Brno University of Technology ECG Signal Database with Annotations of P Wave (BUT PDB)

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Short report

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Abstract

Background: Brno University of Technology ECG Signal Database with Annotations of P Wave (BUT PDB) is an ECG signal database with marked peaks of P waves created by the cardiology team at the Department of Biomedical Engineering, Brno University of Technology.

Results: The database consists of 50 2-minute 2-lead ECG signal records with various types of pathologies. The ECGs were selected from 3 existing databases of ECG signal - MIT-BIH Arrhythmia Database, MIT-BIH Supraventricular Arrhythmia Database and Long Term AF Database. The P waves positions were manually annotated by two ECG experts in all 50 records. Each record contains also dominant diagnosis (pathology) present in the record and annotated positions and types of QRS complexes (from the original database).

Conclusion: The database is created for the development, evaluation and objective comparison of P wave detection algorithms.

Introduction

Electrocardiography (ECG) is nowadays still the most available and widely used method for the cardiovascular system examination [1]. ECG signal reflects the electrical activity of the heart and provides a significant amount of information about the heart function [2]. Accurate detection of ECG components, such as P wave, QRS complex and T wave are fundamental steps of ECG analysis and subsequent cardiac pathological events detection. In practice, automated evaluation of ECG records using software is necessary [3]. The detection of QRS complexes and T waves is usually efficient. However, methods for P wave detection are not so successful in physiological signals and especially in pathological signals. It applies both in real practise and research [4],[5],[6],[7].

One of the reasons that prevents the progress in this field is a lack of publicly available datasets with correct P waves annotations suitable for training and testing of detection algorithms [5],[8].

The methods are usually tested only on a part of publicly available QT database [9],[10] or on a not publicly available CSE database [11], both with manual P waves annotations. In addition to this, there are two new databases, namely MIT-BIH Arrhythmia Database P-Wave Annotations [5],[9],[12] and Lobachevsky University Electrocardiography Database [9],[6], whose use is not frequent yet. There are also two publicly available databases with P waves annotations which contain mistakes - P waves annotations of MIT-BIH Arrhythmia database by Elgendi et al. [13] and automatically annotated part of QT database [10]. Thus, these annotations cannot be recommended to be used for testing of P wave detection algorithms.

The most commonly used databases, QT database and CSE database contain predominantly physiological ECG records, or contain only those pathologies which do not affect P wave detection. However, the content of the pathologies in databases is very important for objective testing of P wave

detection algorithms. During the pathological function of the heart, the information about the positions of the P waves is very important for determining the diagnosis. Unfortunately, current algorithms are not able to detect P waves in pathological signals reliably.

Therefore, we fill this gap and introduce a new database of ECG signals with manually annotated P waves. The Brno University of Technology ECG Signal Database with Annotations of P Wave (BUT PDB) database consists of 50 2-minute 2-lead ECG signals with 23 types of pathologies. The P waves positions were manually annotated by two ECG experts with 7 years of practical experiences with evaluation of holter ECG records in cardiovascular ambulance [5]. The database will help to develop new, more accurate, and robust methods for processing and analysing ECG records in the sense of P wave detection.

Materials And Methods

Selection of data

The ECG signals were selected by two ECG experts from 3 existing databases of ECG signals - from MIT-BIH Arrhythmia Database (MIT-A) [9],[14], MIT-BIH Supraventricular Arrhythmia (MIT-S) Database [9],[15] and Long Term AF Database (LT-AF) [9],[16]. All the databases contain ECG signals and annotations of positions and types of QRS complexes. The MIT-A database additionally contains annotations of types of arrhythmias present in records. The detailed information about these databases is available on Physionet [9] or in the articles [14],[15],[16].

Two ECG experts went through the records and selected interesting two-minute sections with higher incidence of pathologies during which it is usually difficult to detect P waves by automatic algorithms. The signals were chosen to represent as many types of pathologies present in records in real medical practice as possible.

The final database consists of 50 2-minute 2-lead ECG signals with various types of pathologies. The whole database contains 23 different types of pathologies. The amount and type of pathologies is chosen to represent a real sample of data from medical practice. From MIT-A database, 38 signals were selected. From MIT-S database, 5 signals were selected. From LT-AF database, 7 signals were selected. The BUT PDB includes 7,638 QRS complexes of which 2,120 are without P wave (e.g. atrial fibrillation, ventricular beats or during nodal rhythm) and 81 P waves are without QRS complex (e.g. 2nd degree atrioventricular block). Altogether, the BUT PDB includes 5,599 P waves. In the BUT PDB, 23 different types of pathologies are present. Types of pathologies with their abbreviations used in the BUT PDB, number of cases (records) and IDs of the records in which the pathology is present are listed in Table 1.

Annotation Of Data

The P waves positions were manually annotated by two ECG experts with 7 years of practical experiences with evaluation of holter ECG records in cardiovascular ambulance [18], [5]. The first expert provided manual annotations, and the second manually checked them. Unclear parts of the records were discussed by both experts until a consensus was reached. Everything was conducted manually without the use of automated annotating software. To facilitate the work of ECG experts, a free software tool, SignalPlant [17], was used for manual marking of P waves. The experts worked independently. Unclear parts of the records were discussed by both experts until a consensus was reached. The selected records are interesting two-minute sections with higher incidence of pathologies during which it is usually difficult to detect P waves by automatic algorithms.

Table 1

Types of pathologies with their abbreviations used in the BUT PDB, number of cases (records) and IDs of the records in which the pathology is present.

Abb.	Type of pathology	Number of cases	IDs of the records with the pathology
A	Atrial premature beat	14	04,05,09,16,17,18,26,28,35,38,39,40,41,43
AFIB	Atrial fibrillation	9	07,08,44,45,46,47,48,49,50
AFL	Atrial flutter	2	08,38
B	Ventricular bigeminy	3	02,14,27
BI	1st degree atrioventricular block	1	22
BII	2nd degree atrioventricular block	2	01,13
BIII	3rd degree atrioventricular block	1	03
E	Ventricular escape beat	1	09
F	Fusion beat	3	30,31,32
IVR	Idioventricular rhythm	1	30
J	Nodal beat	3	06,07,15
L	Left bundle branch block beat	4	21,22,36,41
NA	Sinus arrhythmia	1	24
NOD	Nodal rhythm	3	06,07,15
P	Paced rhythm	2	03,19
PREX	Pre-excitation	1	12
R	Right bundle branch block beat	4	01,13,26,34
SVTA	Supraventricular tachyarrhythmia	3	09,11,43
T	Ventricular trigeminy	2	27,29
V	Ventricular premature beat	20	05,10,14,19,20,21,25,27,28,29,30,31,32,33,35,36,39,40,41,42
VFL	Ventricular flutter	1	33
VP	Ventricular pair	1	25
a	Aberrated atrial premature beat	1	23

Each record also contains annotation of dominant diagnosis (pathology) and types of QRS complexes (from the original databases) [9],[14]. The information of pathologies present in records was checked (the original annotations were found correct) and taken over from the original databases and supplemented by ECG experts in the cases where the information was missing (all signals from MIT-S). The information about types of QRS complexes is taken over from the original databases.

Results And Discussion

The final database contains 23 different types of pathologies. The amount and type of pathologies is chosen to represent a real sample of data from medical practice.

In Table 2, information about each record from BUT PDB is listed. The information contains: IDs of the record, types of pathologies present in each record, original database, IDs of the record from the original database and the start and the end (in samples) of the selected segment.

Table 2

Information about each record from BUT PDB: IDs of the record, types of pathologies present in each record, original database, IDs of the record from the original database, the start and the end (in samples) of the selected segment and sampling frequency of the record.

IDs of the record	Types of pathologies	Database	Original name of the record	The start and the end of the segment [samples]	Sampling frequency [Hz]
01	'BII, R'	MIT-A	231	[30160,73360]	360
02	'V, B'	MIT-A	106	[34920,78120]	360
03	'BIII'	MIT-A	107	[266400,309600]	360
04	'A'	MIT-A	108	[525600,568800]	360
05	'A, V'	MIT-A	118	[486720,529920]	360
06	'NOD, J'	MIT-A	124	[104400,147600]	360
07	'AFIB, NOD, J'	MIT-A	201	[124200,167400]	360
08	'AFIB, AFL'	MIT-A	203	[572400,615600]	360
09	'E, A, SVTA'	MIT-A	207	[594000,637200]	360
10	'V, T'	MIT-A	208	[414000,457200]	360
11	'SVTA'	MIT-A	209	[518400,561600]	360
12	'PREX'	MIT-A	230	[108000,151200]	360
13	'BII, R'	MIT-A	231	[478800,522000]	360
14	'V, B'	MIT-A	233	[201960,245160]	360
15	'J'	MIT-A	234	[288360,331560]	360
16	'A'	MIT-A	101	[439560,482760]	360
17	'A'	MIT-A	112	[248400,291600]	360
18	'A'	MIT-A	114	[439560,482760]	360
19	'P, F, V'	MIT-A	104	[576000,619200]	360
20	'V'	MIT-A	105	[572400,615600]	360
21	'L, V'	MIT-A	109	[601200,644400]	360
22	'L, BI'	MIT-A	111	[169200,212400]	360
23	'a'	MIT-A	113	[478800,522000]	360
24	'NA'	MIT-A	115	[541800,585000]	360

IDs of the record	Types of pathologies	Database	Original name of the record	The start and the end of the segment [samples]	Sampling frequency [Hz]
25	'V, VP'	MIT-A	116	[550800,594000]	360
26	'R, A'	MIT-A	118	[478800,522000]	360
27	'V, B, T'	MIT-A	119	[97200,140400]	360
28	'A, V'	MIT-A	121	[356400,399600]	360
29	'V'	MIT-A	123	[540000,583200]	360
30	'P, IVR, T, V, F'	MIT-A	124	[367200,410400]	360
31	'V, F, VT'	MIT-A	205	[522000,565200]	360
32	'V, F, VT'	MIT-A	205	[91440,134640]	360
33	'V, VFL, '	MIT-A	207	[55440,98640]	360
34	'R'	MIT-A	212	[518400,561600]	360
35	'V, A'	MIT-A	213	[529200,572400]	360
36	'V, L'	MIT-A	214	[583200,626400]	360
37	'A, FIB'	MIT-A	219	[410400,453600]	360
38	'NOD, AFL, A'	MIT-A	222	[475200,518400]	360
39	'V, A'	MIT-S	801	[26570,41929]	128
40	'V, A'	MIT-S	802	[181220,196579]	128
41	'L, A, V'	MIT-S	886	[202320,217679]	128
42	'V'	MIT-S	851	[150320,165679]	128
43	'A, SVTA'	MIT-S	811	[196820,212179]	128
44	'AFIB'	LT-AF	101	[3865673,3881032]	128
45	'AFIB'	LT-AF	120	[321823,337182]	128
46	'AFIB'	LT-AF	55	[10002594,10017953]	128
47	'AFIB'	LT-AF	56	[5229657,5245016]	128
48	'AFIB'	LT-AF	62	[8495932,8511291]	128
49	'AFIB'	LT-AF	102	[10683803,10699162]	128
50	'AFIB'	LT-AF	117	[4050966,4066325]	128

The examples of records with various pathologies (ie. 2nd atrioventricular block (rec. 01), ventricular premature contraction, ventricular tachycardia, atrial fibrillation (rec. 48)) and newly annotated P waves are shown in Fig. 1.

The BUT PDB is available on Physionet [9],[19]. All data are provided in the WaveForm Database (WFDB) format, which is supported by the WFDB Software Package [9]. The IDs of the recordings are numbers from 01 to 50. The ECG signals are stored in files with suffix *.dat, the annotations of P waves are in stored files with suffix *.pwave, the positions of QRS complexes, their types and sampling frequency of each ECG signal are stored in files with suffix *.qrs. The exact types of pathologies present in each signal are described in the text file with the name README.txt.

The codes needed for the loading of data are available on Physionet [9] (<https://archive.physionet.org/physiotools/wfdb.shtml>). In case of using Matlab, for loading files *.dat with ECG records use function “rdsamp” (eg. [signal, fs, tm] = rdsamp('17.dat')), for loading files with annotations of P waves or QRS complexes and their types use function 'rdann' (eg. [P] = rdann('17', 'pwave') or [QRS, typeQRS] = rdann('17', 'qrs')).

Conclusions

BUT PDB is created for the development, testing and objective comparison of algorithms for P waves detection. For objective comparison, the prerequisite is that they will use the entire database and that they will not select and/or shorten the signals. The database includes a representative sample of pathologies present in records in real medical practice. If the algorithms will be reliably able to deal with P waves detection in all types of pathologies present in this database, they will be usable for implementation to the software for ECG signals analysis in real medical practice.

Declarations

Data Availability

The BUT PDB is publicly available on Physionet [9],[19].

Conflicts of Interest

There are no conflicts of interest..

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Figures

Figure 1

The examples of records with annotated P waves. Subgraph a) 2nd atrioventricular block (rec. 01) b) ventricular premature contraction (rec. 35), c) ventricular tachycardia (rec. 32) and d) atrial fibrillation (rec. 48).