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A LabVIEW based real-time software to automatically recognize off normal ECG values

R. Rossi
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

A.Malizia
Department of Biomedicine and Prevention
&
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy

D. Lucchetti
Istituto Neurotraumatologico Italiano (INI)
Grottaferrata (Rome), Italy
Rome, Italy

M. Gelfusa
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

A. Murari
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

M. Lungaroni
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

E.Peluso
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

Gianluca Gentile
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

Maria Richetta
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

C. Bellecci
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

Pasqualino Gaudio
Department of Industrial Engineering
University of Rome Tor Vergata &
Rome, Italy

Abstract— **Electrocardiography (ECG) is a test able to check heart electrical activity problems, such as atrial fibrillation, atrial enlargements, and myocardial infarction. In no specific medical examinations, doctors may involuntary disregard some pathologies. The authors realize a preliminary software (by the mean of LABVIEW) to recognize off-normal values of ECG, in order to provide an alarm signal instrument. The algorithm works computing positions and shapes of P waves, QRS complexes and T waves. A percentage indicator shows how many P-QRS-T complexes reveals the examined pathology. This is a tool that can help the doctors during medical visits. The software together with the main results obtained in certain case studies will be presented by the authors.**

Keywords—ECG, Automatic computation, myocardial disease

I. INTRODUCTION

Electrocardiography (ECG) is one of the most common diagnostic tests performed in cardiology. The aim of this health check is to gain information about the electrical functioning of the hearth. These kinds of information are usually collected by 12 signals in a graph called electrocardiogram. Each of this signal can be used to recognize many healthy pathologies such as myocardial infarction, pulmonary embolism and cardiac dysrhythmias. Therefore, the importance of this test is huge if we consider that cardiovascular diseases are the principal cause of death globally [1]. Electrocardiographs is the instrument needed to perform the medical measurement. The medical test

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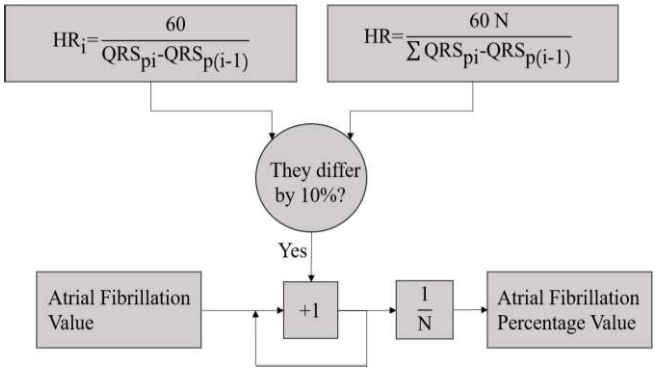

Fig. 2. Algorithm diagram of atrial fibrillation.

is performed by applying ten electrodes which determine twelve leads. Six of these electrodes are placed on the surface of the chest. The four remaining electrodes are the peripheral ones, situated at the end of each limb. The importance of this equipment uses and placements leads to different types of electrodes, such as dry and wet electrodes [2, 3]. The 12 leads can be classified into three main categories: precordial, limb and augmented limb leads. Each lead derives from electrode measurement combination [4]. Medical doctors may involuntary disregard some of the several detectable pathologies, especially in non-specific medical tests. Therefore, software programs able to automatic compute ECG signal are a must. Electrocardiogram signals strongly vary between people so much to be considered a human identification parameter [5]. For this reason, the elaboration of an algorithm that works properly with any signal is complicated. Many research studies are conducted in order to realize stable algorithms able to work with any ECG signal [6, 7]. Furthermore, a software cannot replace a medic examination but it can be only used as alarm signal. The authors develop a preliminary LabVIEW software able to compute some pathologies detectable through ECG.

II. Software Functioning

This paper introduces five ECG analysis: heart rate, atrial fibrillation, old (or former) lateral, septal and inferior myocardial infarctions. These pathologies determine a variation of ECG signals. The software computes each analysis independently and the off-normal ECG values are calculated through the guidelines in [4, 8]. The majority of pathologies can be evaluated analyzing positions and shapes of QRS complex and P and T waves. Firstly, a low-pass filter erases the high-frequency noise and a median filter removed the bias. Then, QRS complex is computed looking for peaks or valleys in precordial lead signals taking into account the standard shape and value of each signal (v1, v2, v3, v4, v5 and v6). Peaks are sought in v6, v5 and v4 because of their high R waves while valleys in v3, v2 and v1 because of low S waves. If a precordial lead signal does not reach the threshold value, the computation is skipped to the following signal. P wave locations are computed through a peak detector algorithm in the limb lead signal II. P peaks are sought in semi-periods forward each QRS complex. T wave detector is not yet implemented. Fig. 1 shows a block diagram section where QRS location, heart rate and atrial fibrillation are computed.

Hearth rate (HR) is an important parameter to determine many characteristics of patients, such as tachycardia, bradycardia and arrhythmia. It is one of the parameters strongly correlated to mortality [9]. Standard values are from 60 bpm to 100 bpm. Heart rate is calculated through (1), where QRS_{pi} and QRS_{pi-1} are two consecutive QRS complex location and N is the number of QRS wave computed.

$$HR\ [bpm] = \frac{60\ N}{\sum QRS_{pi}[s] - QRS_{p(i-1)}[s]} \quad (1)$$

Atrial fibrillation is the irregular heartbeat rhythm. It is an important parameter since its presence is associated with an increase of other pathologies, such as heart failure [10]. It is computed comparing each QRS distance with mean heart rate. Each QRS distance that differs of 10% from heart rate causes an atrial fibrillation detection. Then, the percentage detection is calculated. Diagram in Fig. 2 shows the atrial fibrillation computation functioning.

Inferior myocardial infarction determines the necrosis of inferior myocardial wall. This necrosis reduces R wave amplitude and causes a large pathologic septal Q wave in II, III and aVF [4, 8]. Firstly, the software computes R location by searching the higher peak in QRS range. Q wave location is sought by looking for the nearest valley at the left of R wave location. Then, the software verifies if maximum absolute value of Q wave is larger than 1/3 of R wave peak. If it is verified in two of the three lead signals, old inferior myocardial infarction is detected. Then, the software computes a percentage of detections.

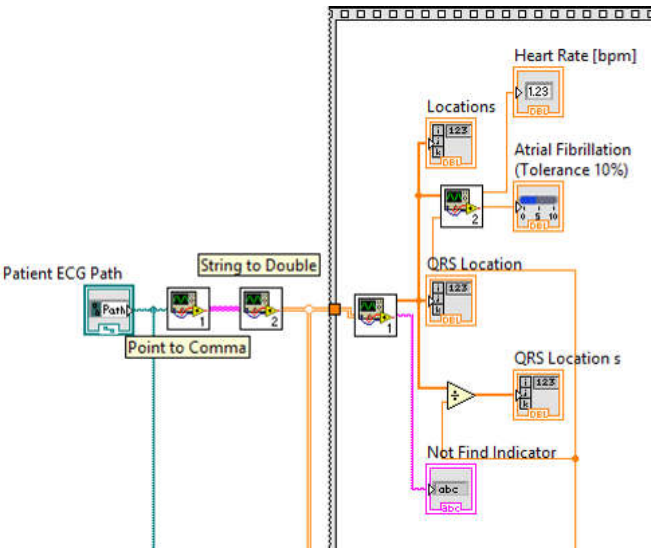

Fig. 1. A block diagram section of ECG software. QRS locations, atrial fibrillation and heart rate are computed in the subvi shown.

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Lead v5 and v6 are placed in the lateral wall of myocardium. Then, they measure a large R wave that defines the electrical activity of the lateral wall. Furthermore, these leads are near the interventricular septum and it determines a small Q wave. If a lateral myocardial infarction occurs, R wave is diminished while Q wave is enlarged [4, 8]. Q wave is considered off-normal or pathologic when its value is higher than 1/3 of R peak. Thus, the software verifies if Q value is in the standard range. A percentage of detection is calculated.

Septal infarction causes the necrosis of the septum. The low R wave in the precordial leads, v1 and v2, are due to electrical septum activation. If the septum necrosis occurs, R wave usually disappears. Few times, R wave persists in v1 and decrease in the following lead v2. Therefore, the software computes old septal infarction through two algorithms. The first one verifies if R waves in v1 and v2 are larger than a threshold value. Threshold value is needed because of noise. A second algorithm detects the pathology if Rv1 is larger than Rv2 (in standard ECGs R wave increases along precordial leads).

Software user interface is composed of signal graph, heart rate indicator and percentage bars, as shown in fig. 3. The signal graph allows to visualize each lead signals at any time instant. Heart rate indicator shows the calculated heart rate. Each pathology has a percentage bar that describes how many times the software compute that pathology.

III. SOFTWARE VALIDATION

A preliminary validation of software is here shown. The software functioning is illustrated through four patients (A, B, C and D) ECGs of an online ECG database [11, 12]. The database provides also the medical record of each patient. The mean patient pathologies are shown in table 1.

TABLE I. MEDICAL RECORDS

Medical Records**Patient**	*A*	*B*	*C*	*D*
Old Infarction	Anterior	Postero-lateral	Inferior	No
Acute Infarction	No	Infero-lateral	Antero-septal	No
Other	Atrial Fibrillation	Hyperglykemia, Gastric ulcers	No	No

Heart rate are not recorded in medical chart and so a comparison between software and clinical data cannot be performed. Anyway, Fig. 4 shows a lead signal of patient A and B. Location QRS complex distances of patient A are approximately 1,2 s which determine a 50 bpm heart rate. In the same way, heart rate of patient B can be evaluated around 100 bpm. The software reveals a heart rate equal to 48 bpm for patient A and 98 bpm for patient B, values that agree with Fig. 4.

The software detects atrial fibrillation pathology on patient A that is confirmed by the medical record. The percentage of detection is around 50%. The not large percentage value may be due to low tolerance used in algorithm. Furthermore, Fig. 5 shows the lead v6 at different time instants, illustrating the large different heart rate. No myocardial infarctions are found, as the medical chart reveals.

Fig. 3. Algorithm diagram of atrial fibrillation.

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Patient C is affected by old inferior myocardial infarction. The ECG software identifies the pathology with an intensity of 100%. Fig. 6 shows the three leads. Each signal illustrates pathologic Q waves and very low R waves. Old septal infarction is also detected with a percentage of 100%. The results are in agreement with the medical record, because the acute infarction may cause also the old implications. Fig. 7 shows the precordial leads v1 and v2 of the patient, where R waves are absented. Software computes heart rate to 97 bpm agrees with these signals. No other pathologies are detected by the software conforming to medical chart (anterior acute infarction is not yet implemented).

Old lateral infarction is detected in patient B ECG with an intensity of 100%. The lateral infarction is also confirmed in medical record. Large Q and small R waves can be seen in Fig. 8. Furthermore, a 95% intensity of old inferior myocardial infarction is identified and it is not shown in medical chart. Anyway, Fig. 9 shows the leads II, III and aVF and it can be noticed how their shape causes the old inferior infarction detection. In fact, their R waves are extremely decreased and pathologic Q waves are found.

Pathologies are not detected in patient D according to the medical chart.

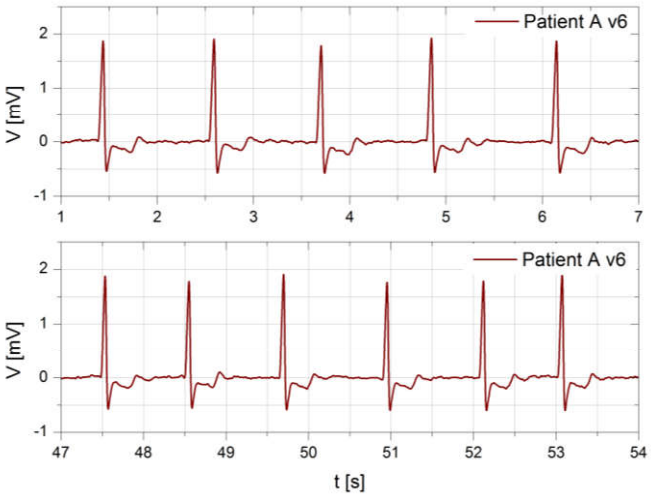

Fig. 5. Patient A: v6 signal over time shows an atrial fibrillation. In the upper graph five QRS complexes are revealed while in the lower graph there are six complexes.

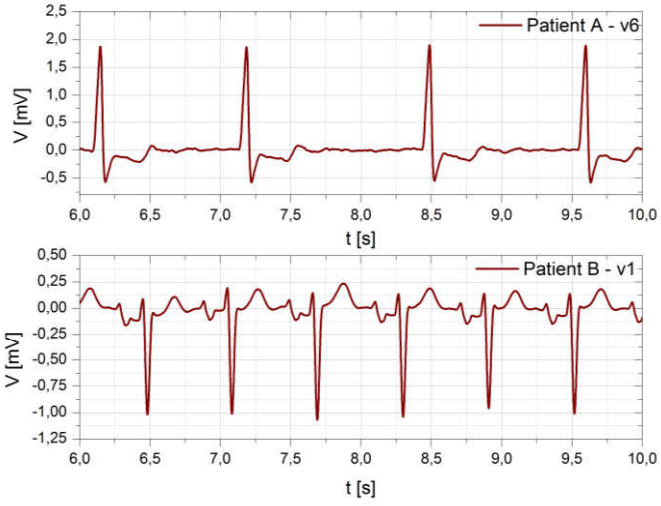

Fig. 4. v6 signal of patient A and v1 signal of patient B. Heart rate can be graphically calculated. Patient A has a heart rate of 50 bpm while patient b of 100 bpm around.

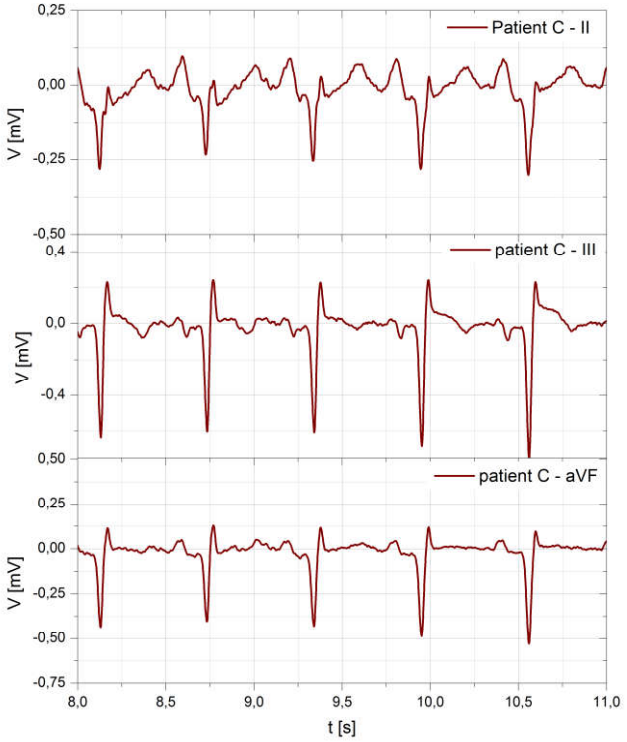

Fig. 6. Patient C: II, III and aVF leads. Pathologic Q waves are shown in each lead signals. Old inferior myocardial infarction is detected.

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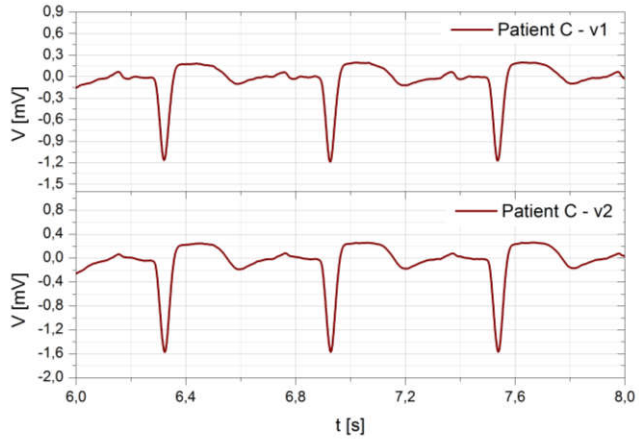

Fig. 7. Patient C: v1 and v2 leads show the disappearance of R wave.The QRS complex becomes a QS complex. Thus, septal myocardial infarction can be detected.

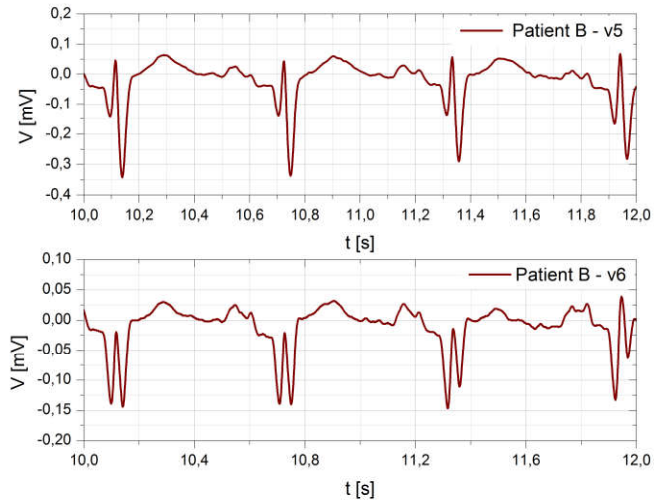

Fig. 8. Patient B: v5 and v6 signal show a large pathologic Q and S waves. Lateral infarction is detected.

The ECG software works properly with the analyzed pathologies. Anyway, some pathologies determine many shape changes of leads. These changes may to produce wrong detection. However, the software computes the non-standard values in ECG signals and thus it may be also useful in these cases by showing where the problem is.

IV. Conclusion

The authors describe a preliminary software made in LabVIEW to automatic analyze ECG. The software represents only an alarm signal, an instrument that helps and do not replaces the medical doctor. The software is able to detect heart rate, atrial fibrillation, and old inferior and lateral infarction. The detection is possible because pathologies cause shape changes in ECG signals. It has been tried analyzing 4 patient ECGs. The results are compared with the medical records, showing a properly functioning of the software. Each

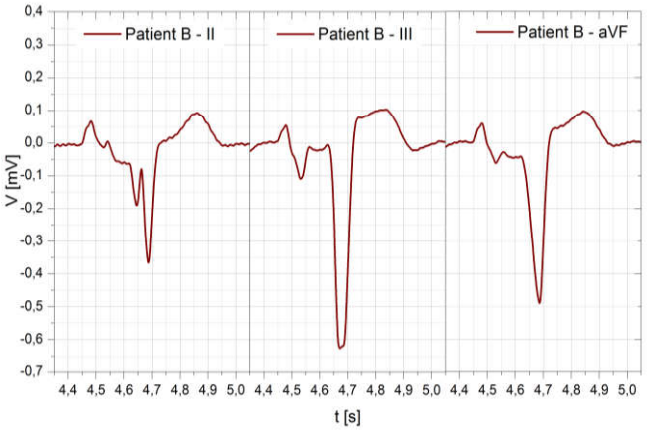

Fig. 9. Patient B: II, III and aVF leads. Old inferiot myocardial infarction is detected by the ECG software because of lead shape. In fact, each lead has a pathologic Q wave that in III and aVF determines a QS complex.

pathology is also analyzed in graphs. Even if the software seems to work accurately, other tests will be conducted to face the large variability of ECG signals. Furthermore, many other pathologies and detection of other non-standard values in ECG will be added to the software.

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