTION

CARDIAC FUNCTION

MULTIMODAL ANALYSIS OF PHYSIOLOGY AND BIOMECHANICS DURING MOVEMENT

Multimodal affective computing: emotion recognition: facial expressions, voice, EEG, ECG

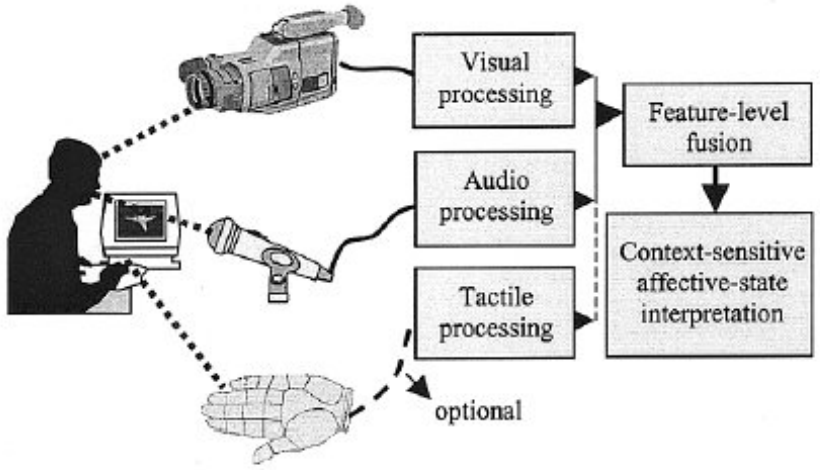
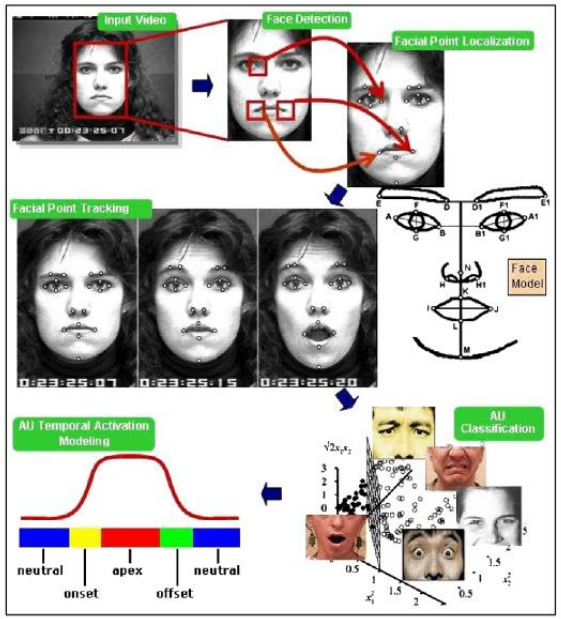
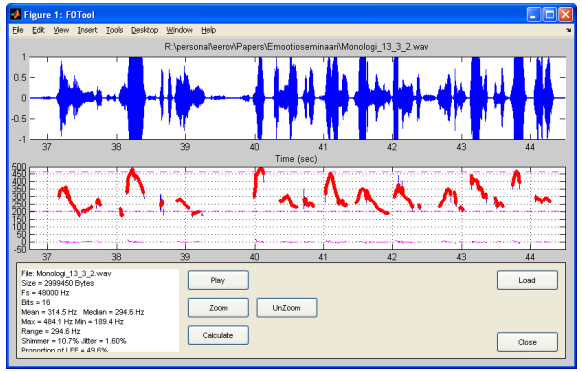
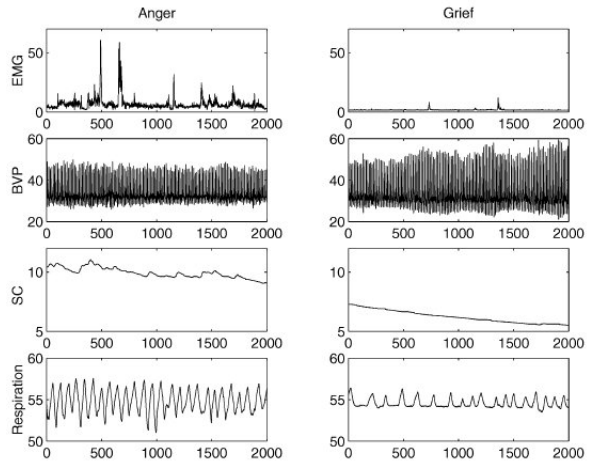


Fig. 1. Architecture of an "ideal" automatic analyzer of human affective feedback.

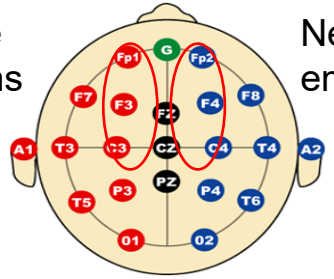






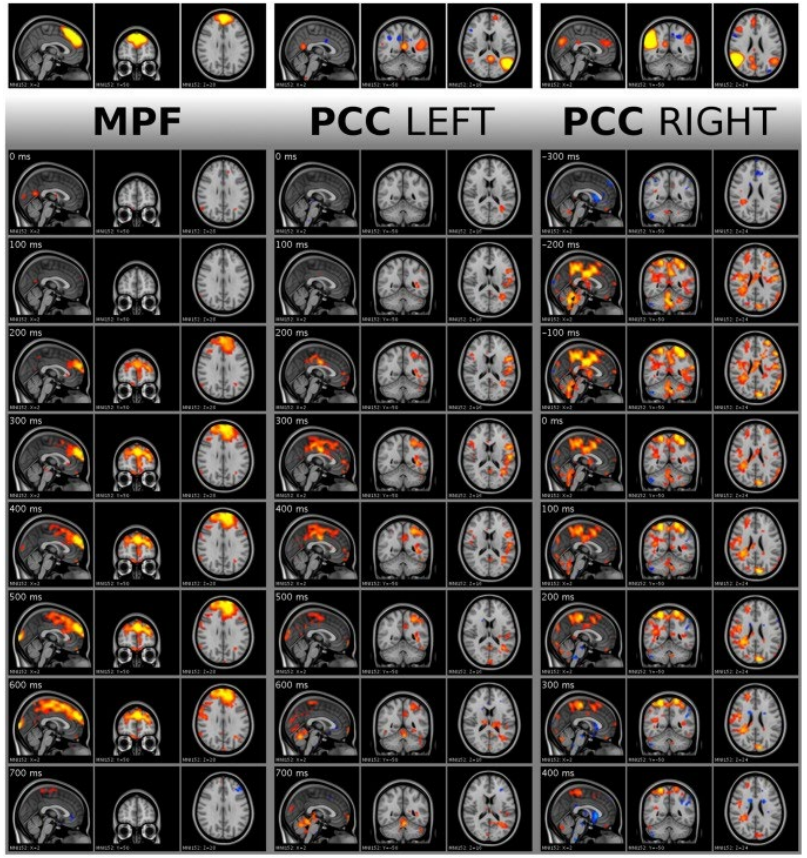
- Assessment of psychosis and schizophrenia
- Assessment of depression and stress
- Monitoring effect of treatment
- Outpatient health monitoring

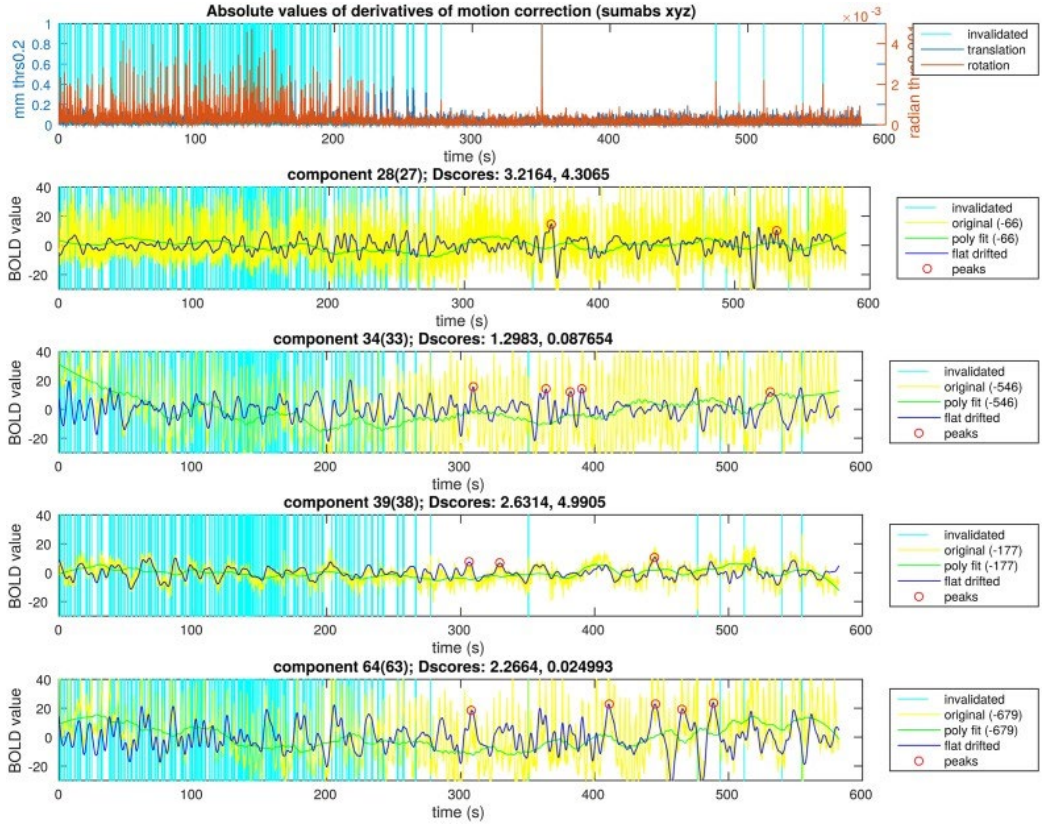
Positive emotions



Negative emotions

Detecting neural avalances in the brain in epilepsy: MREG imaging, multichannel EEG





Cardiac data analytics: heart beat from ECG and video camera

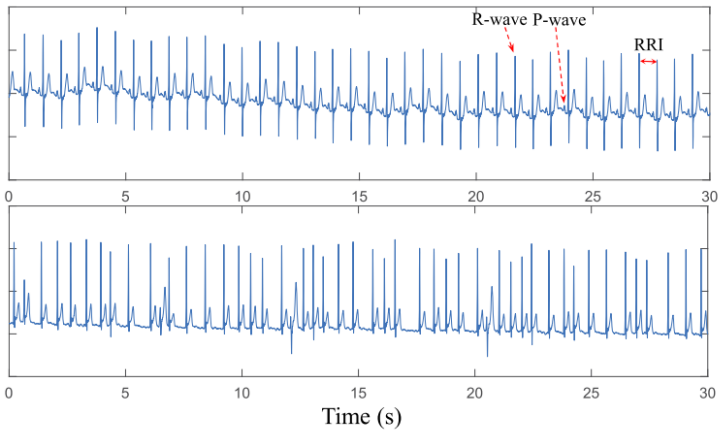
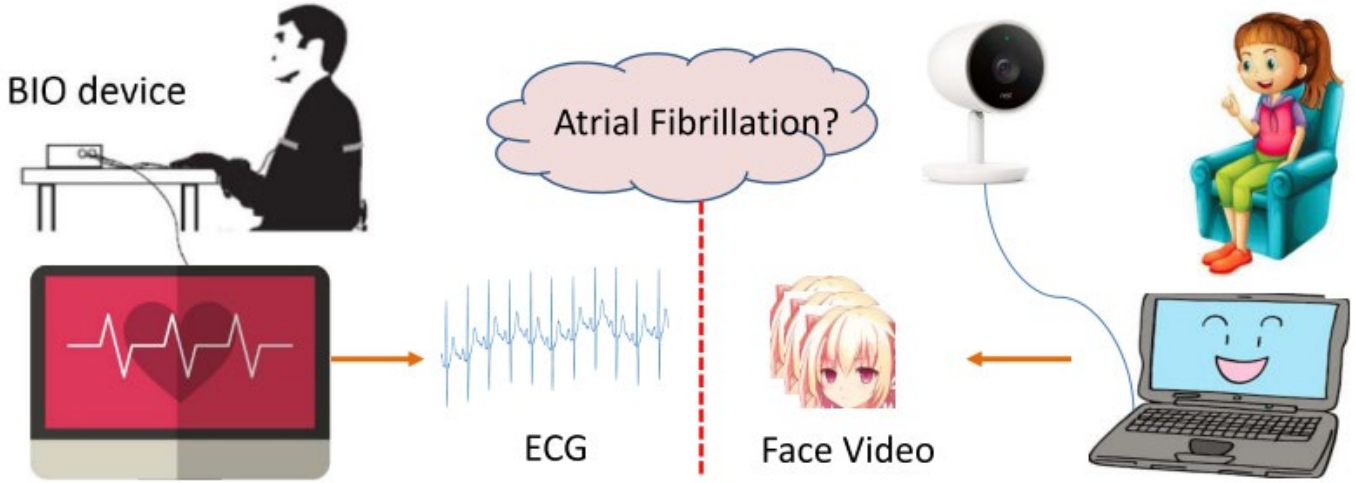
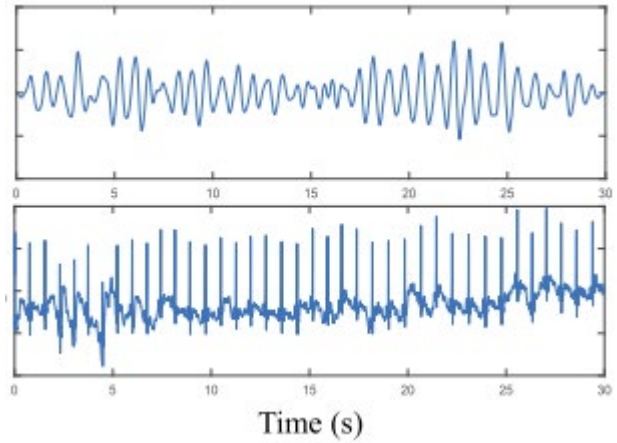


Fig. 2. ECG signals for a healthy individual (top) and an AF patient (bottom) respectively. The irregularity of beat-to-beat variability occurs in the ECG signal of AF patient.

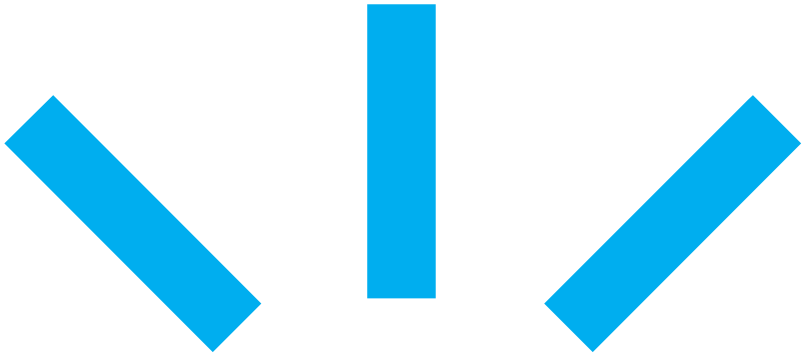




https://doi.org/10.1109/TCSVT.2019.2926632

Future directions and challenges

- Predictive / Preventive / Personalized / Participatory healthcare
- Reliability of data analysis in every-day situations
- Context drifting
- Explanatory / interpretable AI
- Missing modalities (imputation techniques)
- Discordance / noncommensurability issues between modalities
- Measurement noise, data quality issues
- Varying confidence levels of modalities
- Multimodal data collection, data augmentation, labeling challenges
- Privacy and security, availability of data sources for modeling and analytics
- Wearable sensor issues: battery life, computational capacity, memory, data transfer, calibration, body-area networking, …



Thank you for your attention!

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