

Age and Changes in Extracted Features of Lagged Poincare Plot

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Abstract

The Poincare plot is a geometrical representation of RR time series constructed by plotting successive RR intervals on a 2D phase space. In this article, the impact of age on the shape of Poincare plot of RR intervals and extracted features for quantification of this space is considered. Fantasia database from Physionet databank is used in this paper. Two hours of ECG recording (sampling frequency: 250 Hz) for twenty young (21-34 years old) and twenty older adults (68-85 years old) were used while all subjects remained in a resting state. After extraction of RR intervals from ECG, Poincare plot with 10 different lags (1-10) were constructed for each RR series, and eleven different features were extracted for each lag. Extracted features from lagged Poincare plot were used as input to K-nearest neighbor classifier to discriminate between two groups of young and older adults. Sensitivity of 86.5%, specificity of 95.1%, and the accuracy of 91.4% was achieved in the classification.

1. Introduction

Physiological responses such as heart rate and heart rate variability (HRV) change by age and frailty [1]. Previous studies examined the influence of age on the various indexes used for quantification of HRV [2]. Research has shown that aging is associated with a significant decline in HRV features [3, 4]. As the age increases, the heart rate slows down and the blood vessels lose their elasticity to some extent and become tighter. By tightening the arteries, the heart works harder to pump blood into the veins this leads to an increase in blood pressure and other cardiovascular problems in the elderly [2]. Therefore, recognizing the effects of age on cardiac parameters can be useful in preventing many diseases.

The HRV is changes in the time intervals between consecutive heartbeats over time that shows heart adaptation to accept peripheral changes [5]. Analysis of the Poincare plot is a very powerful visual technique that detects hidden patterns in the HRV and provides

summary information about the entire RR interval time series [6]. The plot has two dimensions and each point consists of a pair of successive intervals. Research show that using longer lags have useful information for capturing different information from HRV signal [7].

Furthermore, in recent years different features for quantification of Poincare plot of RR intervals have been introduced and showed promising results in emotion recognition [8, 9] and arrhythmia detection [10, 11].

In this paper, Poincare plot with 10 different lags were constructed, and various features were extracted in each lagged plot. The obtained features were used to evaluate the impact of age on heart behavior as well as for classification of the two groups of young and older subjects.

2. Data and Method

2.1. Data

For analyzing the impact of age on HRV, Fantasia database from Physionet databank was used [12]. Two hours of ECG recording for 20 young (21-34 years old) and 20 older adults (68-85 years old) subjects were used while all subjects remained in a resting state. The sampling frequency for this database is 250 Hz.

2.2. Method

2.2.1. QRS Detection

The Pan-Tompkins algorithm was used for QRS detection [13]. As suggested in the guideline [14], the output of the QRS detection algorithm visually checked by an expert and any ectopic beats were excluded. Finally, RR interval series were created using corrected QRS peaks.

2.2.2. Lagged Poincare Plot

Given RR time series as $(RR_1, RR_2, \dots, RR_n)$, the lagged Poincare plot is constructed by plotting points $p_i(x_i, y_i)$ in which x and y are defined as:

$$x = \{RR_1, RR_2, RR_3, \dots, RR_{n-lag}\} \quad (1)$$

$$y = \{RR_{1+lag}, RR_{2+lag}, RR_{3+lag}, \dots, RR_{n+lag}\}$$

in which lag show the value of delay in lagged Poincare plot.

2.2.3. Standard Descriptors of Poincare Plot

$SD1$ and $SD2$ are defined as the standard deviation of projection of the points in Poincare plot on the line perpendicular to the identity line ($y = -x$) and identity line ($y = x$), respectively [15].

2.2.4. Complex Correlation Measure (CCM)

Complex Correlation Measure (CCM) introduced by Karmakar et al. for quantifying temporal variation in points' distribution in Poincare plot [16]. By considering every three consecutive points $a(x_i, y_i)$, $b(x_{i+1}, y_{i+1})$, and $c(x_{i+2}, y_{i+2})$, the following determinant is computed [16]:

$$A(i) = \frac{1}{2} \begin{vmatrix} x_i & y_i & 1 \\ x_{i+1} & y_{i+1} & 1 \\ x_{i+2} & y_{i+2} & 1 \end{vmatrix} \quad (2)$$

And so CCM is defined as [16]:

$$CCM(m) = \frac{1}{C_n(n-2)} \sum_{i=1}^{n-2} A(i) \quad (3)$$

where m represents lag of Poincare plot and C_n is the normalizing constant which is defined as [16]:

$$C_n = \pi * SD1 * SD2 \quad (4)$$

2.2.5. Global Occurrence Matrix (GOM)

For measuring the distribution of points relative to the identity line ($y = x$), Moharreri et al. proposed GOM features which are the number of points above (N_A), on (N_O), and below (N_B) the identity line [10]:

$$GOM = [N_A \ N_O \ N_B] \quad (5)$$

Table 1. Mean and standard deviation of extracted features for each lag of Poincare plot for young and old groups

Lag	Groups	Extracted Features										
		$SD1$	$SD2$	$SD1/SD2$	CCM	C_n	N_A	N_O	N_B	A	B	C
1	Young	0.12 ± 0.03	0.17 ± 0.03	0.54 ± 0.06	-0.20 ± 0.005	0.16 ± 0.15	1344 ± 1090	105 ± 56	1355 ± 79	0.44 ± 0.07	-1.98 ± 0.83	1.56 ± 0.41
	Old	0.05 ± 0.002	0.08 ± 0.002	0.59 ± 0.09	-0.19 ± 0.007	0.02 ± 0.0007	1273 ± 1027	251 ± 132	1266 ± 77	0.34 ± 0.06	-0.74 ± 0.54	0.41 ± 0.10
2	Young	0.13 ± 0.03	0.17 ± 0.03	0.65 ± 0.03	0.06 ± 0.005	0.16 ± 0.15	1416 ± 251	77 ± 37	1311 ± 46	0.27 ± 0.04	-0.82 ± 0.21	0.60 ± 0.56
	Old	0.05 ± 0.001	0.09 ± 0.002	0.59 ± 0.04	0.09 ± 0.007	0.02 ± 0.0008	1284 ± 680	202 ± 112	1302 ± 62	0.17 ± 0.05	-0.36 ± 0.50	0.20 ± 0.08
3	Young	0.13 ± 0.03	0.17 ± 0.03	0.65 ± 0.03	0.02 ± 0.002	0.16 ± 0.15	1411 ± 476	86 ± 56	1306 ± 44	0.23 ± 0.04	-0.76 ± 0.40	0.57 ± 0.01
	Old	0.06 ± 0.002	0.09 ± 0.002	0.60 ± 0.03	-0.002 ± 0.001	0.02 ± 0.0008	1282 ± 579	206 ± 102	1300 ± 57	0.14 ± 0.04	-0.28 ± 0.45	0.15 ± 0.08
4	Young	0.13 ± 0.03	0.17 ± 0.03	0.69 ± 0.02	-0.02 ± 0.001	0.16 ± 0.15	1393 ± 185	76 ± 41	1333 ± 36	0.20 ± 0.02	-0.68 ± 0.24	0.53 ± 0.65
	Old	0.06 ± 0.001	0.09 ± 0.002	0.63 ± 0.03	-0.005 ± 0.0005	0.02 ± 0.0007	1307 ± 382	174 ± 78	1304 ± 58	0.13 ± 0.03	-0.30 ± 0.36	0.18 ± 0.04
5	Young	0.14 ± 0.03	0.16 ± 0.03	0.74 ± 0.02	-0.003 ± 0.001	0.17 ± 0.15	1388 ± 148	60 ± 28	1352 ± 31	0.15 ± 0.07	-0.50 ± 0.80	0.40 ± 0.73
	Old	0.06 ± 0.002	0.09 ± 0.002	0.66 ± 0.03	-0.004 ± 0.0006	0.02 ± 0.0008	1317 ± 305	152 ± 72	1316 ± 52	0.11 ± 0.02	-0.25 ± 0.30	0.15 ± 0.03
6	Young	0.14 ± 0.03	0.16 ± 0.03	0.75 ± 0.02	0.005 ± 0.001	0.17 ± 0.15	1374 ± 176	70 ± 40	1356 ± 34	0.14 ± 0.07	-0.46 ± 0.85	0.37 ± 0.81
	Old	0.06 ± 0.002	0.09 ± 0.002	0.69 ± 0.02	0.003 ± 0.0003	0.02 ± 0.0008	1320 ± 214	151 ± 68	1313 ± 48	0.09 ± 0.02	-0.21 ± 0.27	0.13 ± 0.02
7	Young	0.14 ± 0.03	0.16 ± 0.03	0.75 ± 0.02	0.009 ± 0.002	0.17 ± 0.15	1368 ± 129	66 ± 33	1365 ± 38	0.14 ± 0.06	-0.56 ± 0.25	0.46 ± 0.65
	Old	0.06 ± 0.002	0.08 ± 0.002	0.70 ± 0.02	0.002 ± 0.0005	0.02 ± 0.0008	1325 ± 185	137 ± 59	1321 ± 48	0.09 ± 0.01	-0.20 ± 0.24	0.12 ± 0.02
8	Young	0.13 ± 0.03	0.16 ± 0.03	0.73 ± 0.01	0.001 ± 0.0003	0.17 ± 0.15	1361 ± 98	65 ± 31	1372 ± 37	0.16 ± 0.03	-1.45 ± 0.29	1.30 ± 0.26
	Old	0.06 ± 0.002	0.08 ± 0.002	0.72 ± 0.02	-0.001 ± 0.001	0.02 ± 0.0008	1326 ± 226	130 ± 56	1327 ± 49	0.08 ± 0.01	-0.18 ± 0.22	0.11 ± 0.01
9	Young	0.14 ± 0.03	0.16 ± 0.03	0.76 ± 0.01	-0.006 ± 0.001	0.17 ± 0.15	1353 ± 123	68 ± 32	1376 ± 38	0.16 ± 0.04	-1.85 ± 0.16	1.70 ± 0.49
	Old	0.06 ± 0.002	0.08 ± 0.002	0.74 ± 0.02	0.002 ± 0.0005	0.02 ± 0.0008	1324 ± 214	135 ± 56	1322 ± 36	0.07 ± 0.01	-0.16 ± 0.20	0.09 ± 0.01
10	Young	0.14 ± 0.03	0.16 ± 0.03	0.76 ± 0.01	0.003 ± 0.001	0.17 ± 0.15	1348 ± 149	68 ± 33	1380 ± 38	0.11 ± 0.02	-1.26 ± 0.89	1.17 ± 0.41
	Old	0.06 ± 0.002	0.08 ± 0.002	0.75 ± 0.02	-0.003 ± 0.0002	0.02 ± 0.0008	1333 ± 170	123 ± 54	1324 ± 44	0.05 ± 0.01	-0.13 ± 0.17	0.08 ± 0.01

Table 2. p -value of extracted features for each lag of Poincare plot for young and old groups

Lag	Extracted Features										
	SD1	SD2	SD1/SD2	CCM	Cn	N _A	N _O	N _B	A	B	C
1	0.137	0.020	0.725	0.552	0.083	0.034	0.033	0.001	0.194	0.213	0.159
2	0.035	0.048	0.372	0.245	0.051	< 0.001	0.011	0.978	0.074	0.055	0.030
3	0.055	0.037	0.317	0.040	0.058	< 0.001	0.026	0.850	0.066	0.070	0.105
4	0.079	0.042	0.256	0.499	0.051	< 0.001	0.046	0.144	0.058	0.083	0.066
5	0.045	0.040	0.130	0.705	0.042	< 0.001	0.005	0.021	0.110	0.105	0.123
6	0.058	0.035	0.223	0.291	0.051	< 0.001	0.059	0.006	0.152	0.130	0.051
7	0.048	0.033	0.344	0.176	0.048	< 0.001	0.062	0.006	0.079	0.130	0.066
8	0.079	0.040	0.978	0.570	0.055	< 0.001	0.233	0.002	0.093	0.117	0.062
9	0.083	0.033	0.935	0.433	0.055	0.026	0.169	< 0.001	0.099	0.137	0.055
10	0.093	0.023	0.685	0.358	0.055	0.213	0.757	< 0.001	0.185	0.317	0.152

2.2.6. Parabolic Phase Space Mapping (PPSM)

Jafarnia et. al. introduced a new phase space which consist the points as follows [17]:

$$(x, (\overline{RR} - y)^2) \quad (7)$$

In which \overline{RR} is the mean of RR intervals that is defined as:

$$mean(RR) = \overline{RR} = \frac{1}{n+1} \sum_{i=1}^n RR_i \quad (8)$$

A two degree polynomial equation in the form of $Y = Ax^2 + Bx + C$ has been estimated for the points distribution, in which [11]:

$$Y = (\overline{RR} - y)^2 \quad (9)$$

And the coefficients of the estimated polynomial (A , B , and C) are the extracted features in this phase space [17].

2.2.7. Statistical Analysis and Classification

Mean and standard deviation were reported for all extracted features in each lag in Table 1. To identify features that are significantly different in two groups of young and old groups, Kruskal-Wallis test was used with the level of significance set to 0.05.

K-nearest neighbor (KNN) classifier was used to classify two groups of young and old that was trained on 70% of data as a train set, and the accuracy was evaluated on 30% of data as a test set.

3. Results and Discussion

As it is shown in Table 1, the obtained results of comparing extracted features of Poincare plot in two

groups of young and old people, prove the results in previous studies, extracted features decrease when the age grows [3, 4].

The results of Kruskal-Wallis test are shown in Table 2. The results show that SD2 and the three parameters of GOM were significantly different between two groups. The selected features which had significant p -value were used as an input for kNN classifier and the two groups of young and old have been considered as an output of the classifier. The classifier performance on test set is shown in Table 3.

Table 3. Classification performance on test data

Accuracy	Sensitivity	Specificity
91.4 %	86.5 %	95.1 %

4. Conclusion

In this article, extracted features from lagged Poincare plot of RR intervals were compared between two groups of young and old subjects to evaluate the impact of age on HRV Parameters. These features were then used as an input for K-nearest neighbor classifier. The results show that the novel features specially GOM which represent the dynamic behavior of RR intervals is a useful measure for studying the impact age on cardiac autonomic nervous system.

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