A NEW FUZZY BASED DIAGNOSING SYSTEM FOR INSTANTANEOUS PROCESSING 12 LEAD ECG SIGNAL

By

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LIST OF ABBREVIATIONS

AV	Atrioventricular
AcMI	Acute Myocardial Infarction
AF	Atrial Fibrillation
ANFIS	adaptive neuro-fuzzy inference system
ANN	artificial neural network
APC	atrial premature contraction
ARVC	Arrhythmogenic Right Ventricular Cardiomyopathy
AV	Atrioventricular
aVF	augmented unipolar limb lead between left foot (+) and common terminal (-)
aVL	augmented unipolar limb lead between left arm (+) and common terminal (-)
AVNB	Atrioventricular nodal block
aVR	augmented unipolar limb lead between right arm (+) and common terminal (-)
BW	Black and White
CRTA1...6	LVH Diagnostic Criteria 1 to 6
CSE	Common Standards for Electrocardiography
CSIEPC	Colored Scanned Image of ECG Printed Chart
DCT	Discrete Cosine transform
DOM	difference operation method
dpi	dot per inch
DSP	Digital Signal Processing

DWT	Discrete Wavelet Transform
EarMI	Earlier Myocardial Infarction
ECG	Electrocardiogram
ECHO	Echocardiography
EKG	Electrocardiogram
EMD	empirical mode decomposition
F Gender	Female
Fd	failure detection
FIS	fuzzy inference system
FN	False Negative
FOAM	first order absolute moment
FP	False Positive
GMMs	Gaussian mixture models
GUI	graphical user interface
HH	Human Heart
HMMs	hidden Markov models
HOCM	Hypertrophic obstructive cardiomyopathy
HRT	Heart Rate Turbulence
HRV	Heart Rate Variability
HSDPTW	high speed approach for detecting time characteristics of P and T waves
Lead I	Bipolar Limb Lead between right arm (-) to left arm (+)
ICA	independent component analysis

Lead II	Bipolar Limb Lead between right arm (-) to left foot (+)
Lead III	Bipolar Limb Lead between left arm (-) to left foot (+)
IMF	intrinsic mode functions
INCART	St. Petersburg Institute of Cardiological Technics 12-lead Arrhythmia Database
KNN	K-nearest neighbor algorithm
LA	Left Arm
LBBB	Left Bundle Brunch Block
LL	Left Leg
LQTcS	long QT corrected syndrome
LVH	Left Ventricular Hypertrophy
m	mean
M Gender	Male
MDV	main decision value
MFs	membership functions
MI	myocardial infarction
MIT-BIH	Massachusettes Institute of Technology and Boston's Beth Hospital
MLP	multilayer perceptron
MOS	mean opinion score
NORM	Normal Beat
NSR	arrhythmias normal sinus rhythm (NSR),
P	ECG P wave
P+	Specificity

PCA	principle component analysis
PQ	ECG time segment between end of the P wave and starting point of the QRS complex
PR	ECG time interval between onset of the P wave and starting point of the QRS complex
PRD	percentage root mean square difference
PT	Pahsor transform
PTB	Physikalisch-Technische Bundesanstalt
PVCs	Premature Ventricular Contractions
Q	ECG Q wave
QRS	ECG QRS complex
QT	ECG time interval between onset of the Q wave and end of the T waves
QTc	corrected QT interval
QTDB	Online ECG Database for Evaluation of Alggorithms for Measurement of QT and Other Waveform Intervals in the ECG
R	ECG R wave
RA	Right Arm
RBBB	Right bundle brunch block
REC-CRTA	Recommended criterion
RFEM	rising falling edge mutation
RGB	Red Green Blue
RR	Interval between two consective R waves
$RR_{successive}$	the distance variation between the present and the next RR interval
S	ECG S wave

s	standard deviation
SA	sinoatrial node
SA-ECG	signal averaged electrocardiogram
SCD	sudden cardiac death
SD	sudden death
SE	Shannon energy
Se	sensitivity
SHT	Standard Hough Transform
SND	Sinus node dysfunction
ST segment	limited time interval between end of QRS complex and onset of T wave
ST	S-Transform
STele	ST elevation
SVMs	support vector machines
SVT	Supraventricular tachycardia
T	ECG T wave
TDV	time deviation
TIA	Transient Ischemic Attack
TN	True Negative
TP	True Postive Beats
TWA	T wave alternans
U	ECG U wave
V1 to V6	precordial chest leads 1 to 6

VBG	Ventricular bigeminy
VF	ventricular fibrillation
VPC	ventricular premature contractions
VT	ventricular tachycardia
WCT	Wilson Central Terminal
WPW	Wolf Parkinson White Syndrome
WT	Wavelet Transform

LIST OF SYMBOLS

P_{Amp}	Amplitude Voltage of P wave
P_{ON}	Onset Time Location of P Wave
P_{PEAK}	Peak Time Location of P Wave
P_{OFF}	End Time Location of P Wave
Q_{ON}	Onset Time Location of Q Wave
R_{Amp}	Amplitude Voltage of R wave
Q_{OFF}	End Time Location of Q Wave
S_{ON}	Onset Time Location of S Wave
S_{OFF}	End Time Location of S Wave
QRS_{Amp}	Positive Amplitude Voltage of QRS Complex
S_{Amp}	Amplitude Voltage of S wave
QRS_{Dur}	Time Duration Between Onset and End Time Locations of QRS complex
T_{Amp}	Amplitude Voltage of T wave
T_{ON}	Onset Time Location of T Wave
T_{PEAK}	Peak Time Location of T Wave
T_{OFF}	End Time Location of T Wave
R_{PEAK}	Peak Time Location of R Wave
J-point	The end of QRS segment and the beginning of ST segment
d1 to d5	First to Fifth resolutions of Wavelet Transform
ECG_{Pre}	Resulted ECG Signal from Pre Processing Stage in Proposed ECG System
RR*int*	Time Interval Between Two Consecutive R Waves

R_{th},	Threshold Value of Red Component in RGB Color
G_{th},	Threshold Value of Green Component in RGB Color
B_{th}	Threshold Value of Blue Component in RGB Color
HS	Height of Slice Image partitioned from CSIEPC
WS	Width of Slice Image partitioned from CSIEPC
M_{left}	Number of Black Pixels in 3x3 Mask to the Left of a Tested Point
M_{Right}	Number of Black Pixels in 3x3 Mask to the Right of a Tested Point
M_{Up}	Number of Black Pixels in 3x3 Mask Above a Tested Point
M_{Down}	Number of Black Pixels in 3x3 Mask Below a Tested Point
PS	Number of Pixels in single Small Square
Raw_Data	Matrix Vector of Resulted Raw ECG Data
Final_Raw_Data	Final Matrix Vector of Raw ECG Data after Shifting Data with Baseline Level and Scaling them by Amplitude Factor
Amp_Fact	Amplitude Scaling Factor
Baseline Level	Determined ECG Baseline Level
R_{th}	Threshold Value of R wave
S_{th}	Threshold Value of S wave
AMP_{i}	Amplitude Voltage Difference between Next and Current ECG Beat
AMP_{i-1}	Amplitude Voltage Difference between Current and Previous ECG Beat
Beat_{i}	Time Event of Current ECG Beat
Q_{END}	Time Event of Q Wave Delineated by RFEM
rm	Time Period of R wave
sm	Time Period of S wave

$TDQ_{O\rightarrow E}$	Time Duration limited by Q_{ONSET} and Q_{END}
$TDS_{O\rightarrow E}$	Time Duration limited by S_{ONSET} and S_{END}
Bt_{Qe}	Voltage of ECG Beat at Q_{END}
Bt_{Qe-i}	Voltage of Previous ECG Beat from Q_{END}
Bt_{So}	Voltage of ECG Beat at S_{ONSET}
Bt_{So+i}	Voltage of Next ECG Beat from S_{ONSET}
P_{start}	Start Limit of Search Period for Delineating P_{PEAK}
P_{end}	End Limit of Search Period for Delineating P_{PEAK}
T_{start}	Start Limit of Search Period for Delineating T_{PEAK}
T_{end}	End Limit of Search Period for Delineating T_{PEAK}
PMX	Primary Time Location of Delineated P_{PEAK}
MPMX	Corrected Time Location of Delineated P_{PEAK}
PUP	Counting of Rising Interval in P Wave
PDW	Counting of Falling Interval in P Wave
Frw_{index}	Forward Iteration with Odd Index
Bak_{index}	Backward Iteration with Even Index
$PS_{ON\sim OFF}$	Subroutine for Delineating Onset and End Time Locations in P wave
$TS_{ON\sim OFF}$	Subroutine for Delineating Onset and End Time Locations in T wave
ANG1	Limited Angle Between P_{PEAK} and Horizontal Line
ANG2	Limited Angle Between P_{ONSET}/ P_{END} and Horizontal Line
X_i	ECG Beat of Index i
BG	Left Iteration Scan of Delineating P_{ONSET}
EF	Right Iteration Scan of Delineating P_{END}
P_{ON}	Delineated Onset Time Location by HSDPTW

P_{OFF}	Delineated End Time Location by HSDPTW
X_{PEAK}	Amplitude voltage (mV) of the pre-detected P_{PEAK}
X_{BG}	Amplitude voltage (mV) of current beat separated by 3 time units
X_{BG-2}	Amplitude voltage (mV) of previous beat separated by 3 time units
X_{PEAK+3}	Amplitude voltage (mV) of ECG beat separated by 3 time units from the right of P_{PEAK}
X_{EF},	Amplitude voltage (mV) of current beat separated by 3 time units, respectively
X_{EF+2}	Amplitude voltage (mV) of nest beat separated by 3 time units, respectively
C_{UP}	Counter of ECG beats in rising edge of T wave
C_{DOWN}	Counter of ECG beats in falling edge of T wave
TUP	Counter of T wave in Up Direction
TDW	Counter of T wave in Down Direction
TN	Left Iteration Scan of Delineating T_{ONSET}
TD	Right Iteration Scan of Delineating T_{END}
TMX	Delineated Time Location of T wave
MDV-Fe-LVH	Output MF for Diagnosing LVH in Female Patients
MDV-Ma-LVH	Output MF for Diagnosing LVH in Male Patients
Gender-CRT	Gender Criterion
Expr1	1st Traditional Diagnostic Criterion in Proposed FIS Diagnosing Approach
Expr2	2nd Traditional Diagnostic Criterion in Proposed FIS Diagnosing Approach
MDV-Normal	Output MF for Diagnosing Normal and Non-LVH Patients

Reka Bentuk dan Pembangunan Sistem Teguh Fuzzy Baru untuk Pemprosesan Serta Merta Isyarat ECG 12 Penunjuk

ABSTRAK

Isyarat elektrokardiagram (ECG) menggambarkan prestasi jantung manusia dalam bentuk isyarat elektrik. Ia terdiri daripada tiga gelombang utama iaitu P, komplek QRS, dan T serta direkodkan oleh mesin ECG dalam bentuk 12 penyadap *(lead)* termasuk maklumat penting mengenai fungsi jantung manusia dan sistem kardiovaskular. Ia dianotasi secara manual oleh pakar kardiologi untuk mendiagnosis penyakit jantung. Namun, untuk mendapatkan kajian mengenai kadar perubahan jantung yang lebih berkesan, rakaman ECG yang lebih panjang diperlukan. Data ECG yang dijana adalah bersaiz besar dan kebarangkalian penganalisa membuat analisa yang salah atau salah baca semasa membuat anotasi secara manual semakin meningkat. Oleh itu, terdapat banyak teknik berasaskan komputer telah dicadangkan dalam kajian literatur untuk menganalisis dan mengesan gelombang ECG dan juga kadar yang lebih rendah untuk mendiagnosis penyakit jantung. Dalam tesis ini, sistem pintar baru yang mantap telah dicadangkan untuk melakukan diagnosis yang lebih tepat bagi penyakit jantung yang berisiko tinggi dikenali sebagai hipertropi ventrikel kiri (LVH). Empat pendekatan dicadangkan untuk membangunkan sistem ECG bagi meningkatkan prestasi pemprosesan isyarat ECG berbanding kaedah yang sedia ada untuk mendiagnosis penyakit jantung berdasarkan teknik pintar berkomputer. Pendekatan pertama yang dicadangkan adalah sistem pemulihan digital yang menekankan pembatasan data ECG 12 penyadap secara digital dengan membina semula mereka daripada imej warna yang diimbas dari carta ECG tercetak. Pendekatan ini dilaksanakan oleh empat langkah pemprosesan imej dan mengambil data ECG mentah berdasarkan garis dasar yang dikesan oleh pendekatan yang sama. Tambahan pula, morfologi ECG yang berbeza dan carta-carta cetakan merupakan data yang boleh dipercayai. Data yang dibina semula dinilai secara kualitatif dan kuantitatif dengan menggunakan beberapa ciri-ciri piawaian yang telah ditetapkan. Keputusan analisis menunjukkan ketetapan dan keteguhan pendekatan ini untuk menjana data ECG 12 penyadap dengan ketepatan yang tinggi (98%). Pendekatan yang kedua dan ketiga adalah dicadangkan untuk mengesan gelombang ECG dan kemudian menggambarkan semua ciri-ciri masa gelombang ini. Berbeza dengan kaedah yang sedia ada, kedua-dua pendekatan adalah berdasarkan algoritma secara terus yang memproses isyarat ECG secara serta merta. Akibatnya operasi pengesanan dilaksanakan dalam kelajuan yang tinggi mencapai 4.5s per 650,000 degupan untuk QRS kompleks dan 2.7 s per 225,000 degupan untuk gelombang P&T. Teknik asas bagi kedua-dua pendekatan pengesanan menggunakan kelebihan mutasi pinggir menaik dan menurun sesuatu gelombang sebagai peraturan asas untuk menggambarkan subjek.Teknik ini dapat mengurangkan degupan yang tidak dapat dikesan dan menghasilkan pengesanan yang lebih tepat berbanding kaedah terkini yang sedia ada. Pendekatan keempat yang dicadangkan adalah sistem untuk mendiagnosis penyakit jantung LVH berdasarkan kriteria diagnostik. Berbeza dengan kriteria diagnostik LVH konvensional, cadangan keputusan mengambilkira tiga ungkapan logik; dua daripadanya adalah ditentukan oleh gabungan kriteria klasik manakala ketiga dapat ditentukan oleh lapan voltan ECG dan mengambilkira dua paras voltan yang berbeza bagi setiap jantina. Ungkapan ini diwakili oleh fungsi keahlian dalam reka bentuk