Automatic time series forecasting

Rob J. Hyndman

www.robhyndman.info

Department of Econometrics and Business Statistics
MONASH University

Outline

Motivation

1. Common in manufacturing to have over one thousand product lines that need forecasting at least monthly.
2. Forecasts are often required by people who do not know how to fit appropriate time series models.

Specifications

Automatic forecasting algorithms must

- determine an appropriate time series model
- estimate the parameters
- compute the forecasts with prediction intervals

Exponential smoothing

Reference

Makridakis, Wheelwright and Hyndman (1998) *Forecasting: methods and applications*, 3rd ed., Wiley: NY.

- Until recently, there has been no stochastic modelling framework incorporating likelihood calculation, prediction intervals, etc.
- Ord, Koehler & Snyder (JASA, 1997) and Hyndman, Koehler, Snyder and Grose (IJF, 2002) showed that all ES methods (including non-linear methods) are optimal forecasts from innovation state space models.

Pegels' (1969) taxonomy

Extended by Gardner (IJF 1985), Hyndman et al. (IJF 2002), and Taylor (IJF 2003).

Trend Component		Seasonal Component N (None)	A (Additive)	M (Multiplicative)
N	(None)	N,N	N,A	N,M
A	(Additive)	A,N	A,A	A,M
A_d	(Additive damped)	A_d,N	A_d,A	A_d,M
M	(Multiplicative)	M,N	M,A	M,M
M_d	(Multiplicative damped)	M_d,N	M_d,A	M_d,M

General notation

E T S

Error Trend Seasonal

Automatic forecasting

From Hyndman et al. (IJF, 2002):

- Apply each of 30 methods that are appropriate to the data. Optimize parameters and initial values using MLE (or some other criterion).
- Select best method using AIC:

$$\text{AIC} = -2\log(\text{Likelihood}) + 2p$$

  where $p = \#$ parameters.
- Produce forecasts using best method.
- Obtain prediction intervals using underlying state space model.

Method performed very well in M3 competition.

ARIMA modelling

Conventional ARIMA forecasting

- calculate forecasts from the best fitting ARIMA model
- Not necessarily the best forecasting ARIMA model.
- Model identification either subjective and complex, or based on information criteria that may not give good *forecasts*.

Automatic Algorithm

Key ideas

- Fit ARIMA model to $y_1, \dots, y_t$ and forecast $y_{t+1|t}, \dots, y_{t+h|t}$
- Calculate out-of-sample error $a_{t,i} = (y_{t+i} - \hat{y}_{t+i|t})$
- Calculate average

$$\text{MSE}_i = \frac{1}{n-h-m+1} \sum_{t=m}^{n-h} a_{t,i}^2 \text{ and MSE} = \frac{1}{h} \sum_{i=1}^{h} \text{MSE}_i$$

- Choose model based on smallest MSE_i or smallest MSE.

Automatic Algorithm

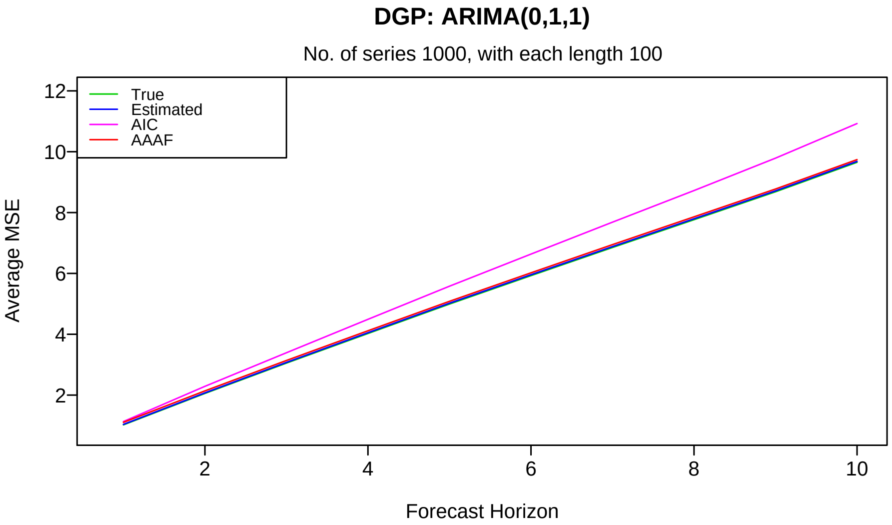
Problem:

- Procedure involves fitting $(n - m)D$ model where D is the number of candidate models.
- Using nonlinear optimization is infeasible.

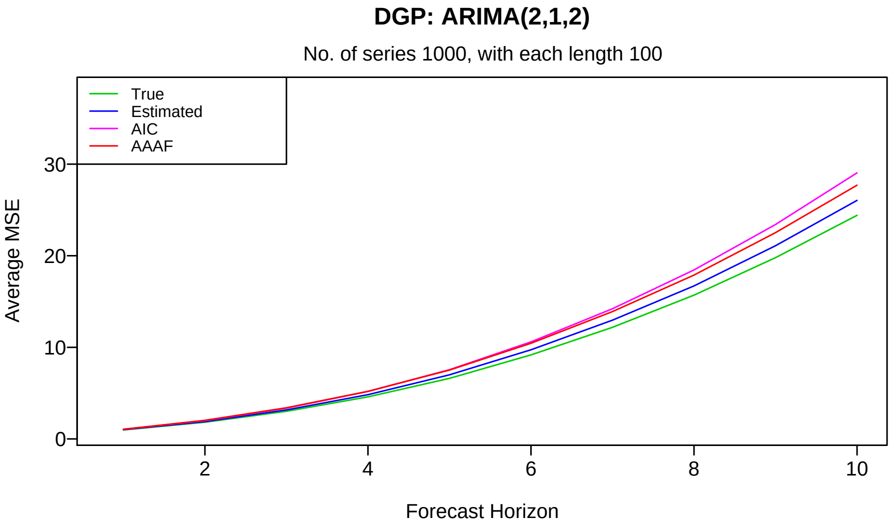
Solution:

- Estimate error series and fit all models using OLS regression.
- Kalman filter provides very fast updating of coefficients for each model.
- Algorithm involves D models passed through a Kalman filter.

Automatic Algorithm



Automatic Algorithm



forecast package

forecast() function

- Takes a time series as its main argument
- Returns forecasts from automatic ES algorithm.
- Yet to implement automatic ARIMA algorithm.
- Also has methods for objects of `arima`, `HoltWinters` and `StructTS` classes
- Calls `predict()` when appropriate.
- Output as class “forecast”.

forecast package

forecast class contains

- Original series
- Point forecasts
- Prediction interval
- Forecasting method used
- Residuals and other information

Methods applying to the forecast class:

- print
- plot
- summary

forecast package

> forecast(beer)

```
         Point Forecast    Lo 80    Hi 80
Sep 1995       138.2864 128.5376 148.2387
Oct 1995       165.8323 154.0843 177.8765
Nov 1995       182.7895 170.0695 195.9814
Dec 1995       186.1633 172.5645 199.7450
Jan 1996       144.6313 133.8904 155.3027
Feb 1996       137.2431 127.2945 147.7794
Mar 1996       155.1601 143.5184 166.8024
Apr 1996       139.7544 129.1742 150.2580
....
```

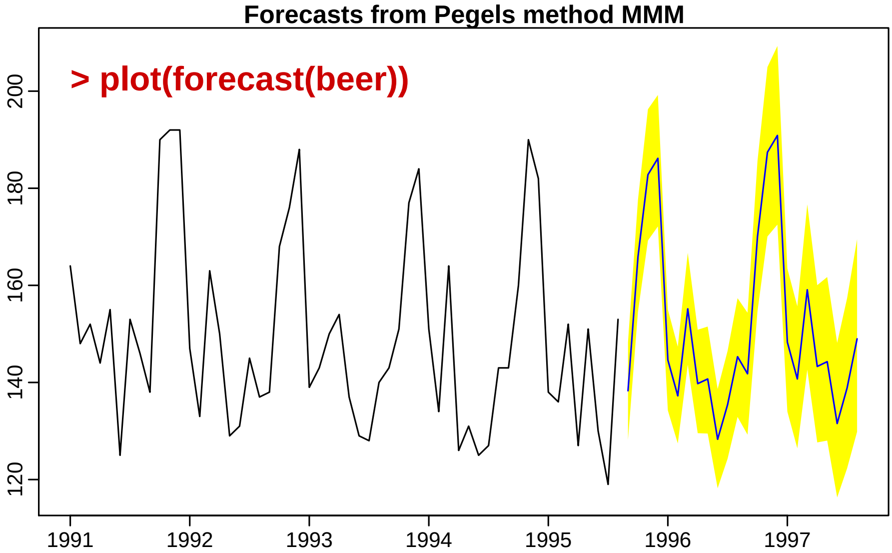
forecast package

> summary(forecast(beer))

```
Forecast method: Pegels method MMM
Model Information:
  Pegels method MMM
  Smoothing parameters:
    alpha = 0.05
    beta  = 0.399
    gamma = 0.05
    phi   = 1
  Initial values:
    l =  160.5127
    b =  0.9965
    s = 0.9652 0.9152 1.0322 0.9294 0.9328 0.8479
        0.8965 0.9565 0.9314 1.1176 1.2275 1.2478

In-sample error measures:
          ME          MSE          MAE          MPE         MAPE
 0.693364420 65.159550580  6.476950267  0.001983306  0.044197349
```

forecast package



forecast package

- Automatic ES forecasting.
- Automatic ARIMA modelling using AIC.
- Forecasting intermittent demand data using Croston's method
- Forecasting using Theta method
- Includes 3003 time series from M3 competition.
- Includes 1001 time series from M competition.
- Includes 90 data sets from Makridakis, Wheelwright & Hyndman (1998)
- Available as compiled Windows binary from

http://www.robhyndman.info/Rlibrary/forecast/

- Plan to upload to CRAN later this year.