CENTRE FOR RESEARCH & TECHNOLOGY - HELLAS
Information Technologies Institute

MultiMoDal Data Fusion and Analytics Group

Stress detection based on wearable physiological sensors: laboratory and real-life pilot scenario application

Vasileios-Rafail Xefteris*, Athina Tsanousa, Spyridon Symeonidis, Sotiris Diplaris, Francesco Zaffanela,

Martina Monego, Maria Pacelli, Stefanos Vrochidis, and Ioannis Kompatsiaris

Presenter: Vasileios-Rafail Xefteris

*Information Technologies Institute - CERTH, Thessaloniki, Greece, Email: vxefteris@iti.gr

IARIA

VASILEIOS-RAFAIL XEFTERIS

Vasileios-Rafail Xefteris received his masters degree in Electrical and Computer Engineering from the Aristotle University of Thessaloniki (AUTH), Greece in 2020. He is currently a research associate in the Information Technologies Institute (ITI) of the Centre for Research & Technology Hellas (CERTH), and a PhD student in multimodal data fusion at the International Hellenic University (IHU).

His main research interests lie in the analysis of data retrieved from sensors (mostly wearables) and multimodal data fusion techniques, focusing on machine learning and deep learning approaches.

CENTRE FOR RESEARCH & TECHNOLOGY - HELLAS
Information Technologies Institute

MultiMoDal Data Fusion and Analytics Group

IARIA

AIMS AND CONTRIBUTION

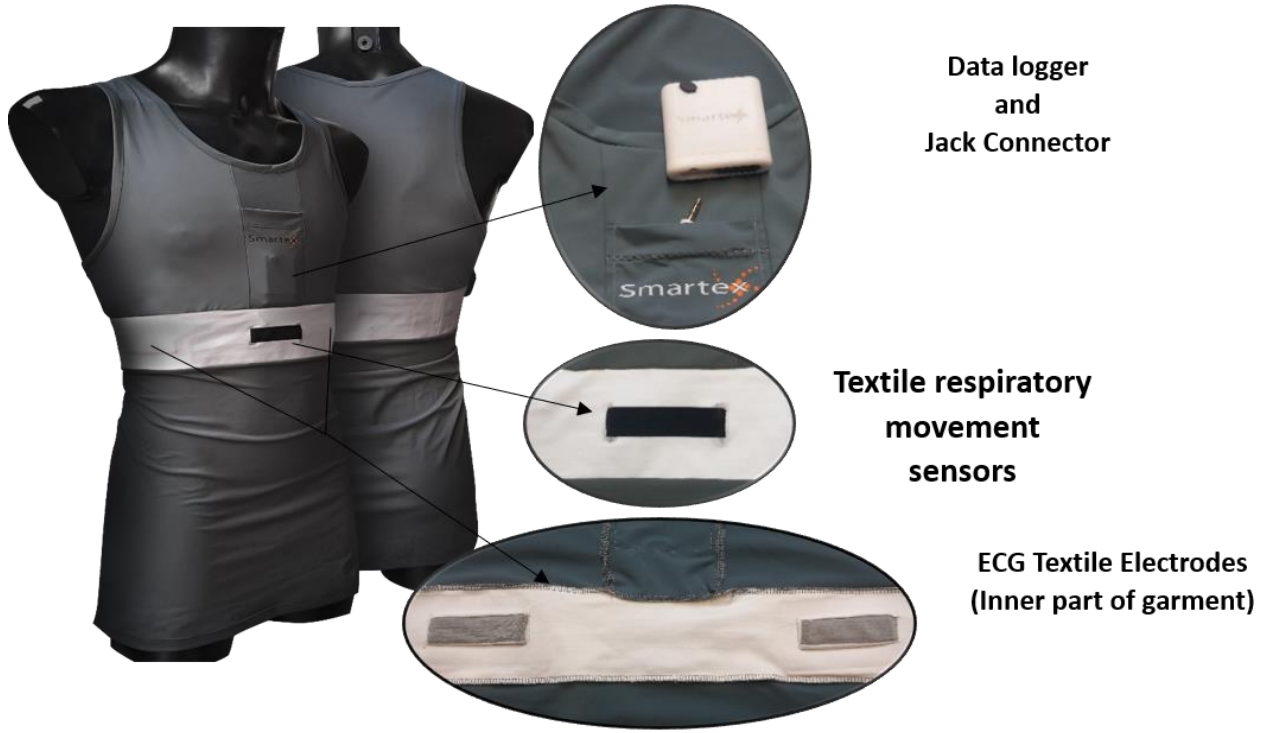
- Presentation of a stress-level component implemented on a real-time disaster management scenario
  - Real-time stress level detection of first responders
  - Stress measured through wearable devices (smart-vest) with embedded physiological sensors
  - Stress reported as a continuous value
  - Evaluation of a variety of fusion and feature selection methods on different prediction algorithms to detect stress from the smart-vest
  - Two different data collection protocols:
    - Training data collection protocol through an experimental design based on interchanges between stressful challenges and relaxing situations
    - Evaluation pilot of disaster management use case of the xR4DRAMA project based on real-life flood scenario

OVERVIEW

- Smart-vest presentation
- Data collection protocol
  - Training data collection protocol
  - Pilot use case protocol
- Data analysis
  - Preprocess
  - Feature extraction
  - Evaluation plan
- Results

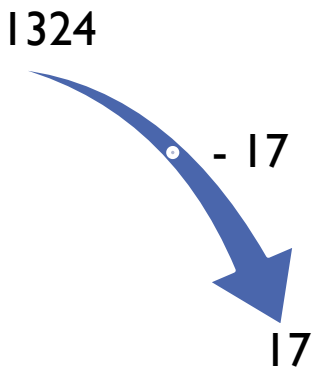
SMART-VEST

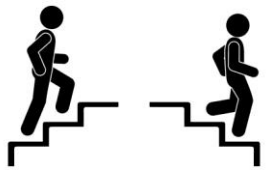
- Two textile electrodes to acquire Electrocardiogram (ECG) signal
- One textile respiratory movement sensor
- One jack connector to plug the garment into the electronic device
- A pocket to hold the electronic device during the activity



TRAINING DATA COLLECTION PROTOCOL

- Psychological:
  - The Stroop test.
  - The descending subtraction test.
  - Explain a stressful situation in your life.
  - Explain how the day has been .
  - Listen to relaxing music.
- Physiological:
  - Place a hand in cold water (2^{o} C) for two minutes, make pause, and then place it again.
  - Ascend and descend four levels of stairs.
  - Tie and untie shoes after exercise.





PILOT USE CASE PROTOCOL

- Pre-emergency phase:
  - Forecasting of flood incidences
  - No stress detection module involved
- Emergency phase:
  - First responders on the field performing certain tasks:
    - Send incidence reports about flood events
  - Smart-vest equipped
  - Real-time stress detection

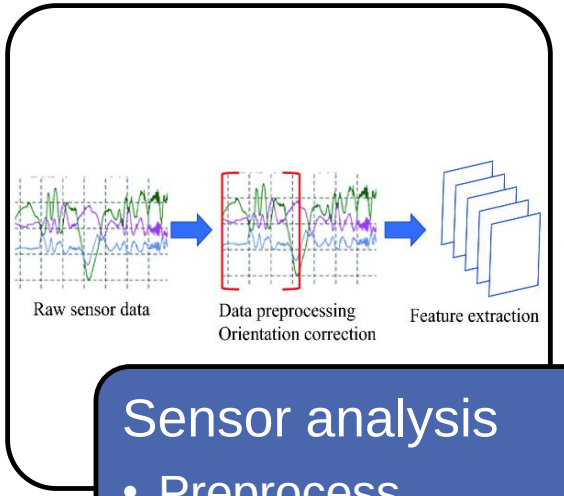
DATA ANALYSIS

- Preprocess
  - Simple weights for each signal
- Feature extraction
  - 60 second window, 50% overlap
  - 314 features in total
    - 94 heart rate
    - 28 respiration rate
    - 192 IMU (16 per single-axis data)
- Evaluation
  - 80/20 split ratio, 10 fold cross validation
  - 4 different machine learning regressors
    - SVM – linear
    - kNN
    - RF
    - XGB
  - 3 feature selection techniques
    - RFE
    - PCA
    - GA
  - Mean square error
    - Normalize stress in range 0-1

DATA ANALYSIS

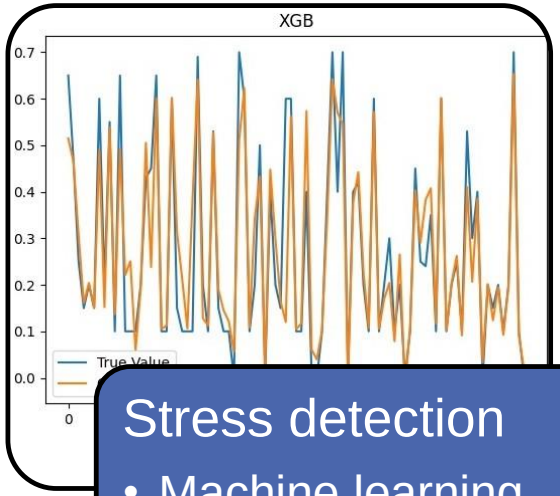
Smart vest

- ECG
- Respiration
- IMU



Sensor analysis

- Preprocess
- Feature extraction



Stress detection

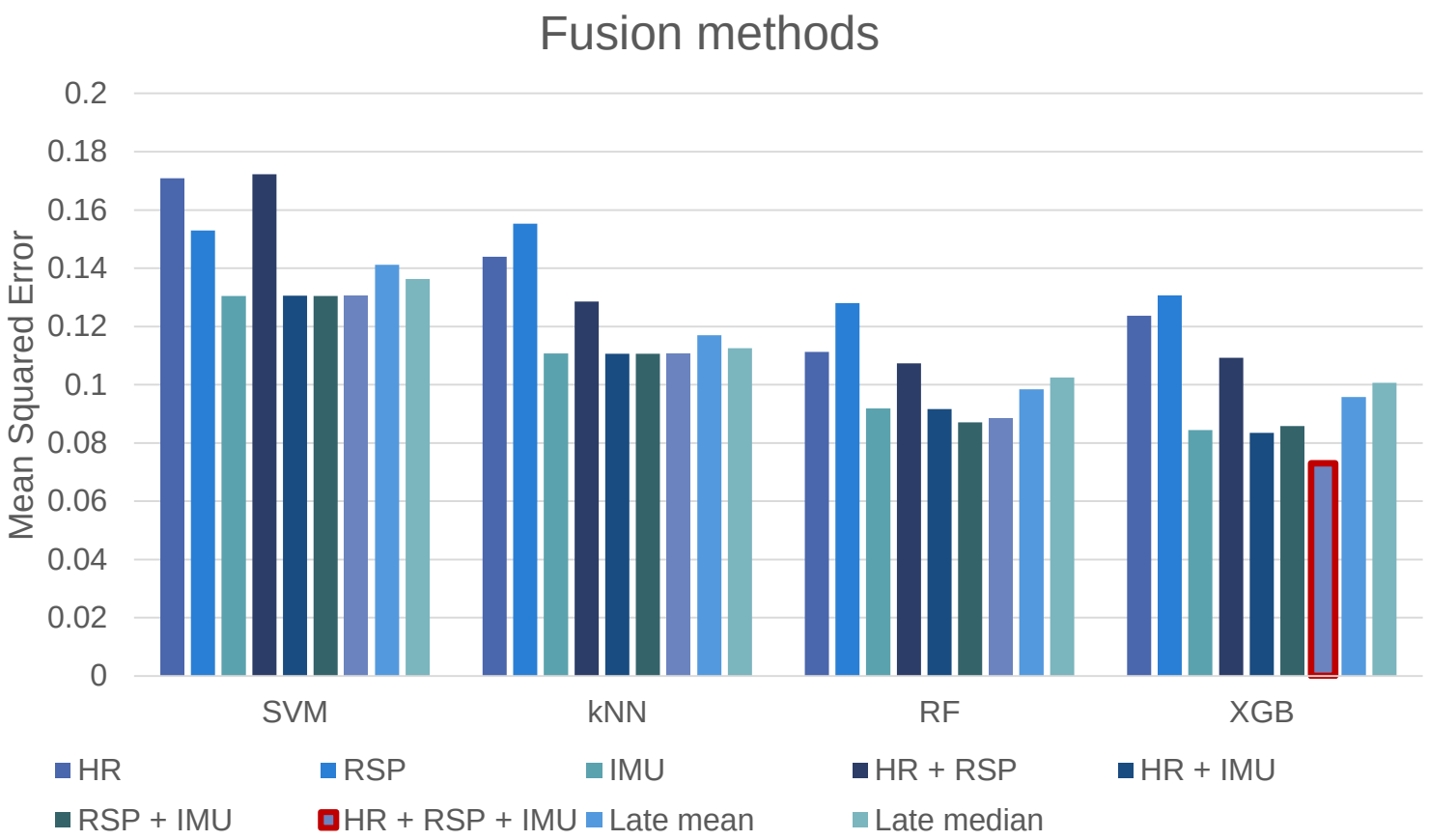
- Machine learning algorithms
- Regression models

RESULTS - FUSION METHODS

- Comparative results of early and late fusion methods
  - Mean Squared Error of predicted values versus ground truth values
- Concatenation of all features with XGB regressor performing the best

	HR	RSP	IMU	HR + RSP	HR + IMU	RSP + IMU	HR + RSP + IMU	Late mean	Late median
SVM	0.1709	0.1530	0.1305	0.1723	0.1306	0.1305	0.1305	0.1412	0.1363
kNN	0.1439	0.1553	0.1107	0.1285	0.1106	0.1106	0.1107	0.1170	0.1125
RF	0.1113	0.1280	0.0918	0.1073	0.0916	0.0871	0.0886	0.0984	0.1025
XGB	0.1237	0.1307	0.0844	0.1092	0.0835	0.0858	**0.0730**	0.0958	0.1006

RESULTS - FUSION METHODS

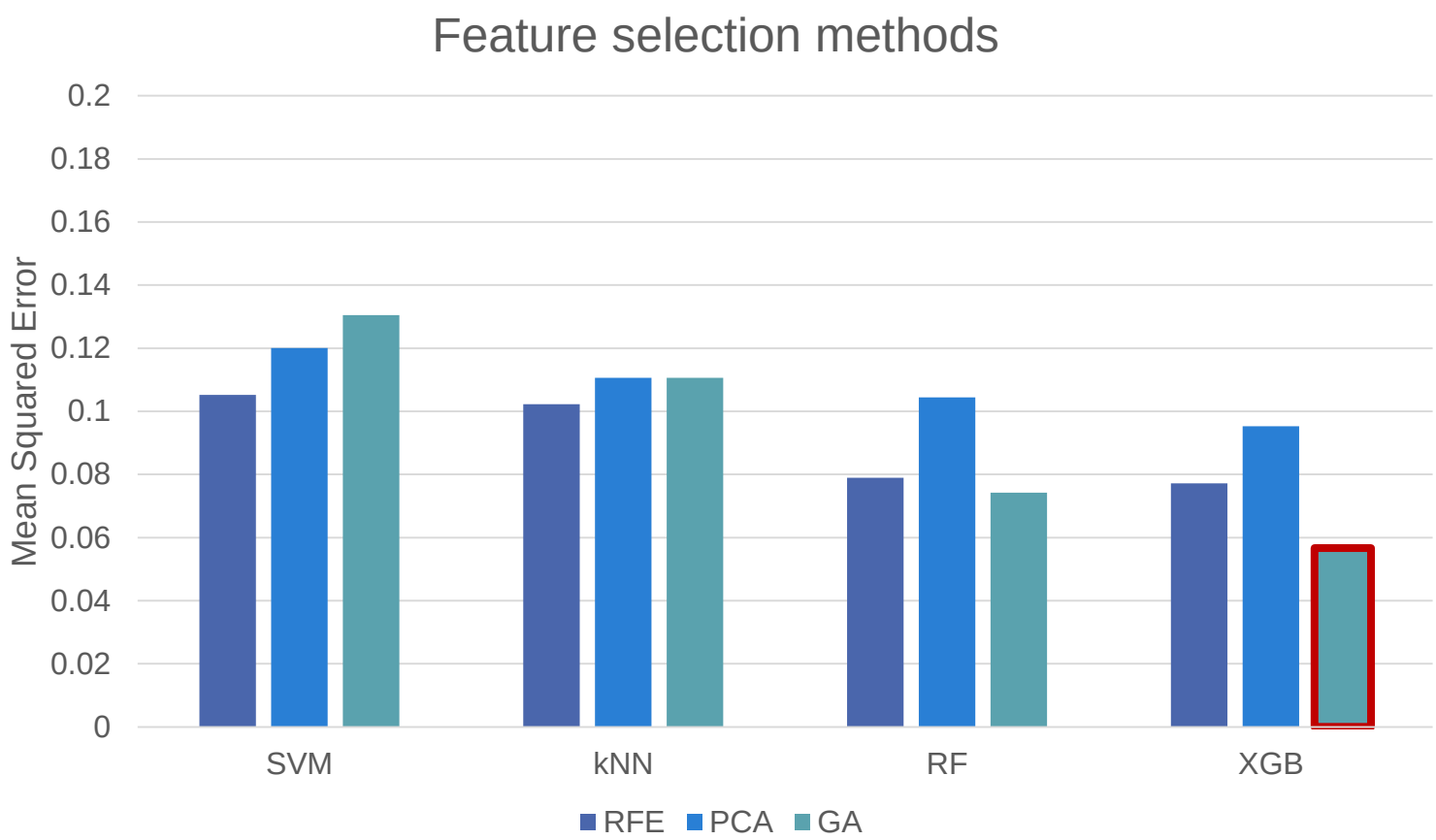


RESULTS – FEATURE SELECTION METHODS

- Comparative results of feature selection methods
  - Mean Squared Error of predicted values versus ground truth values
- Genetic Algorithm (GA) feature selection with XGB regressor performing the best

	RFE	PCA	GA
SVM	0.1052	0.1201	0.1305
kNN	0.1023	0.1106	0.1106
RF	0.0790	0.1044	0.0742
XGB	0.0772	0.0953	**0.0567**

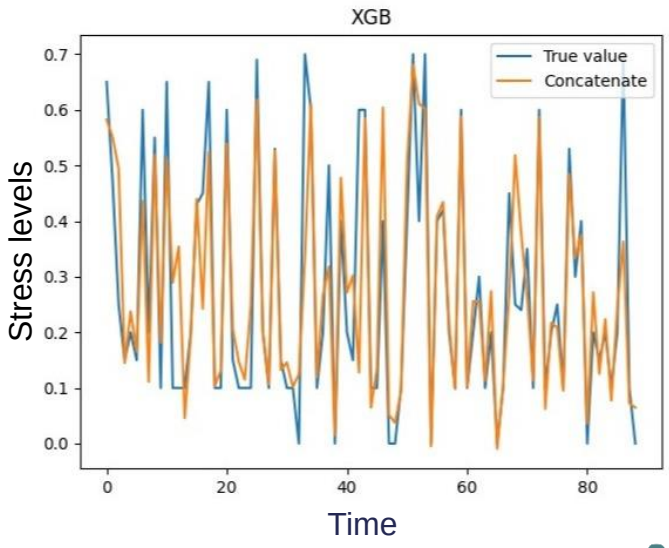
RESULTS – FEATURE SELECTION METHODS



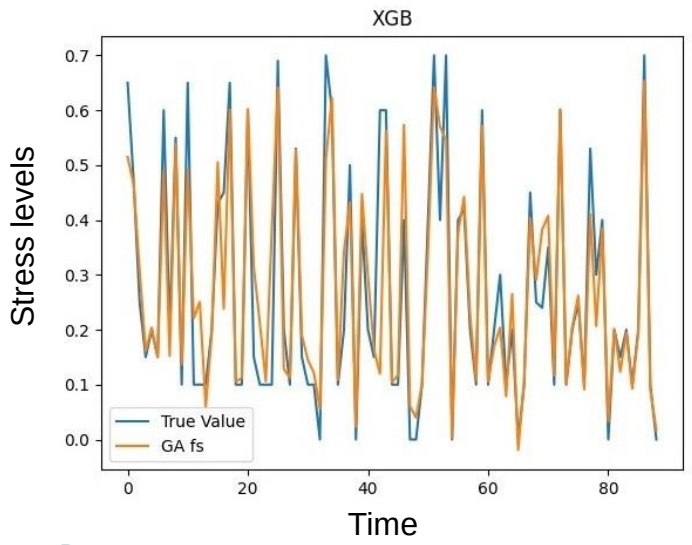
RESULTS – COMPARISON OF FUSION AND FEATURE SELECTION

- Comparative figures of best performing fusion and feature selection methods
- Stress levels over time
- Predicted values (orange) versus ground truth values (blue)

No feature selection

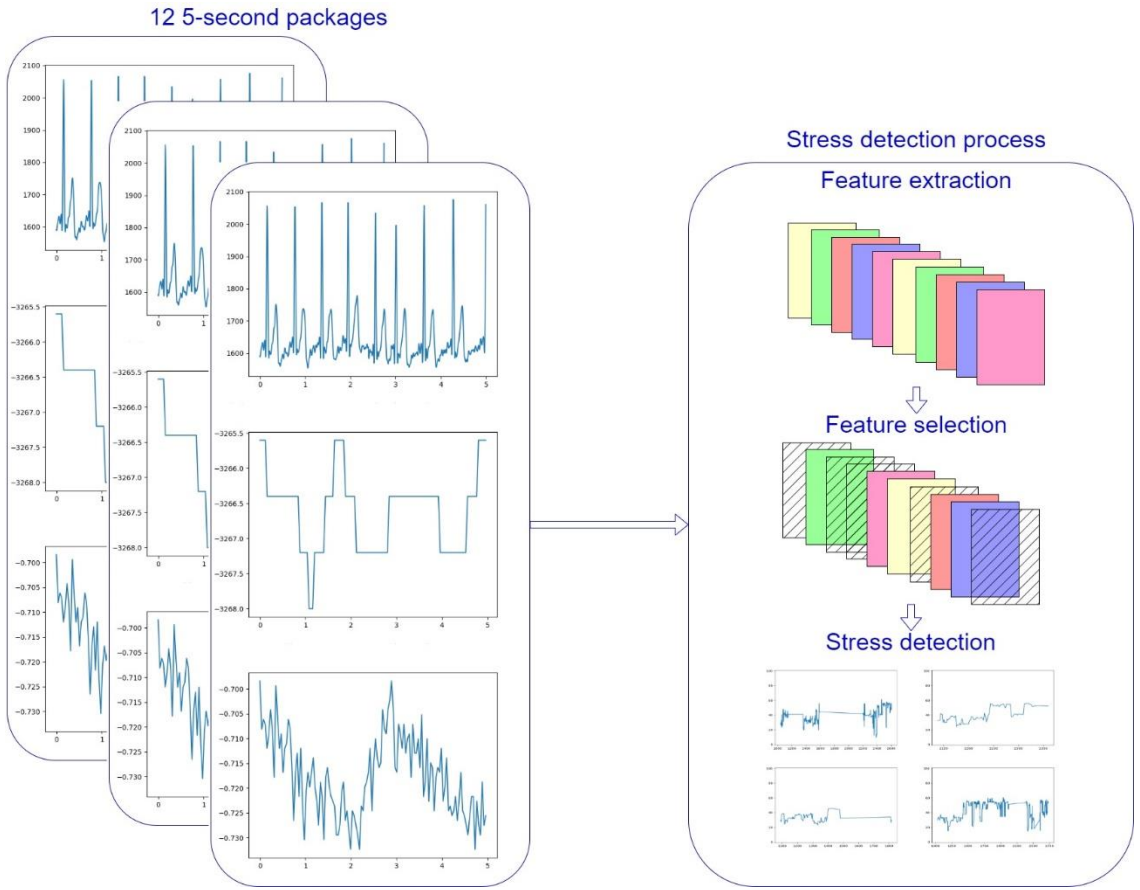


GA feature selection



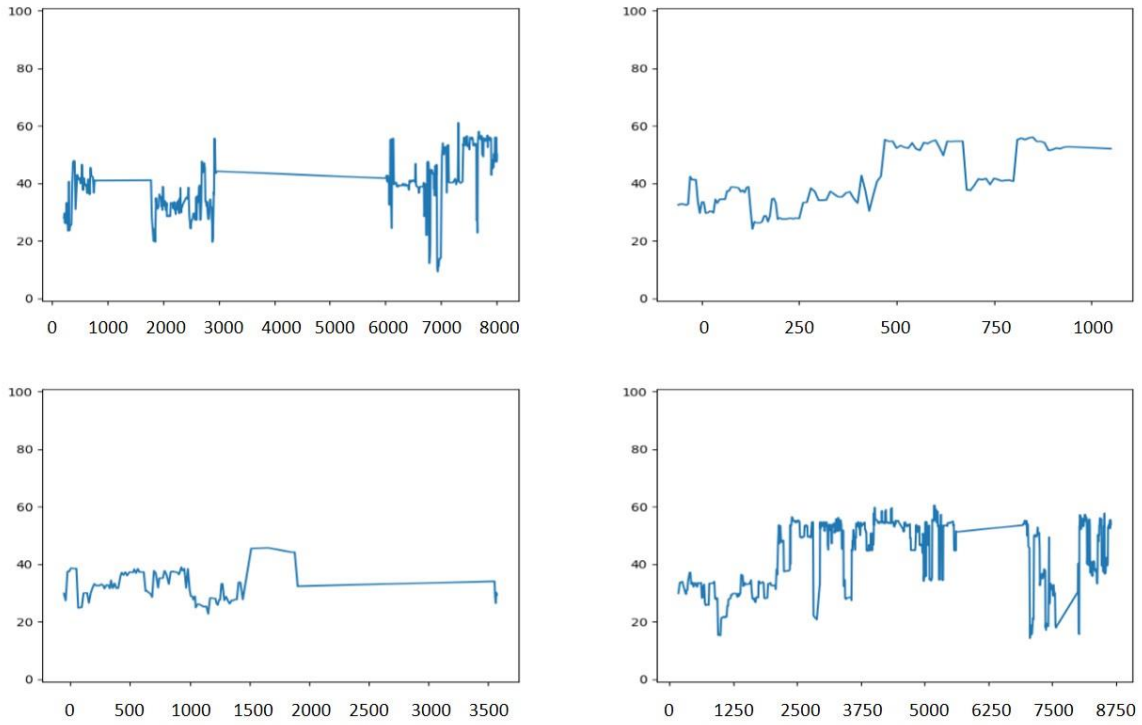
PILOT USE CASE - WORKFLOW

- Stack 5-sec packages of data from smart vest (1 minute window)
- Feature extraction
- Feature selection
- Regression model for stress detection



PILOT USE CASE - RESULTS

- 4 subjects
- Real-time stress detection
- Figures of stress levels over time
  - Medium level stress



CONCLUSION

Conclusion:

- Development of a sensor-based stress level detection module for first responders
- Data gathered using a smart-vest equipped with physiological and IMU sensors
- Two data collection protocols; one protocol for collection of training data and one for the real time simulation of the disaster management scenario
- Feature extraction from all modalities, different fusion methods and feature selection algorithms
- XGB regressor with GA feature selection performed the best, with 0.0567 MSE
- Real-life application with reasonable results and real-time operation

FUTURE WORK

Future work:

- Fusion of sensor-based stress level detection with audio-based stress level detection
- Second disaster management pilot scenario:
  - Test another protocol for controlled stress induction
  - Evaluation of sensor-based and fusion stress level detection modules

CENTRE FOR RESEARCH & TECHNOLOGY - HELLAS
Information Technologies Institute

MultiMoDal Data Fusion and Analytics Group

THANK YOU

IARIA