An Information Cardiac Platform to Support Healthcare

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Abstract—The article presents a software information platform for storing, processing, researching, and protecting cardiology information obtained during the study of patients with various cardiovascular diseases and a healthy control group. The information platform contains non-confidential data about the research subjects, which is freely available; as well as a confidential part; cardiological data, containing information about the biomedical tests carried out; as well as the parametric and graphical results of the mathematical analyzes obtained based on the registered cardiac data. The created integrated information platform can be used by cardiology specialists to evaluate the results of cardiac examinations and assist cardiologists in making a correct diagnosis and prescribing effective treatment. The platform is a tool with a user-friendly interface and can be useful for cardiac data researchers as well.

Keywords—healthcare, medical software platform, cardiology data

1 Introduction

The accumulation of experience for professionals in the fields of medicine and health care is an important starting point on which their successful realization as medical specialists and the adequate treatment of their patients depends. For this reason, all innovative information and technological means to support and increase the correctness of diagnosis should be included in the decision-making process. An additional condition for the development of interactive information systems was given by the global pandemic situation in the last two years, in which a great need for innovative and effective means supporting the healthcare and medicine was felt [1, 2].

Innovative information systems in the field of health care provide an opportunity for additional certainty of doctors for the decision-making process when diagnosing a patient and prescribing appropriate treatment. The input information preceding the decision-making includes the subject‘s account of his state and subjective sensations; information obtained from the biomedical tests and the analyzes from the real examination of the patient.

The purpose of this article is to present the new cardiology information platform with which to enter information about the researched patient, including personal data and results of the mathematical analysis of various types of cardiology signals (Holter, electrocardiographic and photoplethysmographic). Analysis methods are grouped into the following two groups: numerical and graphical. Numerical methods show results in the time and frequency domains. Graphical results were obtained by applying histograms, Poincaré plot and the recurrent method. A database of real holter cardio data was created containing records of heart failure, arrhythmia, syncope and a healthy control group. The platform makes it possible to maintain a history of the monitored subject, by storing the registered previous records of the subjects.

The motivation for the creation of an information cardiology platform is determined by the need to support the diagnosis process by cardiologists by applying mathematical methods in the analysis of cardiac signals.

2 Related works

In recent years of our digital era, the creation and use of digital information platforms in all spheres of public life, including healthcare, have grown. Physicians process and analyze large amounts of biomedical information on a daily basis. The creation of information platforms, giving access to a large amount of data [3], and the possibility of performing analyzes to help health care, is increasingly growing. A study conducted in [4] shows that information platforms increase user satisfaction, contribute to increasing the use of digital systems, and support positive attitudes towards professional development through mobile systems.

In their study of online information platforms, the authors of [5, 6] concluded that online platforms are flexible; offer opportunities to organize the time and place for their use. Recipients cite as a drawback the security issues of networking platforms, where user personal information can be leaked.

3 An cardiology information platform

The "Cardiovision" information platform presented in the article contains cardiology information, to which is attached information about the subject from whom the data was registered (three names (and other confidential information), age, gender, weight, telephone, name of the medical institution where the registered data, name of the attending physician, diagnosis by a cardiologist, description of the subject's condition at the time of data registration) and results of mathematical analyzes in numerical and graphical form. The subject's family history may also be stored.

The presented platform is created in the open source editor Visual Studio Code, which is suitable for developing and compiling applications in the network and in the cloud [7], has a daily integrated update function and supports database managers. The language used for the created cardio platform is C #. The system allows adding, correcting and deleting cardio records, printing the results of the mathematical analysis of a specific record, storing the results of the analysis in a separate file, comparative mathematical analysis of records. The created graphical user interface is friendly, offers a menu for choosing a cardio record; for adding, correction and deletion records; viewing the information for each cardio recording, as well as the results of the mathematical analysis in the time, frequency, time-frequency domain and from the performed non-linear analysis (Poincaré plot, recurrent method and others).

Cardiac data can be recorded by Holter monitoring (continuous cardiac data, recording over 24 hours); electrocardiograph (short-term recordings, about 5 to 15 minutes), or by photoplethysmographic technology [8]. The data obtained using Holter monitoring are for patients with cardiac diseases, in which it is necessary to carry out long-term monitoring (24 hours and more) of cardiac activity. The Holter is placed in a hospital setting by a specialist in this medical field, usually in the morning. Long-term monitoring is carried out in home conditions, with the monitored subjects continuing to carry out their usual activities. The method of conducting this research makes it possible to register rare moments of heart failure, through which an accurate diagnosis can be made and adequate treatment of the patient under study can be carried out.

The "Cardiovision" platform stores the obtained results, providing an opportunity to compare results obtained at different points in time. This is an option for tracking the development of the disease of each specific subject and provides an opportunity for future specialists to gain experience.

The created information platform implements the protection of user information (personal data and biomedical data), through the implementation by the authors of appropriate protection methods presented in [9].

The article presents the results of a study that included two groups: a group with cardiac diseases and a healthy control group. The group of individuals diagnosed with cardiac diseases includes records of patients diagnosed by a cardiologist; a general basic diagnosis is given, as well as a description of the patient‘s current condition. The healthy control group includes recordings of healthy individuals without heart disease.

4 Results

The research conducted in the article is based on Holter recordings obtained from the Medical University, Varna, Bulgaria. The purpose of the study was explained to all participants. Informed consent was obtained from the subjects participating in the study. The study was conducted following the Declaration of Helsinki and approved by the Research Ethics Committee at Medical University – Varna, Bulgaria, Protocol/Decision No 82, 28 March 2019.

Figure 1 shows the general view of the created information platform. The platform provides information about the specific patient (personal characteristics shown in detail in Figure 2), the studied cardiac signal in the form of a graph, a graph of the RR interval time series (known as heart rate variability [11, 12]) obtained from the input signal, tabular results in the time and frequency domain, graphical results of made mathematical analyses (Histogram, Global Power spectral density (PSD), Poincare plot, Recurrence plot).

Features of the created information platform. The created information platform "Cardiovision" has the following capabilities:

- Storage of large amounts of information with an initial capacity of 1000 records;
- Data protection has been implemented by the regulation on the protection of personal data;
- Remote access via the Internet;
- Access at different levels according to the type of user: administrator, doctor, patient;
- Functionality built through linked modules;
- Multilingualism.

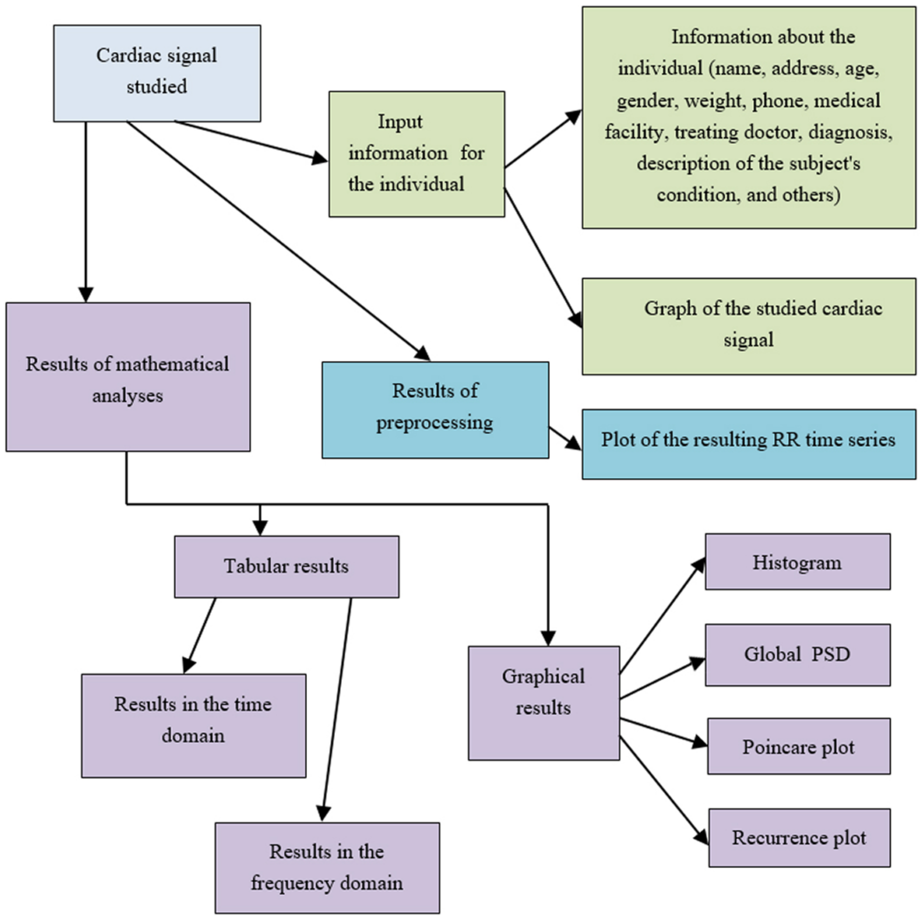


Fig. 1. General view of the information platform "Cardiovision"

Results in the frequency domain and time-frequency domain are calculated for a 5-minute segment of cardiac data (according to the recommendations of "Heart Rate Variability – Standards of Measurement, Physiological Interpretation, and Clinical Use", adopted in 1996 [10]).

Figure 3a presents the results of time domain mathematical studies on an individual with heart failure. The table indicates the reference values of the parameters corresponding to healthy subjects. Parameter values that are outside these limits are colored red. The results showed a maximum heart rate of 176 bpm, which is significantly higher than the accepted normal maximum rate of 120 bpm. SDNN is 89.115ms, which is not within the range of normal values for healthy people specified in the variability standard [10]. SDANN is 86.851ms which is outside the reference values for this parameter. The RMSSD (12.099ms) is also lower than the values for healthy people in [10].

Figure 3b presents in tabular form frequency parameters (obtained by performing mathematical analysis on the time series of RR intervals) of a patient with heart failure. Studies have shown a reduction in heart rate variability in patients with heart failure (compared to a healthy control group). Power spectrum за patient with heart failure (Figure 3b) determined by wavelet-based method in absolute units in the low-frequency range is 252.9 ms^2; in the high-frequency range is 352.4 ms^2, which is significantly lower than the reference values for a healthy subject (1170±416 ms^2 in low − frequency and 975±203 ms^2 in the high-frequency range) recommended in the standard [10].

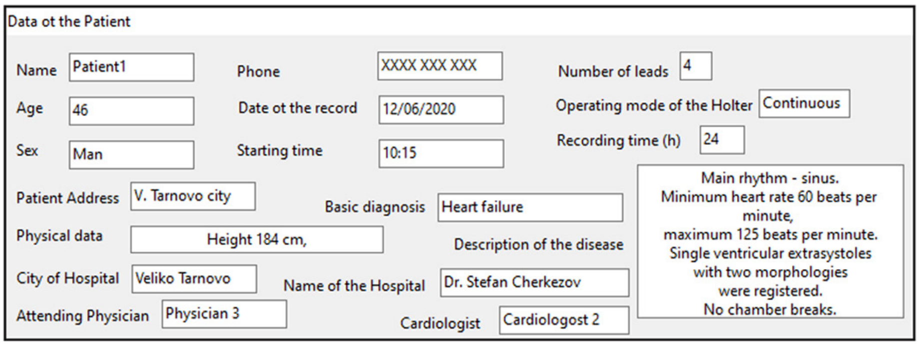


Fig. 2. Characteristics of the patient with heart failure

Parameter	Value	Reference values	Unit of measure
RR average	677.199	-	(ms)
RR min	0.340	>0.333	(ms)
RR max	1.200	<2.0	(ms)
HR average	90.719	-	(bpm)
HR min	50.000	>50	(bpm)
HR max	176.471	<120	(bpm)
SDNN	89.115	141±39 (102 - 180)	(ms)
SDANN	86.851	127±35 (92 - 162)	(ms)
SDhr	14.036	-	(bmp)
RMSSD	12.099	27±12 (15 - 39)	(ms)
NN50	5065	-	(count)
pNN50	5.702	-	(%)
SDindex	37.451	-	(ms)
Geometric parameters			
HRV Triangular Index	8.800	37±15	-
TINN	456.900	-	(ms)

(a)

Frequency range	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)	LF/HF
Burg					
VLF	0.03	152.3	25.8		0.711
LF	0.04	182.2	30.8	0.416	
HF	0.29	258.3	43.4	0.584	
Lomb-Scargle					
VLF	0.04	58.9	14.2		0.717
LF	0.08	147.2	35.8	0.418	
HF	0.29	202.1	50.0	0.582	
Wavelet					
VLF	0.02	212.7	26.5		0.719
LF	0.04	252.9	30.9	0.490	
HF	0.29	352.4	43.1	0.510	

(b)

Fig. 3. a) Time parameters of a patient with heart failure; b) Frequency parameters of a patient with heart failure

Low signal power values indicate low heart rate variability, which is indicative of the presence of disease. The ratio LF/HF (sympathovagal balance) is obtained 0.719 with the wavelet-based method for patient with heart failure, which is less than the values recommended in the standard for a healthy subject (1.5–2.0). Although the three research methods (Burg's method, Lomb-Scargle and wavelet) give different values for the Power spectrum in the individual frequency ranges, the power spectrum in % and normalized units (n.e.) have close values. The index of sympathovagal balance is also obtained with very close values (0.711 (Burg), 0717 (Lomb-Scargle) and 0.719 (wavelet-based method)).

Figure 4 shows a histogram of the intervals between individual heartbeats (RR intervals). In healthy individuals (Figure 4b), the histogram is characterized by a normal distribution, it has the characteristic bell-shaped shape of the Gaussian distribution. with the largest number of RR intervals concentrated around the mode of the histogram (0.7 sec). The histogram has a broad base; intervals of different durations are present, which indicates high variability of the studied time series.

In a subject diagnosed with heart failure (Figure 4a), a shift of the histogram to the left is observed. The figure shows a clustering of RR intervals around one value (0.6 seconds in this histogram), while other durations occur infrequently. This distribution shows low variability in cardio interval durations.

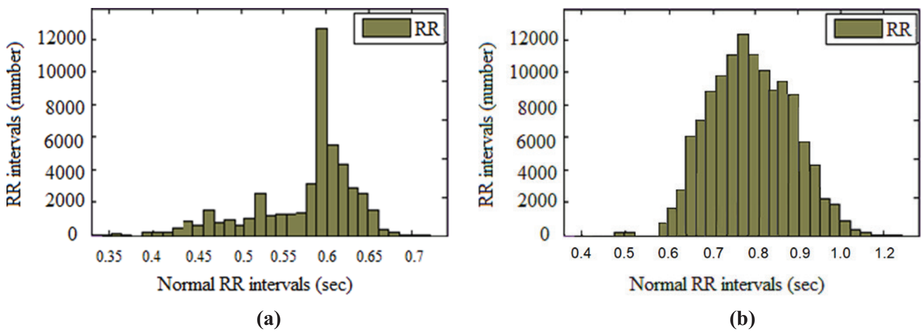


Fig. 4. Histogram of RR intervals of a) patient with heart failure; b) a healthy individual

The Poincarè plot is a geometric method in which each RR interval is represented as a function of the previous interval and plotted in a rectangular coordinate system. Each pair of RR intervals (previous and next) has coordinates (x,y), where x is the value of the RRn interval and y is the value of RRn+1. When forming the graph, a segment of points is obtained, the center of which is located on the line of identity. The line of identity represents the graph of the function x=y (RRn=RRn+1). When the heart beats with little variability associated with cardiovascular disease, the Poincaré points lie close to the line of identity. If the point is located above the identity line, it indicates that the current interval is longer than the previous one, and vice versa, if the point is located below the identity line, then the current interval is shorter than the previous one. Therefore, the shape of the segment of points reflects the variation in the duration of the RR intervals. The shape of the segment of points is categorized for the different functional states of the person, with the graph of the healthy subject having one main segment of points to which more points may be evenly scattered. The main segment has the shape of a comet with a narrow lower part and gradually widening towards the top. The graph of the sick subject has the shape of a torpedo, a fan or a complex shape (consisting of several segments) depending on the type of disease.

Figure 5 shows a Poincaré plot of a patient with heart failure (Figure 5a) and a healthy individual (Figure 5b). In the healthy subject, the plot is comet-shape, while in the subject with heart failure, the plot points are scattered and irregular in shape.

The research done on 24 patients with heart failure showed the same regularity. All healthy individuals (20 per volunteer) from the control group showed the same regular comet-like shape.

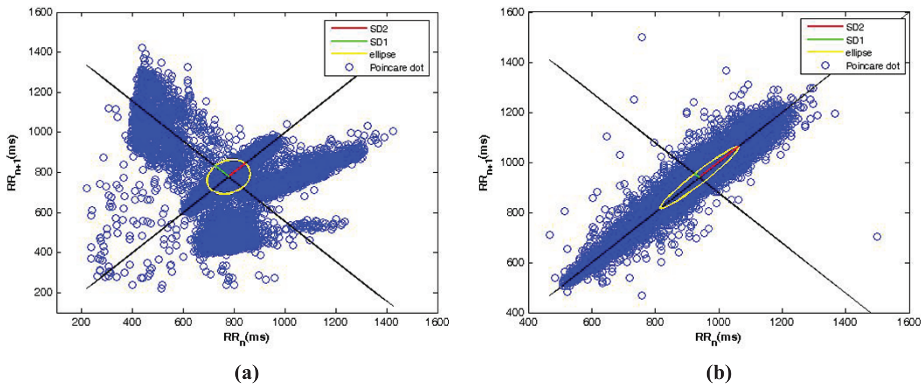
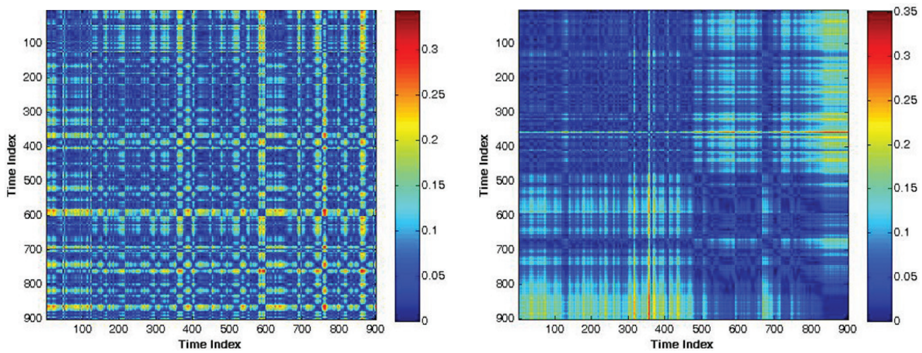


Fig. 5. Poincaré plot of a) patient with heart failure; b) a healthy individual

The recurrent method allows to visually analyze processes, according to their graphical representation. The basis of the method is the construction and analysis of a recursion diagram. There are 4 main elements characterizing the plot: isolated points (reflecting stochasticity in the signal), diagonal lines (index of determinism) and horizontal/vertical lines (reflecting local stationarity in the signal). The graphic representation of these diagrams consists in constructing a square containing elements of the studied signal along the x and y axes. The use of different colors contributes to a better visual analysis of the graph.

For a healthy subject, the graph in Figure 6b (Recurrence plot) has fewer squares compared to patients with cardiovascular disease. In heart diseases (Figure 6a), it is noticed that the number of squares in the graph increases, which indicates a shift in periodicity of the studied signal and a decrease in its variability, which is a sign of a disease state.



(a) **(b)**

Fig. 6. Recurrence plot of a) patient with heart failure; b) a healthy individual

In heart diseases (patient with heart failure – Figure 6a), it is noticed that the number of squares in the graph increases, which indicates a shift in periodicity of the studied signal and a decrease in its variability, which is a sign of a disease state.

The created cardio information platform enables to conduct several studies on the mutual influence between the health status of the individual and the results of numerical and graphical results of the mathematical analyzes carried out. This will contribute to the accumulation of experience in reading the results of cardiological examinations, increasing the correctness of the given diagnosis and increasing the qualification of medical specialists. The platform allows storage of research results over a certain period, and their monitoring, based on which comparisons and analyzes can be made.

5 Conclusion

The created information platform allows users to work with it with minimal training. The system provides the possibility to search by name of the subject, by disease, and by the hospital; allows viewing of informational data, cardio records, and numerical and graphical results. Working with cardio data, their connection with the personal data of the examined patients, and the numerical and tabular results that the platform presents allow cardiologists to check the accuracy of the diagnosis, to prescribe adequate treatment. The system makes it possible to make comparative analyzes between the results of biomedical research carried out in different periods.

The conducted studies show significant differences in heart rate variability parameters in the healthy control group and in patients with heart failure. This is an additional sign to differentiate this heart disease.

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