EMoCy

Physiological Signals-Based Stress Detection in Embedded Scenarios

PRINCIPAL ACADEMIC TUTOR
Marco Domenico Santambrogio
Deib, Politecnico Di Milano

ACADEMIC TUTOR
Alba Cappellieri
Design Department, Politecnico Di Milano
Sara Vinco
Dauin, Politecnico Di Torino
Riccardo Barbieri
Deib, Politecnico Di Milano
Eleonora D'arnese
Deib, Politecnico Di Milano

EXTERNAL INSTITUTIONS
E-Novia

EXTERNAL TUTOR
Ivo Boniolo, E-Novia
Federico Moro, E-Novia

TEAM MEMBERS

Lorenzo Gecchelin
Design & Engineering
Politecnico di Milano

Anisia Lauditi
Biomedical Engineering
Politecnico di Milano

Noemi Gozzi
Biomedical Engineering
Politecnico di Milano

Armando Bellante
Computer Science & Engineering
Politecnico di Milano

Ana Bogdanović
Biomedical Engineering
Politecnico di Milano

Letizia Bergamasco
ICT for Smart Societies
Politecnico di Torino

Moaad Khamlich
Computational Engineering
Politecnico di Milano

Executive Summary

Stress is a psycho-physical condition that has long term social and economic impacts, both on people and on the healthcare system. Continuous stress monitoring can play a key role in improving the quality of life. On one hand, it helps to prevent diseases and enhance efficiency in workplace scenarios, in life-saving jobs and desk-jobs, and in universities and schools.
And at the same time stress monitoring can be considered as an index of the engagement level among people, in entertainment activities.
EMoCy was born through the collaboration of Alta Scuola Politecnica and the NECSTLab, with the vision to improve people's life through innovation.
EMoCy is a small portable device for automatic and continuous stress detection according to how your heart rate is changing, to the regularity of your breath and to the level of sweating.
The first goal is to develop a machine learning model for stress detection based on physiological signals. We reach an accuracy of 97.2% on the stress/not stress discrimination task. On the other hand, we aim to design a prototype of a portable device (PoC) exploiting commercial sensors, which can be easily replicated and used to collect a comprehensive unbiased dataset. For the dataset acquisition we have developed, supported by a psychologist, an experimental protocol based on the standards in the stress induction field.

Key Words

Stress Detection, Machine Learning, Embedded Systems, Physiological Signals

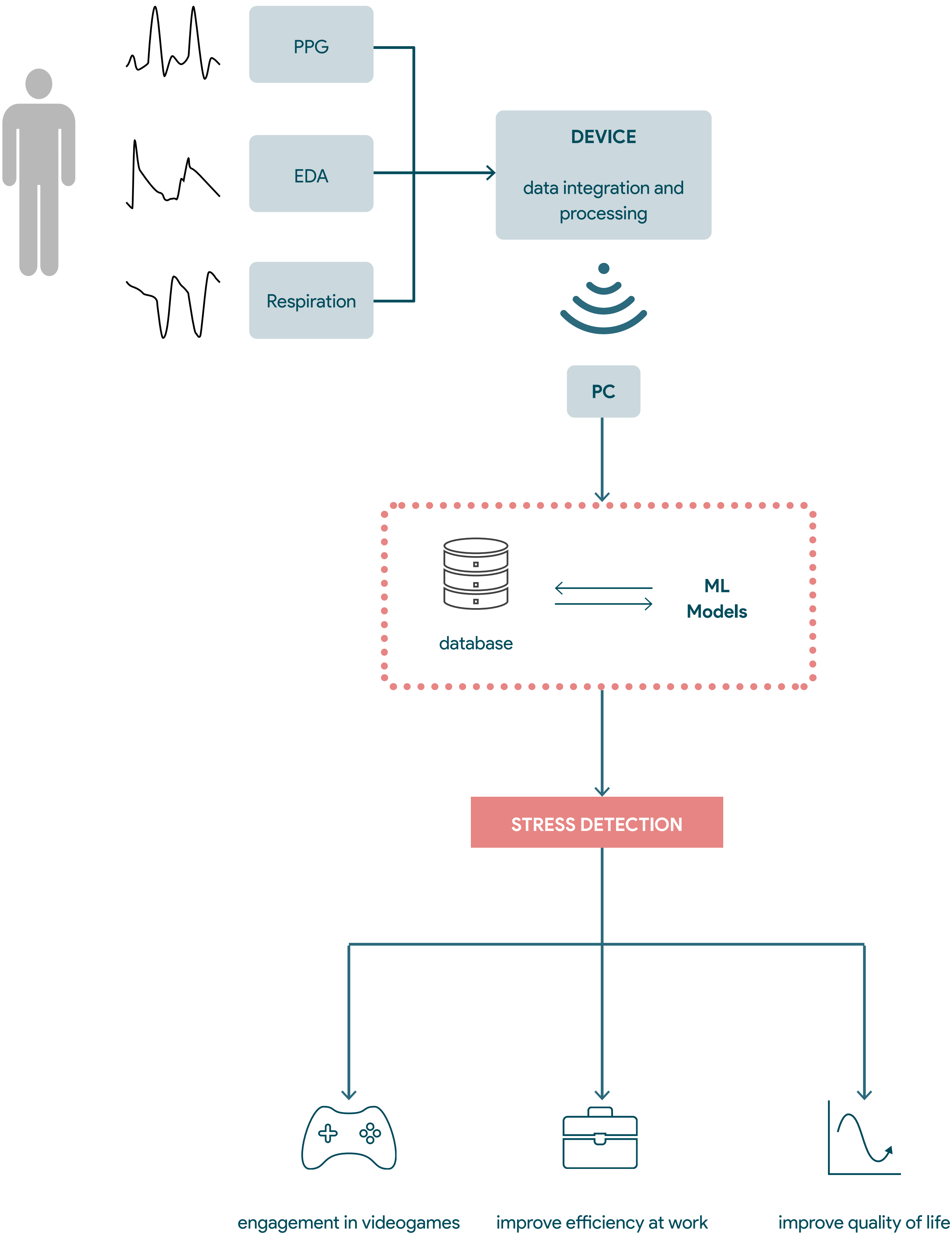

Figure 1: EMoCy framework

Project description written by the Principal Academic Tutor

In recent years, we are hearing more and more about stress, anxiety, and how they can negatively affect our way of living. Recent research works have been focusing both on tackling these situations and on identifying patterns that allow us to recognize them.

The appearance of stress occurs together with physiological manifestations, whose prompt detection can help people in managing the moment. The objective of this work - EMoCy - is to combine the different skills of the team to develop a portable device and a machine learning framework for stress detection, based on physiological signals.

During the development of this project it will be essential to identify the most appropriate signals to be used for the detection. For each of the chosen signals the team will need to define a preliminary signal processing phase and to select a set of features that a classifier can use to learn useful patterns to detect stress symptoms. Once a properly structured dataset has been created, the team will have to select the most suitable classification model through appropriate training and testing strategies. Lastly, it will be necessary to develop a proof of concept of a portable device, with the aim to validate the entire analysis workflow on newly collected data.

Team description by skill

EMoCy team is formed by 7 students from Politecnico di Milano and Politecnico di Torino. The great diversity in back-ground and competencies has created an inspiring environment leading to pursue a complex and complete project: each one has contributed depending on his own skills and wishes, collaborating and learning from other members of the team.

Armando Bellante, Computer Science Engineering, Politecnico di Milano. Machine learning engineer, software designers, network engineer, problem solver.

Letizia Bergamasco, ICT for Smart Societies, Politecnico di Torino. ICT expert, machine learning engineer , team and work organizer and trade-off fixer.

Ana Bogdanovic, Biomedical Engineering, Politecnico di Milano. Machine learning engineer, signal processing expert, biomedical feature analyst, pitcher and communication expert.

Lorenzo Gecchelin, Design Engineering, Politecnico di Milano. Graphic Designer, Consumers and Market analyst, Videomaker and storyteller.

Noemi Gozzi, Biomedical Engineering, Politecnico di Milano. Signal processing expert , machine learning engineer, hardware developer and team motivator.

Moaad Khamlich, Mathematical Engineering, Politecnico di Milano. Numerical analysis expert, protocol test implementer, flexible and critical thinker.

Anisia Lauditi, Biomedical Engineering, Politecnico di Milano. Hardware developer, communication protocol implementer, techno-economic assessor and innovative solutions seeker.

Goal

The aim of this project is to create a framework for detection of acute psychological stress using physiological signals. This can lead to better insights about the stress problem and eventually improve possible treatment and prevention.

The work can be done especially nowadays, thanks to the improvements in the field of machine learning and the availability of commercial sensors.
Therefore, the objective of this project is twofold: on the one hand, we aim at developing a model for stress detection based on the physiological signals, together

with the software needed to process the signals and extract features from them. We aim to improve state-of-the-art performances achieving better results in stress detection. This is done keeping in mind a probable use in real-time applications, such as wearable devices, which are more restrictive and noisy with respect to the laboratory conditions.

On the other hand, we want to create a prototype of a portable device, which can be easily replicated using commercial hardware and cheap sensors available on the market. The PoC must meet the requirements and specifications which ensure the usability and reliability of the system towards a real-time wearable application. Both the software and the hardware are combined to carry out experiments through a stress induction protocol, to validate the entire framework and verify the feasibility of a possible commercial application. In this way we want to set benchmarks for further work in this field

In our vision, this device can be employed in a large variety of scenarios. Ranging from workplace scenarios, where the performances of workers can be severely affected by emotional instabilities that need to be constantly monitored, to the entertainment sector, where stress can be considered as an index of the level of engagement of people.

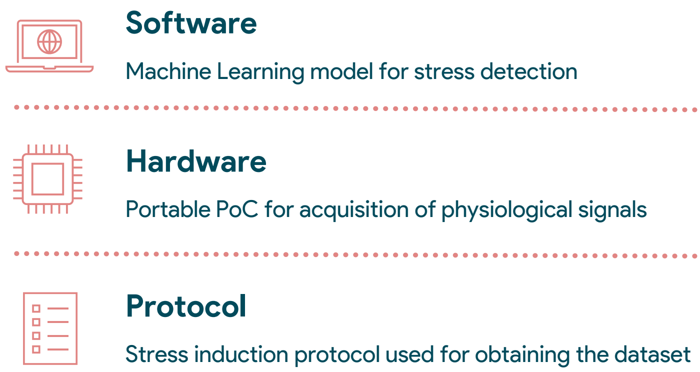

Figure 2: Project outcome

Understanding the problem

The term stress indicates a psychophysical response to an emotional or social load perceived as excessive and not addressable
Although this response is necessary and can sometimes be useful, when it manifests in a prolonged or repeated way, it can have harmful physical and psychological consequences: cardiovascular diseases, diabetes, and disorders such as anxiety and depression are the most common examples. In particular, mental health disorders account for 30% of all non-fatal diseases worldwide as reported by World Health Organization.
Moreover, major implications can be also interpersonal relationships worsening, pressure on the healthcare system and a decline in productivity in the workplace. Generally these consequences are quantified in terms of the economic damage they cause. For instance the American Institute of stress, and it estimated a 300 billion dollars loss due to stress related issues.
Because of these reasons, the interest in stress detection has been increasing in recent years, focusing on the continuous tracking of the emotional state of people with wearable devices, in order to prevent chronic stress consequences.
This can be achieved because when a stressful situation happens, it is perceived as a danger. Consequently, the activity of the sympathetic nervous system increases due to a sudden release of hormones, and this in turn involves the activation of the so-called fight-or-flight response. Therefore, the onset of a stressful situation is accompanied by a change in the temporal dynamics of some physiological signals.
Accordingly, by detecting the onset of dynamic patterns linked to the physiological response to stress, it is possible to create a monitoring system that allows to anticipate the advent of such episodes. This monitoring is of particular interest as following the detection, strategies related to the field of emotion regulation can be put in place.

Exploring the opportunities

In our vision, a device able to detect stress can be employed in a large variety of scenarios.

Stress can have a very negative impact on people's health, if this is frequent and prolonged. Monitoring physiological signals and detecting stress can be useful and important in the workplaces, where stress has a negative impact on both the health and performance of workers. In particular, there are jobs in which one's work performance, if not performed perfectly, can be the cause of life or death of other people. For instance, think of surgeons, scuba rescuers or airline pilots.

While it can be considered an index of malaise, stress can also be seen as an index of the engagement level of a certain event or experience in which a person is taking part. Indeed, for instance, detecting stress in real time could be interesting for videogames developers to design adaptive game levels, whose difficulty changes according to the stress perceived by the gamer.

At the same time, stress detection can be advantageous also for the advertising and film industry. It would be inter-esting for them to understand if a thriller movie conveys the expected vibes or to verify the impact that a TV commercial has on possible costumers.

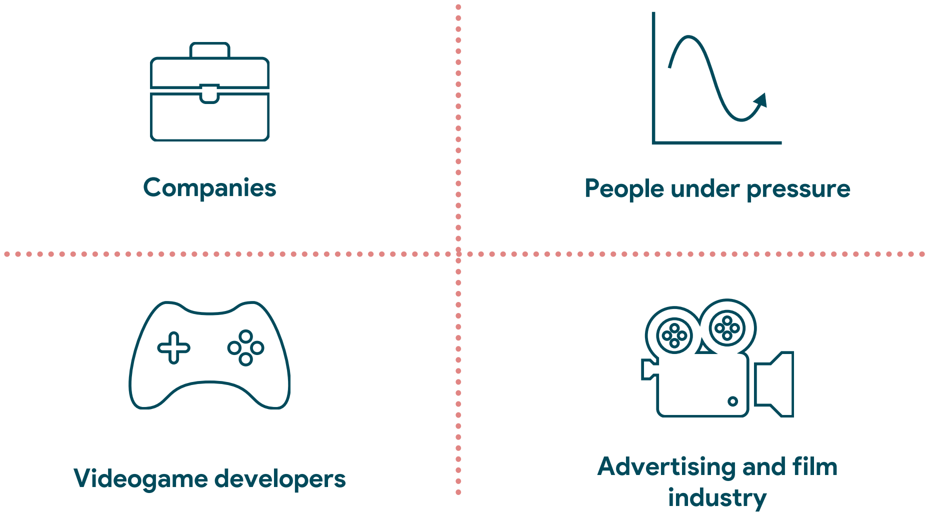

Figure 3: Possible market opportunities

Generating a solution

EMoCy aims at providing a framework for stress detection using physiological signals, involving software, hardware and protocol development. The first step is for sure the signal selection: after an accurate analysis in literature, blood volume pulse (BVP), electrodermal activity (EDA) and respiration (RESP) have been chosen since they are the most informative ones in terms of the presence of stress.

With regard to the software part, we have developed a clear and reproducible pipeline consisting of three fundamental steps: signal selection and preprocessing, feature engineering, and classification with machine learning algorithms. We have

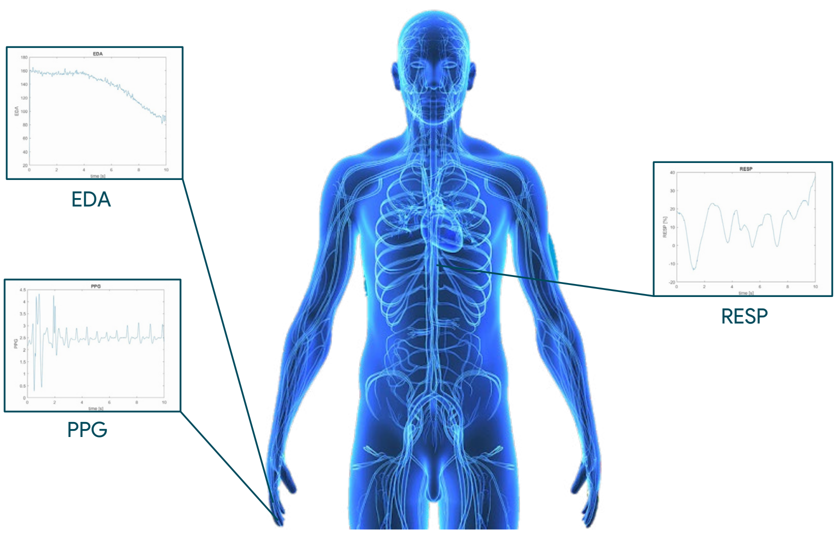

Figure 4: Physiological Signals for Stress Detection

based our study on a dataset for stress and affect detection called WESAD. Our results in the classification task, in terms of accuracy and F1-score, outperformed the benchmark and are still competitive when short window lengths are used. This further supports the application of our methodology in embedded scenarios, since reducing the computational power and the delay for real-time stress detection are provided.

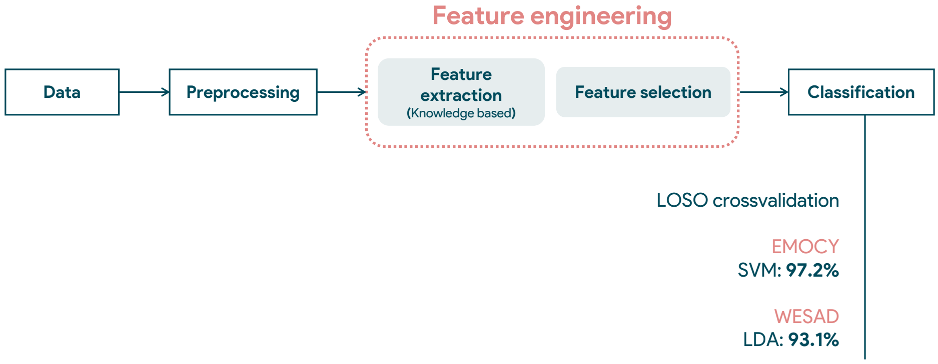

Figure 5: Software pipeline

The hardware part comes as a consequence because of the lack in the market of a ready-made device able to collect the three physiological signals that we had selected. These signals can be acquired with good accuracy also with cheap sensors available on the market and capable of interacting with electronic prototyping platforms. The EmoCy PoC incorporates sensors and Arduino platform for data collection and transmission, exploiting the Wi-Fi connectivity of the board.

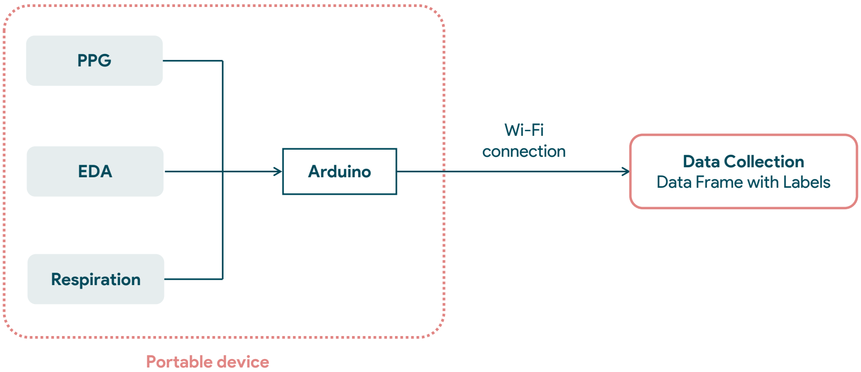

Figure 6: Hardware architecture

The last segment concerns the definition of a proper protocol for the stress induction. With the help of a psychologist, we chose the Montreal Imaging Stress Task and Hamilton Letter transformation test, thus combining arithmetic and logical questions. Feedback about the performance and time flowing increase the under pressure feeling of the participant. Moreover, State-Trait Anxiety Inventory is filled from each participant at the beginning of the test to investigate the links between self perception and physiological signals patterns.

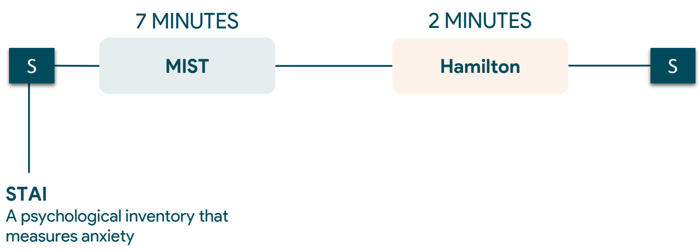

Figure 7: Protocol fro stress induction.

In the end, we have merged the software, hardware and protocol parts in the data collection phase. We have acquired data from 8 willing participants, in a controlled environment. A preliminary data analysis has shown the good outcome of the entire pipeline.