



Intraoperative arterial pressure time series forecasting

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Background

Intraoperative Hypotension

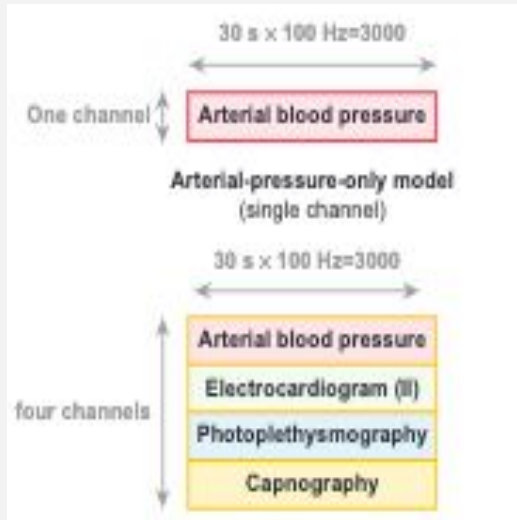
- **Description:** A critical medical condition that occurs during surgery when a patient's blood pressure drops to levels below the normal range
- **Risk:** Lead to organ hypoperfusion, increased blood lost, cardiac events, etc
- **Threshold:** No clear definition; threshold vary depending on patient's age, underlying medical conditions, type of surgeries, etc

Forecasting Importance

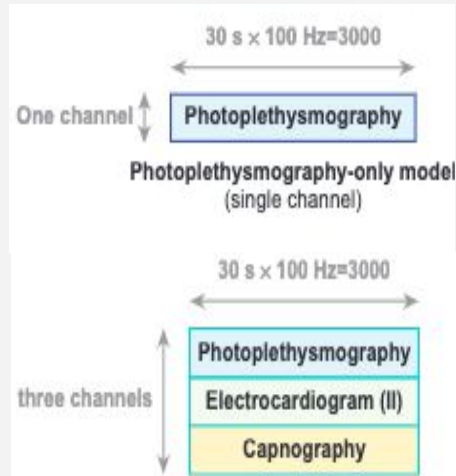
- **Enhance Patients' Intraoperative Safety:** Allows to take proactive measures, preventing complications and improving patient safety during surgery
- **Optimize Anesthesia Management:** Helps maintain stable blood pressure, optimizing anesthesia management for better surgical outcomes
- **Reduces Postoperative Risks:** Risk of postoperative complications, such as organ damage, stroke, or extended hospital stays, is reduced

Literature Review

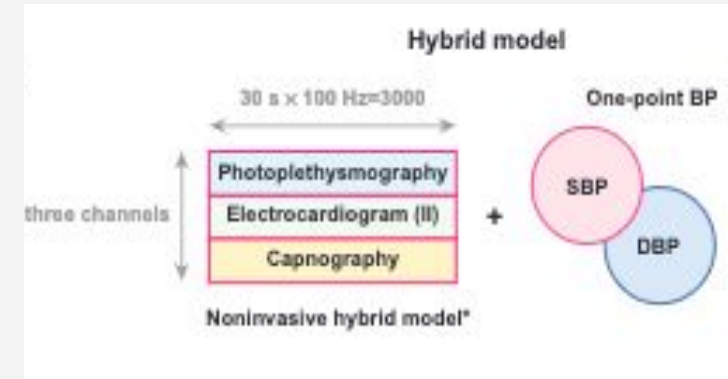
Invasive



Noninvasive



Hybrid



Methodology

Data Source

Data preprocess

Model
preprocess

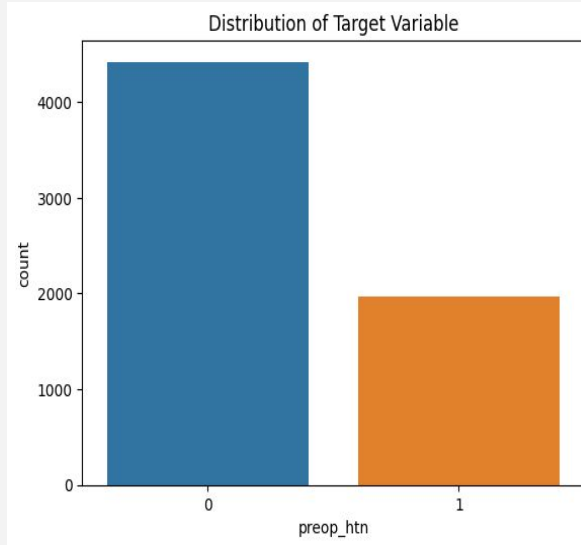
Performance

VitalDB

Vital files

clinical_data

Preoperation hypertension



ARIMA & SARIMA

Event id partitioned
and records limited

Prophet

Data input format
adaptation

Neural Network

Keras format
conformation

MAE

Applicability

Reliability

Features

Feature	Description	Type/Hz	Unit	Significance
SNUADC/ART	Arterial pressure wave; represents the pressure throughout the cardiac cycle	W/500	mmHg	MAP decrease can lead to inadequate perfusion of vital organs, increasing the risk of hypotension
SNUADC/ECG_II	Electrocardiogram; records electrical activity of the heart; provides information about heart's rhythm and rate	W/500	mV	Abnormalities in ECG can be early indicators of cardiovascular issues
SNUADC/PLETH	Plethysmography wave; a non-invasive method for monitoring changes in blood volume in peripheral tissues	W/500	unitless	Decrease in the amplitude or quality of the PPG signal can suggest reduced peripheral perfusion
Primus/CO2	Capnography wave; measures the concentration of CO2 in exhaled breath	W/62.5	mmHg	Sudden decrease in EtCO2 levels may indicate reduced cardiac output and hypotension
Solar8000/BT	Body temperature	N	°C	Elevated body temperature may signal underlying infections, sepsis, or increased metabolic demands

Prophet

- **Model**

- A forecasting model developed by Facebook
- Works best with time series that have strong seasonal effects and several seasons of historical data
- 2 columns input - ds: YYYY-MM-DD HH:MM:SS for a timestamp; y: measurement to forecast

- **Preprocessing and result**

- Train test split for each event: 80% to fit, 20% to predict
- Measurement: MAE (average on all events)
- Final MAE: 24.129

ARIMA

Components

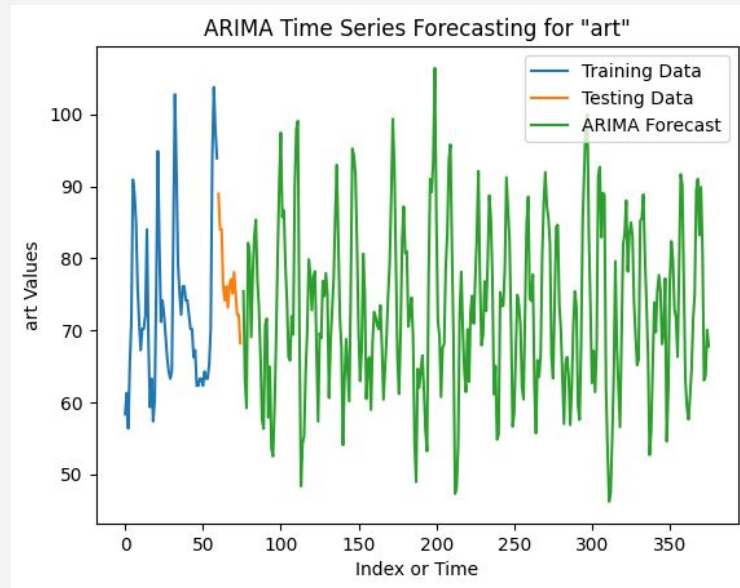
- Auto Regression
Obs and lagged Obs
- Integrated
Differencing of the time series
- Moving Average
Obs and residual error

Parameters

P = #of predictors (points) d = Degree of difference
q = #of residual errors

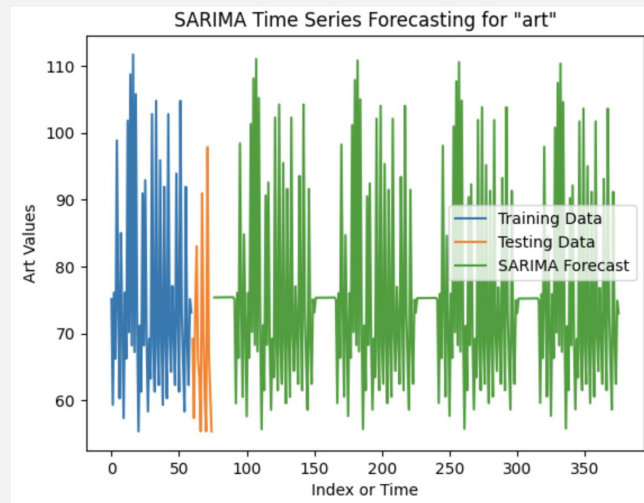
Results

AVG MAE of 98 event_ids = 34.27



SARIMA

- Seasonal Autoregressive Integrated Moving Average
- Evolution from ARIMA: Incorporates seasonality into the traditional ARIMA model.
 - a wider range of data with various levels of complexity, including trends, cycles and seasonal effects
- **Four Additional Parameters**
 - SARIMA Notation: $(p, d, q)(\underline{P}, \underline{D}, \underline{Q})_s$.
 - s : the length of a seasonal cycle
 - extract each of the event id for 75 seconds, consider this duration as one cycle.
- **Result**
 - AVG MAE of 98 event_ids = 18.20



LSTM Neural Network Model

Input data:

- Arterial pressure wave
- ECG lead II wave
- Plethysmography wave
- Capnography wave
- Body temperature
- Used 60 seconds to predict time point at 300 seconds

Model:

- 5 epochs
- 256 batch size

Results:

- Training
 - loss(MSE): 415.0760 -> 483.2746
 - MAE: 13.1318 -> 15.7490
- Testing:
 - loss(MSE): 350.3533
 - MAE: 11.3914

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 60, 720)	2090880
batch_normalization (Batch Normalization)	(None, 60, 720)	2880
lstm_1 (LSTM)	(None, 480)	2305920
dense (Dense)	(None, 120)	57720
dense_1 (Dense)	(None, 5)	605
Total params: 4458005 (17.01 MB)		
Trainable params: 4456565 (17.00 MB)		
Non-trainable params: 1440 (5.62 KB)		

Model Comparisons

Arima & Sarima & Prophet:

- **Pros:**
 - Faster and easy Implementation
- **Cons:**
 - One input only
 - Non flexible model training and building
 - Lower model performance (Variance & Bias)

Neural Network:

- **Pros:**
 - Detailed adjustment
 - Flexible data inputs, evaluation matrix, and activation function
 - Better average performance
- **Cons:**
 - Intense computation power required
 - Longer time to train
 - Relatively hard to implement
 - Potential to overfit
 - Not continuous prediction

Conclusion & Implications

Conclusion

Neutral Network is the best model

Implications

- Effective Product:
 - Proactive intervention
 - Enhance patient monitoring, and offer additional layer of safety
- Target Stakeholders
 - Healthcare Providers: doctors and nurses benefit from more accurate patient monitoring and tailored treatment plans
 - Hospitals: better resource management; optimized operational efficiency
 - Health Insurance Companies: Reduced costs through preventive care
 - Medical Device Companies: Opportunities for integrating predictive models into new and existing devices
 - Research Institutions: inspiration for advanced research in predictive health analytics





Thank you!

