Method Description

General Information

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1st Member	
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3nd Member	
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Information about the method utilized

Name of Method	**Siopred**
Type of Method (*Statistical, Machine Learning, Combination, Other*)	**Combination**
Short Description (up to 200 words)	We forecast the time series involved in the M4-Competition using SIOPRED [3]. This automatic forecasting support system applies an optimization-based scheme that jointly estimates the smoothing parameters and the initial conditions of a generalized exponential smoothing method. The system solves several nonlinear programming problems and uses a fuzzy multicriteria approach [1], which ensures accurate forecasts for h periods ahead. The results shown here are based on the combination of two predictions provided automatically by SIOPRED. In particular, for each time series, SIOPRED considers the raw data and its log-transformed time

	series, and provides, for each one, point-wise forecasts and their corresponding prediction intervals by applying the additive Holt-Winters model with damped trend [2, 4]. Then, a linear combination of both forecasts is built using as weights the inverse of the averaged fitting errors, which are the forecasted results (point-wise, lower and upper bounds of the prediction intervals, respectively). **References** [1] Bermúdez, JD et al., Computational Statistics & Data Analysis 51 (2006) 177-191. [2] Bermúdez, JD et al., Journal of Applied Statistics 34(9) (2007) 1075-1090. [3] Bermúdez, JD et al., TOP 16 (2008) 258-271. [4] Vercher, E et al., TOP 20 (2012) 517-533.

Extended Description:

Apart from the textural description, please consider including an informative flowchart to help researchers better understand the exact steps followed for generating the forecasts. Please also try to clarify any assumptions made, the initialization and parameterization process used, etc., to facilitate reproducibility and replicability.

SIOPRED CODE for M4Competition

1.- **Data Input:**

- All the information about the time series is presented by rows in the text file named "input.txt". Only one series is supported in the input file.
  All the fields are separated by the semicolon (;):
  - Code of the series
  - Number of observations, between 6 and 10000
  - Data set, also separated each one of them by means of the semicolon (;)
  - The semicolon (;) also appears after the last observed data.
- Parameters set in the executable:
  - Length of the seasonal cycle, *p*, from 1, 4, 12 or 24.
  - Number of forecasts ahead, h, from 6, 8, 13, 14, 18 or 48.
  - Exponential smoothing model with additive seasonality; jointly minimizing SMAPE, RMSE and MAD.
  - Bounds for the level smoothing parameter α : [0,0,3].
  - Bounds for the trend smoothing parameter β : [0,0,3].
  - Bounds for the seasonal smoothing parameter γ : [0,0,3].
  - Bounds for the dampen parameter ϕ, from [0,1].
  - We consider the raw data and its log-transformed (ln) time series

2.- **Optimization multi-start techniques**

- As guess initial solutions in the nonlinear optimization procedure, we consider a grid of twelve values of the smoothing parameters ($\alpha, \beta, \gamma, \phi$):

- As guess of the initial values of the local level, trend and seasonality factors we uses the Makridakis et al's proposal (1998):

$$F_0 = \overline{D}_1$$

$$b_0 = \begin{cases} 0 & si\ p > 2n \\ \dfrac{\overline{D}_2 - \overline{D}_1}{2} & si\ p \leq 2n \end{cases}$$

$$I_j = \begin{cases} \dfrac{D_j}{\overline{D}_1} & if\ multiplicative\ model \\ D_j - \overline{D}_1 & if\ additive\ model \end{cases} \quad j = -p+1, \dots, 0$$

where $\overline{D}_i$ is the arithmetic mean of the data for the *i*th cycle. If p=1, then I_0=0.

- The guess of initial values for the parameter of the degree of global satisfaction λ (used in the fuzzy multi-objective optimization problem) are (0,1; 0,4; 0,7; 0,9). So, SIOPRED solves twelve nonlinear programming problems, four problems for each of the better solution associated to one measure of fitting error.

3.- **Nonlinear optimization**

- The nonlinear programming problems are solved using the GRG2 method authored by Lasdon and Waren. In particular, the implementation due to Daniel Fylstra (Frontline Systems) and John Whatson (Software Engines).
- The number of variables in the optimization problem is *p*+6.
- The bounds for the variables are:

0	≤	α	≤	Upper bound_α	
0	≤	β	≤	Upper bound _β	
0	≤	γ	≤	Upper bound _γ	
0	≤	ϕ	≤	1	
-∞	≤	b_0	≤	+∞	
Multiplicative Seasonality					
0,0001	≤	F_0	≤	+∞	
0,0001	≤	I_j	≤	+∞	j=-p+1,…,0
Additive Seasonality					
-∞	≤	F_0	≤	+∞	
-∞	≤	I_j	≤	+∞	j=-p+1,…,0

- For the Exponential Smoothing models with additive seasonality, the objective functions to minimize are:
  - $SMAPE = \frac{200}{n}\sum_{j=1}^{n}\frac{|D_{j+1}-(F_j+b_j+I_j)|}{|D_{j+1}|+|F_j+b_j+I_j|}$
  - $RMSE = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(D_{j+1}-(F_j+b_j+I_j))^2}$
  - $MAD = \frac{1}{n}\sum_{j=1}^{n}|D_{j+1}-(F_j+b_j+I_j)|$
- The constraints of the feasible set are:
  - $\sum_{j=-p+1}^{0} I_j = \begin{cases} p & multiplicative \\ 0 & additive \end{cases}$
  - $\beta \leq \phi$
  - $\gamma \leq p-1$
- Recursive equations for j=0, …, n-1 (additive seasonality):
  - $e_{j+1} = D_{j+1} - (F_j + b_j + I_j)$

- $F_{j+1} = \alpha(D_{j+1} - I_j) + (1-\alpha)(F_j + b_j)$
- $b_{j+1} = \beta(F_{j+1} - F_j) + (\phi - \beta)b_j$
- $I_{j+1} = \gamma(D_{j+1} - F_{j+1}) + (1-\gamma)I_j$

4.- **Multi-objective nonlinear programming problem**

- We find the values of b_i associates to each of the measures of error solving the following system of equations:
  - $0{,}5 = \dfrac{1-e^{\left\{-b_i \frac{Máximo(\varphi_{i,j}) - Mediana(\varphi_{i,j})}{Máximo(\varphi_{i,j}) - Mínimo(\varphi_{i,j})}\right\}}}{1-e^{\{-b_i\}}} \quad i = 1,2,3; j = 1, \dots, 12$
- Three more constraints are added to the nonlinear optimization problem which maximizes the λ value, belonging to the interval (0,1):
  - $\dfrac{1-e^{\left\{-b_i \frac{Máximo(\varphi_{i,j}) - Mediana(\varphi_{i,j})}{Máximo(\varphi_{i,j}) - Mínimo(\varphi_{i,j})}\right\}}}{1-e^{\{-b_i\}}} \geq \lambda \quad i = 1,2,3; j = 1, \dots, 12$

5.- Output files

- SIOPRED generates 3 output files. The linear combination of raw data and its log-transformed (ln) time series forecasts is built using as weights the inverse of the averaged fitting errors, which are the forecasted results (point-wise, lower and upper bounds of the prediction intervals, respectively).
  - forecast.txt : forecasts separated by semicolons (;).
  - lower.txt : lower limit of the prediction intervals separated by semicolons (;).
  - upper.txt: upper limit of the prediction intervals separated by semicolons (;).

References

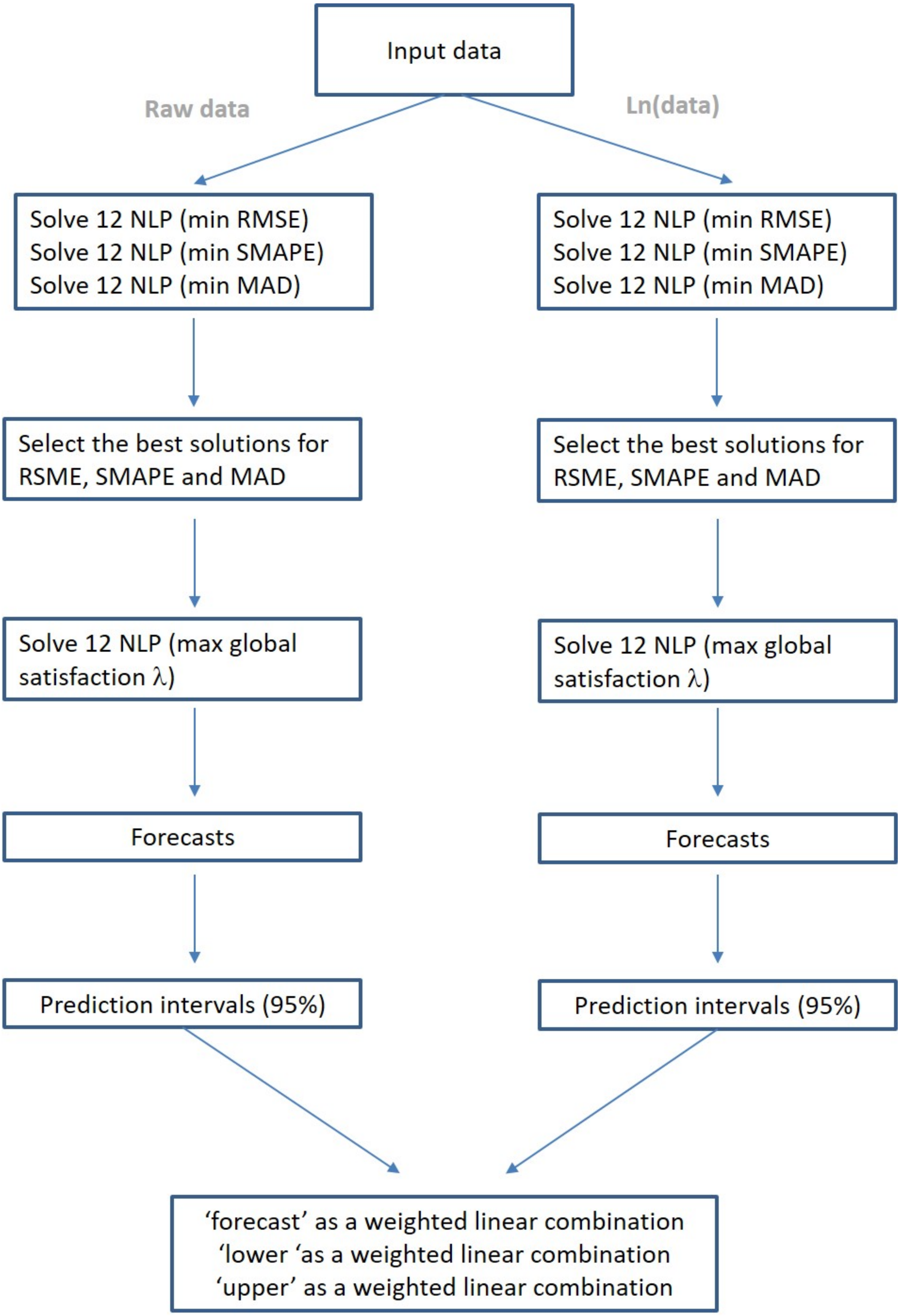
Bermúdez, JD; Segura, JV; Vercher, E (2006) A decision support system methodology for forecasting of time series based on soft computing, Computational Statistics & Data Analysis 51, 177-191.

Bermúdez, JD; Segura, JV; Vercher, E (2007) Holt-Winters forecasting: an alternative formulation applied to UK air passenger data, Journal of Applied Statistics 34(9), 1075-1090.

Bermúdez, JD; Segura, JV; Vercher, E (2008) SIOPRED: a prediction and optimisation integrated system for demand, TOP 16, 258-271.

Makridakis, S; Wheelright; Hyndman, RJ (1998) Forecasting. Methods and Applications (3rd Ed.) Wiley, New York.

Vercher, E; Corberán-Vallet, A; Segura, JV; Bermúdez, JD (2012) Initial conditions estimation for improving forecast accuracy in exponential smoothing, TOP 20, 517-533.


Input data
Raw data
Ln(data)
Solve 12 NLP (min RMSE)
Solve 12 NLP (min SMAPE)
Solve 12 NLP (min MAD)
Solve 12 NLP (min RMSE)
Solve 12 NLP (min SMAPE)
Solve 12 NLP (min MAD)
Select the best solutions for RSME, SMAPE and MAD
Select the best solutions for RSME, SMAPE and MAD
Solve 12 NLP (max global satisfaction λ)
Solve 12 NLP (max global satisfaction λ)
Forecasts
Forecasts
Prediction intervals (95%)
Prediction intervals (95%)
'forecast' as a weighted linear combination
'lower 'as a weighted linear combination
'upper' as a weighted linear combination