Meta-learning how to forecast time series

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Large collections of time series

- Forecasting demand for thousands of products across multiple warehouses.

Time series features

Objective

Develop a framework that automates the selection of the most appropriate forecasting model for a given time series by using an array of features computed from the time series.

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  - strength of trend
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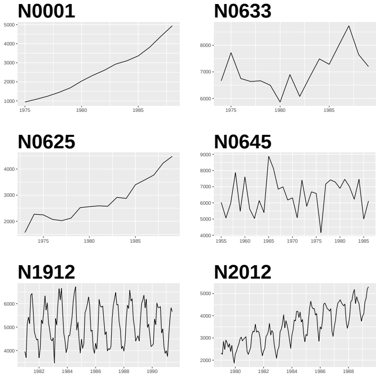
  - lag-1 autocorrelation
  - spectral entropy

Feature-space of time series

STL-decomposition

$$Y_t = T_t + S_t + R_t$$

- strength of trend: $1 - \frac{Var(R_t)}{Var(Y_t - S_t)}$
- strength of seasonality: $1 - \frac{Var(R_t)}{Va(Y_t - T_t)}$



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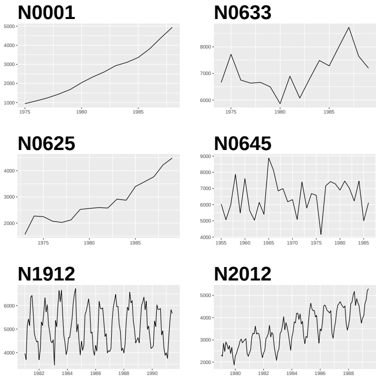
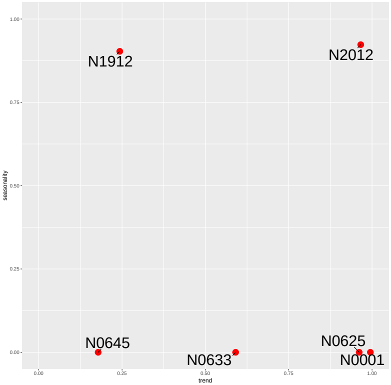




Time series features

- length
- strength of seasonality
- strength of trend
- linearity
- curvature
- spikiness
- stability
- lumpiness
- first ACF value of remainder series
- parameter estimates of Holt's linear trend method
- spectral entropy
- Hurst exponent
- nonlinearity
- parameter estimates of Holt-Winters' additive method
- unit root test statistics
- first ACF value of residual series of linear trend model
- ACF and PACF based features - calculated on both the raw and differenced series

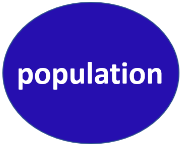
Methodology: FFORMS

FFORMS: Feature-based **FOR**ecast **M**odel **S**election

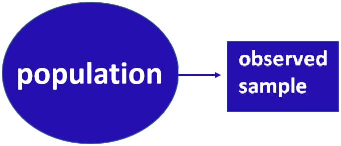
Offline: Classification algorithm is trained

Online: Use the classification algorithm to select appropriate forecast-models for new time series

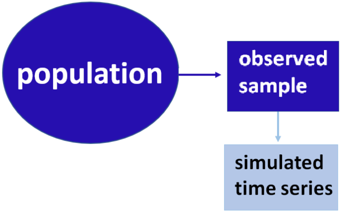
FFORMS: population



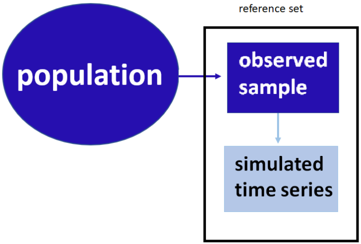
FFORMS: observed sample



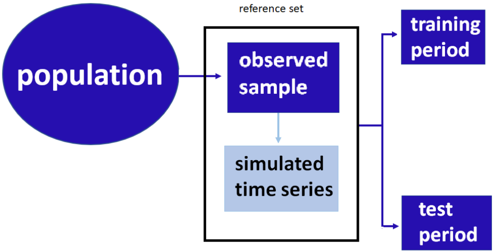
FFORMS: simulated time series



FFORMS: reference set



FFORMS: Meta-data



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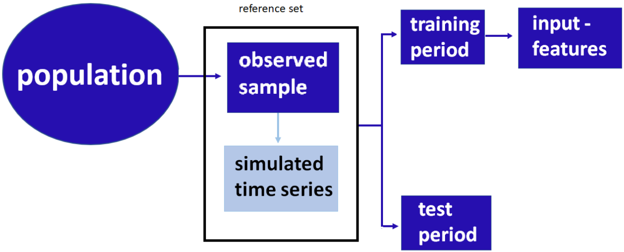

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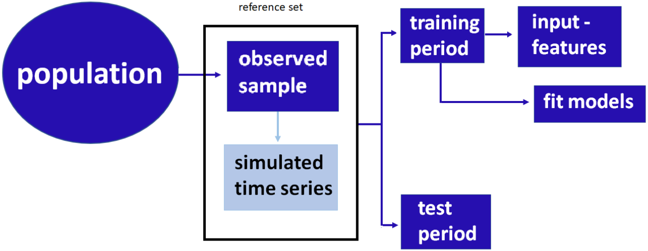

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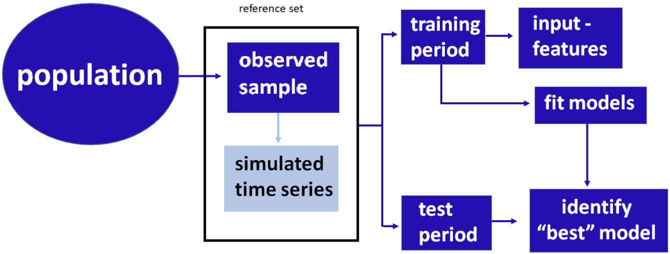

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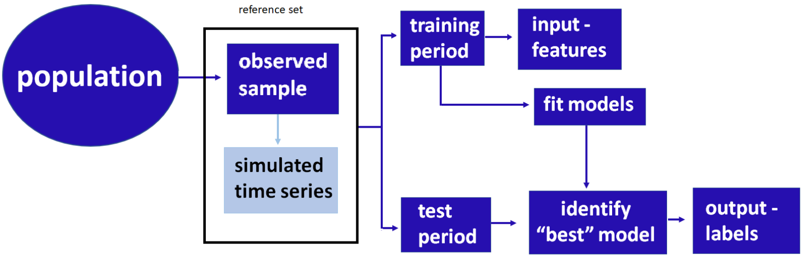

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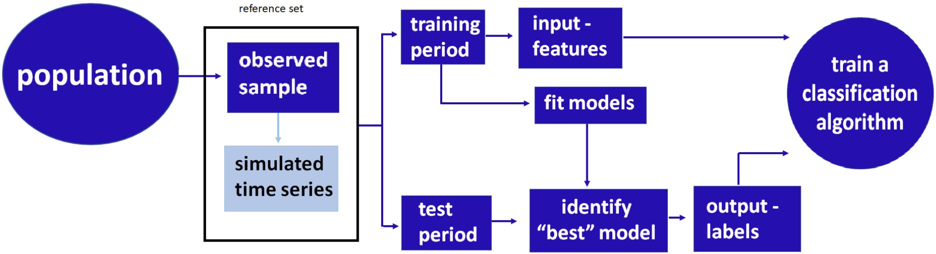
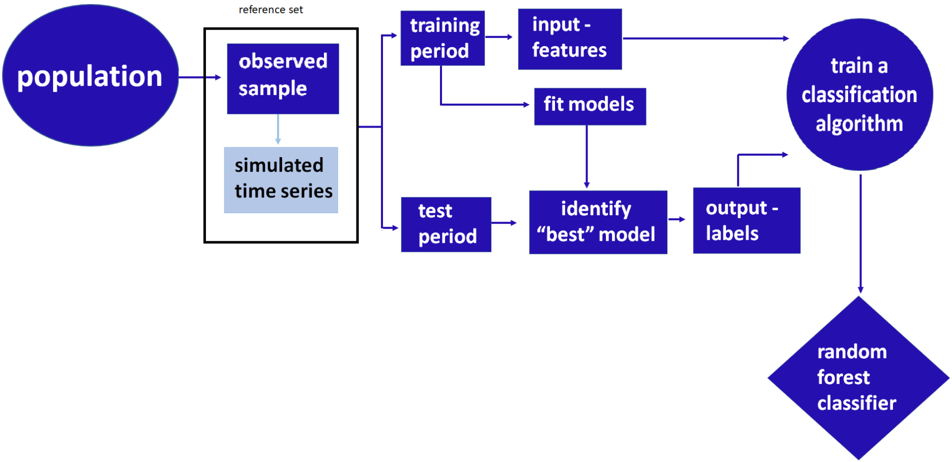
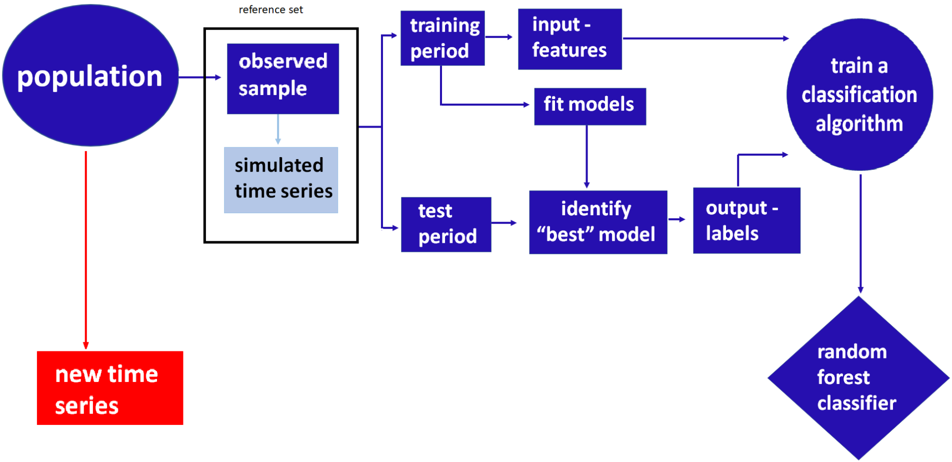


FFORMS: Random-forest classifier



FFORMS: "online" part of the algorithm



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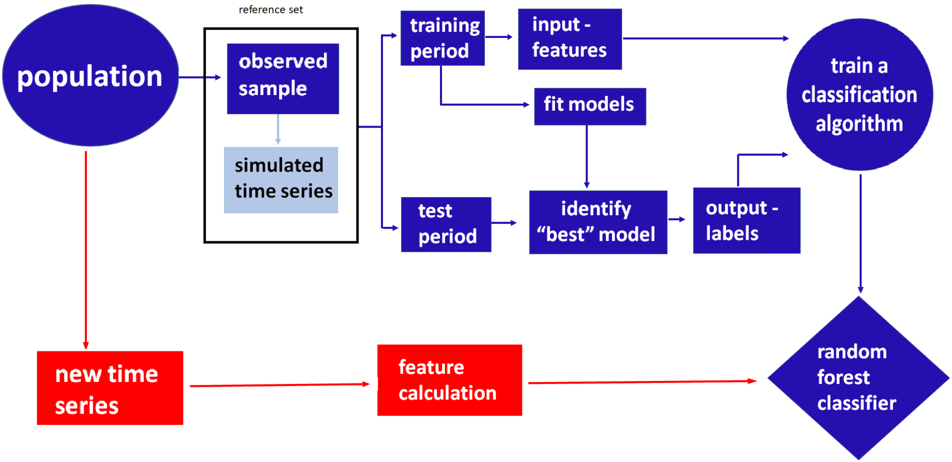

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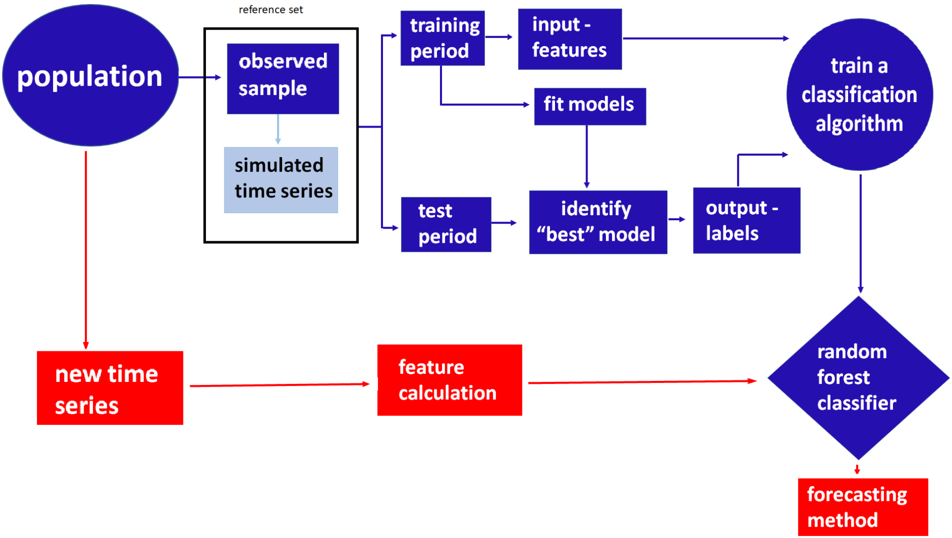


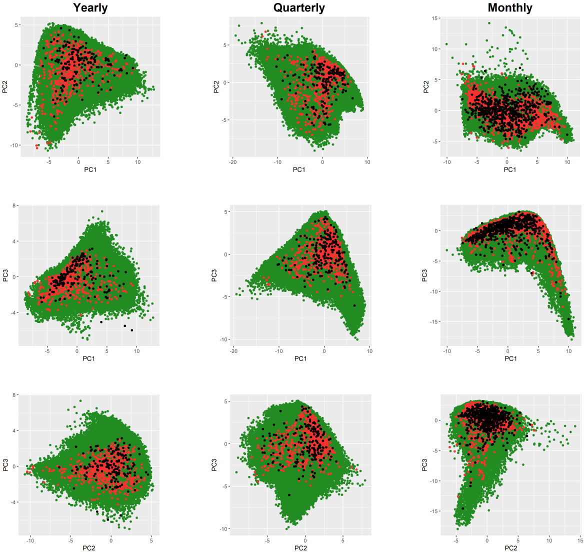
Application to M competition data

- Proposed algorithm is applied to yearly, quarterly and monthly series separately
- We run two experiments for each case.

	Experiment 1				Experiment 2			
	Source	Y	Q	M	Source	Y	Q	M
Observed series	M1	181	203	617	M3	645	756	1428
Simulated series		362000	406000	123400		1290000	1512000	285600
New series	M3	645	756	1428	M1	181	203	617

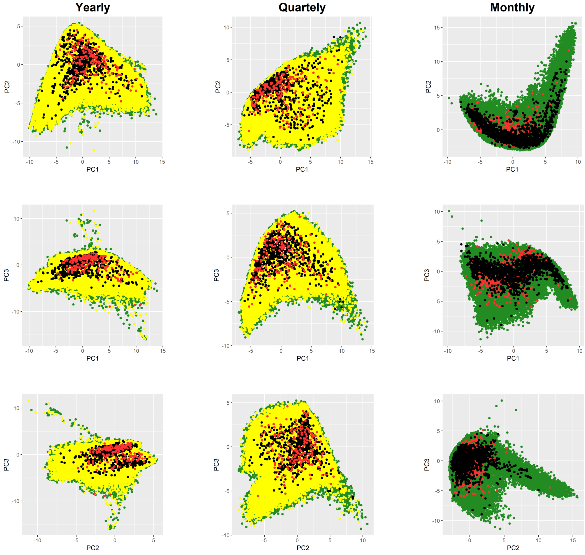
Experiment 1: Distribution of time series in the PCA space

observed - M1 | simulated | new - M3

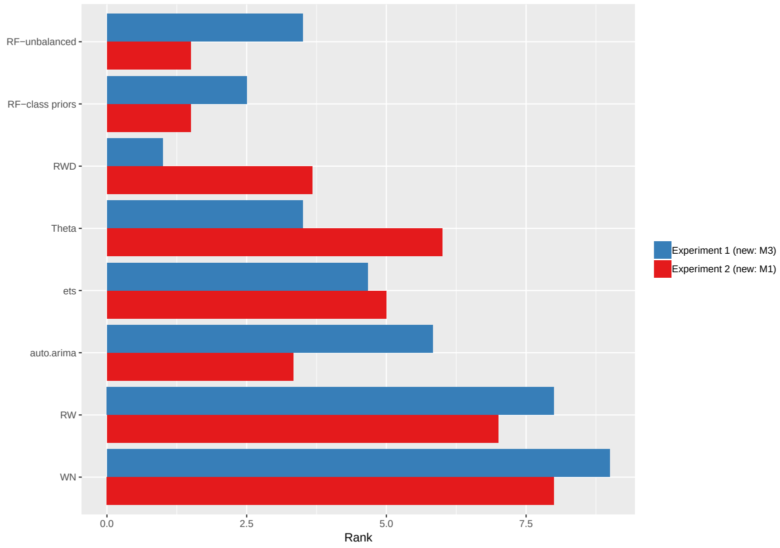


Experiment 2: Distribution of time series in the PCA space

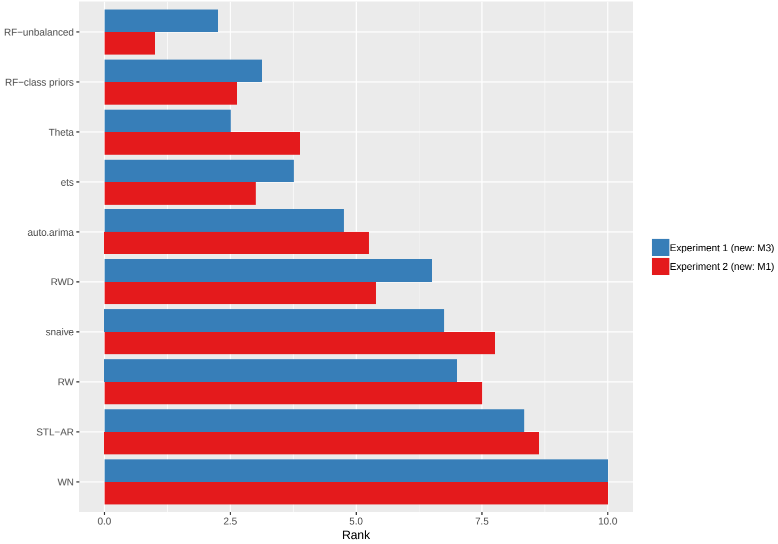
observed - M3 | simulated | subset | new - M1



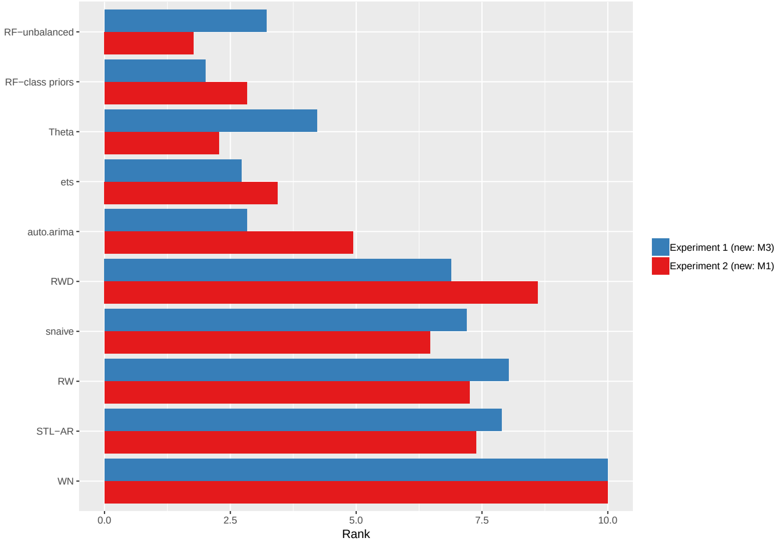
Results: Yearly



Results: Quarterly



Results: Monthly



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- For real-time forecasting, our framework involves only the calculation of features, the selection of a forecast method based on the FFORMS random forest classifier, and the calculation of the forecasts from the chosen model.
- We have also introduced a simple set of time series features that are useful in identifying the "best" forecast method for a given time series.

R package: seer

available at: https://github.com/thiyangt/seer

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