Ατομική Διπλωματική Εργασία

MONITORING HUMAN EMOTIONS THROUGH WEARABLE SENSOR DATA

Γεωργία Καλλή

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΥΠΡΟΥ

ΤΜΗΜΑ ΠΛΗΡΟΦΟΡΙΚΗΣ

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Η Ατομική Διπλωματική Εργασία υποβλήθηκε προς μερική εκπλήρωση των απαιτήσεων απόκτησης του πτυχίου Πληροφορικής του Τμήματος Πληροφορικής του Πανεπιστημίου Κύπρου

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ABSTRACT

The most important and significant thing for every human is healthy life. It is a fact that health influences our daily, physical and psychological situation. During the day people express various emotions which have impact in their viability. In regard, the feelings determinate and enhance the better quality of life. Consequently, everyone ought to manage their negative and injurious behaviors. Principally, the stress acquires an assertive role in our individual personality, when we know our stress levels, we can control and reduce it. It is remarkable that one cheap and efficient system which shows our stress state in real time will be very useful to people.

In order to achieve avoiding pessimistic emotions, a developed system will be indispensable. It makes their lives better and they avoid wasting time at the doctor's. For this reason, I developed a system to present emotional and physical state in real time. Each person who desires to use this system must have a Microsoft BAND and an android mobile phone. Microsoft Band 2 is a digital Watch which is responsible to measure Heart Hate, RR-intervals, Skin Response and daily activities. The humanity recognizes that the android applications are omnipresent. So this system will be very utile and familiar for a lot of people. The output will provide information illustrated in the android application after processing algorithms. Eventually the results will contain the stress levels and the physical state. Accordingly, the users will be allowed to observe their metrics live. It is notable that they have the ability to store their individual data in the database. Furthermore, they will concentrate to tail after the trend of progress in the online dashboard. Hence, they will be able to compare their improvement with their atomic values.

During the project, we organized an experiment to audit the operation of stress and physical algorithms. The evaluation took place 10 users, who were using the phone application. The answers and the initial data was processed for evaluation. For this reason, we have been checking if the results of the algorithms were valid and if they were compatible with the users' feedback.

In the termination of this project, the system was evaluated for the usability from the users. It was given to users for determining the operation. Thus, the functionality of the structure was defined by the perspective of the public. The feedback we got from this whole experiment determined the amount of satisfaction the users got from it. They estimated the necessity, demand and convenience of the system. Their inferences were taken into account for the optimum version of the project.

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Chapter 1

Introduction

1.1 Definition of problem

Everyone is concerned by a huge problem which influences them. It is a fact that stress is a biological and psychological response of our body when encountering a threat that we feel we do not have the resources to deal with. Sudden stress generally raises the heart rate and that provokes negative consequences either on our behavior or our body. Substantially, some of the common effects of stress on our behavior would be outbursts, social withdrawal and the feeling of anxiety, sadness or depression. Additionally, the effects of stress can also be seen on our body by the appearance of headaches, fatigue or even sleeping problems [30]. The most serious chronic problems were the development of cancer and cardiovascular diseases. It is remarkable that the inability of detecting stress, which appears in habitual actions, produces unpredictable situations in human lives. If we all had a device to scan stress, we would certainly have less stress and we would be healthier.

Due to this issue, it is significant to encourage people to regulate their behavior and life through strategies for avoiding stress. So if we have the opportunity to check and inspect our stress then we would be more offish and careful about brusque alternations in emotional situations. In this way we could successfully maintain a more stable heartbeat. Likewise, the necessity to create a system to detect stress in actual time during the day is generated. Additionally, the system will be very useful to store a daily, monthly or yearly historic background of metrics.

1.2 Purpose

It is widely known that people are depended and affected by technology and devices. Because of that, we can exploit the occasion and adopt a system which protects our health. Based on the problem mentioned above, we came up with an essential system, which will be profitable and very helpful. This system will accommodate and interact with the emotional states for each person, specifically, stress. Moreover, the greatest thing about it is that every user will be able to discern his individual and personal metrics in real time. Noteworthy, there is a feasibility to store the history of data. Thereupon, it is equally important to behold the metrics and compare the results for stability, evolution and result to protect ourselves. Finally, the output of processed data through algorithms will detect the levels of stress.

Once smart watches rolled out on the market people started to obtain them in order to monitor their progress. Precisely, the Microsoft Band will provide data from sensors. Spontaneously, the metrics will be transported to the android application, Cogniband, and presented to the users, adjusting their personal information and preparing the stress level in real time which will give them control and the opportunity to reduce it. However, all details will be saved in a database, SQL Server, and then they will have to create an account and exanimate the aftermath of their stress through their own Online Dashboard.

Therefore, the users are reassured for their health. Consequently, they ground on themselves and discover that their activities cause stress. There are times in our lives when we feel particularly overwhelmed with tension. During them we feel really terrible and have highly unpleasant stress. This system fights our damaging attitude, for example if the user detects stress at some point, he will endeavor to reduce it and he will observe his progress in the Online Dashboard, which provides daily/ monthly / yearly information.

Finally, the whole project was evaluated from users and the results indicated that the system was evaluated for its reliability of data and its necessity on the everyday life. They rated the necessity and usefulness of the android application and the Online

Dashboard separately. Additionally, in the android application the StressRR, RRclassification and Classification algorithms detect the stress through the heart. The Physical algorithm, indirectly, detects the stress in real time through reflection of movements. The users take part in the experiment for the accuracy of the algorithms. The effects show that the StressRR and Classification are close in our expectations. Circumstantially, the two algorithms coincided with the answers given by the users about their feelings. Similarly, the physical algorithm achieves to recognize the movement type in actual time.

As a conclusion, the contribution of the system is to provide information about emotional and physical state. It provides information about the stress level in real time and urges the users to manage the hurtful sentiments. The algorithms are effective and they provide remunerative information about stress and by expansion, about people's health. The system proved 86% useful and helpful for people.

1.3 Recapitulation

My thesis consists of chapters. The first chapter denotes the speculation that is plaguing society and denotes the problem that is plaguing society, which is how today's society confronts stress. Further, it mentions the purpose of my Bachelor Thesis. The second chapter defines the fundamental concepts of the elaboration and the understanding of the project. The third chapter indicates the research which evolved at the beginning and during implementation. It contains existing systems, articles and papers. The next chapter describes the architecture, the flow of information and the technologies utilized. The following chapter presents minutely the design of both platforms, android application and Online Dashboard. Moreover, it explains the contribution of database and the execution of certain algorithms. The sixth chapter explicates the evaluation of algorithms and the users' appraisal, which is related to the system performance. The final chapter focuses in the future work and the general conclusion.

Chapter 2

Theoretical Background

2.1 Human Emotions and Stress

Emotions are normal arousals which associate with behavioral and physiological changes. They comprise sensation and trigger the autonomic nervous system. Stress is a complex emotion. Many various situations cause stress by physical to emotional reasons. It is worldwide known that anxiety overcomes us in specific circumstances and we cannot avoid it. Stress is the feeling we have when we are under pressure. It is a common and natural human emotion. The stress emergency response is the body's way of protecting us in intense situations, demands, or perceived threats. Stress causes significant trauma to our health, spirits, productivity, growth and quality of life. Stress in difficult states and activities plays a major role in cardiovascular symptoms, especially heart strike danger. Throughout the time that stress is adaptive or irregular stress can have a negative collision on mental and physical health. Resulting from anxiety, we must miscarry stress from our daily routine and achieve better health.

According to researches, emotions are determinated by Autonomic Nervous System. The Autonomic Nervous System is in charge of enabling and controlling the reaction of the body to external and internal stimuli. This control function is performed through the

two branches of the ANS, sympathetic nervous and parasympathetic nervous. Firstly, the sympathetic is responsible for stimulating the body's fight or flight of the nervous system associated with stress, overtraining, and inflammation. Secondly, the parasympathetic nervous is blameful for the body's resting functions. It also promotes relaxation, digestion, sleep and recovery.

When our brain evaluates stress, the sympathetic nervous system arranges the brain to react to stress. The stress raises the heart rate, increments metabolic rate, expands blood vessels in the heart and other muscles. When the brain accepts the facts, the stress is up beyond, the parasympathetic nervous system helps you back to normal levels. In such a way, the sympathetic nervous system is aroused during stress and releases energy. Conversely, the parasympathetic nervous system executes the contrary operation.

2.2 Detect Stress

Regrettably, alternations in parasympathetic and sympathetic nerves are probably indistinguishable. According to the Autonomic Nervous System, I will be explaining how to detect Galvanic Skin Conductance (GSC), Heart Rate(HR), RR Intervals and finally, Heart Rate Variability because they relate to the heart and by extension to stress [29]. Next, I will show how they are all connected to emotions and how they can be affected by stress. One way to calculate stress is a smart watch which provides sensors for the recognition of the GSC, HR and RR-Intervals. These three motivations are used for the algorithms to distinguish the emotional state. In addition, the Heart Rate Variability is a procedure which aims to find the stress level utilizing RR-intervals. Also the Accelerometers define the movements which reflect with stress, considering that if somebody is siting, he is more relaxed than somebody who is running.

2.2.1 Galvanic Skin Conductance

The functions of the sympathetic nervous system lead us to the skin conductance through sweat glands. While this part of the sympathetic nervous system is activated, the palmar and sweat glands congest, and the skin conductance increases before the sweat is removed and the skin conductance decreases. A raise in the number of skin

conductance fluctuations and amplitude of skin conductance fluctuations can therefore be interpreted as increased activity in this portion of the sympathetic nervous system. This method is specific for the stimuli that induce the stress response.

The skin conductance consists of two main components: Skin Conductance Level and Skin Conductance Response. Each one of them has different utilities. Firstly, the tonic level, known as skin conductance level, slowly varies and changes slightly within tens of seconds to minutes. The rising and declining SCL is constantly changing within an individual respondent, depending on their hydration, skin dryness, or autonomic regulation. The tonic level can also differ markedly across individuals. This has led some researchers to conclude that the actual tonic level on its own is not that informative. Secondly, the phasic response rides on top of the tonic changes and shows significantly faster alterations. Variations in the phasic component are obvious as "GSR bursts" or "GSR peaks". The phasic response is also labeled skin conductance response as it is sensitive to specific emotionally arousing stimulus events. These bursts occur between 1-5 seconds after the onset of emotional stimuli. By contrast, non-specific skin conductance responses happen spontaneously in the body at a rate of 1-3 per minute and are not related to any eliciting stimulus.

Through some research and experiments, measurements were taken from individuals, on a time period where they were calm, and other measurements after causing them anxiety. We observed that the voltage output tension was inversely proportional to the value of the skin resistance. When the individual's hands sweat, his resistance decreased. Therefore, we concluded that the more stress the person was under, the higher output voltage was. Based on Skin Conductance Response we cannot extract whether the arousal was due to positive or negative stimulus content. The real power of and Skin Conductance Response unfolds as it is combined with other sources of data.

2.2.2 Heart Rate

Generally, the Heart Rate (HR) calculates the number of beats per minute. The average resting HR is between 60 and 90. A well-trained athlete might have a normal resting heart rate closer to 40 beats per minute. The HR is directly affected by the ANS; the

heart continually oscillates between acceleration and deceleration in a tug-of-war. An increase in activity of the sympathetic nervous system leads to an increase in HR, whilst an increase in parasympathetic activity causes a decrease in HR. The influence of the parasympathetic branch is greater than that of the sympathetic branch on HR. The parasympathetic branch tends to cause HR activity across the entire frequency spectrum, whilst sympathetic nervous system regulation tends to be detected in the low frequency spectrum. Negative emotions have been reported to have a stronger influence on HR.

One's personal HR varies with age, gender, ability to perform, performance related to a type of sport and the person's physical fitness.

2.2.3 RR Intervals

There is a necessity to measure the number of seconds that elapse between one heart beat and the next one. The differences between beats are called RR intervals.

The R-R interval spectral analysis is usually based on heart rate data accumulated in two ways. In the first method, the data are collected by analog to digital conversion of the electrocardiogram (ECG) signal and computer evaluation of the RR intervals from the ECG signal. In the second method, devices are used; whose output is the RR interval alone. The advantage of the first method is the control of accuracy and flexibility of the evaluations. The second method has the advantage of storing smaller amount of data, and it can be easily used online.

2.2.4 Heart Rate Variability

Meanwhile, our body responds to whole things existing around our mood, character, thoughts and activity. Our brain leads us by heart via Autonomic Nervous System. This normal alteration of heart rate, controlled by autonomic nervous system, is called Heart Rate Variability (HRV). It is liable to respond to natural regulatory impulses. As a matter of fact, calculating heart rate variation uncovers broad sequence of information about our body and finally our health.

In widespread, HRV is a metric that produces the balance between the parasympathetic and sympathetic nervous of the Autonomic Nervous System. The parasympathetic nervous is motivated when the HRV is high and a human is relaxed, or digesting, or sleeping, or recovering. Additionally, the sympathetic indicates low HRV and the human is dominated by stress, overtraining, and inflammation. Simply put, monitoring parasympathetic activity through HRV can provide individual's physiological stress level, with higher levels of stress resulting in lower HRV.

HRV is estimated by series of RR intervals or differences between heart beats. After, HRV is relatively with Heart Rate. We calculate the number of seconds that elapse between one heart beat and the next one. HRV requires a certain amount of data to be collected, before it can be calculated. Subsequently, the HRV is able to distinguish environmental, digestive, psychological, physical and other stressors. In spite of this, it is very complicated during exercises. For this reason, we determine the stress level by using a combination between HRV and HR. At the moment that HRV is low and HR is high, enormous stress prevails. Instead, HRV is high and HR is low, so relaxation preponderates.

2.2.5 Accelerometers

Accelerometer is the rate of change of velocity with respect to time. It is a sensor, which generate a signal in response to acceleration that is enforced along its axis. It has a frequency range which determinates a filter on the output of the X, Y and Z axes. Accelerometer surveys the quantity, tension, frequency, and duration of movement. Moreover, it can measure acceleration of the body part in 1 (uni-axial), 2 (bi-axial), or 3 (tri-axial) layers. In fact, it is suitable to measure physical activities. Wearable, activity sensors with accelerometer can be placed on a human body whose movements are being studied. In many occasions, it is needful to measure the whole-body movement. Motion indicates stress indirectly, and by every movement the heart rate increases or decreases. The fatigue after running does not denote stress, although the heart rate is high. For this reason, the combination of accelerometers metrics and the level of stress are interdependent.

Chapter 3

Related Work

3.1 Existing Systems

In the inception of my thesis, research has been accomplished for existing systems. Indeed, these systems comprise Heart Rate, RR-Intervals and Heart Rate Variability. The commercial is intended to be used by users. These existing systems approach people who are concerned, affected and want to have fraught control over their health. The existing systems were source of ideas because they have the same structure with my project. Particularly, they transfer the data from a smart watch sensor in an android application that controls stress. Some of them support the historical data. My system was developed in the same layer with the divergence that it maintains the historic in the database. This gives the opportunity to the users to observe their historical data, daily, monthly and yearly, by logging in to the Online Dashboard and therefore, peruse the stressed period.

Olive [6] is an armlet equipped with LED lights on our wrist which perceives stress. This system is our private guide to stress because it alarms the user when damaging emotions appear. Moreover, the breath is a semantic factor which influences the stress, and then *Olive* helps to control it. The sensors include Heart Rate, Skin Conductors and Heart Rate Variability. Further, *Olive* interacts with smartphone through an application for the stress management. More concrete, the application has the capacity for keeping the data safe. After processing data via algorithms, it presents the aftermaths of stress. The application accommodates the users to have an integrated image of their activity and psychological conditions. The data are shown in real time through Bluetooth.

Additionally, it provides ranges of biometrics, habits analysis and lifestyle trends.

©http://urbanwearables.technology/olive-bracelet-stress-management/

Picture 1- Olive Wearable

Embrace wearable [10] was created to recognize the stress level. This bracket can detect the harmful feelings through the combination of sensors. Additionally, during our daily routine, this system notices the level of stress. Specifically, if the users have stress then the *wearable* is set to vibrate slightly and if the users have high stress the warning is more powerful. The *Embrace* is linked with the user's smartphone. This gives the user the ability to connect with another user of the *Embrace wearable* so one user can check the emotional state of the other. The most intriguing part is that the *Embrace* does not contain a sensor for Heart Rate, however it is calculated by the existing sensors. Also, it has equipment which ensures security and privacy of data.

© http://www.sociale.it/2016/05/16/embrace-il-braccialetto-salvavita/

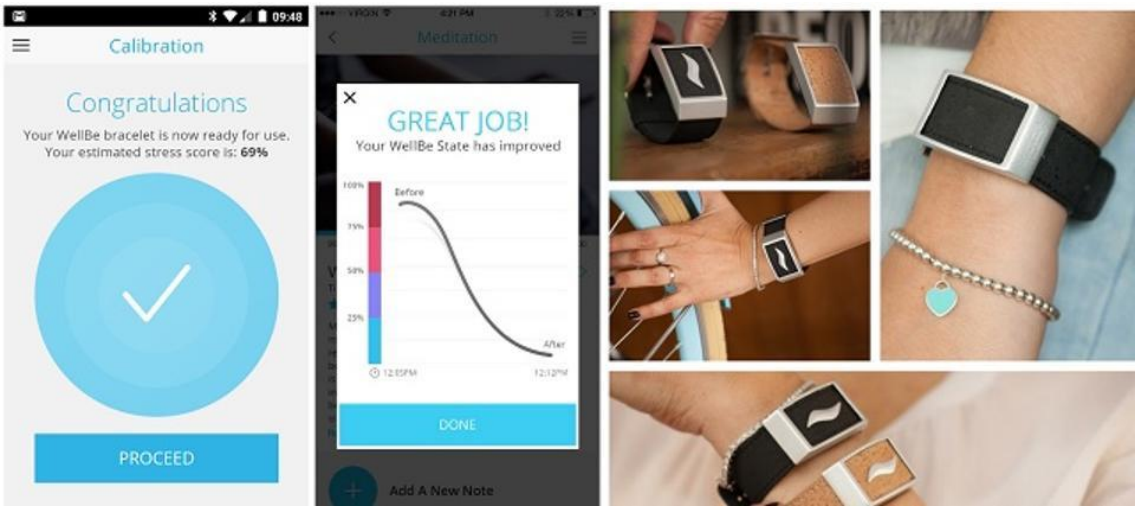
Picture 2 - Embrace Wearable

Zenta [13] is a biometric bracelet which gives information about pessimistic and positive emotions in workaday activities through the compatible application *Vinaya*. It is one of the few which does not have fitness as their main concern, it is appropriate for creating a personalised profile on emotions. All implementations are based on the enhancement of cheerful attitudes and therefore attenuates the stress. The biggest benefit is that the system possesses a mechanism which processes body, brain, and digital existence, so it operates with a machine learning algorithms. The *Zenta* measures the Heart Rate, respiration and perspiration rates. Actionable insights become over time associated with metric signal patterns. Also, it supports a great range of notifications and vibrations for each appearing emotion.

© https://techcrunch.com/2016/06/20/the-zenta-wrist-wearable-tracks-your-mental-health-not-just-physical/

Picture 3 – Zenta Wearable

The *WellBe* [14] device is constructed for users which desire to intern activities and situations. It is a fact that people claim to know what causes the stress and get round to avoid it. The aim of this bracket is therapy and exemption of people from the stress. From this perspective the algorithms approach the Heart Rate Variability. The *WellBe* application has the capability to suggest methods for stress-free and recovery of a normal situation. The application tenders the level of stress every hour of the day and allows displaying the weekly and monthly thought diagrams. Additionally, it bestows a list of various prospectus and activities by means of the personal data.



© https://www.forbes.com/sites/curtissilver/2016/12/22/wellbe-bracelet-is-one-wearable-not-trying-to-stress-you-out/#354eeda529d4

Picture 4 – WellBe Wearable

Zensorium Being [11]is a tracker which attains to be a cognizant for the separation of good and bad stress. The most zestful feature is that it pursues to create an emotion list for every individual user. This map is attained by the Heart Rate Variability. It contains different levels and zones of sundry feelings. The emotions are separated in stress, excited, normal and calm. Further, it provides monitoring heart rate, steps, distance, speed, and calories, according the movements and emotion state.

© http://khroton.com/design/?p=1

Picture 5 – Zensorium Wearable

Emvio [4] is a smart watch that follows both your stress levels and quotidian activity. The uncommon function, which *supplies Emvio* is that users are able to designate the provoking stress. Besides all conveniences, the bracket has LED which changes colour, depending on the emotional state. The red colour indicates high stress, the green low stress and the yellow medium stress. Apart all of the above, *Emvio's* system is compatible with mobile applications. Towards this point, the users can profit through the application, because it contributes to management of stress though trends. More specifically, it alerts every stress lever and saves the cause of stress.

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Picture 6– Emvio Wearable

Feature	Heart Rate	Heart Rate Variability	Skin Conductance	Skin Temperature	Accelerometer	Dashboard	Application	Exercises for stress decrease	Notifications for emotions
Olive	✓	✓	✓	✓	✓	Web	✓	✓	✓
Zenta	✓	✓	✓	✓	✓	application	✓		✓
Embrace			✓	✓	✓	application	✓		✓
WellBe	✓	✓	✓			application	✓	✓	
Zensorium	✓	✓			✓		✓		
Emvio	✓	✓			✓		✓		✓

Table 1- Comparison table with features of each system

3.2 Articles

Throughout the achievement and integration of the project, the articles and the papers, there was a guide. All information aid, apart from the theoretical part and the programming portion. Under these circumstances, the necessary scholarliness from articles was a source of inspiration and perception of new concepts. Research was made to better understand the human body and its reactions.

The physical algorithm is depended on the article *Toward Physical Activity Diary: Motion Recognition Using Simple Acceleration Features with Mobile Phones* [16], which explains the exact operation of ordinary movements. The comprehension of how the accelerometer data corresponds to the various actions became through certain devices. The activities which were involved in the experiment were sitting, standing, walking, running, driving and cycling. The accelerometer consists of X, Y and Z axis which defines the local coordinate. The main manipulation of data is a decision tree which is branched for quality responses. The experiment contains 1153 samples, and each sample has a duration of about 10 seconds. After processing, every metric takes place in the evaluation for an efficiently physical algorithm.

In the paper *Mathematical Algorithm for Heart Rate Variability* [17], the analysis clarifies the significance of Heart Rate Variability (HRV). It refers to the time between two heart beats, which is a very attractive time for research, so the HRV is an easy way to find out the emotional state of someone. Specifically, every 20 seconds a "Central Index (CI)" is calculated and provides an answer about the HRV. The indication reveals the level of stress. Additionally, they developed an algorithm with heart rates to detect the number of HRV. Finally, they pointed out that mood changes at least once every 1 to 6 minutes. For this reason, every correct answer of the algorithm lasts 60 seconds.

In the article *Stress and Heart Rate Variability* [8], stress is separated in good and bad. Firstly, good stress is created from good news and bad stress is caused by bad situations. Stress always depends on our emotions, our thoughts and our body's reaction to occurrence. It is worth mentioning that when we observe stress through Heart Rate

Variable (HRV), we are able to control the high levels that occur. We can measure HRV from a monitor, which supplies real-time-data. By monitoring the HRV, we can improve our daily routine. When the HRV levels are low, it means that we are highly stressed and when the HRV is high, we are relaxed.

According to the article *a robust, simple and reliable measure of Heart Rate Variability using relative RR intervals* [15] the HRV is determined by calculating features, beginning from a series of RR intervals. Usually, it is measured by the methods Time domain, Spectral and Geometric. Time domain methods are affected by the heart rate. In addition, it gives us the SDNN (standard deviation of NN-intervals, intervals of difference between adjacent RR intervals, which reflect the average level of the short-term HVR), RMSSD (square root of the mean squared difference of successive NN intervals) and pNN50(number of pairs of successive RRs that differ by more than 50 ms). Spectral methods give low frequencies (LF)/ high frequencies (HF) ratio. Finally, the Geometric methods use triangular interpolation for TINN which describes the total variation of the RR series. Furthermore, the insertion of Relative RR intervals determines the relation between RR-interval sequences and avoids the filtering outliers and artefacts from RR sequences.

The one entitled *Using Heart Rate Monitors to Detect Mental Stress* [18], supports that stress can be controlled by the Autonomic Nervous System (ANS) which is in charge of enabling and controlling the reaction of the body to external and internal stimuli. This control function is performed through the two branches of the ANS: Sympathetic Nervous System (SNS) and Parasympathetic Nervous System (PNS). The SNS is responsible for stimulating the body's fight or flight of the nervous system associated with stress, by raising the heart rate. On the other side the PSN is responsible for the body's resting functions. It also promotes relaxation and causes reduction in heart rate. The ANS can be examined through the Heart Rate Variability. The HRV measures the number of seconds that elapse between one heart beat and the next one. For the recognition of this relation between ANS and HRV, we are called to utilise one non-linear system, which is called principal dynamic modes (PDM). An experiment was done by modelling a discrete-time Volterra series to show how the PNS and SNS are

calculated from HRV through the equations and it was proved through the experiment. The last experiment was consisted from mental and relaxed situations. For the comparison, they used power spectral density (PSD). So PDM features were more stable than spectral features, but in the combination stressful events had a success rate of 83%.

The article *Listen to Your Heart: Stress Prediction Using Consumer Heart Rate Sensors* [2] refers to Galvanic skin response (GSR), heart rate variability (HRV) and how to detect the stress. The target was to determine the stress only from heart rate sensors and electrocardiogram (ECG) devices without GSR. The last would be useful for the comparison of the results. The GSR can be detected through the palms and feet where there is a high density of the eccrine sweat glands and for this reason they provide successful effects. First of all, they took values of the GSR and ECG signals. They then set windows for the records and one cut-off for GSR records. All values over cut-off, defined the windows "stress" and under cut-off "rest", which indicated a binary classification. The ECG guided to take HRV. So, they used time-domain features from RR-intervals and calculated frequency-domain features from Lomb periodogram, an alternative method of Fourier transform. They used the results and tried to create windows from the values of GSR windows. Furthermore, the class distribution was calculated based on the windows. In the end, they tried many classifiers and combinations for the best results. The conclusion was that the ECG came closer the GSR measures.

Revealing Real-Time Emotional Responses: a Personalized Assessment based on Heartbeat Dynamics [12] indicates that the cardiovascular dynamics come from the RR interval. To detect heart rate, they presented pictures with valence and arousal emotions. Valence represents how much an emotion is perceived as positive or negative, whereas arousal indicates how strongly the emotion is felt. For these two emotions, we have low-medium and medium-high. The procedure for detecting emotional stimuli consists of three steps. Firstly, they extracted RR interval series from the ECG. Secondly, they used the autoregressive coefficients of the quadratic NARI expansion to extract the input-output kernels. Finally, they estimated the instantaneous spectral and bispectral feature by using the autoregressive coefficients of the cubic NARI expansion and fast

orthogonal search algorithm to estimate the instantaneous dominant Lyapunov exponent. During the experiment, the emotion “sadness’’ appeared from L-M valence and L-M arousal, the “anger” one from L-M valence and M-H arousal, the “happiness’’ one from of M-H valence and M-H arousal and eventually, the one for ‘‘relaxation’’, from of M-H valence and L-M arousal. In the algorithm the kernel function played a very important role. The results were called recognition accuracy.

In *Influence of Mental Stress on Heart Rate and Heart Rate Variability* [9], an experiment is described for understanding HR, HRV and stress in different alteration. 28 participants took part in the research. At the begin, they discerned pictures which emit relaxed emotions. Thereafter, they were evaluated in mental task. During the experiment the Heart Rate was recorded for future analysis. In addition, the HRV was measured in time domain and frequency domain. The results denoted that in mental task the RR-intervals was lower than in relaxed situation. Consequently, the stress is displayed in low values of RR-intervals.

Chapter 4

Description of System

4.1 Flow of Information

Initially, every user acquires the Microsoft Band. Relying on this, it offers particular sensors. The useful sensors are used to detect stress through human emotions which affect the heart by measuring the Heart Rate, RR-Intervals and the Galvanic Skin Conductance. Moreover, the movements influence stress and the heart. For this reason, we retrieve the accelerometer metrics to recognize motion in real time.

The quality metrics of the sensors go through the android application, namely *CogniBand*. In this case, the user creates an account for privacy. At that time, the initial metrics from Microsoft Band are illustrated in a visual and graphical layout. The application contributes to the conduction of the results on the emotional and movement algorithms. All information is stored in a file and when the user connects to the internet, he has the opportunity to synchronize his data with the database SQL Server to save the

metrics and the outcomes of the algorithms. Automatically, this procedure operates whenever and wherever, without a continuum connection to the internet.

The personal profile is saved in a relate through their account in a spatial database. In addition, tables contain all new answers which spring up from algorithms. Finally, the RR-Interval, Heart Rate, Skin Conductance are a department of the database.

With an intention to awaken people about a healthier life, the Online Dashboard contains all the available elements for examination and observation. The reconnaissance of data gives the chance to people to recognize the psychological state and rehabilitate their behavior in burdensome situations. The Online Dashboard involves the initial information and the outcome for emotional algorithms. Further, the Online Dashboard provides the profile for the user, so that the user processes and changes the private information for saving them in accuracy in database.

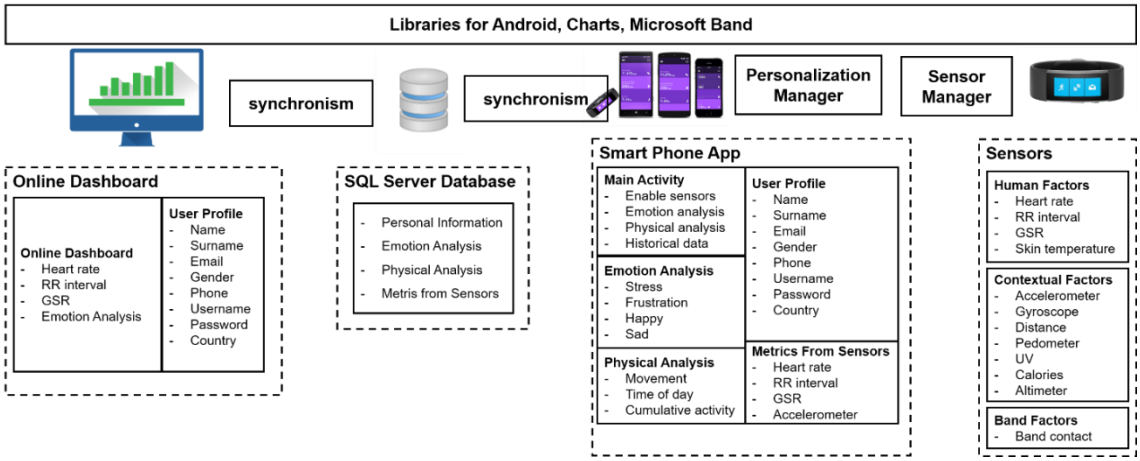

Figure 1 –Flow of Information

4.2 Microsoft Band 2

Microsoft Band 2 is a smart watch which was developed by Microsoft and provides necessary features for everyone, especially for athletes. Obviously, the device is a strong wearable option. The stats it gathers are accurate, and seriously useful.

Microsoft Band succeeds more by tracking your heart rate, various exercises, calorie burn, and sleep quality, and helps you be productive with email, text, and calendar alerts. Certainly, it assistances you live healthier and more efficiently. The Band includes 11 sensors involving Heart Rate, RR-intervals, Accelerometers and skin conductance.

It is an undeniable fact that the Microsoft Band has a wide range of sensors which we have the opportunity for access. Enhance the experience of users which in possession of digital watch because purvey many details about our live, especially our health. For this reason, we are exploited the device to retrieve immediate the data of Heart Rate, RR-intervals, Galvanic Skin Conductance and Accelerometer.

Firstly, the GSC can be detected through the palms and the feet where there is a high density of the eccrine sweat glands. These are known to be responsive to emotional and other psychological stimuli. A Microsoft Band is placed in either of these areas, where the conductance is measured by placing two electrodes next to the skin and passing a tiny electric charge between the two points. When the person increases alertness, skin him forthwith becomes a triflingly better conductor of electricity. This response can then be measured and passed along.

Moreover, Heart Rate is described as follows by our heart beats, capillary vessels expand and contract confirmed on blood volume variations. PurePulse LED lights on the band reflect into the skin to detect blood volume changes and finely tuned algorithms are applied to calculate heart rate consecutively and continuously. Obviously, Microsoft Band 2 provides the RR- intervals between the most recent two continuous heart beats in seconds.

Accelerometer provides metrics from X, Y, Z axis in meters per second squared units. The Microsoft Band controls and measures the user's movements.
Finally, the Band interacts with android through Microsoft Health application. Additionally, the user must to enable the mobile Bluetooth for coax to pass to the application the metrics.

In my thesis, the Band is valuable due to retrieve the metrics through sensors for each person. Especially the heart rate, RR-intervals and Accelerometer are requisite values for the algorithms to distinguish the emotional state and physical moving. In addition, their presentment is imperative by the presupposing everybody needs to have awareness for his measurements.

Microsoft Health is a compatible android application with Microsoft Band 2. One can install the application from android store and create his account on their platform. The Band syncs their data up with a phone if the person wants to look at it later. It has simple navigated structures which show their unique data and, in matter of fact this gives you the possibility to check out trends (day, week, and month) based on your recordings, indicates reveals result, fitness levels and observes your progress.

Microsoft Health has the lineament that every person must to create his account to preservation their distinct data. My android application acquires the data from Microsoft Band and the only way to reclaims is through the Microsoft application.

4.3 Android Application CogniBand

A fundamental tool in my Bachelor Thesis is the Android studio, which is accountable for android application implementation. The application generates a personalized, abundant in details, modifies experience and enhances the emotional well-being. In this way, I created an interface for the interaction between the user and the Microsoft Band. Every person who utilizes the application has the opportunity to observe their metrics from the Microsoft Band and he has access to perceive the stress level in real time. Finally, the application receives the physical state and presents it. It is worth to mention that the application is a link to transmit the data on an Online Dashboard. Additionally, I have to mention, connecting the sensor's Band with the application can only happen by using Microsoft Band library (com.microsoft.band)

4.3.1 Design of CogniBand

First of all, it is a requisite preference that the Bluetooth of mobile must pair with the Microsoft Band to connect and receive data in real time. So, for this reason the first control we need to do, is to present notification of connection with Band through the Bluetooth. Once connected, equitable, the user triggers off the sensors with an affirmative answer in the permission notification. While the sensors work, they constantly track aspects of our health.

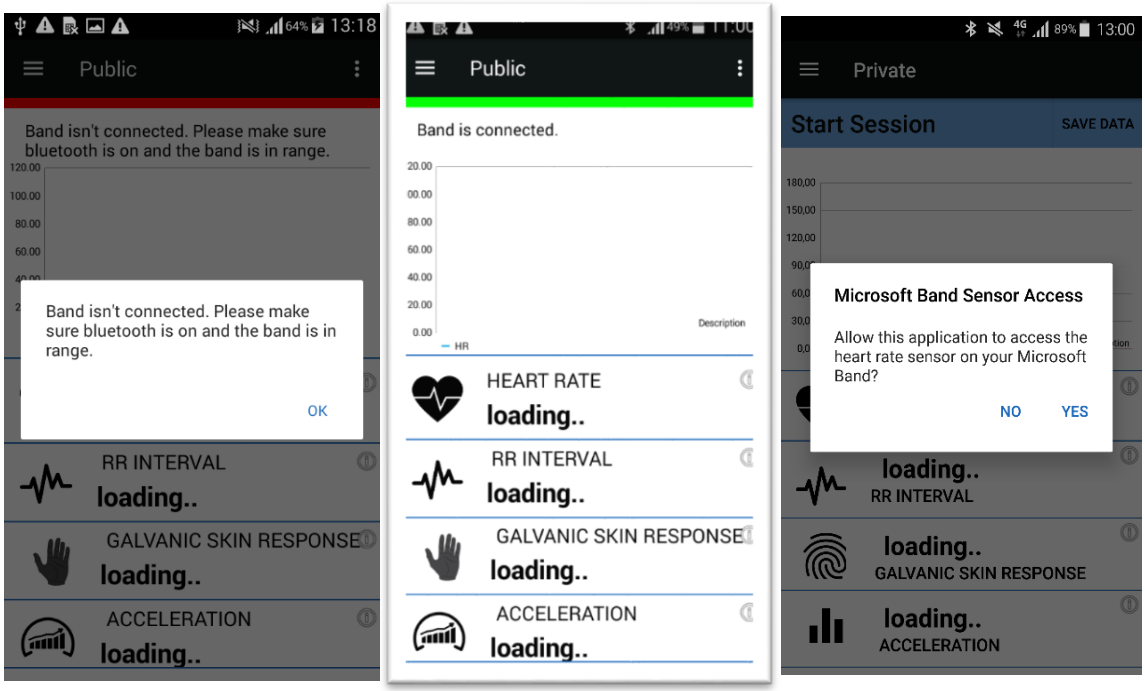

Figure 2 – Application connects with Band

Unambiguously, the first time the users create his account. The registration form contains the username, first name, surname, password, email, age, date of birth, phone, country and gender. All trusted information are saved in the SQL Server. Therefore, the personal elements provide individual management for their data. The account is a feature which assists to connect in the Online Dashboard.

Indeed, when the user exploits the opportunity to navigate in the android application, he logs in with his account via form, which comprises username and password.

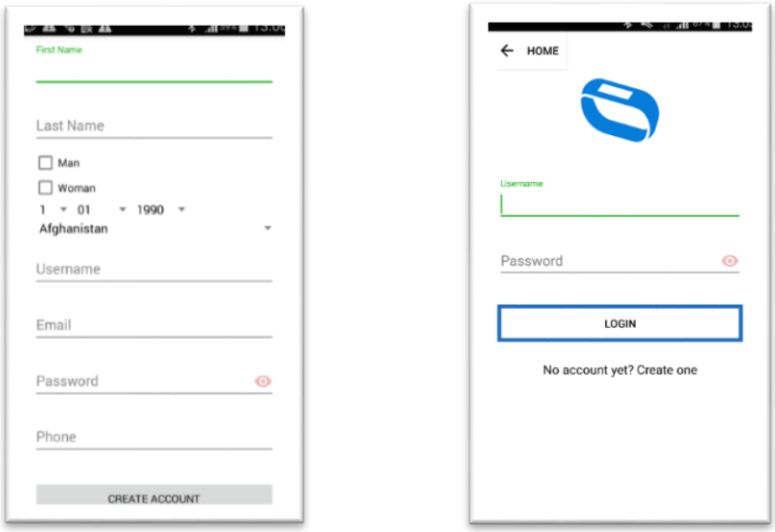

Figure 3 – User Account in application

The foremost layout reveals the Heart Rate, RR-Interval, Galvanic Skin Response and Accelerometer. All of the metrics above are displayed in both ways in genuine time. The first method offers the metrics through text numbers. The second approach presents an in line graph in real time. Each different line has its own color, which terminates the dissimilar measures. Y- axis reflects the value and X-axis the time. Further, I import com.github.mikephil.charting.charts library for line chart which make the application more attractive.

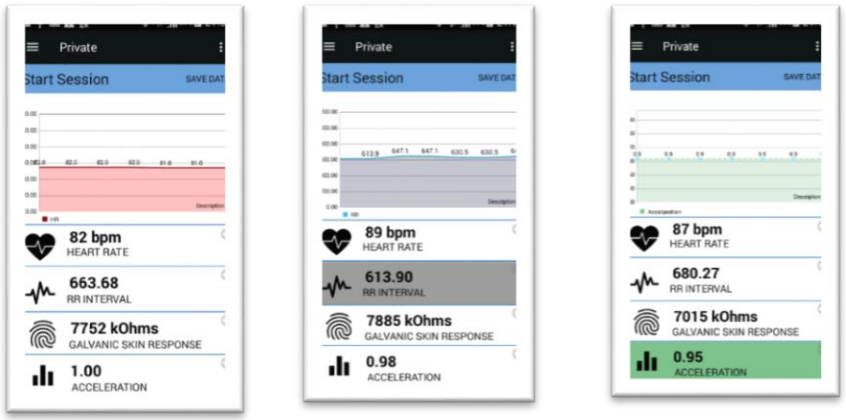

Figure 4 – Initial Metrics from Band

Moreover, a menu is embodied in the android application. The menu button includes the pages which present the stress and physical algorithms.

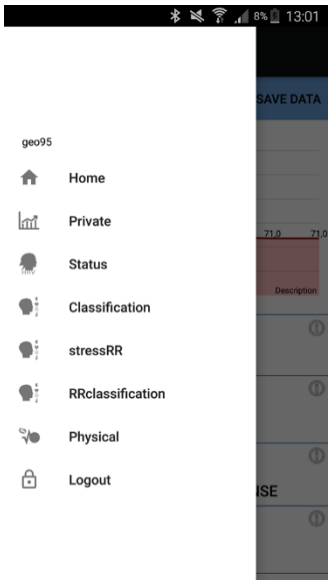

Figure 5 – Menu

The layout for physical algorithm indicates the actual user's move by the way of text. Someone may discern the status sitting, standing, walking and running in text. Beforehand, the appropriate algorithm arranges and processes the Accelerometer metrics which emanate from the Microsoft Band.

Figure 6 – Physical Algorithm

Besides that, the stress layout acquaints the emotional state in real time. In the meantime, the mobile screen reveals the emotional well-being. In that spirit, it uncloaks the outputs of the algorithms with a line chart. Additionally, it indicates stress through a text. The stresses levels are distinct in four classifications: very stressed, stressed, very relaxed and relax. The declaration of return value and, by extension, the cognitive state, become through two algorithms. The process of data obtains access in RR-Interval, Heart Rate and the skin conductance.

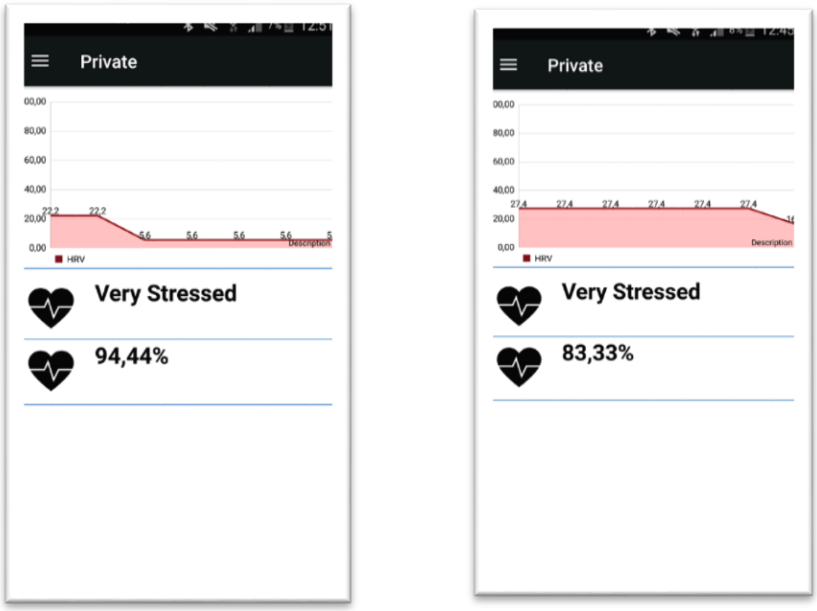

Figure 7 – Emotional Algorithms

I completed the presentation of the application with the last layout. This design is composed out of four cycles, each one of them portrays one proportion. The green cycle puts forward happiness, the yellow color sadness, the red stress and finally the blue one relaxation state. Additionally, this layout offers the initial metrics from the Microsoft Band.

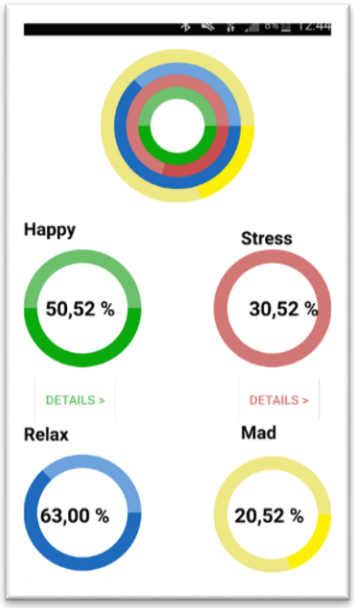

Figure 8 – Classification Algorithm

4.3.2 Algorithms for Detecting Stress and Movements

The Android Application executes three algorithms for stress detection. The classification of the algorithms exploits the Heart Rate and Galvanic Skin Conductance sensor. The amalgamation of two data bring to fruition the percentage of stress. The stressRR algorithm is based on the sliding window which saves 21 RR-Interval. The principal function is to find out median of processing information to calculate the stress level and discard which failed. The processing is done between two consecutive RR. Finally, the third algorithm, RRclassification, likewise recognizes the stress. It occupies RR-Intreval and works with a sliding window. It provides a solution about the HRV, thus it measures an index based on hinge on four seriatim RR.

The physical algorithm is accomplished with the help of the accelerometer's metrics. Principally, and most importantly it is how the algorithm operates. Firstly, the accelerometer metrics are separated in X, Y, Z axis. Every 100 new values of the accelerometer's metrics are stored in two-dimensional arrays. After processing, the algorithm defines three variables, which determinate the movement. The combination of

these variables separates the movements into two parts. The first delineates the actions without movement and the second contains motion. Categorically, the immovability is divided into two subcategories sitting and standing. Similarly, the actuation is split in walking and running.

4.3.3 Technologies and Tools for Creating Application

The **Android Studio** is an open source and Linux-based operating system for mobile devices such as smartphones and tablet computers. Every project contains java programming language and XML layouts. It supports building android wear app with the appropriate libraries and connects with database.

In my Thesis, android studio is the sole way to develop android applications. I construct an application which is blameful to display individual metrics for each person. Likewise, it informs for stress and motion in real time. Besides the based operation, it is a conjunction between Microsoft Band's metrics and online dashboard. The most significant function is store abundance data and transferred in database.

Extensible Markup Language (XML) is a markup language from the World Wide Web Consortium (W3C), is similar to HTML. It has a standard formal recommendation which is human legible and machine readable. It is designed to store and transport data. The structure is embedded system with the data, thus when the data arrives there is redundant to pre-build the structure to store the data because it is dynamic
Xml code is obligatory in android studio. It designates and designs layouts. For this reason, it manages the presentation of items in my android application.

4.4 Online Dashboard

An interesting aspect of the system is the mindful monitoring of data in daily, monthly and yearly. The most intriguing part is that the user will be capable of comparing the values and perceive trends over time. The online dashboard is befitting for the resolution of information which brings about the inevitable stress. It is absoluteness that, if we append more, current and supplementary experiences in our forthcoming

dashboard, we will devise a complete picture of our lifestyle and what precipitates our stress. Further, if we want to keep an eye on our general stress levels, it is sufficient to recur in our personal online Dashboard. With a meaningful way, today's society can observe headway and determine the convenient interventions for a more balanced life barren of stress.

4.4.1 Design of Online Dashboard

Firstly, each user who desires to acquire an individual online dashboard is obliged to create an account either from their mobile application which is connected to the Microsoft Band or the Online Dashboard. The personal navigation is required forasmuch as the operation of the Online Dashboard which provides you with the opportunity to analyze metrics for a particular period.

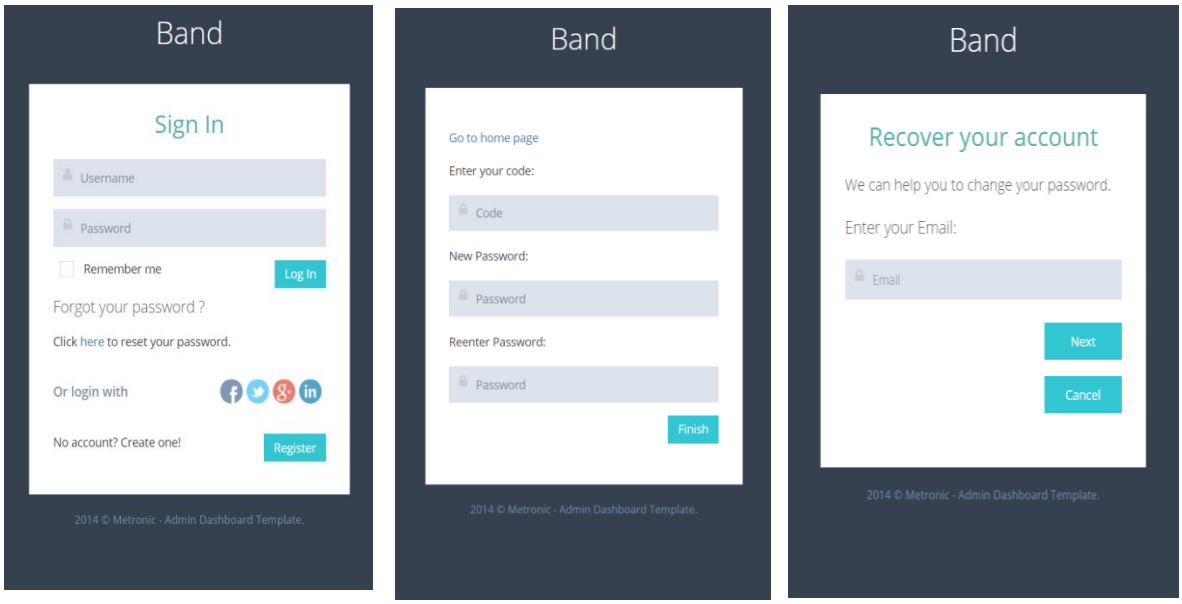

Figure 9 - User Account in Online Dashboard

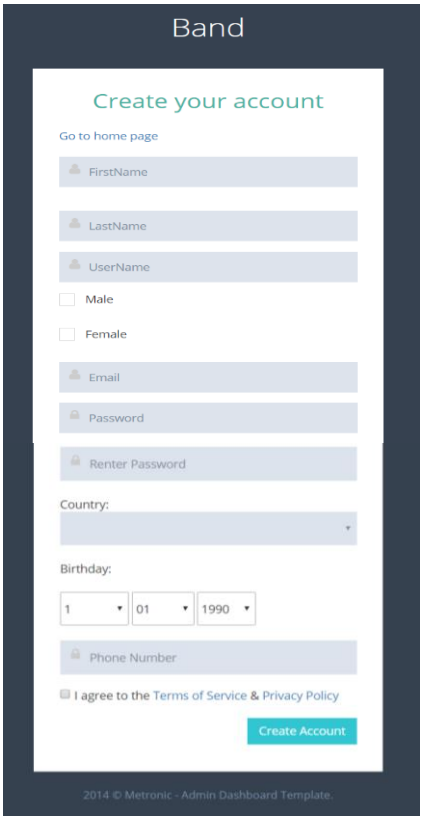

Figure 10 - Register

The account can be corrected and processed. Specifically, the user repairs or compliments a field which contains personal information for the improvement of the profile and detail registration of private elements

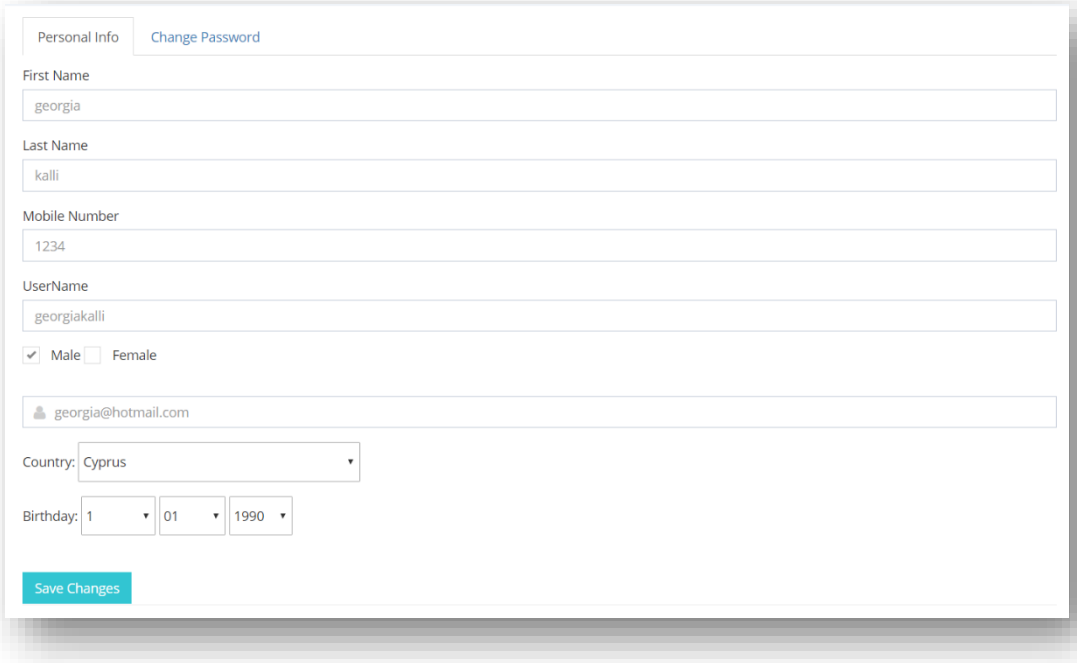

Figure 11 - Profile

The most considerable component of the account is the Online Dashboard. It retrieves distinguished data from tables of the SQL Server Database. More definitely, the data is presented in lines graphs. The data indicates the initial metrics from the Microsoft Band, which are saved in the android application store in each personal account. Those are: heart rate, RR-interval, the skin conductance, accelerometer metrics and the three algorithms of stress. Also, the Online Dashboard is separated with daily, monthly and yearly measurements. It is remarkable that, all this information raise the users' concern about their health. Additionally, they will subconsciously create a more absolute picture of their emotional state. This will take effect and enable a more balanced life if the user takes into account the outcome from the graphs. Generally, anyone who utilizes the system, observes, analyses and focuses on metrics in any specific period of time.

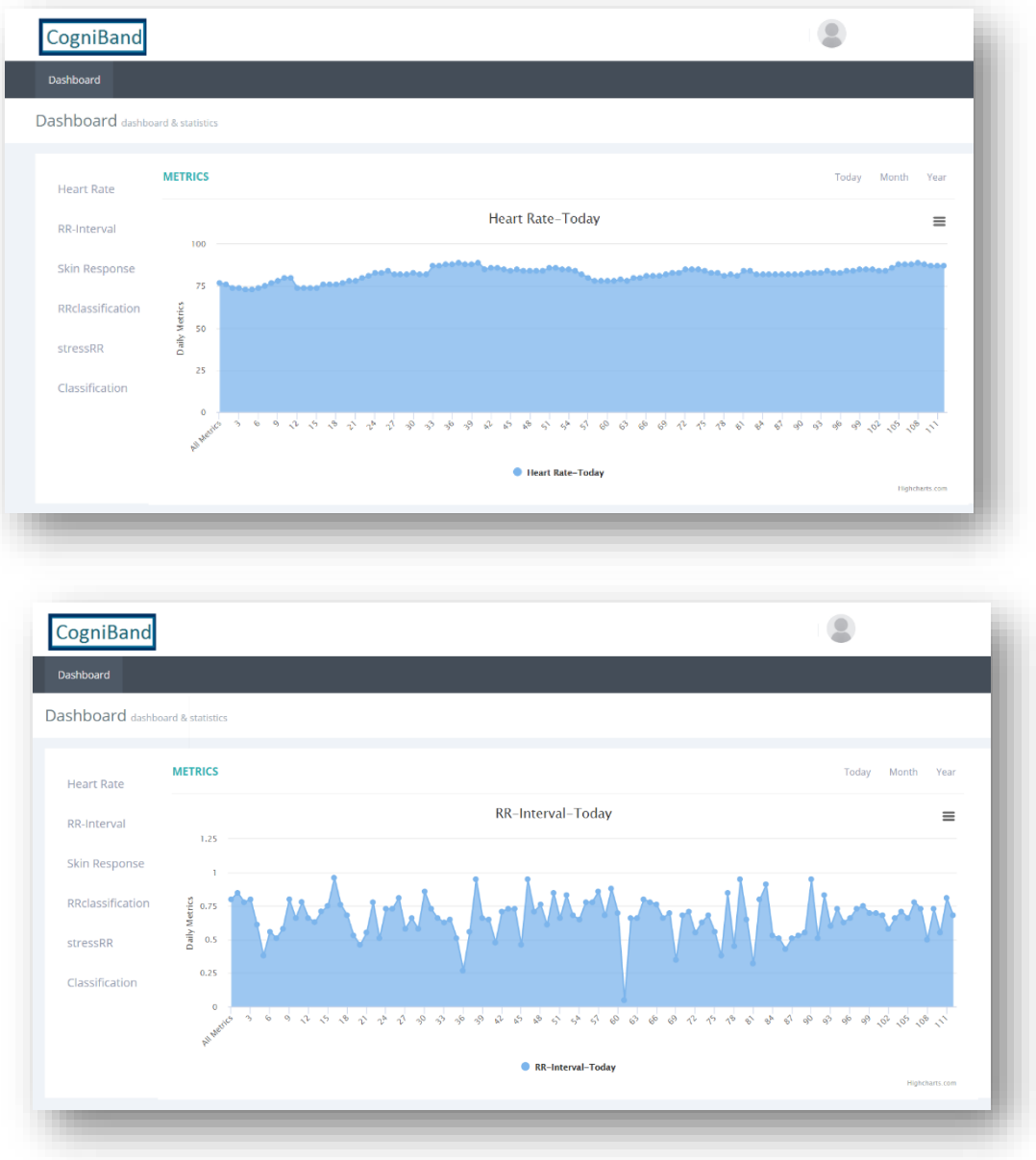

Figure 12 – Historical data

4.4.2 Technologies and Tools for Creating Online Dashboard

Asp.Net is web application designed for web progress by Microsoft to permit programmers to developing dynamic websites, web services and web applications. It includes scripts and source codes which interact in a browser how a web page should be

illustrated. During the time the page is running, it can execute any task; involve values, reading or updating database, or communication with other programs.
My web page is completed with the use Asp. It is controller and piece together the web design and coding. It processes the various elements for an accuracy result and finally one efficient website. My design implicates JavaScript, CSS and Html. Eventually, the code is writing in C# program language.

Visual Studio is an integrated set of development tools for building ASP.NET Web applications based on use of the Extensible Markup Language (XML). It includes several programming languages such c# and c++. It is used to develop web-sites, web applications, web services and mobile applications. Finally, Visual Studio manages Microsoft SQL Server.

Visual Studio is the program which i use for deployment a web page. It is convenient to build an online dashboard, on account of it provides combination betwixt design and code. Moreover, it proffers a manageable access in database.

JavaScript is a dynamic programming language or script language, which can be imbedded in HTML pages HTML and interactive in Web browser. It is used to create effects within websites. It has potential to unlocking a capacious amount of functionality with diminutive attempt. Script language takes longer for processing but is practical and helpful for small programs. JavaScript code is based on Java.

JavaScript improves the graphical interface and coding components in web pages. Following it is appropriate to create cause to exist the online dashboard with every detail. Whole web site hinges on JavaScript.

Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a markup language. It is commonly used for visual style and user interfaces in Html. CSS adjusts different styles and methods in the same page and can display or resize the screen depending on the device. Also, it involves shadows, gradients, transitions and animations.

In my web page the CSS complements the JavaScript.

Hypertext Markup Language (Html) is the basic markup language for devises, Web pages and Web applications. It is a scripting language, for this reason, the content of a website is defined by Html. It provides a means to design composition documents by structural semantics.

Beside JavaScript, the web page utilises and html. This combination makes the online dashboard more efficiently

C # is an object-oriented programming language developed by Microsoft. Microsoft's C# is a tool which Visual C #.NET uses. Visual C #.NET consists interfaces, visual designers, suitable code, XML Web services and database applications for Web applications based on C #. The main role of C # is making easy the implementation a web page.
Online Dashboard is developed in Asp.Net. Accordingly, C# is the language which manages the web pages and controls the data in Database SQL Server.

4.5 SQL Server Database

Microsoft SQL Server is a database management system. It stores and retrieves data from other software applications across a network. A database is lists of values and attributes. Microsoft SQL Server provides an environment used to generate databases that can be accessed from workstations, the Internet, or other media such as a personal digital assistant.

In the implementation Microsoft SQL Server is indispensable tool owing to that is the storage which it cherishes and keeps values security and safe. Additionally, it is interconnected with android application in which it has the accountability to save the metrics. Afterwards it has conjunction with web page which demonstrates the results from database.

The SQL Server is an equilibrium linkage between android application and online dashboard. The system compel database to play dominant role due to it allows the flow of data from one component in other. An important aspect is that the database keeps the data secure and safe with appropriate manage. The SQL Server saves the personal information from profile and the metrics of Band broken down per user. Beginning with the register of user, which save in table in SQL Server. After, everyone logs in android application, then all data store in another table in database and they are separated by the username of every person. Therefore, the user if login in online dashboard the first procedure is to reclamation the data from database organize and order by date and time in graphs.

Chapter 5

Evaluations

The confirmation of the functionality happens through experiences. Twenty people participated for the two evaluations. The first ten people dealt with their physical and psychological state. Precisely, they checked the three emotional algorithms and the movement algorithm. The other ten users approved the usability and functionality of the System. Expressly, they attempted the android application and the Online Dashboard.

5.1 Algorithms Evaluation

The first experiment was achieved based on the algorithms. It is a fact that to attain this we invited willing people. Each person wore a Microsoft Band for approximately 24hours. Thereafter a connection was established between the Band and their phone. Additionally, the installation of the android application had to be made. The users were responsible to check their stress level every hour through the application. Every time they checked their stress level, they had to complete a form for their current opinion. The form summons to complete the emotional and movement state of the user at that moment. Thereupon their initial metrics of the Band and the output of the algorithms were stored in the database for the upcoming process. The four algorithms, stresRR, RRClassification, Classification and Physiacal, executed in parallel for the following estimation.

Interaction Devise Types Each user during the experiment was wearing a Microsoft Band 2, which is responsible for tracking the Heart Rate, RR-Intervals, the Galvanic Skin Conductance and Accelerometers. Additionally, smartphones, which developed

with the Android mobile operating system and they are compatible with Microsoft Bans 2 were used for the implementation of the algorithms.

Graphic Design for Recognition of the Emotional and Physical state an android application was developed for the participants to record the outcome of the algorithms and save the feedbacks. The last registered how the user was feeling and what was doing. More specifically, the form of feedback was composed of check boxes for feelings and a drop down list with options of movements. As view in figure 13, the check boxes contain the alternatives very relaxed, relaxed, stressed and very stressed and the list contain the choices running, walking, talking, eating, sitting, speaking, standing, watching TV, reading, dancing, working, driving and exercising. After the user was transported in a layout which illustrated the results of the algorithms in a line graphical and the percentage of stress in real time.

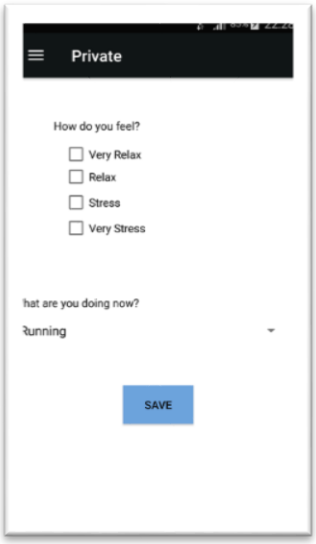

Figure 13- Feedback

Participants in the experiment, 10 participants (6 females, 4 males) took part, between the ages of 16 and 55. All users had previous experience with mobile phones, but no one had practiced wearables. They were all easily familiarized with the whole experiment.

Procedure in the beginning, the participants payed heed to the directional instructions for the correct usage of the Microsoft Band 2 and the android application in relation with the experiment. All users held the Microsoft Band 2 and used the application for one day. Following, they created their individual account and every one hour they had to fill in the form. Consequently, for two minutes the input for the sensors of the Microsoft Band 2 and the results of the four algorithms were saved in a file. In the end, the file was transmitted to the database SQL Server through Wi-Fi internet.

Analysis of results the table shows the percentage of validation between three algorithms and the user's feedback. They completed 56 samples in total.

The pie chart presents the percentage of feedback, which the users chose. The participants distinguished their emotional state and 35 answered relaxed in questions. Furthermore, they determinated 17 stressed situations during the experiment. They affirmed 3 times very relaxed and once very stressed.

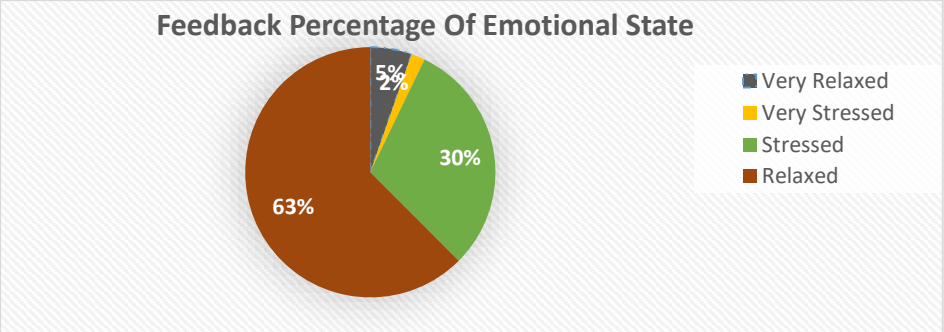

Chart 1 – Feedbacks Analysis

The table below depicted the success rate of the algorithms concerning the users' feedback. Specifically, the table indicates the proportion of how much agreement there was between the user feedback and each algorithm. As we can see in the relaxed option the Classification algorithm possessed the optimum performance. Additionally, in the stressed option the RRClassification held a large percentage compared to the other two algorithms, although, the StressRR wears a high portion. In the three algorithms, the very stressed option was 100% consistent regarding the reviews. Unfortunately, 1

sample was very stressed, for this reason the outcome was not objective. In the fourth option, very relaxed, the stressRR and Classification algorithms acquired 66,66%. Overall, the StressRR algorithm was the most accurate because it was the only one in accord with the feedbacks of the users. The results of the Classification algorithm are approaching the ones of the StressRR algorithm. It is remarkable that the results of the three algorithms are differentiated from wearable to wearable.

Feedback / Algorithms	Relaxed	Stressed	Very Stressed	Very Relaxed
RRClassification	25.71%	88.23%	100%	0%
StressRR	65.71%	76.47%	100%	66.66%
Classification	60%	58.82%	100%	66.66%

Table 2 - Emotional Analysis

The table displays the proportion of correctness between physical algorithm and the user's reaction. 10 person filled 81 specimens in aggregate. The feedbacks comprise various movements. The 65 simples were sitting, 8 were walking. 5 were standing and 3 were running.

Feedback	Sitting	Walking	Standing	Running
Algorithm	89.87%	87.5%	100%	75%

Table 3 - Physical Analysis

5.2 System Evaluation

The second experiment was carried out with the objective to decide the proportion of satisfaction. It is a fact that, a questionnaire is a way to measure the usability and the necessity of the system. The System Usability Scale (SUS) [28] supports stochastic questions. It is a veritable simple scale to measurement the usability of the system through management of the answers of the users. It collects the answers of 10 inquiries in the questionnaire. The five questions in the odd numbers are to strongly agree with the system and the other five in the even number are to strongly disagree. The SUS was

answered by the users before we explained anything about our system, but after the respondents had the opportunity to use the system and appraise it.

Concretely, the users sought to put the whole system in use. They mentioned the utility and the functionality, from the application and the Online Dashboard, so that the overall level could be defined. Finally, the feedback of the users was reported. Their opinion was registered in a questionnaire. According to the following results, we were able to state that the System is serviceable, advantageous and convenient.

We shared the questionnaire with ten people between the ages of 20-50. Firstly, the participants navigated and explored the android application. Thereupon, the users completed the questionnaire. Immediately after, each user created his individual profile in order to connect with the Online Dashboard. Further, they controlled and processed the historical data in the Online Dashboard. Finally, they filled out a second questionnaire which was based on the functionality of the Online Dashboard. Once they have completed the process, I asked open-ended questions about the usefulness of the system. The users understood the usability of the system, because in my questions they answered clearly that they cognized how the system operates and how many information can be retrieved for their health. It is important to emphasize the significant question "if the system was available on the market, then what exactly would it provide in your life?" The users mostly referred to health, a better life, reducing stress, and more management in daily routine.

The retrieved information had reflected in the usefulness of the system for the daily of every person. The users' difficulties appeared in the application and the Online Dashboard. In the CogniBand, the users declared that the application is complex in the navigation. On the other hand, the Online Dashboard illustrates the historical data without clarity. They had difficulty understanding the monthly and yearly data.

Indeed, the SUS yields a total number representing a calculation of the overall usability of the system. The outcome of the questionnaire indicated an average of 86% usability for the Android application. Additionally, the results for the Online Dashboard showed an average of 86.75% usability.

The tables below present the score of each user based on their answers in SUS questionnaire about the usefulness of the Android Application and the Online Dashboard.

Users	1	2	3	4	5	6	7	8	9	10
Android Application	97.5%	90%	82.5%	65%	80%	95%	85%	92.5%	85%	87.5%

Table 4 - Questionnaires each user for Android Application

Users	1	2	3	4	5	6	7	8	9	10
Online Dashboard	90%	92.5%	90%	90%	85%	82.5%	80%	82.5%	85%	90%

Table 5 - Questionnaires each user for Online Dashboard

Chapter 6

Conclusion

6.1 Summarize of Thesis

The Oppressive life and fast rhythms of current days provoke crucial emotions and health is neglected. The stress can result to illness directly, through its natural effects, or indirectly, through maladaptive health behaviors. Stress is your body's reaction to occurrence, thoughts, or emotions. Understanding this hypothesis allows you to take control of how you respond and conduct. Therefore, the concrete system provides immediate information about this obtrusive factor, so users must exploit everything that it offers for a stress-free society.

Procedurally, the Microsoft Band offers sufficient sensors, henceforward we transport the zestful metrics in the android application. The operation of the application is to present the initial metrics from the Band's sensors. Additionally, it analyses the emotional and physical state in real time. Subsequently, the Online Dashboard retrieves all information through SQL Server, so every user has the opportunity to observe his data. The system grounds on protection of users' privacy, also it maintains the individual metrics.

My thesis involves an experiment where algorithms are evaluated in order to measure accuracy. The stressRR, RRClassification and Classification algorithms detect stress and the physical algorithm measures movements in real time. The users were invited to use the Microsoft Band and the android application for 24 hours and complete feedbacks for their emotional and physical state in the current time. The outcomes were

processed and we resulted that the stressRR has the best performance. For the usefulness of the whole system, questionnaires were provided to the users for the accomplishment of their opinion about the android application, the CogniBand and the Online Dashboard. The system was appreciated to be understandable and lucrative for people.

Stress is an inevitable feeling of life. If stress is incessant, it can be detrimental to your health over time. As a consequence, stress prevention and management is noteworthy, and will help you juggle the many things going on in your life. The goal of avoiding stress isn't to completely get rid of stress, but to eliminate unnecessary stress and help you cope with inescapable stress. As a general conclusion we consider the system backed by people who want to supervise their health and explore the occasions that provoke stress

6.2 Future Work

This intriguing project has the capability to continue and expand, because all this semantic information is profitable and useful for modern society, which is possessed with stress. The expectations of the project are to turn into a more efficient and attractive project for everyone. The details make the system more manageable and functional. For this reason, the application and the Online Dashboard can improve.

Firstly, the application will develop in such a way that will pontificate the user when feeling pessimistic emotions. Additionally, in this case it will suggest solutions for avoiding stress and negative emotions. The android application will recommend specific exercise for relaxation, for example breathing exercises according to the combination of physical movement and emotional state. On the other hand, the Online Dashboard will process a peculiar period of time through the graphics. The providing of outlandish data will remind the users to take care of themselves.

It is remarkable that the system can be useful not only to the user, but also to another system. In the android application four algorithms exist, which can be used by other systems and presume upon their own operations. For this reason, the application could

be transformed on an application programming interface (API) which is a series of tools and protocols for the structure of new applications. Additionally, with this viewpoint the programmers will be felicitated in creating and expanding similar systems.

Bibliography

[1] *Android Studio*. (n.d.). Retrieved from https://developer.android.com/studio/intro/index.html

[2] David Liu, M. U. (2013-2014). Listen to Your Heart: Stress Prediction Using Consumer Heart Rate Sensors.

[3] Development of a Wireless Computer Vision Instrument to. (2014, September 23). *Mdpi*.

[4] Emvio. (2014). Retrieved from http://emvio.watch/

[5] Microsoft. (n.d.). *Microsoft Band 2*. Retrieved from https://www.microsoft.com/microsoft-band/en-us

[6] Olive is the wearable for managing your stress. (2017, Mar 8). *The Daily Dot*. Retrieved from https://www.dailydot.com/debug/olive-wearable-for-stress/ Silver, C. (2016, DEC 22).

[7] STORM, H. (2002). Skin conductance correlates with perioperative stress. *ACTA ANAESTHESIOLOGICA SCANDINAVICA*.

[8] Stress and Heart Rate Variability. (2011). *SweetWater Health Beat Healthy*.

[9] Taelman, J. (n.d.). Influence of Mental Stress on Heart Rate and Heart Rate Variability. p. 2.

[10] Team, E. (2015, Aug 8). Embrace is a watch that looks great on anyone. It can track your activity, stress and overall balance. *Indiegogo*. Retrieved from https://www.indiegogo.com/projects/embrace-a-gorgeous-watch-designed-to-save-lives#/

[11] THAVEEPRUNGSRIPORN, V. (n.d.). Zensorium Being. Retrieved from https://www.zensorium.com/being#introduction

[12] Valenza, G. (2014, May 21). Revealing Real-Time Emotional : a Personalized Assessment based on Heartbeat Dynamics. *Scientific Reports*.

[13] VINAYA. (2017, Feb 28). ZENTA: Stress & Emotion Management On Your Wrist. *Indiegogo*. Retrieved from https://www.indiegogo.com/projects/zenta-stress-emotion-management-on-your-wrist#/

[14] WellBe Bracelet Is One Wearable Not Trying To Stress You Out. Retrieved from https://www.forbes.com/sites/curtissilver/2016/12/22/wellbe-bracelet-is-one-wearable-not-trying-to-stress-you-out/#915ec829d4d8

[15] Vollmer, M. (n.d.). A robust, simple and reliable measure of Heart Rate Variability using relative RR intervals.

[16] Yang, J. (2009, 8 Jun). Toward Physical Activity Diary: Motion Recognition Using. Simple Acceleration Features with Mobile Phones

[17] ALDERSONS, A. (n.d.). Mathematical Algorithm for Heart Rate Variability.

[18] Choi, J. (2009, August 28). Using Heart Rate Monitors to Detect Mental Stress. *IEEE Xplore*.

[19] Morris, M., & Guilak, F. (17, April 2009). Mobile Heart Health: Project Highlight.

[20] J.A. Healey, & R,W, Picard. (2005, June 06). Detecting stress during real-world driving tasks using physiological sensors. σσ. 156 - 166.

[21] Julian F. Thayer, Fredrik Åhs, Mats Fredrikson, John J. Sollers III, & Tor D. Wager. (2012, February). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*, pp. 747–756.

[22] Alexandros Liapis, Christos Katsanos, Dimitris Sotiropoulos, Michalis Xenos, & Nikos Karousos. (2015, August 30). Recognizing Emotions in Human Computer Interaction: Studying Stress Using Skin Conductance. *Human-Computer Interaction*.

[23] Jawahar Jain, D. L. (2011, May 13). Continuous monitoring of stress using accelerometer data.

[24] George Boateng, D. K. (2017). StressAware: An App for Real-Time Stress.

[25] McLeod, S. A. What is the Stress Response Retrieved from www.simplypsychology.org/stress-biology.html? (2010).

[26] Sun, Feng-Tso, et al. "Activity-aware mental stress detection using physiological sensors." International Conference on Mobile Computing, Applications, and Services. Springer Berlin Heidelberg, 2010

[27] Desok Kim, Y. S.-H. (2008, October 14). Detection of subjects with higher self-reporting stress scores using heart rate variability patterns during the day.

[28] *System Usability Scale (SUS).* (n.d.). Retrieved from https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html
[29] Article Explains Importance of Heart Rate Variability for Your Health. (2015, January 26).
[30] The Effects of Stress on Your Body. (2016, June 12).

Appendix A – Pseudocodes

```
ArrayList<Double> d
 ArrayList<Double> rr
for i → RR.length do
      number ← (2 * (RR[i] – RR[i-1])) / (RR[i] + RR[i-1])
      add number in rr
for j → rr.size do
    IF rr[j] < 0,2 then
          centre ← centre + rr(j)
          count++
centre ← centre / count;
for j → rr.size do
      a ← Math.sqrt ((centre - rr (j)* centre - rr (j))+ (center - rr (j + 1)* centre – rr (j + 1)
      add a in d
sort(d)
median ← d (middle + 1)
value ← media *100
```

pseudocode 1- stressRR

```
hrate_w ←  0.555
skinrsp_w ← 0.445
IF heart_rate < = 40 then
        h_value=0;
Else IF  heart_rate >40 and heart_rate < 100 then
        h_value ← 0.01666666 * heart_rate - 0.66666666
Else
        h_value ← 1
IF Skin_Response > 70 and S Skin_Response < 1000 then
```

```
        s_value ← 0.001205 * Skin_Response - 0.0845
Else
        s_value ← 0.0;
Stress ← hrate_w * h_value + skinrsp_w * s_value
```

Pseudocode 2- Classification

```
PBFS ← 0
NBFS ← 0;
While i → rr.length do
        P[3] ← rr [i] ,    P[2] ← rr [i+1] ,     P[1] ← rr [i+2] ,   P[0] ← rr [i+4] ,
        T[0] ← P[0] - P[1] ,    T[1] ← P[1] - P[2] ,   T[2] ← P[2] - P[3]
        IF T[0] > T[1] then
                Vn ← 1
         Else IF T[0] < T[1] then
                Vn ← -1
         Else
                Vn ← 0
         IF   T[1] > T[2] then
             Vn1 ← 1
         Else IF T[1] < T[2] then
             Vn1 ← -1
         Else
             Vn1 ← 0
         IF (Vn == 1 and Vn1 == 1) or (Vn == -1 and Vn1 == -1) then
              PBFS++
          Else
               NBFS++
Answer ← (PBFS / (PBFS + NBFS)) * 100
IF Answer >= 50.0
          IF Answer >= 75.0
                You are Very Relaxed
```

```
        Else
            You are Relaxed
Else
        IF Answer <= 25.0
            You are Very Stressed
        Else
            You are Stressed
```

Pseudocode 3- RRclassification

```
a_count ← 0,   A ← new float[100][3], U ← new double[3], Ulen ← 0, Unorm ← new
double[3], datanum ← A.length, Pin ← new double[datanum], P ← new
double[datanum][3], H ← new double[datanum][3], Hval ← new double[10], mH ← 0,
mV ← 0, double stdH,  double stdV,   double tX ← 0,   double tY ← 0,  double tZ ← 0
For i = 0; i < A.length; i++ do
        tX ← tX + A[i][0]
        tY ← tY + A[i][1]
        tZ ← tZ + A[i][2]
U[0] ← tX / 10
U[1] ← tY / 10
U[2] ← tZ / 10
Ulen ← Math.sqrt(Math.pow(U[0], 2) + Math.pow(U[1], 2) + Math.pow(U[2], 2))
Ulen ← Math.round(Ulen * 1000d) / 1000d;
For  i = 0; i < Unorm.length; i++ do
        Unorm[i] ← U[i] / Ulen
        Unorm[i] ← Math.round(Unorm[i] * 1000d) / 1000d
For  i = 0; i < Pin.length; i++ do
        Pin[i] ← (A[i][0] * Unorm[0]) + (A[i][1] * Unorm[1]) + (A[i][2] * Unorm[2])
        Pin[i] ← Math.round(Pin[i] * 1000d) / 1000d
For  i = 0; i < Pin.length; i++ do
        For  int j = 0; j < 3; j++ do
           P[i][j] ← Pin[i] * Unorm[j]
```

```
            P[i][j] ← Math.round(P[i][j] * 1000d) / 1000d
            count++
            IF (count > 2 then
               count ← 0
For i = 0; i < H.length; i++ do
         for  j = 0; j < 3; j++ do
            H[i][j] ← A[i][j] - P[i][j]
            H[i][j] ← Math.round(H[i][j] * 1000d) / 1000d
For  i = 0; i < Hval.length; i++ do
         Hval[i] ←Math.sqrt(Math.pow(H[i][0],2)+Math.pow(H[i][1],2)+
Math.pow(H[i][2], 2))
         Hval[i] ←Math.round(Hval[i] * 1000d) / 1000d;
For  i = 0; i < Hval.length; i++ do
         sumH ←sumH + Hval[i]
         sumV ←sumV + Pin[i]
         mH ←sumH / Hval.length
         mV ←sumV / Hval.length
         mH ←Math.round(mH * 1000d) / 1000d
         mV ←Math.round(mV * 1000d) / 1000d
 For  int i = 0; i < Hval.length; i++ do
         tempH2 +=tempH[i];
         tempV2 += tempV[i];
 tempH2 ←Math.round(tempH2 * 1000d) / 1000d;
tempV2 ←Math.round(tempV2 * 1000d) / 1000d;
stdH ←Math.sqrt(tempH2 / Hval.length);
stdV ←Math.sqrt(tempV2 / Pin.length);
stdH ←Math.round(stdH * 1000d) / 1000d;
stdV ←Math.round(stdV * 1000d) / 1000d;
if (mV <= 1.0 and  mH<0.4 and stdV < 0.01 then
         You are Sitting
      else if mH > 0.110 and mV >= 0.5 and stdV >= 0.07 and  stdV <= 0.200 then
         You are Walking
     else if mV > 0.8 & mV < 1.3 & stdV < 0.07 then
```

You are Standing

else if mV > 1.3 **then**

else Calculating State

Pseudocode 4- Physical Algorithm

Appendix B - Questionnaire

System Usability Scales

	Strongly Disagree				Strongly Agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5