

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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- Examples for time series features

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

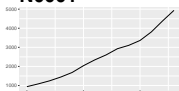
Feature-space of time series

STL-decomposition

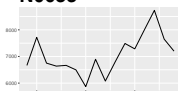
$$Y_t = T_t + S_t + R_t$$

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

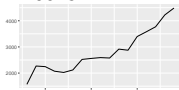
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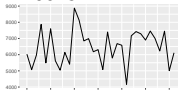
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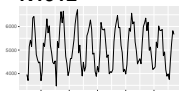
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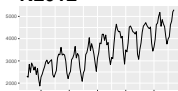
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N1912



N2012

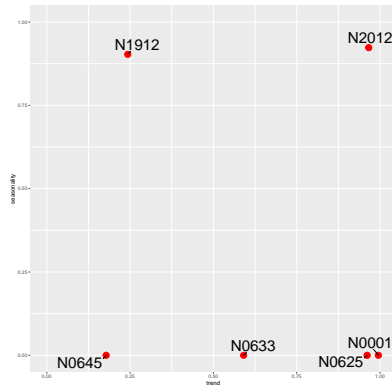
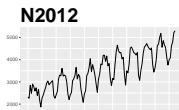
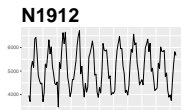
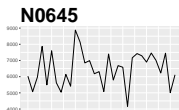
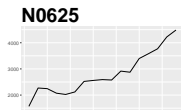
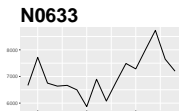
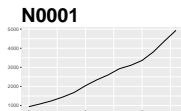


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- strength of trend: $1 - \frac{\text{Var}(R_t)}{\text{Var}(Y_t - S_t)}$
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Time series features

- 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

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

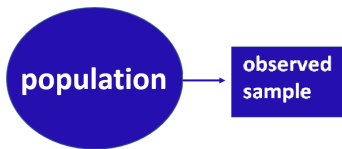
Offline: Classification algorithm is trained

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

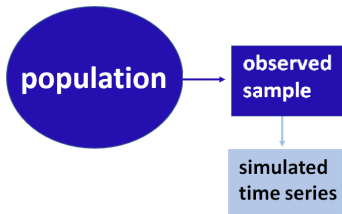


population

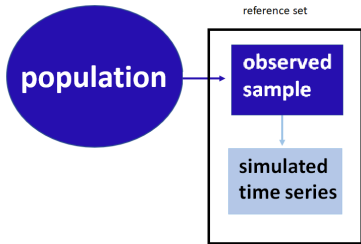
FFORMS: observed sample



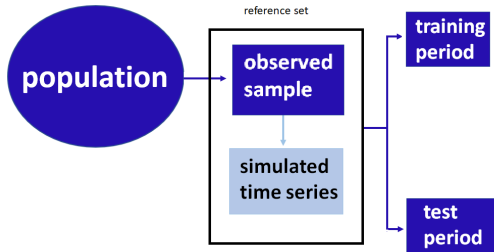
FFORMS: simulated time series



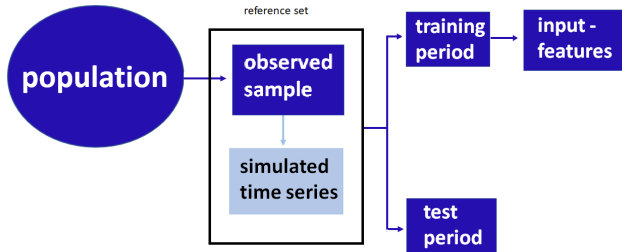
FFORMS: reference set



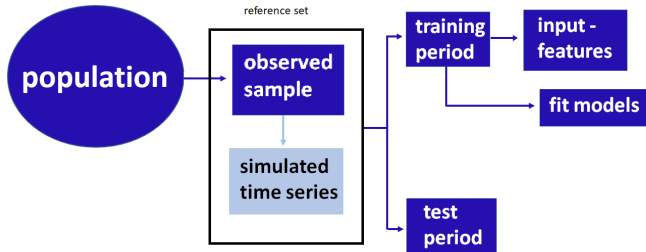
FFORMS: Meta-data



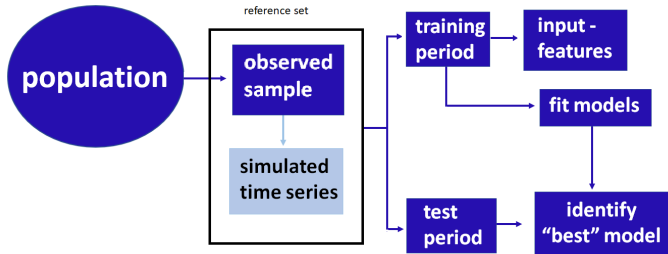
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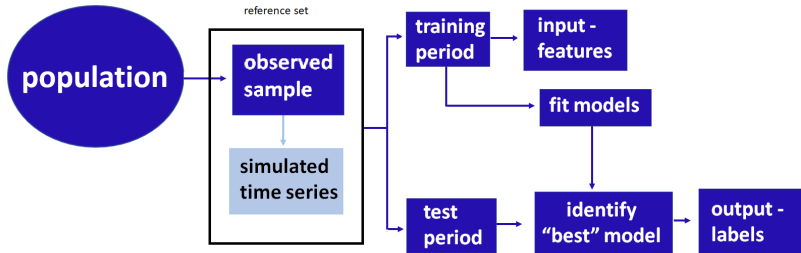
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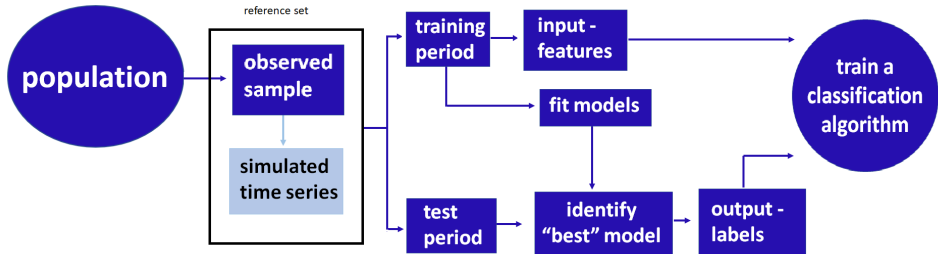
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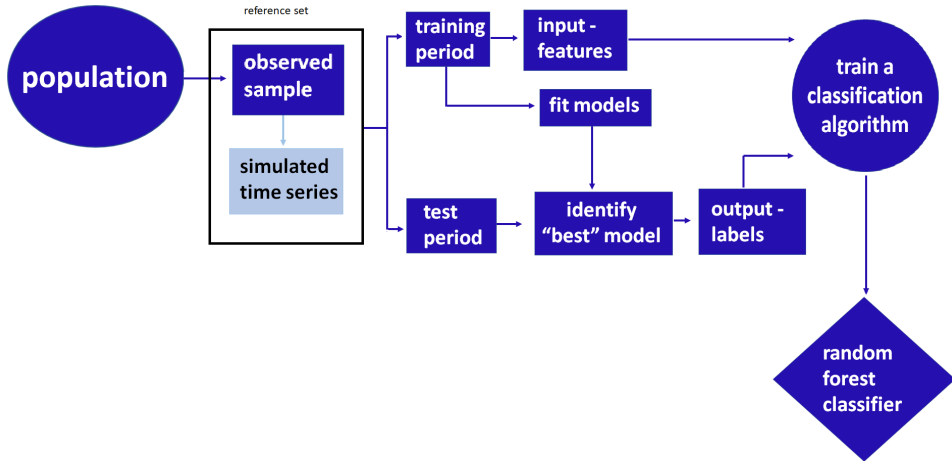
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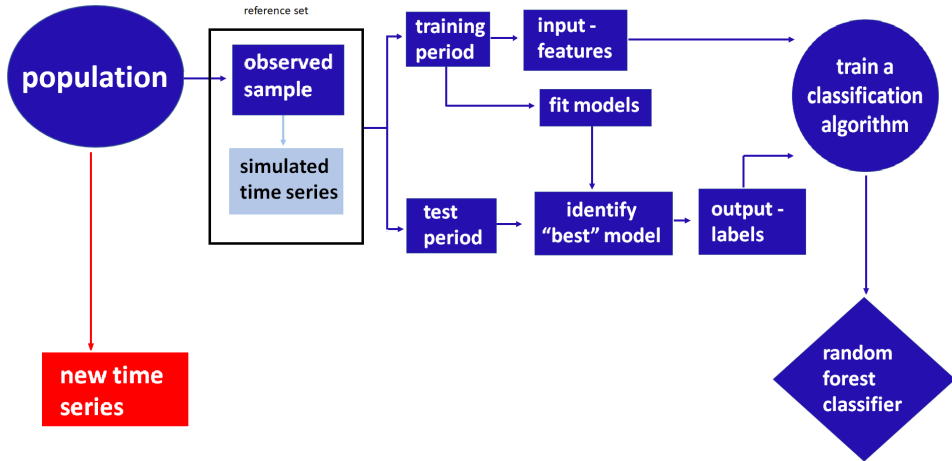
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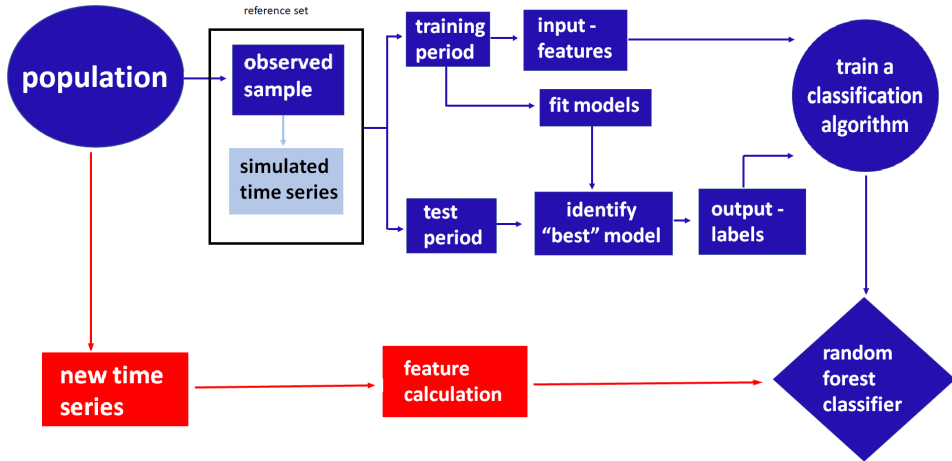
FFORMS: Random-forest classifier



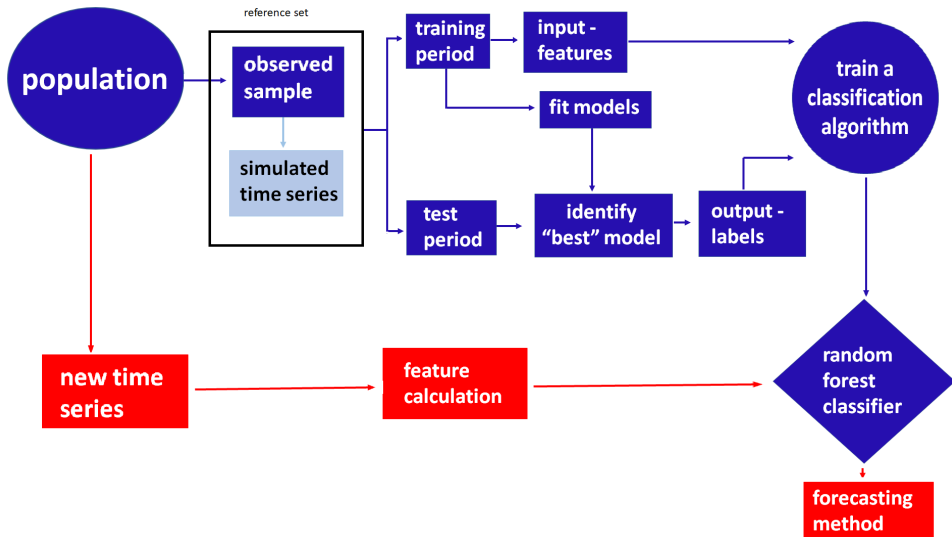
FFORMS: “online” part of the algorithm



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Application to M competition data

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

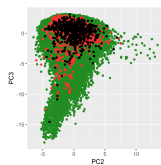
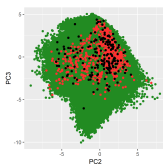
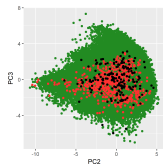
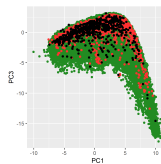
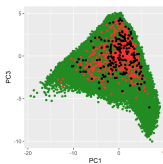
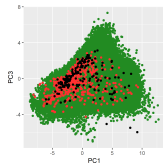
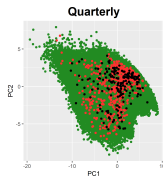
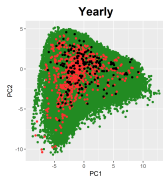
	Source	Experiment 1			Source	Experiment 2		
		Y	Q	M		Y	Q	M
Observed series	M1	181	203	617	M3	645	756	1428
Simulated series		362000	406000	123400		1290000	1512000	285600
New series	M3	645	756	1428	M1	181	203	617

Experiment 1: Distribution of time series in the PCA space

observed - M1

simulated

new - M3



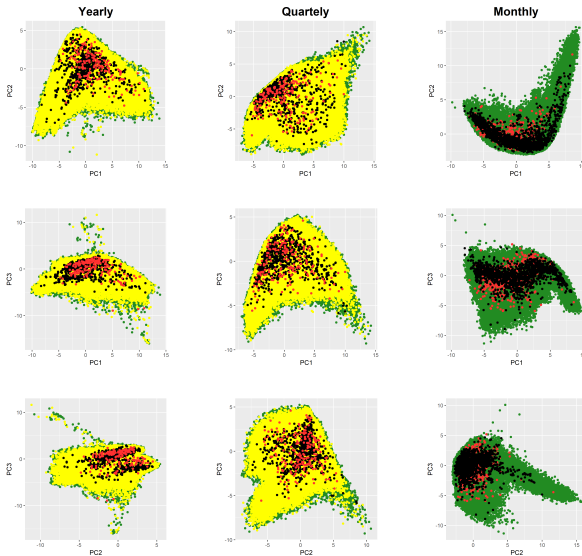
Experiment 2: Distribution of time series in the PCA space

observed - M3

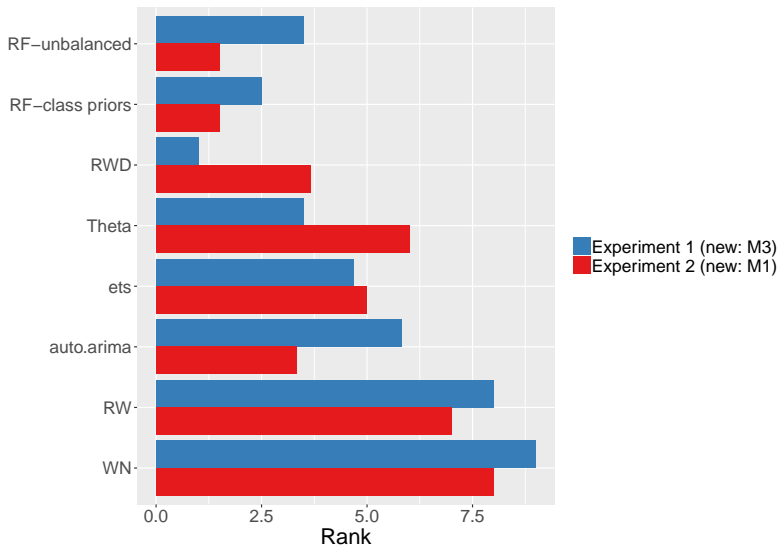
simulated

subset

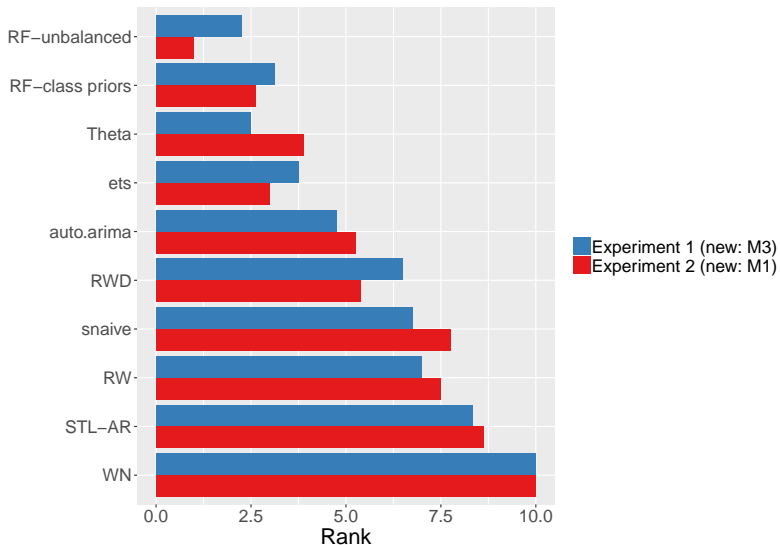
new - M1



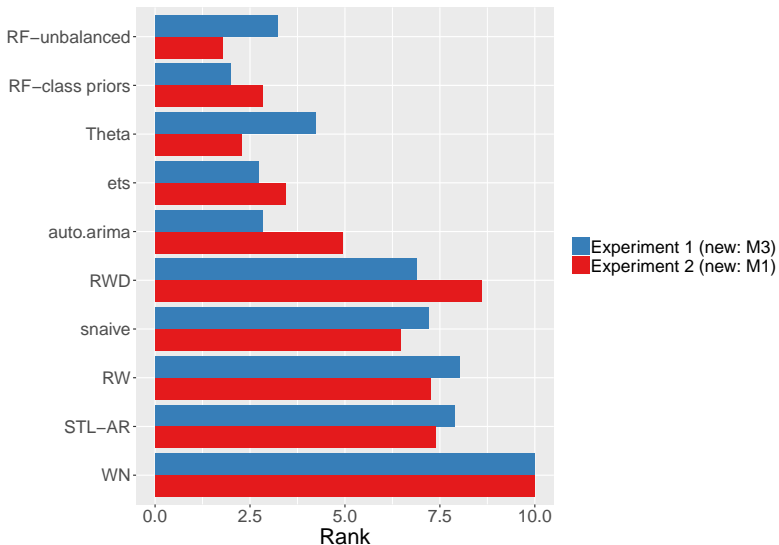
Results: Yearly



Results: Quarterly



Results: Monthly



- FFORMS: framework for forecast-model selection using meta-learning based on time series features.

Discussion and Conclusions

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- 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.



available at: <https://github.com/thiyanngt/seer>

Installation

```
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library(seer)
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