Cerebromicrovascular Disease in Elderly with Diabetes
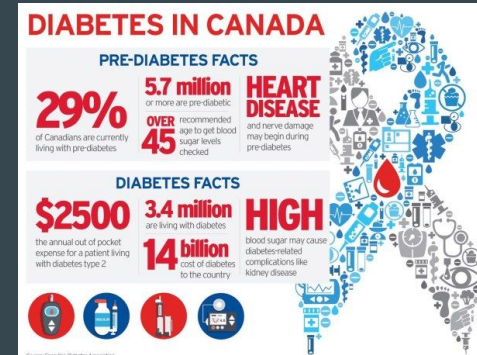
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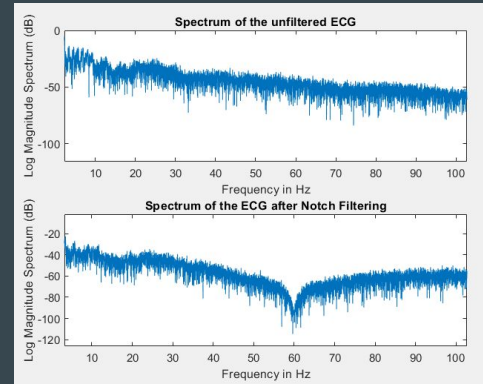By: Aemen Mohsin, Matthew Lam and Lazar Zivkovic

Background

- Diabetes Mellitus (DM), prevalent in around 200 000 Canadians
- Cerebromicrovascular disease: small vessel disease
- DM is alters blood barriers affecting microcirculatory regulation
- Dataset: 120 participants aged 55 to 75, with 60 diabetics and 60 control
- Analysis: 1 minute of 15 control signals and 18 diabetic signals
- In open literature, ML used to detect diabetes and pre-diabetes using ECG signals [1]
  - DiaBeats algorithm using 1262 subjects
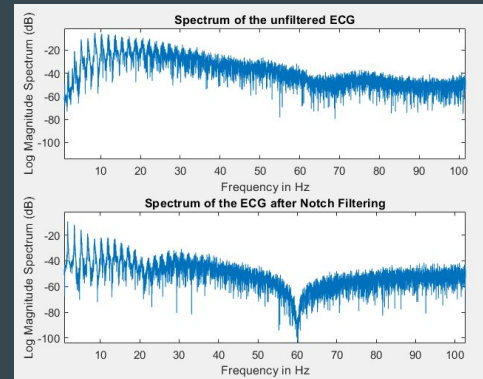 - 97.1% precision, 96.2% recall, and 96.8% accuracy

Pre-processing Methods

Method 1: Notch Filtering

Subject 4, Control

- Used to Filter 60 Hz power-line interference (PLI)
- Occurs at 50 - 60 Hz
- Notch filter removes noise at 60 Hz point by adding a zero
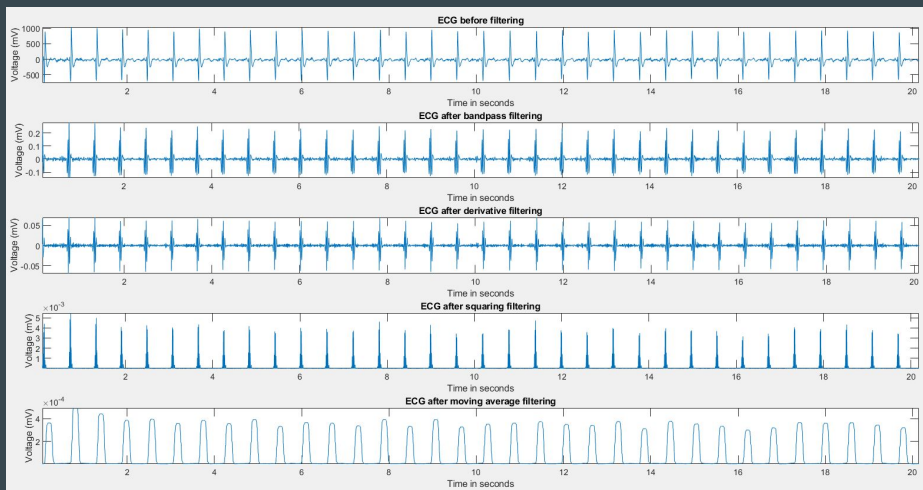

Subject 20, Diabetic

Pre-processing Methods
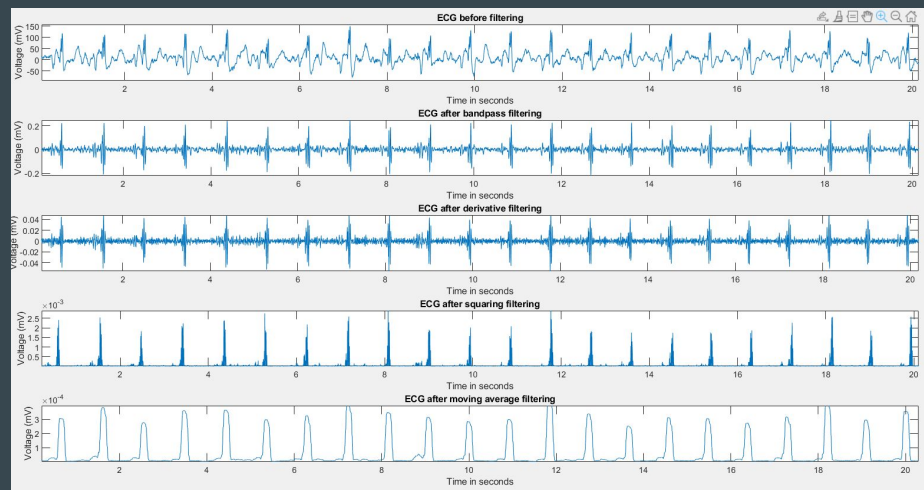
Method 2: Pan-Tompkins Algorithm

- Low-pass and high-pass filter cascaded for bandpass
- Differentiator to detect high vs. low peaks
- Squaring operator to amplify peaks and positive values
- Moving window integrator for definitive peaks

Pre-processing Methods

Method 2: Pan-Tompkins Algorithm

Subject 4, Control

Subject 20, Diabetic

Feature Analysis

Only the 6 important features were sent to the classification. These features are most affected in diabetic patients in ECG.

1) heart rate / mean RR
2) std from R-R
3) mean interval from S-T
4) std interval from S-T
5) mean interval Q-T
6) std interval Q-T

Method 1: Find the PQRST points (ECG toolbox by Rohan Sanghavi)
R Detection:
    The moving window average plot with peak detection
S Detection:
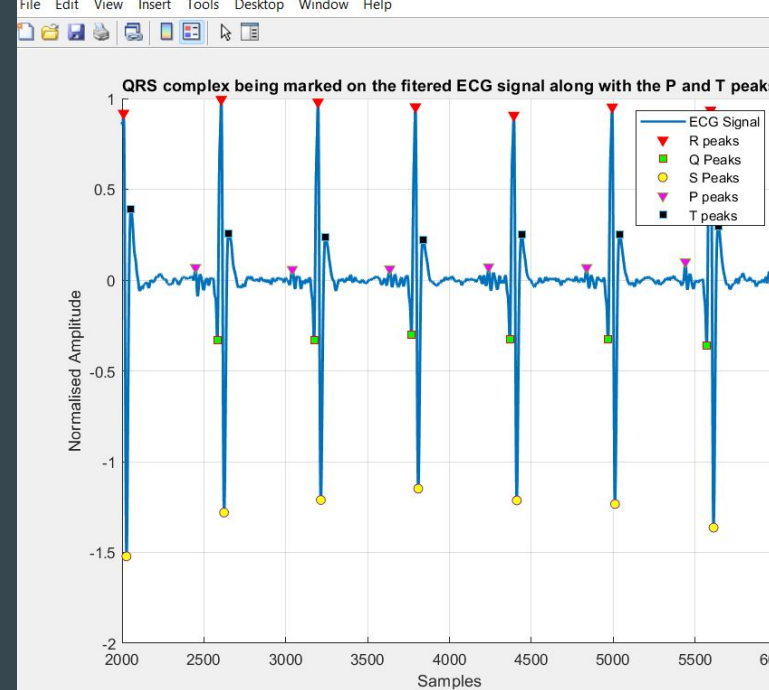   The S point is located right after the R peak, minimum point is located between the R point and 0.1*sampling frequency.
Q Detection:
    The Q point is before the R peak, minimum point between the R point and 0.08* sampling frequency.
P and T Detection:
    Searching half of the R-R distance before the R peak but after the S peak.

From here we are able to determine: 1) heart rate / mean RR 2) std from R-R

QRS complex being marked on the fitered ECG signal along with the P and T peak

Heart Rate:

$$HR \text{ (bpm)} = \frac{60}{RR \; interval} *1000 \qquad (9)$$

Mean:

$$\overline{X} = \frac{\sum X}{N} \qquad (10)$$

Standard deviation:

$$SD = \sqrt{\frac{\sum |x - \bar{x}|^2}{n}} \qquad (11)$$

Method 2: Finding the PQRST intervals (ECG toolbox by Rohan Sanghavi)
1) Finds the closest R points and pairs them up with the closest P, Q, S, and T points.
2) Remove any points need that are not close to R peaks, max period length/2.
3) The intervals were calculated by finding the difference between the points.

From here we determine: mean interval from S-T , std interval from S-T, mean interval Q-T, and std interval Q-T

Limitations: Our findings estimated the separation between the peaks. P-T intervals, S-T intervals take into account the ends of curve of P and T.

Machine Learning
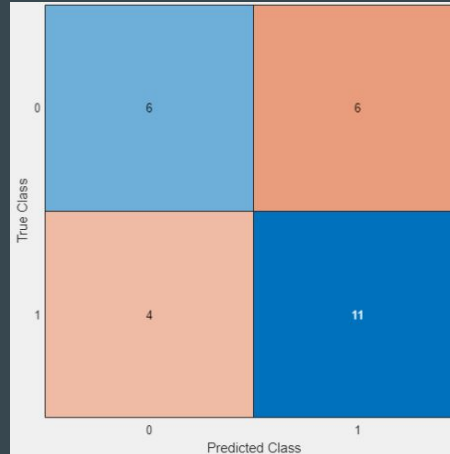
5 Fold cross validation

3 Machine Learning Algorithms were trained and tested:

- Decision Tree: Branching nodal classification, 70.4%
- Linear Discriminant Analysis: Dimensional reduction linear combination, 63.0%
- Logistic Regression: Logit estimation linear combination, 77.8%
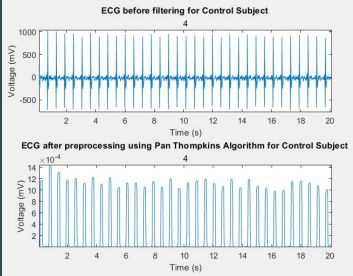
Decision Tree

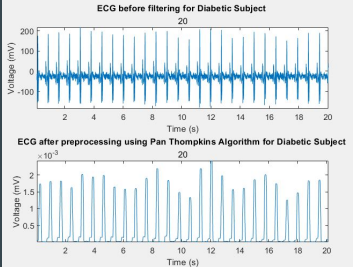Linear Discriminant

Logistic Regression
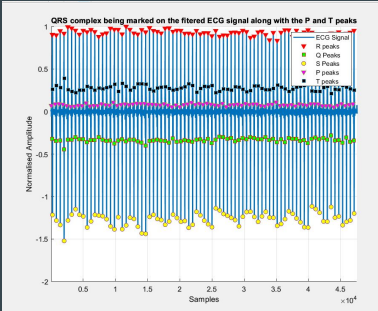
Results

Preprocessing

Subject 4, Control

Subject 20, Diabetic

Feature Analysis

Subject 4, Control

Machine Learning

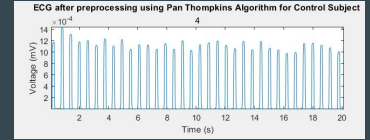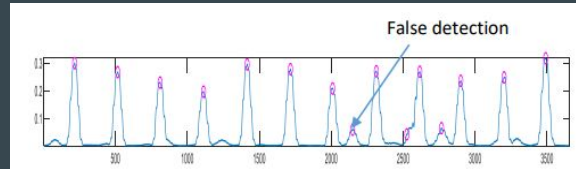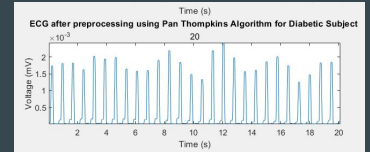| Model	Validation %	Testing %
Decision Tree	70.4	66.7
Linear Discriminant	63.0	50
Logistic Regression	77.8	66.7

Discussion of Results

Preprocessing:

- Notch filter effective but no visible noticeable change
- Control ECG resembled signal of open literature
- Diabetic had false peak detection due to lots of noise

Subject 4, Control

Subject 20, Diabetic

Open Literature

Discussion of Results

Feature Extraction Result:

Heart Rate / RR-mean and standard deviation R-R
    Research shows that a normal elder aged 45 to 70 has an average heart rate between 60 to 100 bpm [8].
    Patients with diabetes have an increased heart rate reaching more than 86 bpm. [9]
    Our similar result
        Diabetes(126 bpm - 65 bpm).
        Control (106.9 bpm - 58.47 bpm)

Label	HR (bpm)	meanST (ms)	std_ST (ms)	RR_mean (ms)	mean_QT (ms)	RR_std (ms)	std_QT (ms)
0	87.2596617	34.9130435	3.8184503	687.6029412	72.8115942	17.2030366	10.2645526
0	106.972548	59.4166667	7.93225584	560.8915663	105.6190476	8.99595037	8.04341347
1	84.812919	168	82.9954362	707.4393939	234.5522388	4.93068504	82.1429433
1	101.795378	108.3125	77.2240852	589.4177215	161.3625	17.1206934	76.3289423

2) mean interval from S-T / std interval from S-T
    According to Shlomo Stern, patients with diabetes have high changes in S-T intervals [10].
    This conclusion is supported by our results where the standard deviation of S-T intervals is way
    higher than the standard deviation of the S-T intervals on the constant patient.

4) mean interval Q-T/ std interval Q-T
    According to Shlomo Stern, patients with diabetes have long Q-T intervals [11].
    The results reflect this where mean Q-T is higher in comparison to normal patients.

Discussion of results

- XGBoost-based DiaBeats model trained on ECG signal extracted features
    - Diabetes classification prediction accuracy of 96.8%
- Quan Zou decision tree and random forest classifier models

Dataset	Classifier	ACC
Luzhou	RF	0.8084
	J48	0.7853

Predicting Diabetes
w/ ML (2018, Zou)

- An Dinh weighted feature extraction
    - Logistic regression: 82.7%
    - SVM: 84.9%

Optimal Features (2019, Dinh)

References

[1]　　　A. R. Kulkarni, A. A. Patel, K. V. Pipal, S. G. Jaiswal, M. T. Jaisinghani, V. Thulkar, L. Gajbhiye, P. Gondane, A. B. Patel, M. Mamtani, and H. Kulkarni, "Machine-learning algorithm to non-invasively detect diabetes and pre-diabetes from Electrocardiogram," BMJ Innovations, 06-Jul-2022. [Online]. Available: https://innovations.bmj.com/content/early/2022/07/06/bmjinnov-2021-000759. [Accessed: 29-Nov-2022].

[2]　　　P. H. A. of Canada, "Government of Canada," Canada.ca, 17-Aug-2020. [Online]. Available: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html. [Accessed: 28-Nov-2022].

[3]　　　C.-Ł. J. D. E. Z. A. P. B; "Cerebral Small Vessel Disease: A Review," Advances in clinical and experimental medicine : official organ Wroclaw Medical University. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/33768739/#:~:text=Cerebral%20small%20vessel%20disease%20(CSVD,over%2080%20years%20of%20age. [Accessed: 28-Nov-2022].

[4]　　　V. Novak and R. Quispe, "Cerebromicrovascular disease in elderly with diabetes," Cerebromicrovascular Disease in Elderly with Diabetes v1.0.1, 05-Aug-2022. [Online]. Available: https://doi.org/10.13026/00bm-0x81. [Accessed: 28-Nov-2022].

[5]　　　M. A. Z. Fariha1, R. Ikeura2, S. Hayakawa2, and S. Tsutsumi2, "IOPscience," Journal of Physics: Conference Series, 01-Jun-2020. [Online]. Available: https://iopscience.iop.org/article/10.1088/1742-6596/1532/1/012022#:~:text=The%20Pan%2DTompkins%20Algorithm%20is,quality%20clinical%20ECG%20signal%20data. [Accessed: 28-Nov-2022].

[6　　　https://www.frontiersin.org/articles/10.3389/fgene.2018.00515/full

[7]　　　https://bmcmedinformdecismak.biomedcentral.com/articles/10.1186/s12911-019-0918-5

[8]　　　A. J. Rodriguez, "Normal heart rate for elderly adults," Griswold Home Care, 07-Sep-2021. [Online]. Available: https://www.griswoldhomecare.com/blog/2021/september/normal-heart-rate-for-elderly-adults/#:~:text=A%20normal%20heart%20rate%20for,heart%20rate%20with%20regular%20exercise. [Accessed: 28-Nov-2022].

[9]　　　Organization, Healio, and ImageObject, "Higher heart rates related to type 2 diabetes risk in normal-weight adults," Healio, 18-Feb-2019. [Online]. Available: https://www.healio.com/news/endocrinology/20190215/higher-heart-rates-related-to-type-2-diabetes-risk-in-normalweight-adults#:~:text=The%20researchers%20found%20that%20heart,%3D%201.24%3B%2095%25%20CI%2C. [Accessed: 28-Nov-2022].

[10]　　　S. Stern, Shlomo Stern From The Hebrew University of Jerusalem, S. Sclarowsky, Samuel Sclarowsky From The Hebrew University of Jerusalem, and C. to S. Stern, "The ECG in diabetes mellitus," Circulation, 20-Oct-2009. [Online]. Available: https://www.ahajournals.org/doi/full/10.1161/circulationaha.109.897496. [Accessed: 28-Nov-2022].

[11]　　　M. D. Lawrence Rosenthal, "Normal electrocardiography (ECG) intervals," Normal Electrocardiography Intervals, 16-Jul-2021. [Online]. Available: https://emedicine.medscape.com/article/2172196-overview. [Accessed: 28-Nov-2022].