Sleep detection using physiological signals from a wearable device

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DESCRIPTION

Internet of Things for medical devices is revolutionizing healthcare industry by providing platforms for data collection via cloud gateways and analytics. In this paper, we propose a process for developing a proof of concept solution for sleep detection by observing a set of am-bulatory physiological parameters in a completely non-invasive manner. Observing and detecting the state of sleep and also its quality, in an objective way, has been a challenging problem that impacts many medical fields. With the solution presented here, we propose to collect physiological signals from wearable devices, which in our case consists of a smart wristband equipped with sensors and a protocol for communication with a mobile device. With machine learning based algorithms, that we developed, we are able to detect sleep from wakefulness in up to 93\% of cases. The results from our study are promising with a potential for novel insights and effective methods to manage sleep disturbances and improve sleep quality.

OBJECTIVES

Our objective in this work, is to study and show to what extent it is possible to accurately detect the regularity of the sleep patterns in ambulatory conditions. For this purpose we use a wearable device that is equipped with multiple sensors and is usually worn on the wrist. The device is comfortable, easy to use and poses absolutely no harm or risk to the user. Our contributions are the following:

- To the best of our knowledge we are the first to use at the same time, combined the electrodermal activity (EDA), heart rate variability (HRV), accelerometer data and blood volume pulse (BVP) together with body temperature in order to classify sleep and wakefulness. Previous works for sleep classification have concentrated on one or the combination of some of the aforementioned signals.
- We provide a study about various features and their relevance to the sleep classification problem.
- We have developed and presented a mobile application that is connected with the sensor equipped bracelet to collect the physiological signals, provide data visualization and information about the regularity and duration of sleep patterns.
- We have proposed a support vector machine (SVM) based model to classify sleep and wakefulness, tested several kernels and optimized the parameters such that the classification F1 score is up to 93\%.

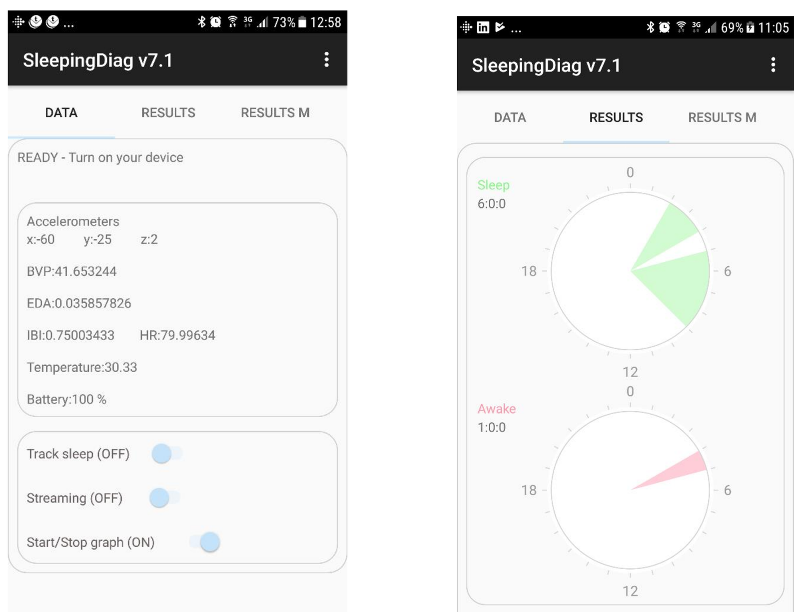

Fig 2: User interface with sleep pattern representation

RESULTS

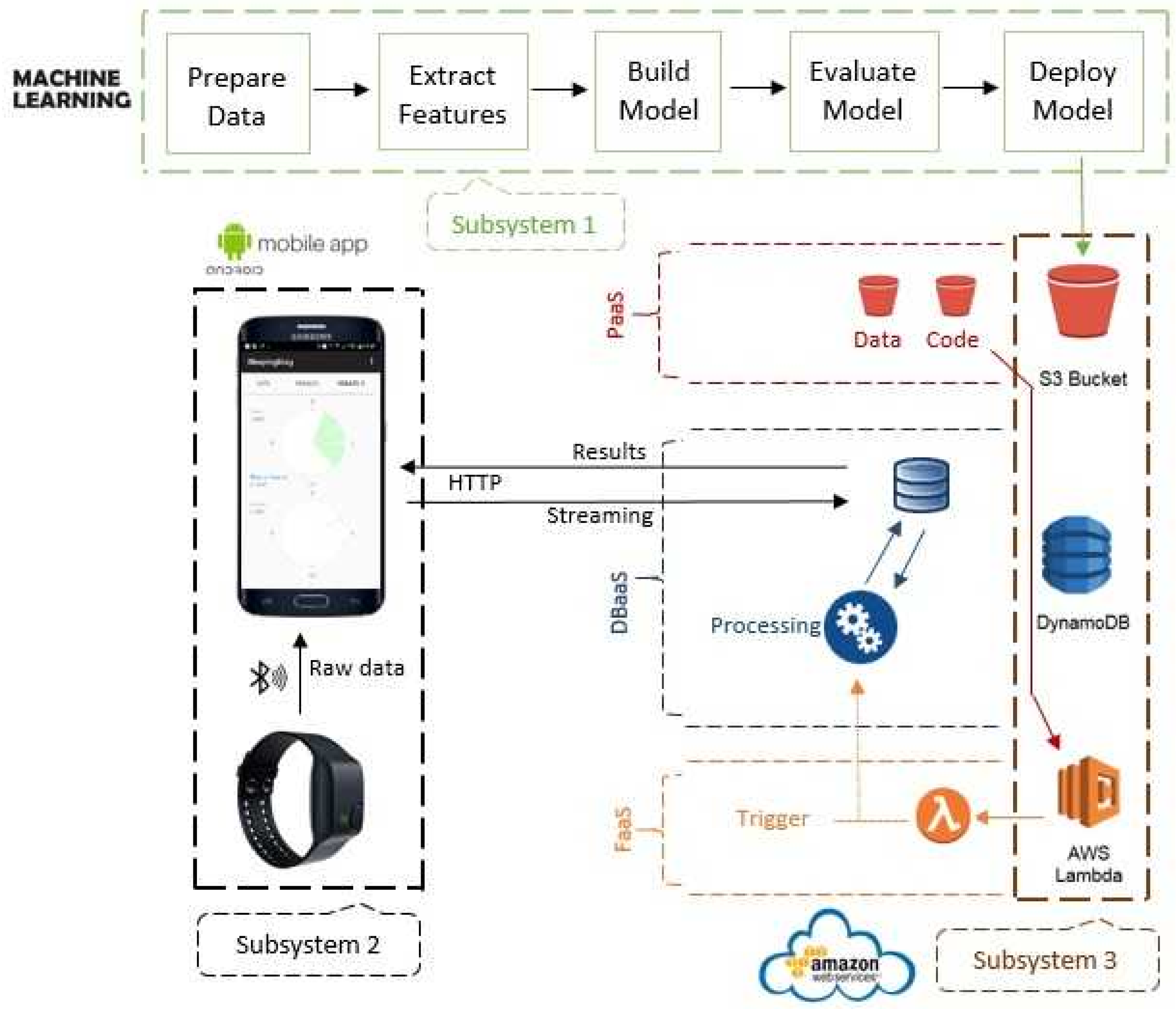

Fig 1: Project architecture

kernel	sigmoid	linear	rbf
std(BVP)	0.81	0.82	0.82
mean(ACC)	0.93	0.92	0.87
std(HRV)	0.82	0.82	0.82
mean(IBI)	0.89	0.89	0.89
mean(EDA), mean(ACC)	0.68	0.92	0.91
mean(EDA), mean(ACC), std(BVP)	0.83	0.93	0.86
mean(EDA), mean(ACC), std(BVP), mean(HRV)	0.90	0.92	0.89

Table : Classification results : F1 score

CONCLUSIONS AND FUTURE WORK

In this work we present a system that integrates a wearable sensor equipped bracelet, a mobile application and a cloud-based back-end application that allows non-invasive monitoring of sleep patterns. We further analyzed a set of physiological signals and their features to explore which features among them indicate significant differences between sleep and wakefulness. Our study is fairly comprehensive with regard to the variety of physiological signals that we collect in ambulatory settings without disturbing the patient. In our analysis various signals such as electrodermal activity, heart rate variability and blood volume pulse and patients' movements registered via an accelerometer are taken into consideration. We show that by carefully estimating a rich set of parameters for support vector machine based classification algorithm we can achieve up to 93 % of correct classification when classifying sleep and wakefulness periods for the analyzed subjects. Our study shows that such a system can be of great use for medical health practitioners who are interested to follow sleep patterns and regularity for patients whose condition is at risk either during sleep or due to lack of sleep.

In the future we aim to investigate more in details the different types and phases of sleep such as nREM1, nREM2, slow-wave and rapid-eye movement REM. For this purpose, we plan to compare a completely non-invasive methods such as the method proposed here, with hospital grade quality sleep evaluation methods. Integrating user feedback about the mobile application is also planned as a part of our future work.

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