Supporting lung protective ventilation with predictive analytics in ICU using HPC

QUEEN'S UNIVERSITY BELFAST

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INTRODUCTION

We apply machine learning techniques for the prediction of tidal volume values up to 1 hour ahead in order to prevent lung injury.

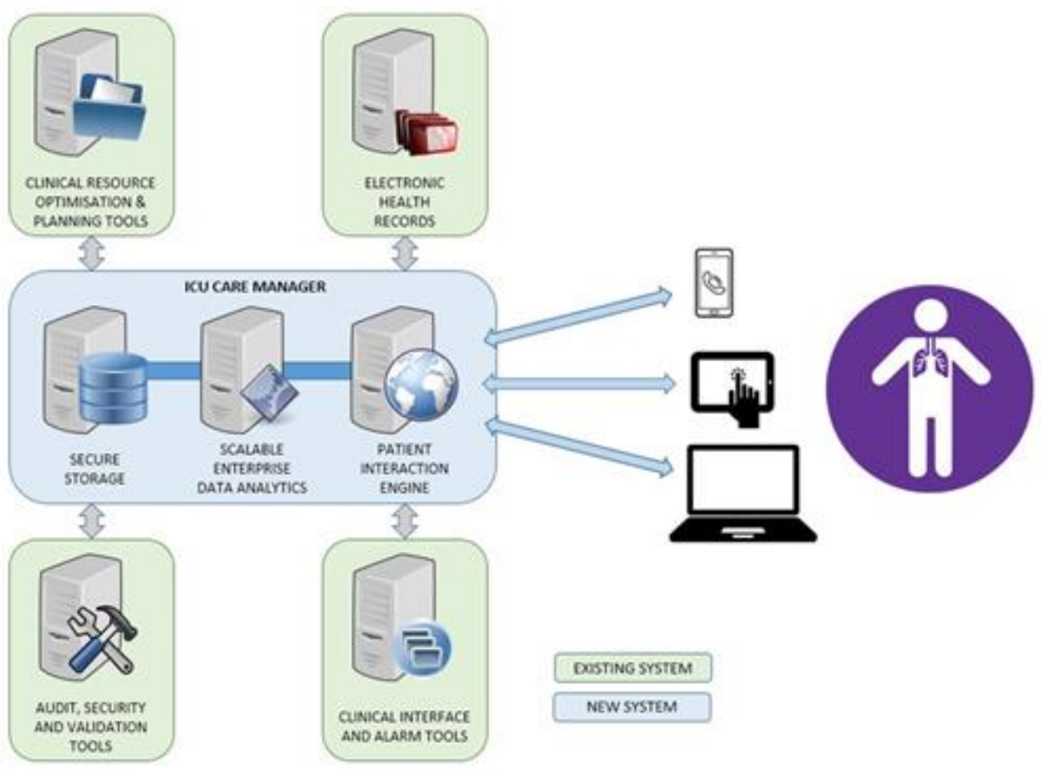
This work originated from the VILIAlert system as part of the NanoStreams project (2013-17).

Data acquisition taken place in the Royal Victoria Hospital, Belfast. Recording 4 million per minute tidal volume readings for around 1000 patients.

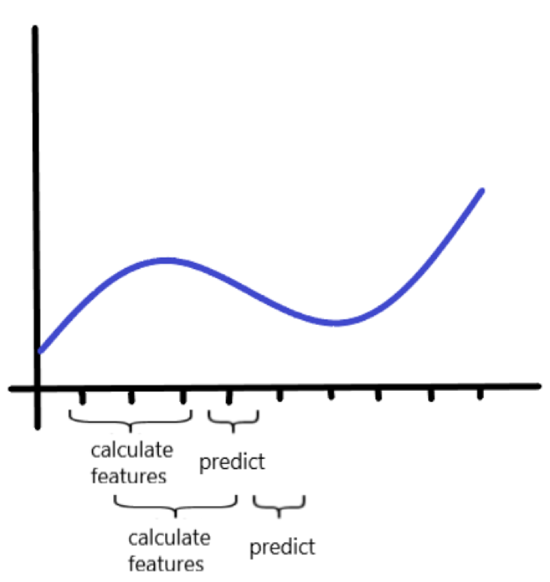
Alerts generated after repeated breaches of tidal volume threshold.

METHODOLOGY

We take 15 minute averaged bins as our time series in order to smooth random fluctuations in the data.



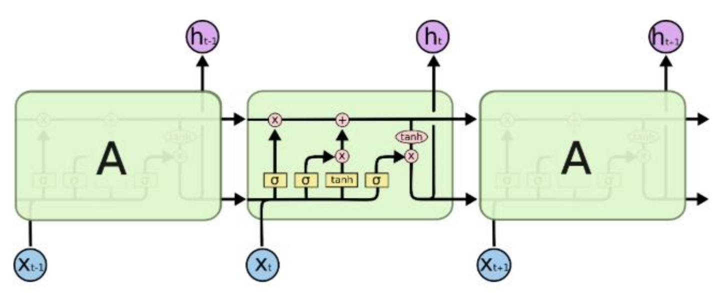
Extract features from the time series using Python package *tsfresh*.



Use these features as input into an Ensemble Learner, comparing both boosting and bagging methods.

Ensemble learners allow for the best prediction to be made by combining regression tree predictions either sequentially or in parallel.

ESPRC Kelvin Supercomputer to train and test our LSTM Neural Network models for prediction.



Kelvin Supercomputer:
NI Tier 2 supercomputer centre.
1000 nodes increasing to 3000 Intel and AMD nodes.

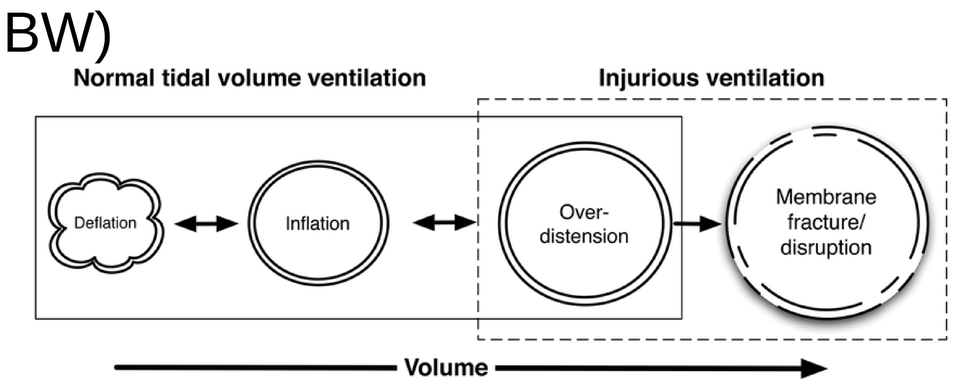
CONCLUSION & FUTURE DIRECTIONS

Explore parallelisation of patient analysis to increase speeds.

Explore the scalability of predicting for multiple patients in multiple locations.

MEDICAL BACKGROUND

Mechanical ventilation allows for the support of respiratory function. Important to carefully adjust tidal volume per predicted body weight (PBW)



Tidal volume being the measure of the volume of air delivered to a patient during mechanical ventilation.

From literature, the recommended TV in 6-8ml/kg predicted BW but not exceeding the 8ml/kg PBW.

If alerts can be prevented, we can ensure lung protective ventilation which can lead to decreased mortality rates and better utilisation of ventilatory resources.

RESULTS

Predicting tidal volume for 1 patient 15 minutes ahead using different ensemble learners:

Regressor	RMSE	Time (secs)
AdaBoost	0.69	151
Random Forest	0.68	534
Bagging	0.70	523
Extra Trees	0.68	190
Gradient Boosting	0.84	60

Predicting tidal volume for 1 patient 1 hour ahead using AdaBoost:

Regressor	RMSE	Time(secs)
AdaBoost	0.74	68

Predicting for the same patient, 1 hour ahead using LSTM models:

LSTM Model	RMSE	Time (secs)
ModelA : 1 layer	4.97	39
ModelB : 3 layer	2.74	1317

Taking 70% training data we can only perform predictions on final 30% of data for LSTM models.

Predicting the alerts that were generated by the VILIAlert system:

Alerts	AdaBoost	LSTM
Total	84	4
TP	81	3
FN	3	1

True Positives **(TP)** = Alerts correctly predicted

False Negatives **(FN)** = Alerts that would not have been predicted

Probability of Detection = $\frac{TP}{TP+FN}$

Probability of Detection = 0.96

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