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Feature-based forecasting algorithms for large collections of time series

George Athanasopoulos, Rob J Hyndman, Pablo Montero-Manso & Thiyanga Thalagala

22 February 2019

Outline

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1. Makridakis forecasting competitions
2. Time series features
3. Feature based forecasting algorithms

M competition: 1982

Journal of Forecasting, Vol. 1, 111–153 (1982)

The Accuracy of Extrapolation (Time Series) Methods: Results of a Forecasting Competition

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ABSTRACT

In the last few decades many methods have become available for forecasting. As always, when alternatives exist, choices need to be made so that an appropriate forecasting method can be selected and used for the specific situation being considered. This paper reports the results of a forecasting competition that provides information to facilitate such choice. Seven experts in each of the 24 methods forecasted up to 1001 series for six up to eighteen time horizons. The results of the competition are presented in this paper whose purpose is to provide empirical evidence about *differences* found to exist among the various extrapolative (time series) methods used in the competition.

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M-competition

- 1001 series from demography, industry, economics.
- Annual, quarterly, monthly data.
- Anyone could submit forecasts.
- Multiple forecast measures used.

M3 competition: 2000

ELSEVIER

International Journal of Forecasting 16 (2000) 451–476

international journal of forecasting

www.elsevier.com/locate/ijforecast

The M3-Competition: results, conclusions and implications

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Abstract

This paper describes the M3-Competition, the latest of the M-Competitions. It explains the reasons for conducting the competition and summarizes its results and conclusions. In addition, the paper compares such results/conclusions with those of the previous two M-Competitions as well as with those of other major empirical studies. Finally, the implications of these results and conclusions are considered, their consequences for both the theory and practice of forecasting are explored and directions for future research are contemplated.

Keywords: Comparative methods — time series: univariate; Forecasting competitions; M-Competition; Forecasting methods, Forecasting accuracy

M3 competition: 2000

> "The M3-Competition is a final attempt by the authors to settle the accuracy issue of various time series methods... The extension involves the inclusion of more methods/ researchers (in particular in the areas of neural networks and expert systems) and more series."

- 3003 series
- All data from business, demography, finance and economics.
- Series length between 14 and 126.
- Either non-seasonal, monthly or quarterly.
- All time series positive.

M4 competition: 2018

International Journal of Forecasting 34 (2018) 802–808

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The M4 Competition: Results, findings, conclusion and way forward

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ARTICLE INFO

Keywords:
Forecasting competitions
M Competitions

ABSTRACT

The M4 competition is the continuation of three previous competitions started more than 45 years ago whose purpose was to learn how to improve forecasting accuracy, and

M4 competition: 2018

- January – May 2018
- 100,000 time series: yearly, quarterly, monthly, weekly, daily, hourly.
- Point forecast and prediction intervals assessed.
- Code must be public
- 248 registrations, 50 submissions.

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Winning methods

1. Hybrid of Recurrent Neural Network and Exponential Smoothing models
2. FFORMA: Feature-based FORecast Model Averaging (based on FFORMS)

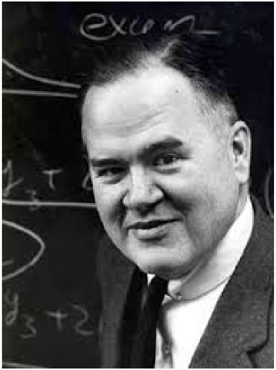
Outline

1. Makridakis forecasting competitions
2. Time series features
3. Feature based forecasting algorithms

Time series features

Cognostics

Computer-produced diagnostics (Tukey and Tukey, 1985).



John W Tukey

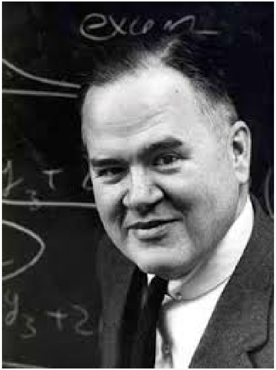
Time series features

Cognostics

Computer-produced diagnostics (Tukey and Tukey, 1985).

Examples for time series

- strength of seasonality
- size and direction of trend
- lag correlation
- spectral entropy



John W Tukey

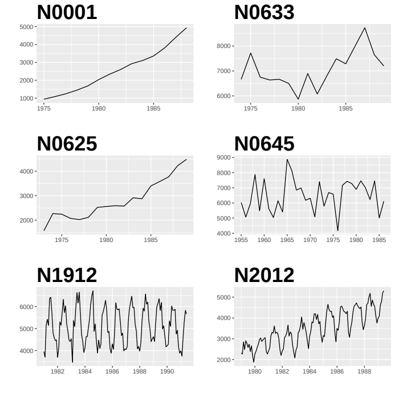
Called “features” in the machine learning literature.

Feature-space of time series

STL-decomposition

$Y_t = T_t + S_t + R_t$

- strength of trend: $\max[0, 1 - \frac{Var(R_t)}{Var(Y_t - S_t)}]$
- strength of seasonality: $\max[1 - \frac{Var(R_t)}{Va(Y_t - T_t)}]$



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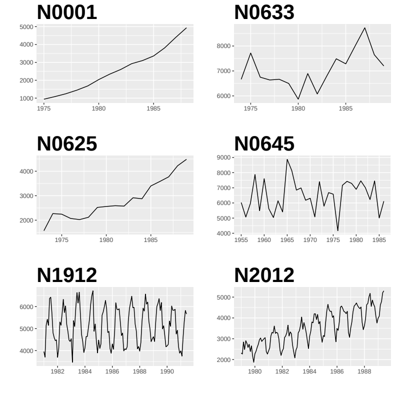

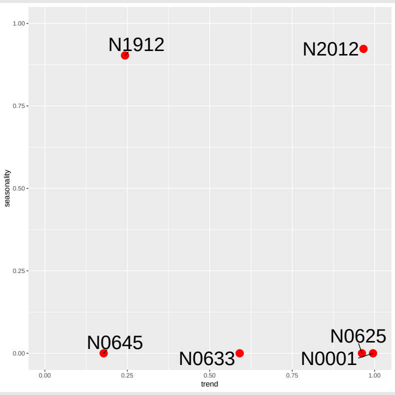

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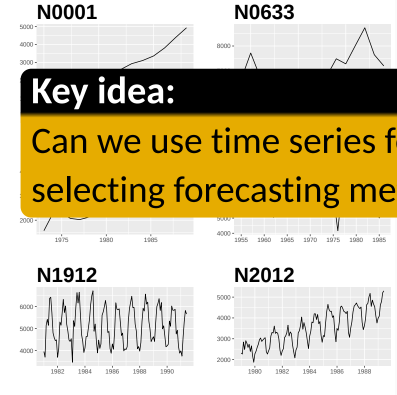
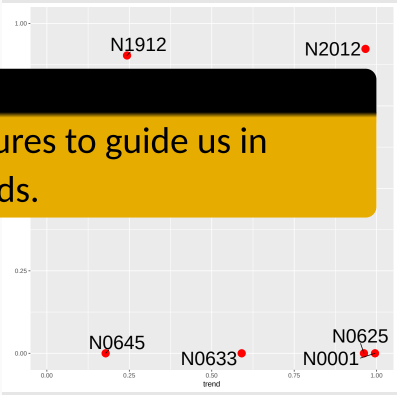




Key idea:

Can we use time series features to guide us in selecting forecasting methods.

Outline

Features used to select a forecasting model

- length
- strength of seasonality
- strength of trend
- linearity
- curvature
- spikiness
- stability
- lumpiness
- parameter estimates of Holt’s linear trend method
- spectral entropy
- Hurst exponent
- nonlinearity
- parameter estimates of Holt-Winters’ additive method
- unit root test statistics
- crossing points, flat spots
- peaks, troughs
- ACF and PACF based features - calculated on raw, differenced, and remainder series.
- ARCH/GARCH statistics and ACF of squared series and residuals.

Models included

1. Naïve
2. Seasonal naïve
3. Random walk with drift
4. Theta method
5. ARIMA
6. ETS
7. TBATS
8. STL decomposition with AR for seasonally adjusted series

FFORMS

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

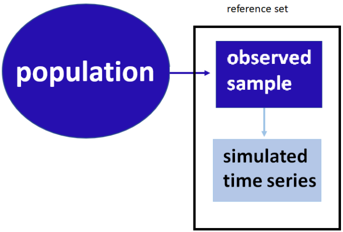
Offline

- A classification algorithm (the meta-learner) is trained.

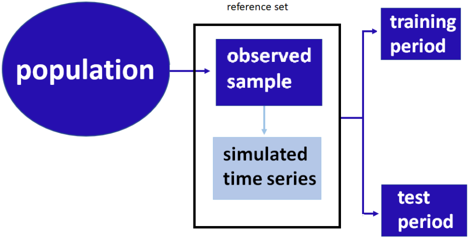
Online

- Calculate the features of a time series and use the pre-trained classifier to identify the best forecasting method.

FFORMS: reference set



FFORMS: Meta-data



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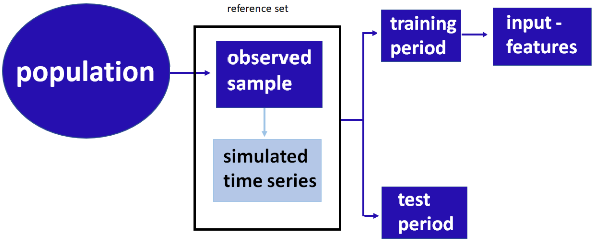

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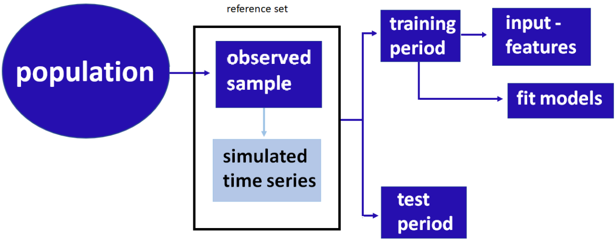

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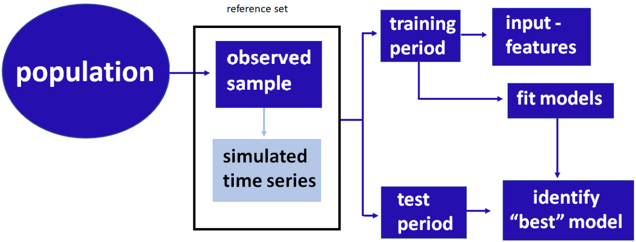

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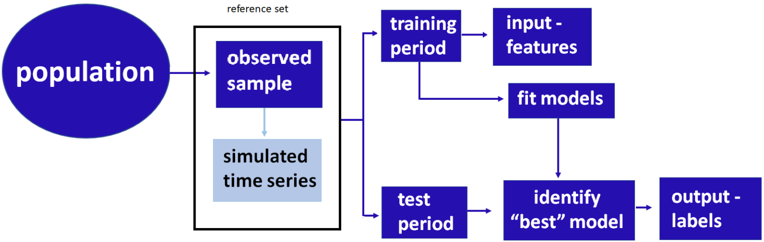

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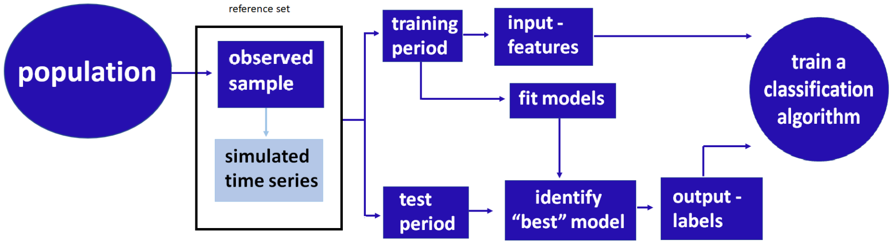
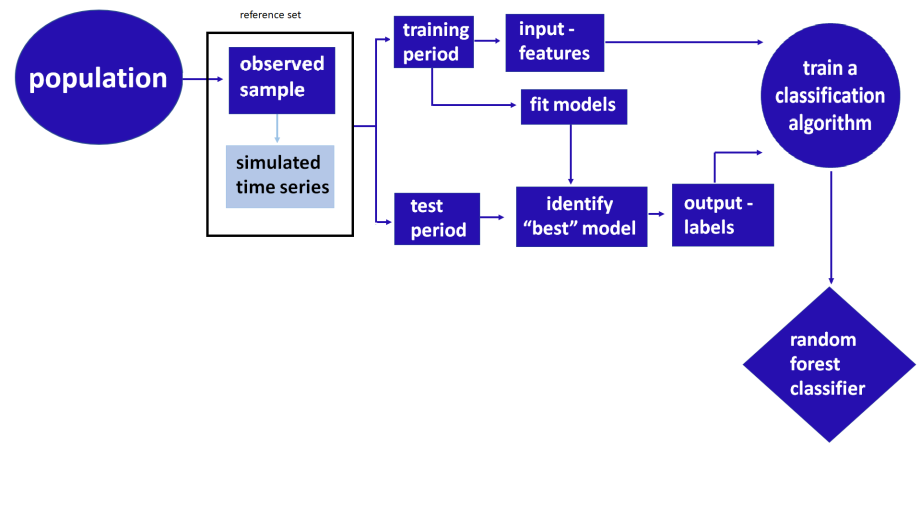
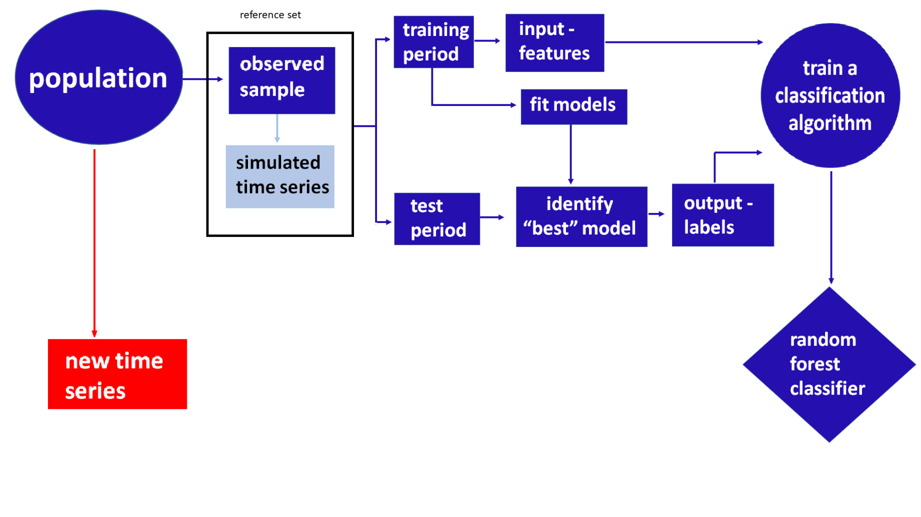


FFORMS: Random-forest classifier



FFORMS: Online part of the algorithm



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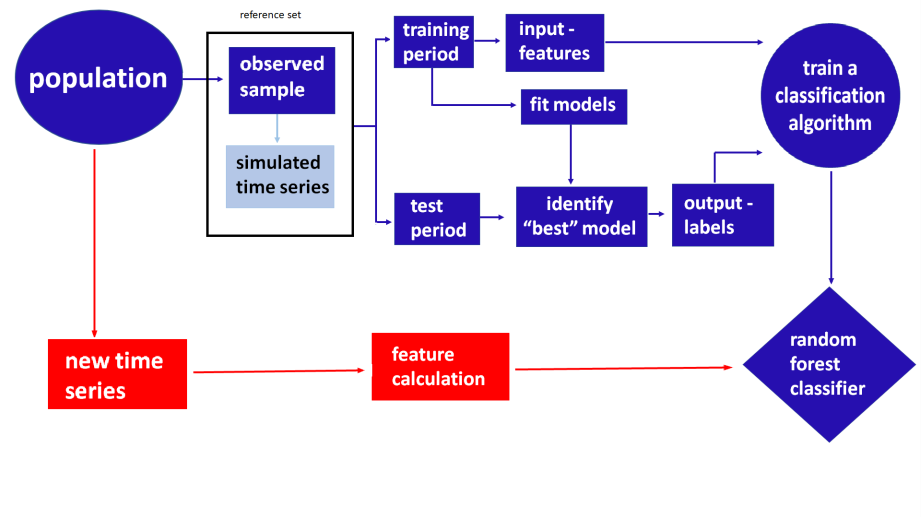

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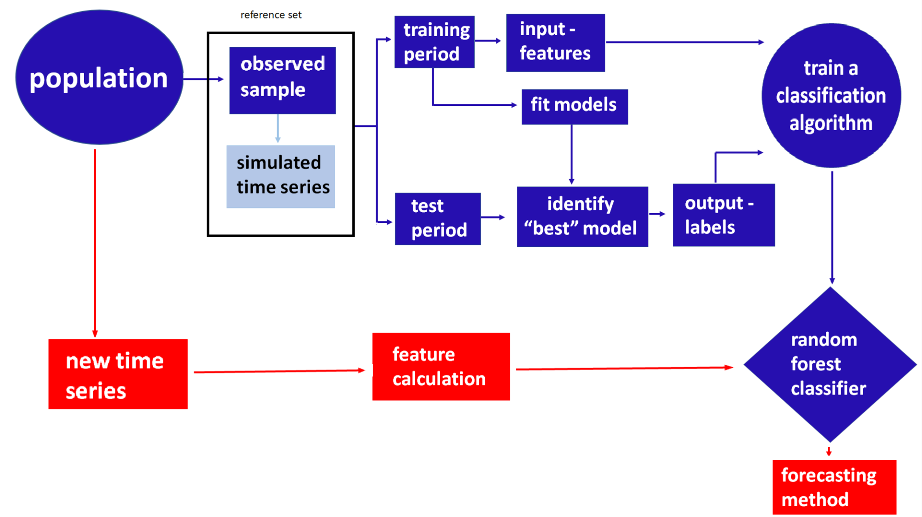
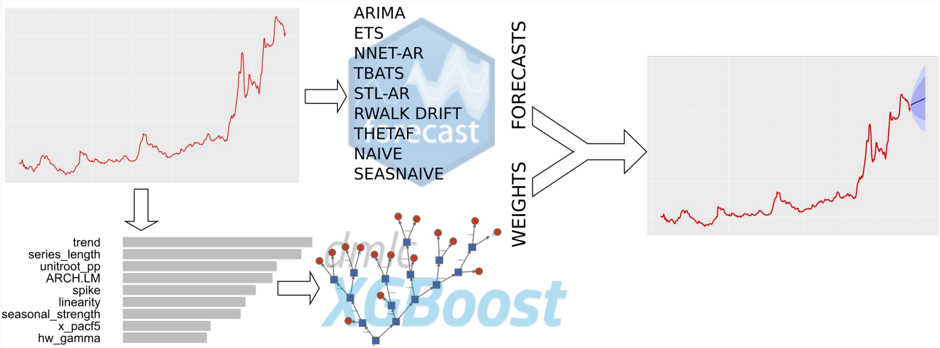


FFORMA: Feature-based FORecast Model Averaging

- Like FFORMS but using gradient boosted trees (xgboost) rather than random forest.
- Trained on temporal holdout version of M4 dataset, where size of test sets equal to required forecast horizons
- Optimization criterion: forecast accuracy not classification accuracy.
- Probability of each model being best is used to construct model weights for combination forecast.
- 5 days computing time.

FFORMA: Feature-based FORecast Model Averaging

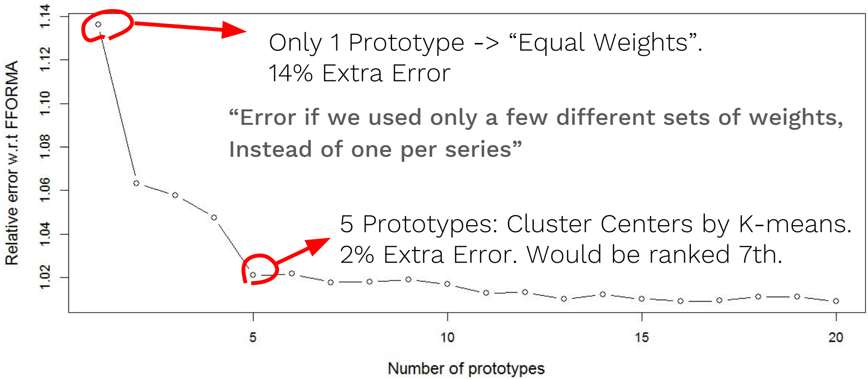


M4 competition results (based on average OWA)

1st	0.821	
2nd	0.838	(FFORMA)
3rd	0.841	

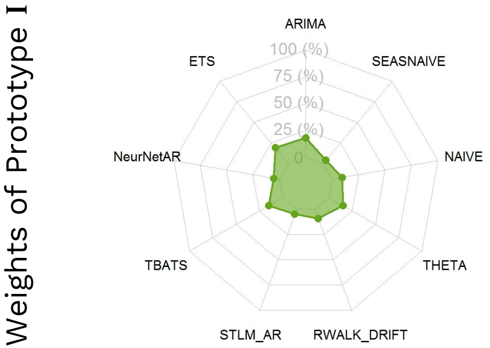
FFORMA: Feature-based FORecast Model Averaging

Looking for Prototypes in the weights



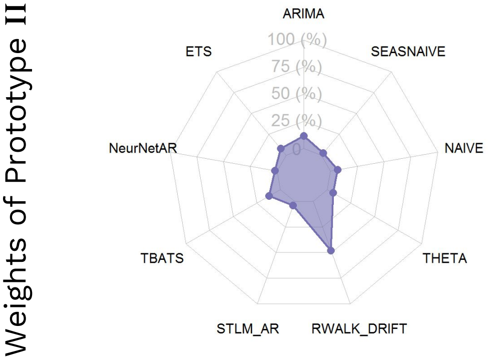
FFORMA: Feature-based FORecast Model Averaging

“Roughly Equal Weights”. 40000 Series in M4



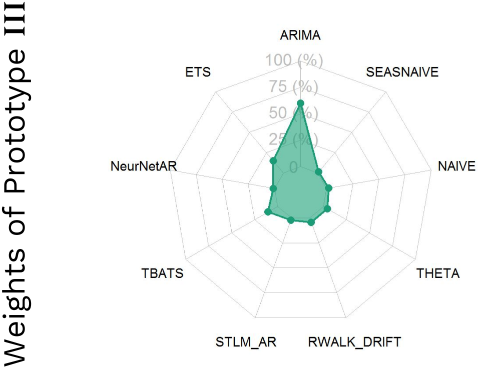
FFORMA: Feature-based FORecast Model Averaging

“Mostly RandomWalk Drift”. 20000 Series in M4



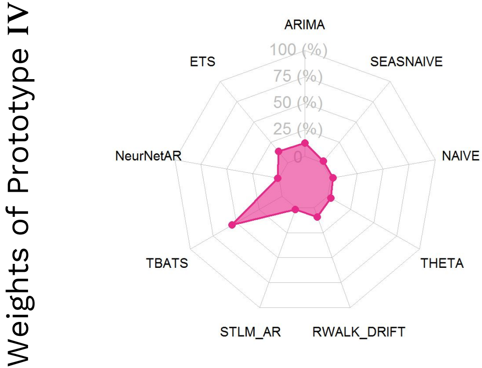
FFORMA: Feature-based FORecast Model Averaging

“Mostly ARIMA”. 16000 Series in M4



FFORMA: Feature-based FORecast Model Averaging

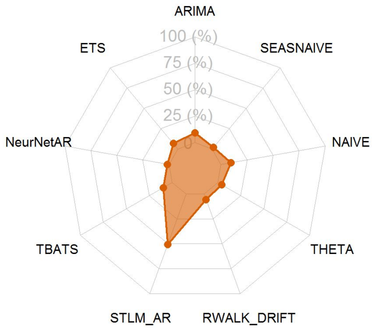
“Mostly TBATS”. 13000 Series in M4



FFORMA: Feature-based FORecast Model Averaging

"Mostly STLM-AR". 8000 Series in M4

Weights of Prototype V



Papers and packages

R packages

- **tsfeatures**: Calculating time series features.

  `github.com/robjhyndman/tsfeatures`
- **seer**: FFORMS — selecting forecasting model using features.

  `github.com/thiyangt/seer`
- **M4metalearning**: FFORMA – forecast combinations using features to choose weights.

  `github.com/robjhyndman/M4metalearning`

Papers

Available from `robjhyndman.com`