Prediction of Heart Rate based on Respiratory Rate for Neonates using Machine Learning Models

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Introduction

- **Neonates** refers to children in the first 4 weeks of their lives. At this early age, vitals such as their heart and respiratory rates are important clinical indicators to monitor their health conditions.
- There are different ways to measure heart rates, including electrocardiography (ECG) and pulse oximetry. However, both involve attaching many devices to the neonates and are not suitable for them.
- In this project, we will investigate the possibility of estimating heart rate directly from the respiratory signal. We will use ECG and respiratory data from 10 different infants to train a machine learning model, then predict the heart rate based on the respiratory signal of an infant.

$$f(x) \rightarrow y$$

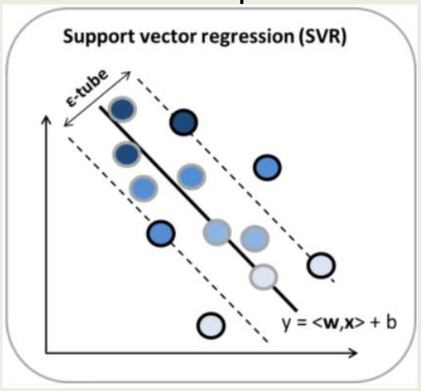
$$where\ x = Respiratory\ Signal,\ y = Heart\ Rate$$

Relevant Literature

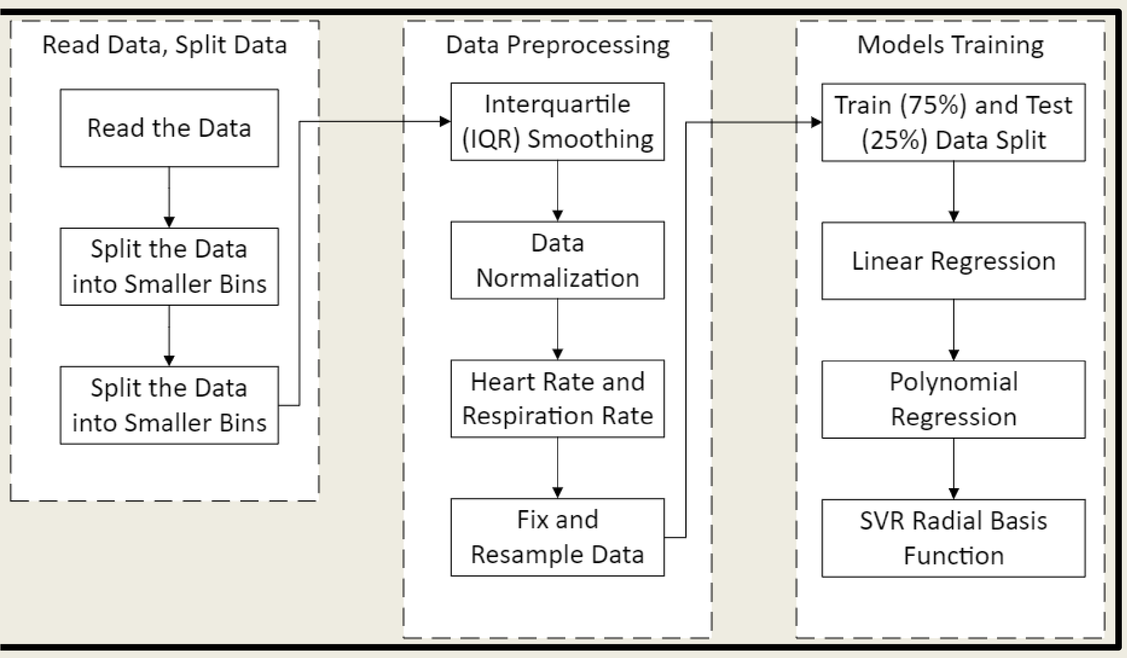
Heart Rate:
- Displays the balance of the cardiovascular system.
- Evaluates the rhythm and frequency, the large square method is used at R-R intervals.
- For newborns, the average heart rate is 110-150 bpm.

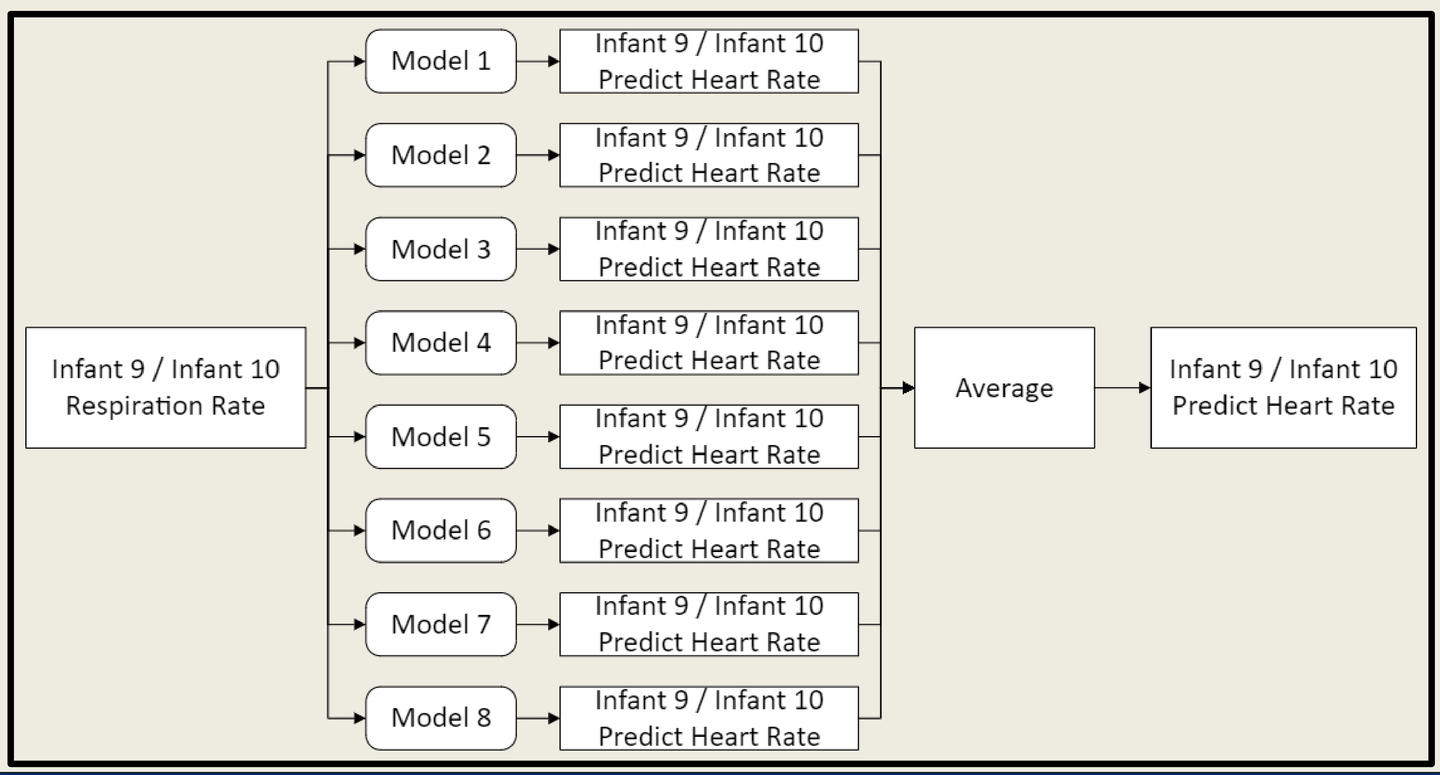
Respiration Rate:
- Assumption is made that the consecutive peak represent 1 breath.
- Similar calculation can be as heart rate for respiration in breath per minute.

Strengths of using SVM in regression:
- L2 regularization feature to prevent overfitting
- Good in handling outliers
- Perform better when there is limited training data

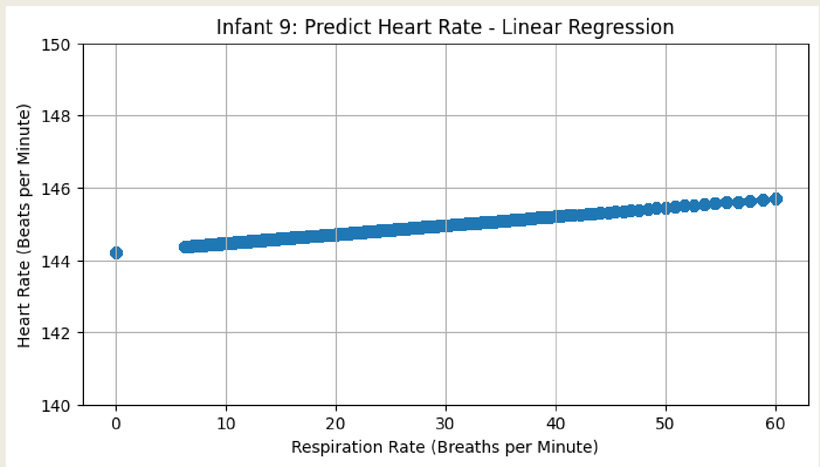


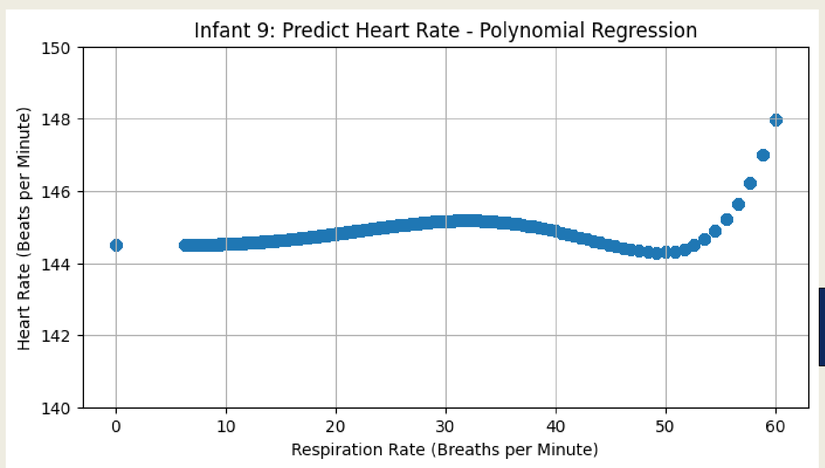
Research Methodology

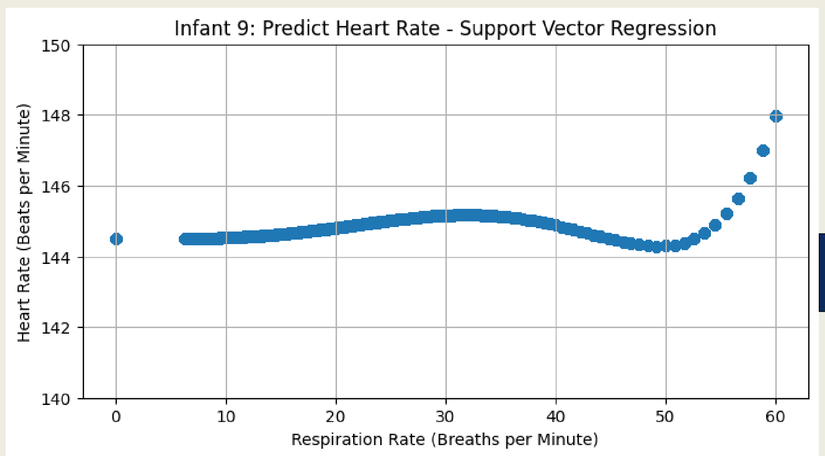




Results







Infant 9: Linear Regression			
Model	MAE	MSE	RMSE
1	10.71	512.33	22.63
2	21.35	897.26	29.95
3	20.59	862.98	29.38
4	20.71	848.51	29.13
5	14.32	604.16	24.58
6	17.42	743.76	27.27
7	14.50	610.13	24.70
8	17.57	747.98	27.35
Average	9.85	513.59	22.66

Infant 9: Polynomial Regression			
Model	MAE	MSE	RMSE
1	10.75	512.93	22.65
2	21.44	898.72	29.98
3	20.67	865.38	29.42
4	20.69	847.56	29.11
5	14.15	600.03	24.50
6	17.83	756.45	27.50
7	14.58	612.49	24.75
8	17.85	756.79	27.51
Average	9.86	514.04	22.67

Infant 9: Support Vector Regression			
Model	MAE	MSE	RMSE
1	10.75	512.93	22.65
2	21.44	898.72	29.98
3	20.67	865.38	29.42
4	20.69	847.56	29.11
5	14.15	600.03	24.50
6	17.83	756.45	27.50
7	14.58	612.49	24.75
8	17.85	756.79	27.51
Average	9.86	514.04	22.67

Infant 10: Linear Regression			
Model	MAE	MSE	RMSE
1	13.91	501.52	22.39
2	28.69	1152.01	33.94
3	27.68	1091.23	33.03
4	17.69	668.22	25.85
5	14.36	519.22	22.79
6	24.80	943.45	30.72
7	14.51	526.26	22.94
8	24.80	942.13	30.69
Average	15.97	576.64	24.01

Infant 10: Polynomial Regression			
Model	MAE	MSE	RMSE
1	13.85	499.59	22.35
2	28.37	1128.55	33.59
3	27.44	1072.41	32.75
4	17.64	666.82	25.82
5	14.34	517.75	22.75
6	24.95	946.56	30.77
7	14.70	532.37	23.07
8	24.68	929.23	30.48
Average	15.91	574.21	23.96

Infant 10: Support Vector Regression			
Model	MAE	MSE	RMSE
1	13.85	499.59	22.35
2	28.37	1128.55	33.59
3	27.44	1072.41	32.75
4	17.64	666.82	25.82
5	14.34	517.75	22.75
6	24.95	946.56	30.77
7	14.70	532.37	23.07
8	24.68	929.23	30.48
Average	15.91	574.21	23.96

Discussion

There are a total 24 models trained with each infant 1 to infant 8 trained with linear regression, polynomial regression, and SVR RBF model.

There are no obvious improvement of the prediction accuracy from the metrics generated from the predicted value for infant 10 and infant 9. It is most obvious with the identical metrics value for polynomial regression and SVR.

The phenomenon might be due to the outlier and noises which are not properly filtered from the data. Furthermore, hyperparameters tuning is not performed thus, the performance improvement would not be obvious.

Future step for the study is to implement frequency-based filter (band-pass, low-pass, high-pass) to improve the ECG and RESP signal. In addition, the hyperparameters tuning would be implemented.

Conclusions

The data pipeline is built with 3 sections from reading the data, data preprocessing, to model training. The results shows the models has a performance of 22 to 24 RMSE value for the 3 tested regression models. The contribution from this study is to setup a foundation for further exploration.