Scoring System for 12 Lead ECG Quality Assessment

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Abstract

We continue to work on the PhysioNet/CinC Challenge 2011: Improving the quality of ECGs collected using mobile phones and we have developed a scoring system, which determines the quality of recorded ECG. Our motivation was to extent the applicability of simple decision rules to support quality assessment of electrocardiogram. However, it is difficult to achieve better classification results using our approach rather than simple rules (e.g., zero lead and high-amplitude artifacts) because of the inconsistency in training database. The scoring system works with standard 12 lead ECG. Our algorithm is based on four simple rules. We assessment bins of ECG using rules and results of the classification are used to calculate index quality of ECG record.

1. Introduction

Cardiovascular diseases (CVD) are the number one killer in the world [1]. In low-income countries people have problem with non-existent or poor care. This is major reason deaths caused cardiovascular diseases in these countries. Electrocardiogram has been used to evaluate state of patient's heart. Quality of measurement is fundamental requirement of applicability the record. Diagnose diseases of heart timely increase chances to recovery. The lack of specialists in many countries increase the need of easy and efficient measuring device, which can send measured data to specialist.

We have developed scoring system in order to inform user about quality of measured ECG. This method can be used to quickly detect useless record and decrease number of worst quality records send to the specialist. Our also approach reduce requirements of user experience with assessment of electrocardiogram.

We have focused to inapplicable signals because we suppose lower cost for re-measuring than providing useless record specialist. Scoring system algorithm is divided into three steps:

1. Separate signal into bins
2. Application of four rules to bins
3. Computation of final score

In the first step signal from each lead is divided into bins with fixed length.

The second step contains four simple rules - zero signal, maximal value in a bin higher than threshold value, variance of differences in single bin greater than threshold and maximal value in a bin lower than threshold value. These rules are applied on each bin individually. Output from second step is decision of applicability of the bin.

The third step describes computation of final ECG score. The score is mapped to classification scale from 1 to 10 representing the quality of the ECG.

This paper is organized as follows. Section 2 describes computation of final score. Next sections of the paper include results of method, discussion and conclusions.

2. Method

Method allows to determine the degree of ECG usability at scale from 1 to 10, where 1 represent high quality signal and 10 completely unacceptable signal. Our algorithm is divided into three steps (see Fig. 1).

2.1. First step

Electrocardiogram of length 10 second is divided into 120 bins. Exactly, each lead (I, II, ..., V5, V6) contains 10 bins with fix length 1 second ($12 \cdot 10 = 120$).

2.2. Second step

The second step is represented by four binary rules. The thresholds used in the rules were determined by training dataset from physionet.org. These rules are described below.

Rule I - max value higher than threshold

Simple rule compares maximal value within bin with the threshold. This rule should fire, when there is high-amplitude artefact. The bin is determined as useless if the maximal value is higher than threshold.

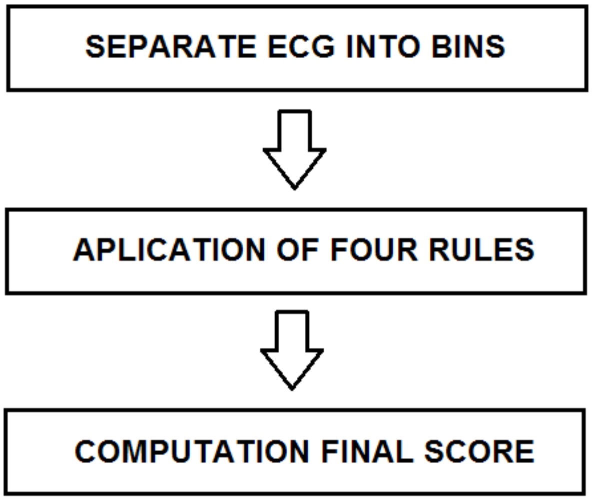

Figure 1. Description of scoring system

Rule II - zero lead

This rule detects mistake caused by missing contact of electrode. Bin containing zero signal in at least one half second (500 ms) is determined as unacceptable.

Rule III - max value lower than threshold

Rule compares absolute minimal value within bin with threshold. This rule should fire, when there is poor lead contact. The bin is determined useless when absolute minimal value is lower than threshold.

Rule IV - variance of differences

This rule should detect very fast signal changes. These changes could be caused by interference comeing from the external environment. The rule exclude bin if variance of differeces is higher than threshold.

2.3. Third step

Computation of final score is based on output of previous step. Each bin has to assign a feature representing rule which determined bin as unacceptable. Overall score is composed from two contributions - contribution of a bin (C_1), contribution of a number consecutive useless bins (C_2).

Size of bin contribution is determined using rule and lead, where is detected as unacceptable. Each rule has associated weight, which represent its ability to separate good and poor signal (see Tab. 1). Similarly, each lead has associated weight which takes into account importance of lead for ECG diagnostics (see Tab. 2).

Table 1. Weights of rules

Rule	Weight W_F
max value higher than threshold	0.0580
zero lead	1.0000
max value lower than threshold	0.0128
variance of differences	0.0095

Rule II - zero lead was most succesful on the training set and its weight is set to 1. Other weights were related to rule II. Rule I, III, IV separate bins contain interferences or other mistakes of measurement.

Table 2. Weights of lead

Lead	Weight W_L	Linear indep./dep.
I	1.0	indep.
II	1.0	indep.
III	0.1	dep.
aVR	0.1	dep.
aVL	0.1	dep.
aVF	0.1	dep.
V1	0.5	indep.
V2	0.5	indep.
V3	0.5	indep.
V4	0.5	indep.
V5	0.5	indep.
V6	0.5	indep.

Weights of leads are diveded into three levels. The most significant are leads I and II. We have assigned to these leads top weights (Tab. 2). These leads [2, 3] are linear independent. Leads I and II allow computation of lead III, aVR, aVL and aVF. We have determined these leads to be least important. Chest leads are also linear independent. We have assigned middle level of importance to these leads.

Contribution C_B represents addition to the final score caused usseles bin. Computation of C_B is done as follows:

$$C_B = W_L \cdot W_F, \tag{1}$$

where W_L is weight of lead, W_F is weight of rule. Then the contributions C_B of each bin are summed in order to create C_1.

$$C_1 = \sum_i C_{B_i}, \tag{2}$$

where C_{B_i} is contribution of i-th usseles bin.

The second part score (C_2) is computed for each lead individually. Contribution of a number consecutive useless bins represent long time mistake of measurement. We supposed more significant long time mistake. Contribution of a number consecutive useless bins (C_L) follow as:

$$C_L = W_L \cdot W_F \cdot N, \quad (3)$$

where N is number of consecutive usseles bins. These contributions are summed and represent second part of final score C_2.

$$C_2 = \sum_j C_{L_j}, \quad (4)$$

where C_{L_j} represents contribution of j-th long time mistake (at least 2 consecutive bins).

Final score is defined as:

$$S = C_1 + C_2 \quad (5)$$

This score is mapped to scale from 1 to 10. This quality index can help user with assessment of applicability of ECG.

3. Results

Our scoring system algorithm determine usability of 12 lead ECG into 10 level. We have to divide scale of index quality into two groups - acceptable, unacceptable.

Firstly we marked signals with index quality from 1 to 5 as acceptable and other as unacceptable. In this case our algorithm achieved results which are shown in Tab. 3. We ascertained quality of algorithm also using sensitivity (SE) and specificity (SP) on training dataset. Sensitivity a specificity on the testing datase could not be determined because we do not have labels to available.

Table 3. Results case I

Dataset	Result	SE	SP
Training	0.9108	93.53	82.67
Testing	0.8980	-	-

Secondly we divided signals with index quality from 1 to 8 as acceptable and other as unacceptable. Results are shown in Tab. 4.

Table 4. Results case II

Dataset	Result	SE [%]	SP [%]
Training	0.9198	97.83	67.56
Testing	0.9200	-	-

In this case is better overall rate. However, specificity is very low. Trainig dataset contains majority acceptable records. The results show that acceptable records are majority in testing dataset also. We can assume low specificity for testing dataset.

4. Discussion and conclusions

This paper describes scoring system for determining quality of 12 lead ECG. Our approach was to develop algorithm using simple rules. In order to detect distortions of the signal, we take into account different importance of these distortions.

Our algorithm separates ECG record into 120 bins with fixed length (1 second). These bins are then processed by four simple rules, using results of classification is computed contribution of usseles bin. Algorithm detects long time mistakes of measurement. Contribution of long time mistakes constitutes second part of final score.

Final score represents applicability of ECG record which we can send to a specialist. Index quality should help user assess of quality of ECG.

We think that simple rules are sufficient for detect common mistakes of measurement. Simple implementation and speed of calculation allows the use our algorithm on mobile devices.

Acknowledgements

Research described in the paper has been supported by the VUT Grant SGS10/279/OHK3/3T/13 and research program No. MSM 6840770012 ”Transdisciplinary Research in Biomedical Engineering II” of the CTU in Prague.

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