Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University

Faculty of Computer Information Systems and Software Engineering
(full name of faculty)
Computer science
(full name of department)

QUALIFYING PAPER

For the degree of

Bachelor
(degree name)

topic: Information Technology: heart rate variability analysis based on data collected from fitness sensors

Submitted by: fourth year student 4 , group ICH-42

specialty 122 Computer Science
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Ternopil
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Ministry of Education and Science of Ukraine
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« » 2021

ASSIGNMENT
for QUALIFYING PAPER

for the degree of Bachelor
(degree name)

specialty 122 Computer science
(code and name of the specialty)

student Kashosi Aser
(surname, name, patronymic)

1. Paper topic Information Technology: heart rate variability analysis based on data collected from fitness sensors

Paper supervisor Oleg Nazarevych, Associate Professor, Ph.D.
(surname, name, patronymic, scientific degree, academic rank)

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2. Student's paper submission deadline 26.06.2021

3. Initial data for the paper

4. Paper contents (list of issues to be developed)
Abstract. 1. The problem and its background. 2. Implementation and Methodology. 3. Heart rate tracking devices and the correlation between HRV and stress. 4. Life safety, fundamentals of labor protection. Conclusion. Bibliography. Annexes.

5. List of graphic material (with exact number of required drawings, slides)

6. Advisors of paper chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
Life safety, fundamentals of labor protection			

7. Date of receiving the assignment January 25, 2021

TIME SCHEDULE

LN	Paper stages	Paper stages deadlines	Notes
1.	Familiarity with the qualifying paper's assignment.	25.01.2021	Completed
2.	Sources on heart rate variability were selected.	26.01.2021-28.01.2021	Completed
3.	Processing of sources on HRV analysis	30.01.2021-2.02.2021	Completed
4.	Conducting HRV analysis research	2.02.2021-13.02.2021	Completed
	Development of the heart rate variability analysis web tool		
	with Django/Python, Celery, RabbitMQ and Heroku		
5.	Outline of the section « The problem and its background »	14.02.2021-15.02.2021	Completed
6.	Outline of the sections « Review of literature »,	16.02.2021-17.02.2021	Completed
	« Implementation and methodology »		
	« Heart rate tracking devices and the correlation between		
	HRV and stress »		Completed
7.	Execution of the task assigned to the subdivision	17.06.2021	Completed
	«Life safety»		
8.	Execution of the task assigned to the subdivision	24.02.2021	Completed
	«Fundamentals of labor protection»		
9.	Registration of qualification paper	07.06.2021	Completed
10.	Standardization control	09.06.2021	Completed
11.	Plagiarism check	12.06.2021	Completed
12.	Preliminary defense of qualifying paper	18.06.2021	Completed
13.	Defense of qualification paper	26.06.2021	

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ANNOTATION

Information Technology: heart rate variability analysis based on data collected from fitness sensors // Qualification work of the educational level "Bachelor" // Kashosi Aser // Ternopil' Ivan Pul'uj National Technical University, Faculty of Computer Information System and Software Engineering, Department of Computer Science // Ternopil, 2021 // P. , Tables – , Fig. – , Diagrams – , Annexes. – , References – .

The paper discusses the architecture and implementation of a web-based tool for heart rate variability analysis.

First, this project covers the need for analysis of heart rate variability. Then lay the foundations for the need for an effective analysis tool accessible to all.

Second, the architecture of the web application is studied in detail. The application is implemented with a pattern design which is a variant of the model-view-controller. For efficiency and performance, heart rate variability analysis is performed asynchronously using a task queue. The system also provides a REST service for GET and POST data.

Finally, the results of using the application are presented from the perspective of a web browser user.

Keywords: heart rate variability (HRV), pyHRV, Django, web application

LIST OF SYMBOLS, SYMBOLS, UNITS, ABBREVIATIONS AND TERMS

HRV – Heart rate variability

TD – Time-Domain

FD – Frequency-Domain

LN – Non-Linear

NNI – Normal-to-Normal Intervals

HR – Heart Rate

HR STD – Heart Rate Standard deviation

NNI DIFF MEAN – Mean NNI difference

NNI DIFF MIN – Minimum NNI difference

NNI DIFF MAX – Maximum NNI difference

SDSD – Standard deviation of NNI differences

NN50 – Number of NN interval differences greater 50ms

PNN50 – Ratio between NN50 and total number of NN intervals

NN20 – Number of NN interval differences greater 20ms

PNN20 – Ratio between NN20 and total number of NN intervals

TRI INDEX – Triangular index

BPM – Beats per Minute

DFA – Detrended Fluctuation Analysis

HF – High Frequency Band

HR – Hear Rate

LF – Low Frequency Band

PSD – Power Spectral Density

RMSSD – Root Mean of Squared Difference NNI

SDANN – Standard Deviation of the Mean of NNI in all 5-minute Segments

SDNN – Standard Deviation of NNI

TINN – Triangular Interpolation of the NNI Histogram

VLF – Very Low Frequency Band

CONTENTS

INTRODUCTION

The human body holds many secrets, and one of the most interesting is the psycho-physiological phenomenon of oscillation in the time intervals between consecutive heartbeats called HRV.

HRV is a noninvasive, practical, and reproducible method of assessing the functioning of the autonomic nervous system. While the heart generally maintains a constant rate, the interval between heartbeats (R-R) may vary considerably. Heart rate variability is the fluctuation in time between two successive heartbeats. Parasympathetic and sympathetic impacts on the intrinsic rhythm of the sinoatrial node are thought to correlate with HRV. Smoking, physical activity, diet, and sleep affect the overall health of your heart. An analysis of HRV and hypertension has linked it to an increased risk of cardiac mortality and has shown it to be a predictor of hypertension. Research is also looking at the prognostic potential of HRV in predicting life expectancy and overall health. Your daily lifestyle modifications cause alterations in your heart rate variability before you have cardiovascular disease. A significant portion of doctors and public health experts are interested in measuring HRV and its constituent components because of their application in cardiometabolic risk assessment. [1]

Many researchers claim that stress index influences HRV. As a result, the main goal of the project is to design a web application toolkit to be utilized in the near future to research the relationship between stress and HRV.

It is now easier than ever for anybody to collect HRV data from a portable device or a sensor at a low-price using technologies and equipment that are widespread throughout the Internet of Things. With this data as a start, we'll utilize the pyHRV [3] /Django [9] combination to gather and analyze the ECG data from uploaded files.

1 THE PROBLEM AND ITS BACKGROUND

1.1 Background of the study

Several commercially available software systems have gained considerable ground in measuring heart rate variability. It is an excellent occasion to get HRV data due to the recent proliferation of wearable devices.

However, most of the tools already in place prove to be complex for people not oriented towards research such as athlete coaches. It is necessary to create a software tool for researchers and developers while exposing a part accessible to the ordinary person who needs to analyze HRV data without needing to manipulate the parameters of the algorithms.

A web application is a system in which the status of the business is affected by user input (navigation and data entry). This definition aims to describe the general characteristics of a Web application, in which it is characterized as a software system with a business state and the majority of its front end is provided via a Web system.

For all intents and purposes, the basic structure of a Web application may be defined as a client/server system, with several noticeable deviations. A Web application's greatest benefit is that it can be deployed quickly. Once you have the necessary server-side components on a network, deploying a Web application is often a simple process. The user doesn't need any particular software or settings on their end.

In the case of a Web application, the client and server communication are significantly different because of the nature of client and server interaction. When choosing a Web application's communication protocol, HTTP is often used, since it is connectionless and hence has more resilience and fault tolerance when used. The majority of Web application communication takes place via the use of hyperlinks and is not based on sending or receiving information directly between

server-side and client-side objects. Message handling in a Web application may be seen at a high level of abstraction as the retrieval and processing of Web page entities. From the standpoint of a typical Web application, the architecture of a Web application is similar to that of a dynamic Web site. To differentiate between a Web application and a Web site, it is essential to understand their utilization. Business logic is implemented via web apps, and this has a big impact on the status of the business (as captured by the system). This is essential since it helps guide the overall modeling strategy. [2]

In order to support and assist business functions, Web applications primarily conduct business logic and, as a result, the most critical system models concentrate on business logic and business state rather than on presentation details. However, clear distinction between business and presentation issues should be sought for. It is vital to model both presentation and business logic aspects if presentation difficulties are relevant or if the matter is intricate. Even more importantly, the resources which concentrate on presentation have a bias towards creative, non-technical resources, and are less focused on rule execution [2].

1.2 Statement of the Problem

The price to pay to acquire the rights to access the advanced functionalities of the standard software in the field of HRV research is an obstacle for most researchers. The available applications are effective, but they present a challenge for inexperienced users. Despite the presence of a few open-source tools, they do not offer a user-friendly graphical interface for non-developers.

1.3 Objectives of the study

The main purpose of this project is to implement a web application to first store HRV data for Research and then to calculate heart rate variability parameters from descriptive files that contain heart rate signals. The program should generate a report as a PDF file after the analysis. The main purpose of this project is to implement a web application to first store HRV data for Research and then to calculate heart rate variability parameters from descriptive files that contain heart rate signals.

1.4 Significance of the Study

The importance of this project is reflected in the need for a collection of HRV data from multiple sources for research. Provide a graphical interface, alleviating the task of knowing the inner workings of algorithms for people who are not in research. Keep the means to access more advanced settings for developers and researchers.

1.5 Scope of the study

This study presents the implementation structure of the web application as well as the methods used to store and present data to users.

1.6 Limitation of the study

In the evaluation, short-term parameters have been computed from 50 Normal-to-Normal Interval (NNI) series of 5 minutes in duration, with long-term parameters being computed from 50 NNI series of 60 minutes in duration. The results have been computed using the pyHRV toolbox and the KUBIOS HRV

gold standard software, against which the pyHRV results have been compared. Overall, pyHRV computes a total of 78 HRV parameters (23 TD, 48 FD, 7 NL), from which 12 have achieved identical results as the gold standard software, 38 showing marginal and/or neglectable differences, and 26 showing significant differences, thus requiring further investigation [3].

1.7 Review of literature

1.7.1 Related work

The field of research on HRV is vast. And most analysis applications are not web-based.

Kubios HRV is a powerful and simple-to-use HRV analysis program. In the program, the electrocardiogram (ECG) and beat-to-beat RR interval data are supported in various different input data formats. The toolkit comprises a QRS detection algorithm that can identify changes in the QRS waveform and correction for artifacts, as well as trend removal and analysis sample selection. All widely used time-domain and frequency-domain HRV parameters as well as some non-linear parameters are computed by the program. Customized analysis settings enable you to tailor the analysis techniques for various data. Also included in the study are ECG-derived respiratory frequencies, which are critical for the interpretation of the data. An ASCII text file (simple to import into MS Excel or SPSS) may be generated; however, it is also possible to generate a MATLAB MAT-file or a PDF report. The simple and user-friendly graphical user interface makes using the program simple. http://kubios.uef.fi is accessible for free for both Windows and Linux. [4].

The software solution provided by ARTiiFACT helps researchers from data collection and data processing phases all the way to obtaining HRV values for statistical analysis. Import options for raw ECG data and IBI data are offered

by ARTiiFACT along with automated artifact detection according to distribution-related criteria. Also, missing data can be interpolated or the artifact IBI can be interpolated (using linear or cubic spline interpolation). Also, HRV parameters in both time and frequency domains can be calculated and exported. Furthermore, ARTiiFACT makes it easy to connect to RSAtoolbox (Schulz, Ayala, Dahme, & Ritz, 2009), a freely available RSA algorithm implementation that corrects for individual differences in vagal tone in accordance with how long and how much each breath is (on respiratory control see e.g., Grossman & Taylor, 2007, Ritz & Dahme 2006). IBI time series may be used to estimate respiratory parameters, as in the case of O'Brien and Heneghan (2007). This permits the partial regulation of respiratory effects on HRV even while respiratory information has not been recorded. One of the things that makes ARTiiFACT's I/O settings especially user-friendly is that you may adjust any of these modifications prior to transmitting data to the HRV analysis module. Manual intervention options were highlighted. The program is a 32-bit Windows program built using MATLAB software. [5]

The RR-APET software was created in the Python programming language and is modular in design, allowing the user to choose from a variety of modules, including R-peak detection techniques, to customize the software to their needs. It also provides an integrated template for alternatives methods. ECG signal and database optimization additionally make these modules ideal for varied users. Both researchers and medical practitioners may utilize the easy-to-use GUI to carry out various activities, such as the advanced visualization of a single ECG, or the batch processing of numerous signals in a single iteration. While RR-APET can read some common data formats, such as text, HDF5, Matlab, and Waveform Database (WFDB) files, it doesn't provide support for other file types. The RR-APET platform showcases many R-to-R interval series measurements, including time-domain, frequency-domain, and nonlinear metrics. When there are R-peak annotations that are known, the validated R-peak detection technique may also be used to offer measurements of positive predictability, sensitivity, detection error

rate, and accuracy. The simplicity of use that was shown on a trial basis earned the RR-APET a usability grade of 4.16 out of a possible 5. Using this software, researchers may do more HRV analyses and investigate how this correlate to patient healthcare outcomes. This free and accessible software is available for both Windows, Mac, and Linux platforms. [6]

Furthermore, Kuopio University has also created software that incorporates sophisticated HRV analysis for both home health care providers and sports scientists. This software has been developed to do extensive HRV analysis. All time-domain and frequency-domain metrics of HRV as well as the nonlinear Poincaré plot are included in the software. Spectrum data is first quantized, then parameterized. A report in printed form is produced which is also exportable in a wide range of formats, including the portable document format (PDF). Saved results may be imported into a spreadsheet software such as Microsoft Excel, and results may be exported as an ASCII file. These two tools, a contemporary pulse rate sensor and the freely downloadable application mentioned above, provide a full HRV measurement and analysis system with a minimum of expense. [7]

The application was initially designed using the Matlab 6.1 programming language (Release 12.1). The software has been turned as a standalone C-language application using the free Borland C-Builder 5.5 compiler, which is integrated with the Matlab Compiler Suite 2.3. This, therefore, ensures that the application is not dependent on Matlab, and hence will operate well without a Matlab installation. [7]

1.7.2 Summary

HRV research is filled with a multitude of proven software packages, and our project strives to relieve the problems that most of them have. Kubios HRV is a powerful and simple to use HRV analysis program. The solution provided

by ARTiiFACT encompasses all of the data processing procedures required for HRV analysis.

1.8 Conclusion to the section

A web application is a software system with a business state that provides its front-end through a web system. Business logic is implemented inside web applications, and its usage alters the business state.

Unfortunately, sophisticated capabilities of traditional HRV analysis software are more often limited to researchers, thereby necessitating the use of a more accessible HRV analysis tool. The results were obtained using the pyHRV toolbox, which were compared with the KUBIOS HRV reference program.

2. IMPLEMENTATION AND METHODOLOGY

2.1 Research methodology

This online application incorporates Electrocardiography (ECG), SpO2, blood pulse (BVP), and other measurements of heart rate to support other signals in the form of medical records. Parameter analysis is done using the pyHRV python package.

PyHRV calculates TD and FD parameters in accordance with the HRV standards and HRV research results, as well as the use of modern approaches for the extraction of NL parameters. All spectral parameters in the FD are generated using algorithms from the NNI series that calculate Power Spectral Density (PSD). According to the HRV recommendations, the Welch's and the AR techniques have been applied using the FFT-based Fast Fourier Transform (FFT) as well as the Lomb-Scargle approach. [3]

2.2 Implementation

2.2.1 Tools and techniques

The main tools used in the development process of this web application are Python, Django, and PostgreSQL

Python

The most distinctive feature of Python is that it is interpreted, object-oriented, and dynamically typed. The feature set of the built-in data structures, dynamic typing, and dynamic binding make it an excellent candidate for usage in applications that need to be constructed quickly and in a modular way. It may also be used as a connecting language to assemble preexisting components.

This emphasis on readability minimizes the overall maintenance cost of programs in Python. With modules and packages in Python, modularity and code reuse are encouraged. Python comes in source and binary form and is completely free and open source for all main platforms [8].

Django

Django is a general-purpose Python web framework that makes it possible to rapidly and simply develop secure and well-maintained websites. It is open-source, available for free, and provides both free and paid assistance.

A wide range of websites, from CMS and wikis to social networks and news sites, may be created using Django. Capable of providing any kind of content, regardless of whether the client-side framework supports it (including HTML, RSS feeds, JSON, XML, etc.) [9].

It offers an array of internal capabilities such as different kinds of databases, template engines, and so on, but it can also be reconfigured to include other components if needed.

Because the application defaults to security enhancements, such as preventing SQL injection, cross-site scripting, cross-site request forgery, and clickjacking, Django offers significant security protection by default.

In line with design ideas and standards, Django programming is designed using elements that make code comprehensible and reusable. Another feature that Django advocates is the use of "applications" to group similar functionality, and at a deeper level, the use of "modules" to group similar code.

Django is written on Python, a programming language that is prevalent across several platforms. Also, Django has several web hosting businesses, many of whom provide dedicated Django hosting together with instructions and support [9].

PostgreSQL

The PostgreSQL open-source object-relational database system is powerful, flexible, and safe for handling large-scale data. PostgreSQL's roots go back to 1986, and it has a rich history of development on the core platform with more than 30 years of use.

With such an established architecture, excellent dependability, good data integrity, a full feature set, good extensibility, and open-source backing, PostgreSQL has garnered a great reputation for stability, performance, and novel features. Because it operates on every major operating system, has ACID compliance since2001, and includes popular add-ons such as the PostGIS geographical database extension, PostgreSQL is considered a popular database solution. Given the open-source nature of PostgreSQL, it's not surprising that many individuals and businesses are using it as their relational database of choice [10].

2.2.2 Project description

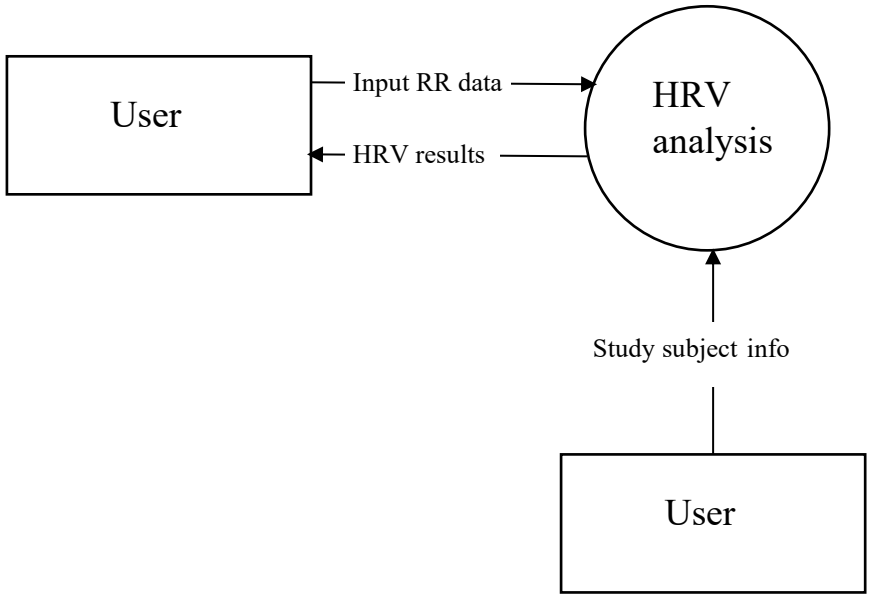


Figure 2.1 – DFD context diagram

The platform is designed to provide users with ease of access to data that is either personal or about their study subjects. The web application is called "HRVscihub" and is implemented using Django python.

After the user submits the files, the NN intervals are extracted from the files and the data is sent to the Django REST framework using AJAX (Asynchronous JavaScript and XML) calls.

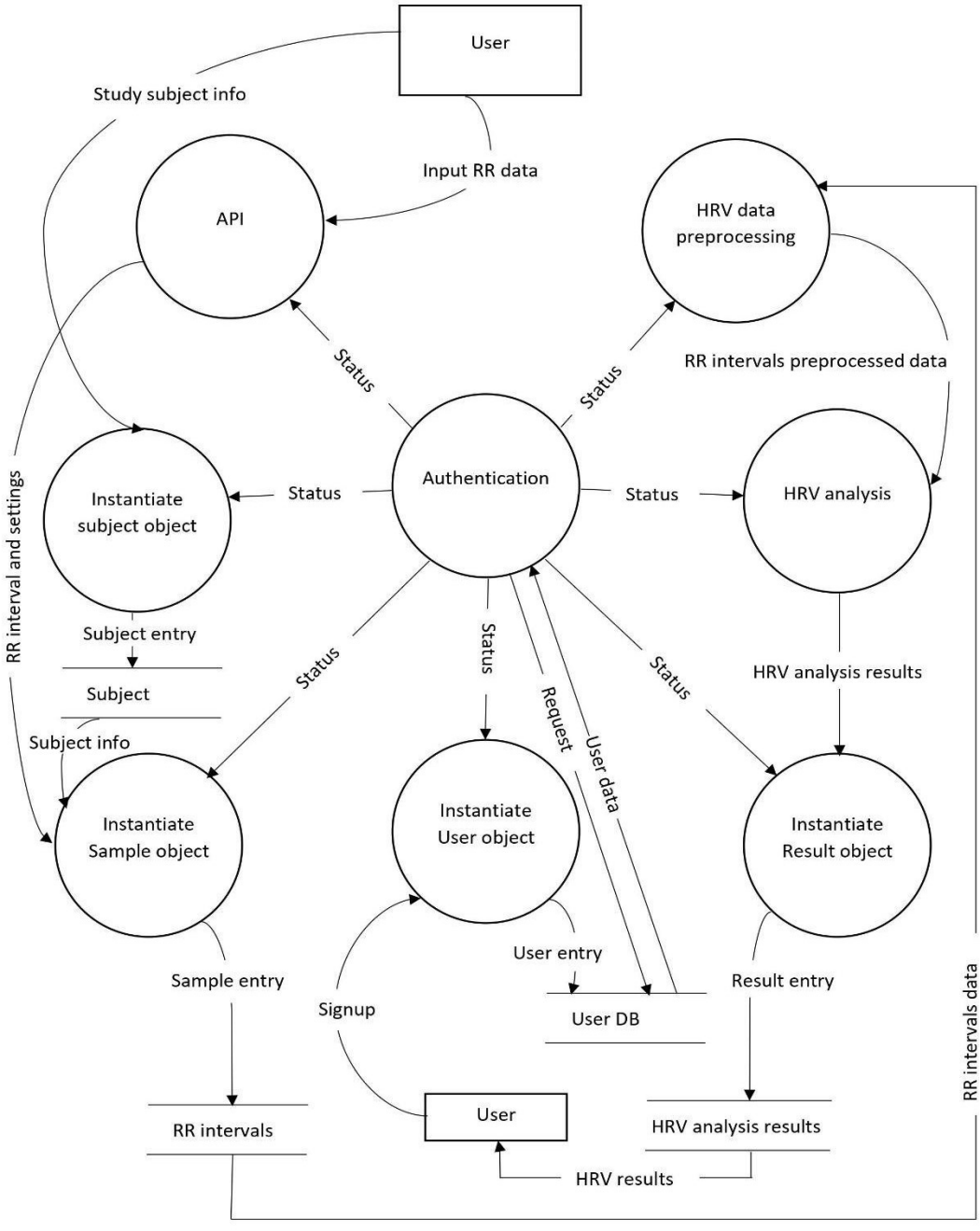


Figure 2.2 – DFD level 2

Access to HRV services can be provided through two channels:

– Users who access through a web browser.

– Other users will access the application through the REST service to GET or POST the data.

The Django framework uses a 3-tier architecture, the Model View Template (MVT).

The MVC denotes a model, view, and controller arrangement. Web application development is accomplished by using a design pattern or a software development process, which is in turn being utilized to develop the apps. This design pattern has the primary goal of promoting code reusability. Additionally, the MVC paradigm implements these three components, referred to as Model, View, and Controller, to develop the program or web application. To provide details on each component's duty, see the description below:

– Model: Everything relevant to data processing is included in this section. The interface is used to access the data stored in the database without the need to know any database-specific specifics. This results in a model that can interact with several databases.

– View: This is the presentation layer. The software is intended to help designers come up with creative ways to exhibit the information on the display, such as layout, color, etc. To gather user inputs, the view components will constitute the user interface.

– Controller: This component will be responsible for passing information between requests from users and the models. The overall goal is to ensure that information can flow between the view and the model. In addition, it will also collect the information gathered by the view and utilize that information to either adjust the display or update the data.

As a result, the following is the usual flow: The user will interact with the view's interface. The interaction will be forwarded to the controller, which will determine whether or not to send any request to any model. The models will

receive the request, do the necessary data processing, and then return the data to the controller. The controller then utilizes the model's data and passes it to the view. While this is the MVC pattern's overall approach, many frameworks interpret it differently [11].

Django adheres to the MVC style closely, yet it implements parts of its logic. The primary distinction is that the framework manages the controller component. Thus, every request is sent straight to the view classes, which contain the application's logic and various methods for handling different types of requests. Models are object entities that represent the database tables. The view will make use of these model objects to fetch, update, remove, and do other data processing tasks. The view will then employ templates, which serve as the presentation layer, to replace the data in these templates with variables. As a result, Django's design is called MVT, which stands for Model, View, and Template. Each component is defined in detail below:

– The model is the layer that connects data access to the application. The database is made up of many tables, and each table has an object that simulates the tables in the database. It contains the related fields and techniques for processing data for validation purposes.

– The Template is the presentation layer. This component implements the original MVC paradigm as the view component. This offers an interactive look at the process of data presentation including HTML page layouts and CSS and JavaScript code.

– The View is the component that defines business logic. It has the rules to access the data through models and pass them to the appropriate templates [11].

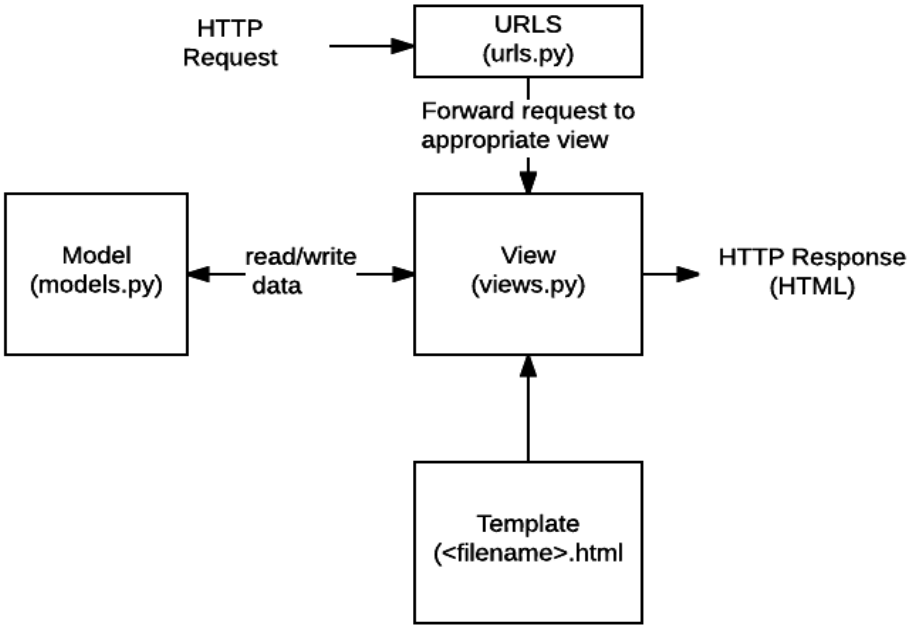


Figure 2.3 – Django MVT architecture

The platform contains the present functionalities:

– An interface to add or remove subjects.

– An interface for uploading files containing data associated with HRV.

– A dashboard to analyze the results of HRV and to generate a report in the form of a .pdf file.

– An interface to manage the user's information and profile.

– A REST service, implemented with the Django Rest Framework (DRF).

A Django project can contain multiple applications. In the case of the HRVscihub project, we have four (Fig. 2.4)

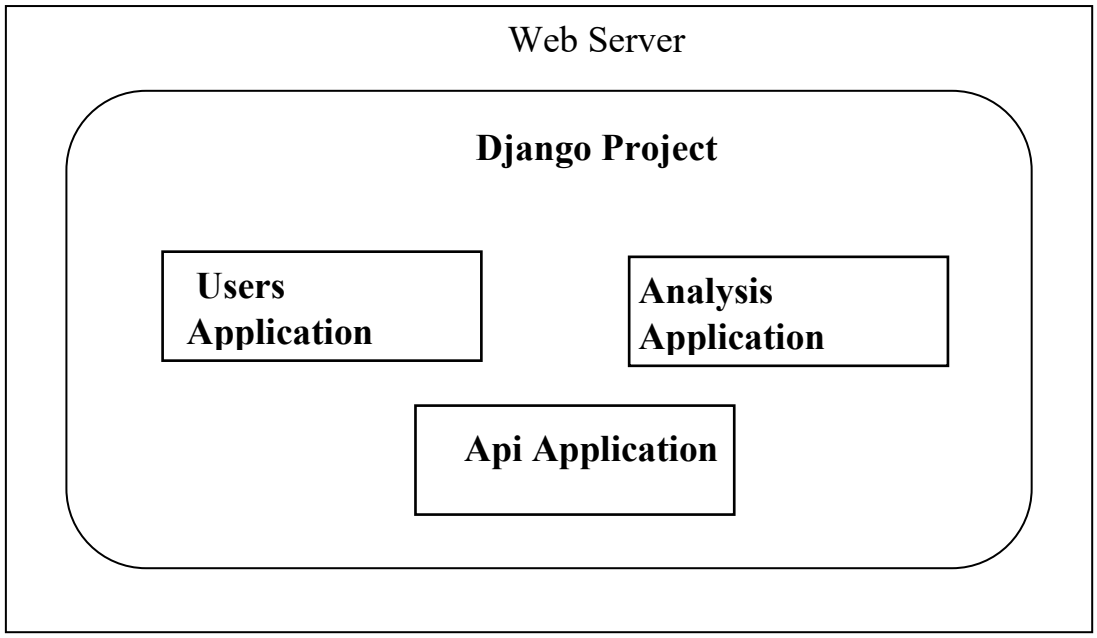


Figure 2.4 – Layers Diagram

The Users application and the Analysis application are applications designed according to the standard MVT model of the Django framework. The API application follows the REST architecture and it is the application that is based on Django REST. The HRVscihub project is divided into several applications to keep the functionalities within the project apart. This modularity improves the flexibility of adding new features or modifying existing features. The project is hosted on an online Heroku server.

2.3 Results and discussion

The object of this project was a web application to collect and analyze HRV parameters, (Fig. 2.5) shows the analysis interface of the web application, and the (Fig. 2.6) to (Fig. 2.11) is a copy of the report generated by the HRVscihub application:

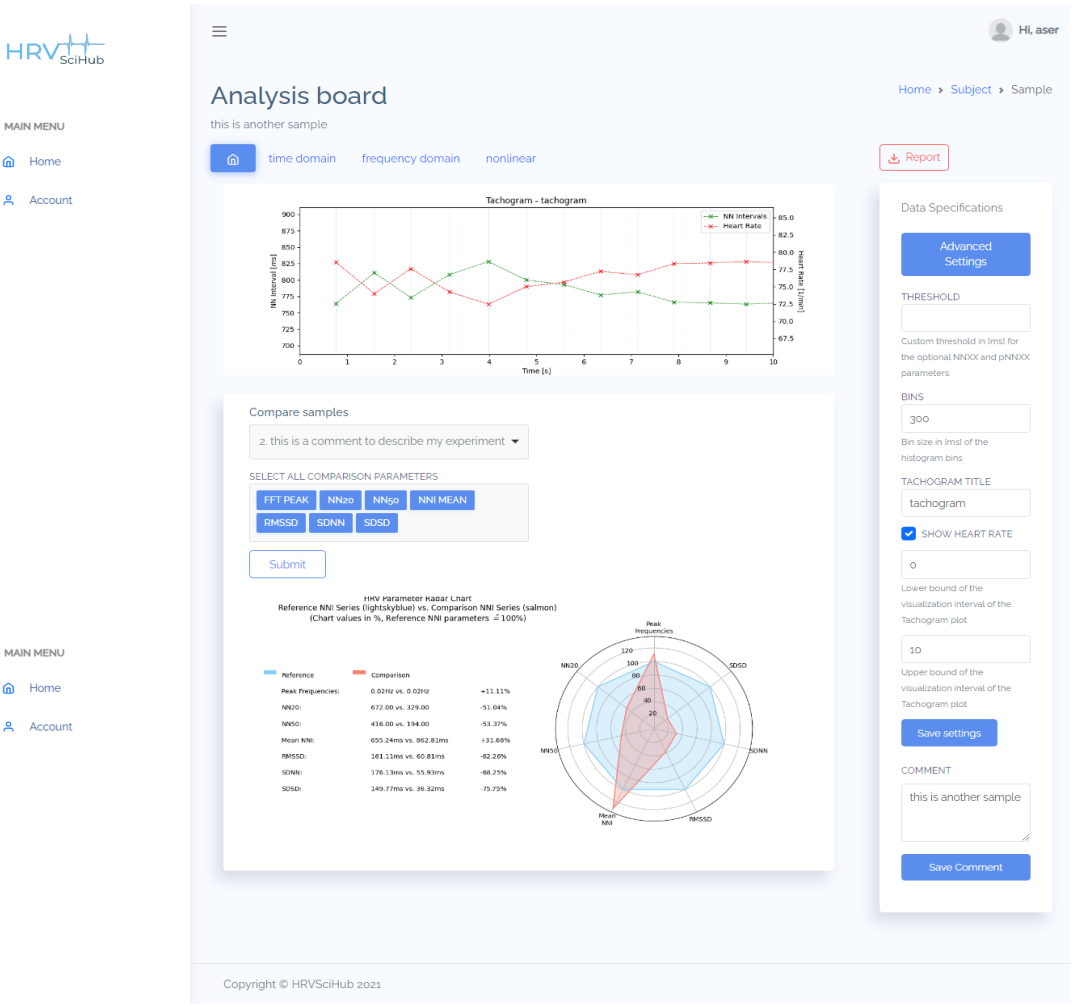


Figure 2.5 – HRVscihub analysis board

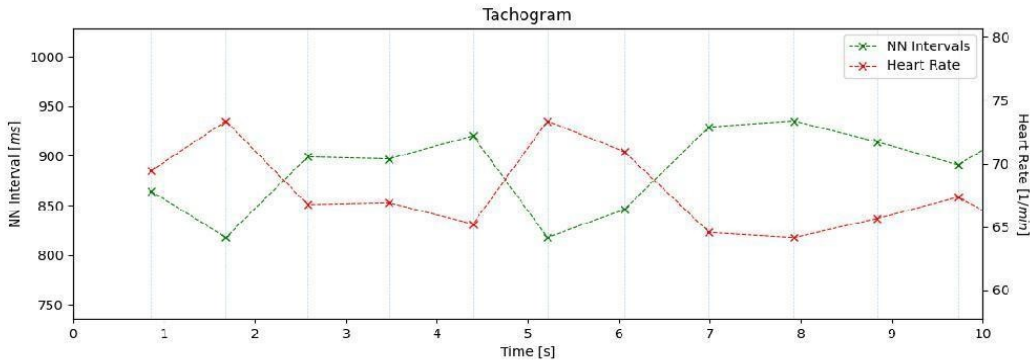
HRV SciHub 19th April 2021 14:29

HRV Analysis Results

General information

Subject: aser
Age: 23 years old
Gender: male

comment: this is my test comment

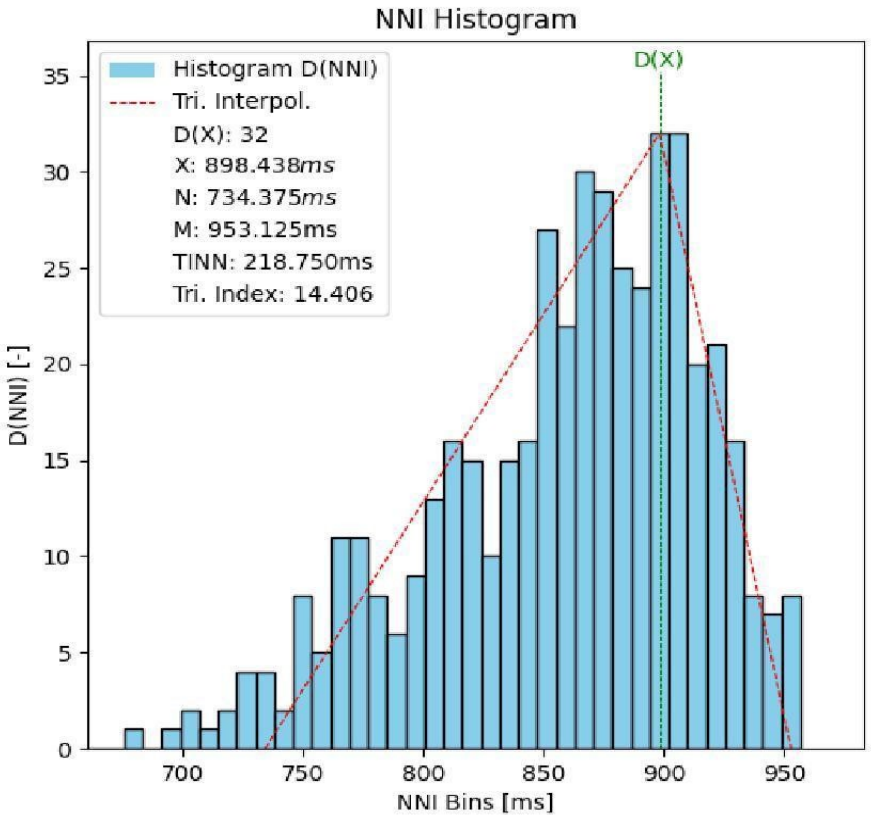


Time domain results

parameter	value	unit
NNI	-	461.000
NNI MEAN	ms	862.813
NNI MIN	ms	684.000
NNI MAX	ms	960.000
HR MEAN	bpm	69.848
HR MIN	bpm	62.500
HR MAX	bpm	87.719
HR STD	bpm	4.781
NNI DIFF MEAN	ms	48.770
NNI DIFF MIN	ms	0.000
NNI DIFF MAX	ms	160.000
sdnn	ms	55.913
SDNN INDEX	ms	56.984
SDANN	ms	5.649
RMSSD	ms	60.775
SDSD	ms	36.304
NN50	-	194.000
PNN50	-	42.174

Figure 2.7 – PDF report page 1

NN20	-	329.000
PNN20	-	71.522
TRIANGULAR INDEX	-	14.406



Frequency domain results

Welch's Method

parameter	unit	vlf	lf	hf
Peak Frequencies	Hz	0.020	0.086	0.234
Absolute Powers	ms2	353.179	768.044	1,538.030
Relative Powers	%	13.281	28.882	57.837
Logarithmic Powers	-	5.867	6.644	7.338
LF/HF Ratio	0.499			
Total Power	ms2	2,659.254		

Configurations:

- Resampling frequency: 4.000 Hz
- Interpolation: cubic
- Window: hamming
- NFFT (over entire signal): 4,096.000

Figure 2.8 – PDF report page 2

Lomb-Scargle Method

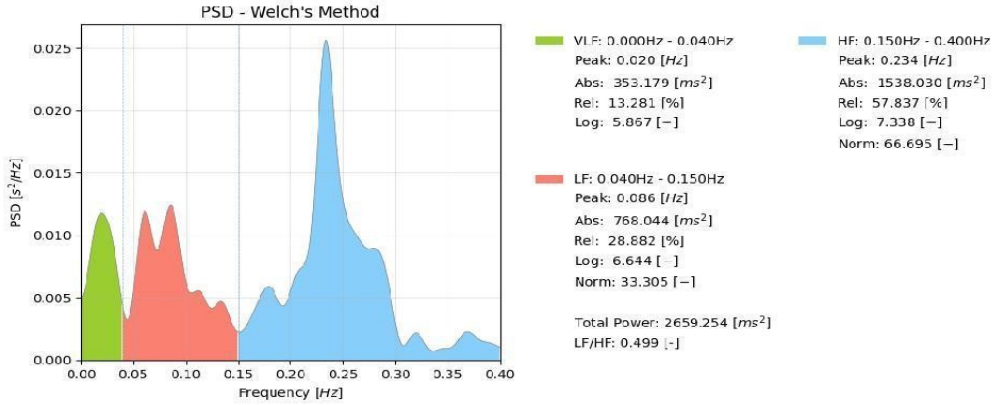
parameter	unit	vlf	lf	hf
Peak Frequencies	Hz	0.032	0.130	0.187
Absolute Powers	ms2	158.375	463.672	1,156.638
Relative Powers	%	8.904	26.068	65.028
Logarithmic Powers	-	5.065	6.139	7.053
LF/HF Ratio	0.401			
Total Power	ms2	1,778.684		

Configurations:

- Moving Average Window Size: n/a Hz
- NFFT (over entire signal): 256.000

Selected Frequency Bands

VLF Band	Hz	0.000-0.040
LF Band	Hz	0.040-0.150
HF Band	Hz	0.150-0.400



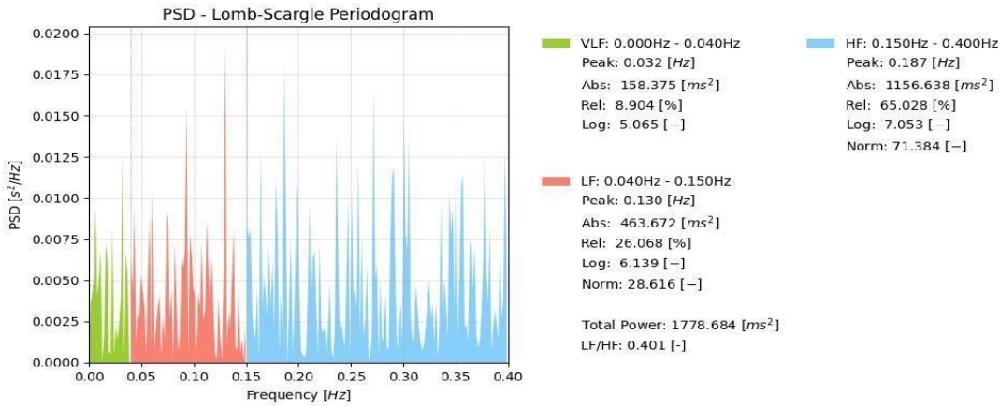


Figure 2.9 – PDF report page 3

Nonlinear Parameters

Poincare Plot Parameters

parameter	value	unit
SD1	ms	42.974
SD2	ms	66.352
SD1/SD2	-	1.544
Ellipse Area S	-	8,958.063
Sample Entropy	-	1.742
DFA alpha 1	-	0.745
DFA alpha 2	-	0.748

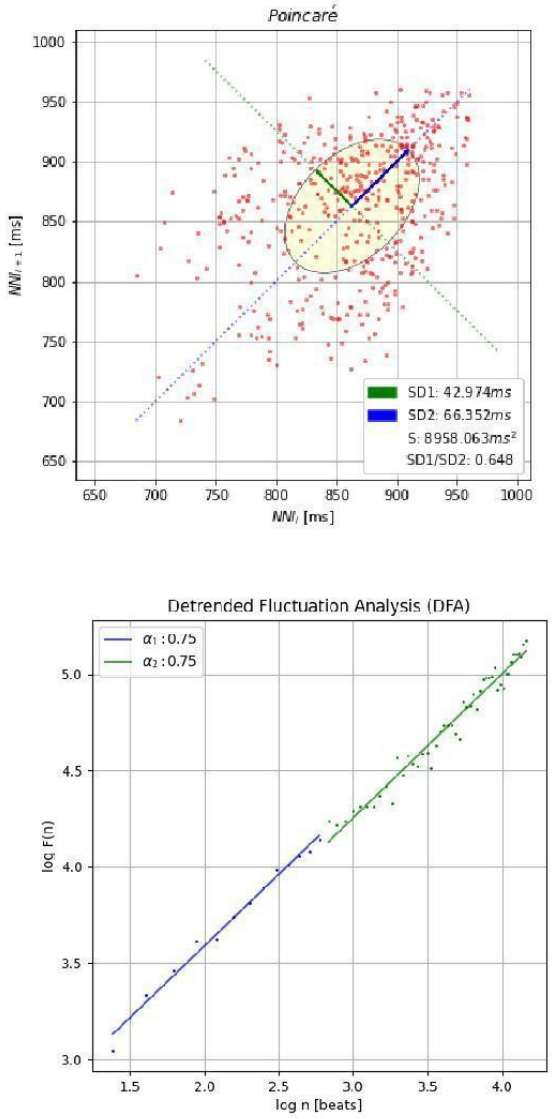


Figure 2.10 – PDF report page 4

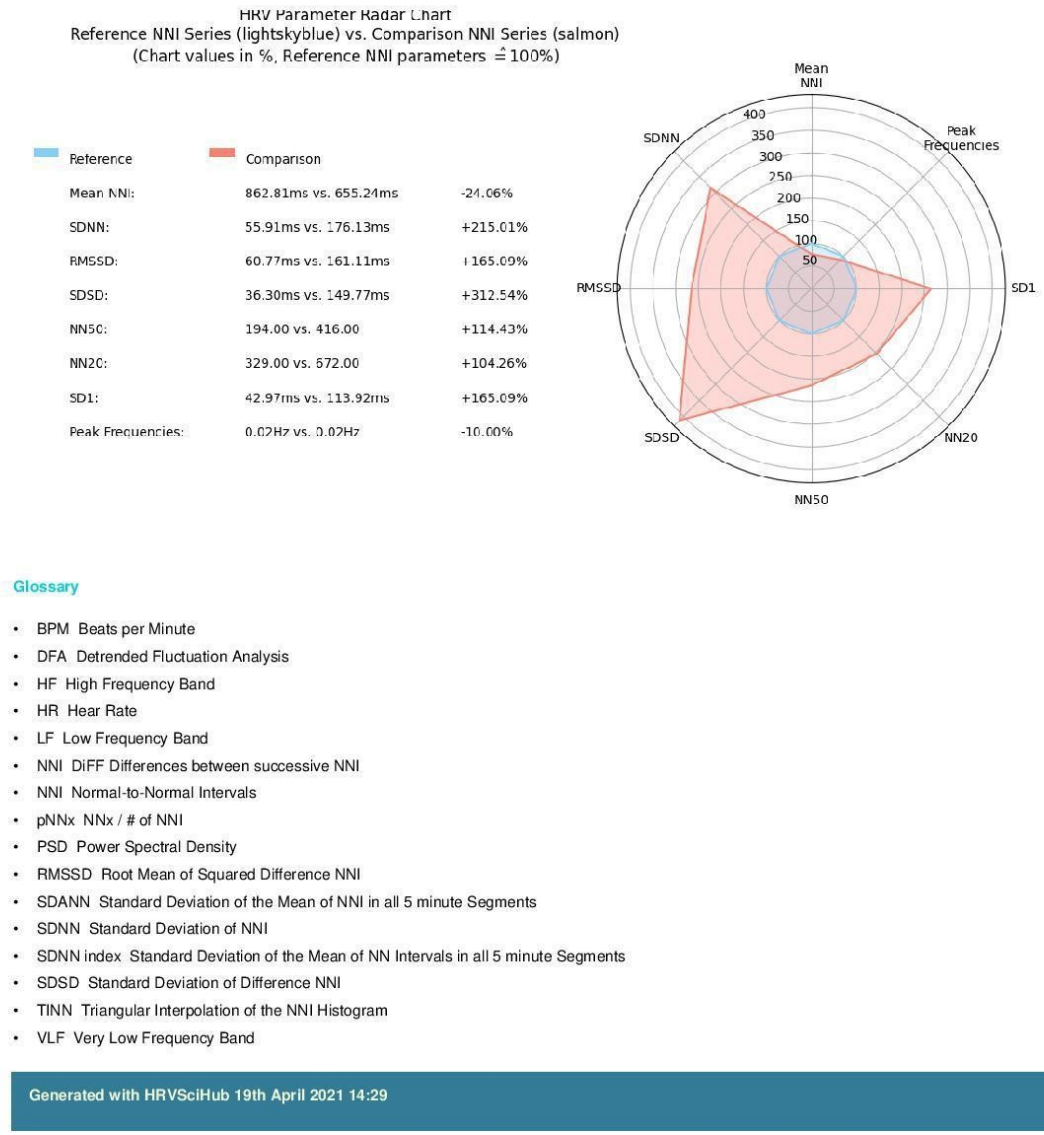


Figure 2.11 – PDF report page 5

The project was deployed on Heroku. The real-time test has taken place and, the application is proving effective. Users can perform bulk analysis by simultaneously uploading multiple files with signals with heart rate indicators then the computations take place in the background. The user is notified by email once the results are ready.

2.4 Summary

Python is an interpreted, object-oriented, high-level programming language with dynamic semantics.

Django is a framework written in Python, which uses a 3-tier architecture Model View Template (MVT).

PostgreSQL is an object-relational database system that uses SQL language.

The architecture of the project is designed with three sub-applications to ensure reusability and ease of extension for features:

- USERS: handles authorization and authentication.
- ANALYSIS: handles HRV computations.
- API: provides REST services.

3. HEART RATE TRACKING DEVICES AND THE CORRELATION BETWEEN HRV AND STRESS

3.1 Heart rate tracking devices

This project (HRVscihub) receives input data for RR intervals from files containing information generated by fitness trackers or ECGs.

In this part, we review the technology behind fitness trackers with the specific cases of Polar H10 and Welltory Smartphone PPG.

3.3.1 Polar H10 sensor

Figure 3.1 – Polar H10 sensor

Polar Electro, the company behind the H10 sensor and Pro Strap, has been dedicating itself to heart rate monitoring systems for athletes and fitness fans for many years. H10 sensor paired with the Pro Strap has outperformed all competitor's strap solutions, as well as the Holter monitors evaluated, in the accuracy tests. [13]

Additionally, the H10 sensor has great heart rate measurement performance, is compatible with widely varying user requirements, and has great water resistance to 30 meters, transmitting HR when swimming as well. An OTA (over-the-air) update to the H10 firmware results in an expansion of the lifetime

of the system due to the software continuing to get further capabilities from Polar Electro. [13]

3.3.2 Welltory

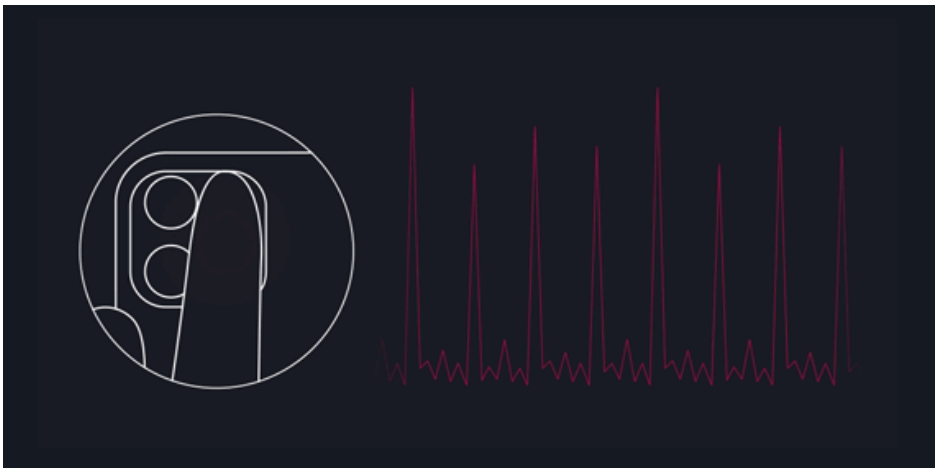


Figure 3.2 – Smartphone PPG

PPG is a non-invasive and low-cost optical measurement technique that tracks blood volume changes in peripheral blood vessels. It has been widely applied in daily monitoring of vital physiological parameters such as heart rate (HR), arterial oxygen saturation, respiratory rate, blood pressure, and heart rate variability (HRV). [15]

Welltory uses the phone's flash to illuminate your finger, while the camera tracks changes in blood volumes. This lets the app register the time elapsed between each beat and create a photoplethysmogram (PPG) record of your heartbeat. [14]

3.2 Stress and Heart Rate Variability

The use of HRV as an objective means of assessing stress and mental health is supported by findings of stress-associated change in HRV and current

neurobiological data. Despite this, because there are multiple causes and symptoms in psychiatric diseases, taking reliable biological data is challenging in those with mental illness. When determining HRV, it is important to take into consideration the patient's psychological and medical background. This thus means HRV measures general cardiovascular health, not mental sickness or disease situations. Because stress is defined as both a psychological and biological phenomenon, objective and physiological assessments, as well as self-reporting, should be used when examining stress levels in therapeutic practice, and HRV measurements are an effective tool for this. HRV has been connected to mental health in several research. It is difficult to decipher the results of these research since HRV is closely linked to a variety of stressors, such as stress duration, individual coping abilities, and lifestyle behaviors. Health conditions and lifestyle habits, such as physiology, genetic factors, and non-modifiable factors, can all influence HRV measurements. These include things like age, sex, and body type. Other factors, such as prescribed medication, medication side effects, and diseases, can all affect HRV measurements. [16]

The first model developed by Hans Seyle, established a three-stage stress response paradigm. The "alarm reaction stage" consists of a stressor, and the body's SNS will respond by activating fight-or-flight to deal with it. The second stage is the “resistance stage,” once the stressor has been introduced, the body must then adjust to it. When the PNS is through regaining many of its physiological functions, the body will allocate its energies toward stress. Despite seeming healthy, the amount of glucose, cortisol, and adrenaline remain increased in the body. When the body's resources are exhausted, the organism is vulnerable to sickness or death. This “exhaustion stage” is reached when the acquired adaptation or resistance is lost. When assessing the degree of stress, a patient is experiencing in a therapeutic environment, it is essential to bear in mind the three-stage approach. An increase in stress means that changes in physiological function occur, which is seen in the fluctuations in heart rate variability. In order

to recognize and analyze a wide range of stressors and individuals' differing stress reactions, it is vital to comprehend the patient's total stress response and medical and psychological history while investigating HRV and stress correlations. [16]

3.3 Summary

H10 sensor has proven to be a reliable heart rate measurement system.

Welltory uses photoplethysmography (PPG) for the analysis of HRV.

Based on observations of stress-associated variation in HRV and existing neurobiological evidence, studies have shown that HRV can be used as an objective assessment of stress and mental health.

4. LIFE SAFETY, FUNDAMENTALS OF LABOR PROTECTION

Occupational safety and health issues are considered for the design and development phase of the HRV analysis system.

Occupational safety is a system of legal, socio-economic, organizational and technical, sanitary and hygienic and treatment and prevention measures and tools aimed at preserving human life, health and ability to work. Working conditions at the workplace, safety of technological processes, machines, mechanisms, equipment and other means of production, condition of collective and individual protection means used by the employee, as well as sanitary and living conditions must meet the requirements of the law. An employee has the right to refuse the assigned work if a work situation has arisen that is dangerous to his life or health or to the people around him, or to the work environment or the environment. He must immediately notify his immediate supervisor or employer. The existence of such a situation is confirmed, if necessary, by labor protection specialists of the enterprise with the participation of a representative of the trade union of which he is a member or a person authorized by employees on labor protection (if the trade union was not established), as well as an insurance expert [18]. The task of labor protection is to minimize injuries and illnesses of the employee while ensuring comfort with maximum productivity. The main objectives of labor protection are the formation of specialists with the necessary knowledge and practical skills on legal and organizational issues of labor protection, industrial sanitation, safety, fire safety.

4.1 General characteristics of the room and workplace

The development of the analysis and visualization system is performed in a room located on the fourth floor of an eight-floor building with general and local lighting. The room has one-sided lighting, the windows are oriented to the

east, the windows have shutters. White ceiling with a reflection coefficient of 0.7, light brick walls with a reflection coefficient of 0.5. There are 4 people working in the room, in accordance with this we obtain input data for the analysis of potentially dangerous and harmful production factors, which are given in table. 4.1.

Table 4.1 – Incoming data

Room parameters	**Value**
Length x width x height	6.6 x 6.1 x 2.7 m
Area	40.26m²
Volume	108,70 m³
Workplace number	**Specifics of work**
I workplace	Front-end programmer (web application client development specialist)
II workplace	Back-end programmer (specialist in the development of the server part of web applications and database design)
III workplace	Business analyst (also acts as a product manager)
IV workplace	UI-UX web designer
Technical means (quantity)	**Name and characteristics**
Monitor (4 pcs.)	HP 22Xi / 21.5 "/ 1920x1080px / IPS
Computer (4 pcs.)	HP ProBook 440 G6, 14 "IPS screen (1920x1080) Full HD, Intel Core i7-8565U (1.8 – 4.6 GHz) / RAM 16 GB / SSD 256 GB
Floor cooler (1 piece)	CRYSTAL YLR3-5V208
Air conditioner (1 piece)	DEKKER DSH105R / G / 26m2 / 2,65kW- 2.9 kW / 25x74.5x19.5 cm / 9 kg
General purpose luminaries (3 pcs.)	The lamp raster built-in 4x18W
Local lamps (4 pcs.)	Delux Decor TF-05/1 x 40W

According to NPAOP 0.00-7.15-18 [20], the area S 'allocated for one workplace with a personal computer must be at least 6 m2 and the volume – at least 20 m3. There are 4 workplaces in the room, which fully meets the required standards.

We calculate the actual values of these indicators by dividing the volume of the room and the total area by the number of employees.

Therefore, based on the results obtained in terms of area and volume, the room meets the standards.

Table 4.2 – Workplace characteristics

№	The name of the parameter	Value	
		in fact,	normative
1.	Height of a working surface, mm	780	680 – 800
2.	Width of a working surface, mm	1500	not less than 600
3.	Depth of a working surface, mm	750	not less than 600
4.	Height of space for legs, mm	750	not less than 600
5.	Width of space for legs, mm	800	not less than 500
6.	Depth of space for legs, mm	750	not less than 450
7.	Seat surface height, mm	480	400 – 500
8.	Seat width, mm	500	not less than 400
9.	Seat depth, mm	500	not less than 400

Extension of the table 4.2

10.	Height of a basic surface of a back, mm	550	not less than 300
11.	Width of a surface of a back, mm	470	Not less than 380
12.	Length of armrests, mm	300	not less than 250
13.	Width of armrests, mm	60	50 – 70
14.	Distance from eyes to the screen, mm	650	600 – 700

It is possible to draw a conclusion that the sizes of a workplace of the programmer correspond to the established norms, proceeding from the set parameters.

4.2 Analysis of potentially dangerous and harmful production factors in the workplace

When creating a system of analysis and visualization, the work is performed sitting without physical effort, so it belongs to the category of light Ia [21].

Premises for work must be equipped with heating, air conditioning or supply and exhaust ventilation in accordance with DBN B.2.5-67: 2013. Normalized parameters of the microclimate, ionic composition of air, content of harmful substances meet the requirements of LTO 3.3.6.042-99, GN 2152-80, GOST 12.1.005-88, DSTU GOST 12.0.230: 2008 and DSTU GOST 12.4.041: 2006. Ventilation is understood as a set of measures and means designed to ensure meteorological conditions and cleanliness of the air environment that meet

hygienic and technical requirements at permanent places and service areas. The main task of ventilation is to remove polluted, humid or heated air from the room and supply clean fresh air.

The sources of noise in the room are the fan of the system unit, laptop and air conditioner. The sound generated by the fan and air conditioner can be classified as constant.

According to DBN B.2.5-28: 2018 the work belongs to the category of visual works. The use of natural, artificial and mixed lighting is envisaged.

The computer is a single-phase consumer of electricity powered by 220V AC from a network with grounded neutral. IBM PC refers to electrical installations up to 1000V closed version; all conductive parts are in the casings. According to the method of protecting a person from electric shock, computers and peripherals must meet 1 class of protection.

Technical methods of protection against electric shock is reduced to the use of current of safe voltage, protection in case of accidental touching current-carrying parts and against excessive currents, protection in case of voltage transfer to non-current-carrying metal parts of the installation.

Safe voltage is obtained from the high voltage grid (110-120 V) by means of step-down transformers.

Protection against contact with live parts of the installation is achieved by means of insulation, fencing off the use of blocking safety devices and inaccessibility of the location of the installations.

Switchboards are placed in closed metal casings-boxes.

Safety alarm is used in the form of posters and inscriptions. The best light alarms are double, which in the presence of voltage lights a red light, and in its absence – green.

Protection against excessive currents – short circuits and overload currents, which can cause insulation to ignite, is provided by fuses and circuit breakers,

and protection against voltage transfer to live parts by means of protective earthing and protective disconnection.

Fire prevention is achieved by eliminating the formation of sources of ignition and combustible environment.

Fires of the following classes are possible in this room: A – combustion of solids, E – combustion of live electrical installations.

4.3 Summary

Analysis of work circumstances in the examined workspace revealed that work circumstances with the PC meet requirements.

Learning and training all working and safe working practices are the primary requirements for sharp decrease and even total injury eradication.

The major objective of education and coaching is for employees to understand the required safety skills and safety standards before entering the workplace.

Because this sort of job is damaging due to stress, a vacation from small gymnastics and eye training is suggested for software developers.

The peculiarities of rescue and other urgent action for eliminating the dumps of large industrial accidents and installation disasters have also been examining and considering ways for eliminating these effects.

CONCLUSION

This project presents a means accessible to all for the analysis of heart rate variability. In the implementation of the web application, we considered the execution time of the request to calculate the parameters of the HRV. To alleviate the problem of synchronous HTTP requests and achieve good performance, the project runs HRV calculations asynchronously using Celery and Redis.

pyHRV performs HRV analysis in the background and results are stored in a PostgreSQL database. RR and ECG files used to test the system; are received from heart rate trackers. The project implements the possibility of comparing HVR parameters between states of the same person. Although, the report is still only in PDF format, as of this moment.

The web application is built in a manner that allows for future expansion. This gives researchers the ability to get novel interpretations and models of RR intervals, while also providing a base for study into obtaining data from several people.

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ANNEXES

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HEART RATE VARIABILITY ANALYSIS TOOLKIT FOR FURTHER ANALYSIS OF HUMAN STRESS

Supervisor: Oleg Nazarevych, Ph.D.

Keywords: heart rate variability (HRV), stress analysis

Heart rate variability (HRV) is a noninvasive, practical and reproducible measure of autonomic nervous system function. Although the heart is reasonably stable, the time between two beats (R-R) can be very different. HRV is the time variation between two consecutive heartbeats. HRV is believed to correspond to the balance between the sympathic and parasympathic influences on the intrinsic rhythm of the sinoatrial node. HRV is influenced by lifestyle factors, including physical activity, eating habits, sleep pattern, and smoking. In adults, decreased HRV is associated with a higher risk of cardiac events, including death, and is a predictor of hypertension. HRV may also have predictive value for life expectancy and health. HRV changes due to lifestyle factors precede the onset of cardiovascular disorders. Measurement of HRV and its components is of major interest for medical practitioners and public health specialists, in order to predict and evaluate the risk of cardiometabolic events related to lifestyle factors [1]. Several studies assert that HRV is liable to stress index. And thus, the purpose of the current work is to develop a web application toolkit that will, later on, be used to investigate the correlation between HRV and stress.

With commonly available tools and gadgets provided by the Internet of Things, it is now easy for anyone to access and read HRV data from portable devices or affordable sensors. We will use this as an opportunity to collect ECG data from uploaded files and process them using several python libraries namely. Biosppy: The toolbox bundles together various signal processing and pattern recognition methods geared towards the analysis of biosignals [2]. Numpy: NumPy is the fundamental package for scientific computing in Python. It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random simulation and much more. Scipy: SciPy in Python is an open-source library used for solving mathematical, scientific, engineering, and technical problems. It allows users to manipulate the data and visualize the data using a wide range of high-level Python commands. SciPy is built on the Python NumPy extension [3]. Matplotlib: Matplotlib is a cross-platform, data visualization and graphical plotting library for Python and its numerical extension NumPy (https://matplotlib.org/) Nolds: Nolds is a small numpy-based library that provides an implementation and a learning resource for nonlinear measures for dynamical systems based on one-dimensional time series [4].

We use Django (as it is a native python framework) with the Django Rest Framework (DRF) and PostgreSQL on the backend along with mainly known technologies like Javascript, Bootstrap 5, and CSS3/HTML5 on the frontend.

The structure of the tables in the database is: table "subject" to store the data related to the study subject, such as the name, gender, age, along with their measurements in a JSON supported field. Table "Result" has a one-to-one relation to its subject and stores the computed HRV data.

MPLD3 is used to display matplotlib generated figures to templates.

The web application is currently going to provide quick access to HRV data and computation methods but with the emergence of machine learning, the app platform will surely include use case of machine learning techniques for a deep analysis of the HRV correlation to stress.

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УДК 004.418

Тригубець Б. - аспірант
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ТЕХНОЛОГІЇ ЗАХИСТУ ІНФОРМАЦІЇ В ЕЛЕКТРОННІЙ КОМЕРЦІЇ

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INFORMATION SECURITY TECHNOLOGIES IN E-COMMERCE

Supervisor: Zahorodna N. V.

Ключові слова: електронна комерція, захист інформації, інтернет-магазини
Keywords: e-commerce, data protection online shopping

З кожним роком інформаційні технології все глибше інтегровуються в життя кожного користувача інтернету. Цей вплив замітний всюди: в онлайн-ЗМІ, онлайн-навчанні, онлайн-покупках. Останній напрямок розвивається найстрімкіше. Причина його розвитку проста — через веб-сайти та мобільні додатки бізнес отримує найкоротший шлях до кінцевого споживача. На нього не впливають карантинні обмеження, актуальні у 2021 році, не впливає віддаленість кінцевого споживача до фізичного місця перебування власника бізнесу та його товарів [1]. Тому з кожним роком на ринку з'являється все більше компаній, які надають свої послуги лише в онлайн-форматі [2]. Саме цю сферу і називають електронною комерцією.

Проте одночасно з розвитком та спрощенням взаємодії користувача з процесом купівлі товарів виникає інша проблема — безпека користувача та інтернет-магазину під час цих покупок. Злоумисники розвивають свої інструменти паралельно з розвитком індустрії, а тому перед компаніями стоїть задача надавати не лише зручні, але й безпечні послуги.

Адже на відміну від звичайних інформаційних сайтів, інтернет-магазини та мобільні додатки, пов'язані з онлайн-продажами, володіють набагато детальнішою