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Coláiste na Tríonóide, Baile Átha Cliath
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Business Analytics using Data Mining & Forecasting

BU7143 & BU7144

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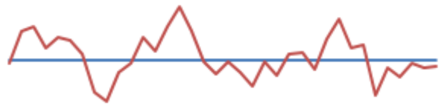
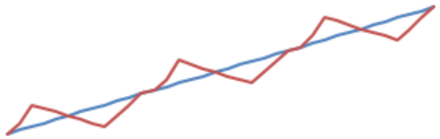
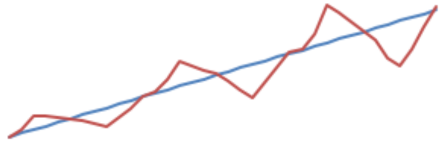
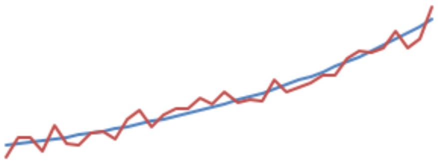
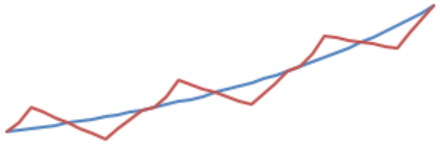
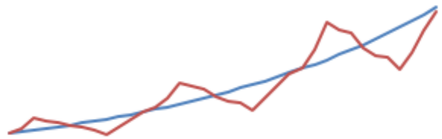
Overview of Forecasting Methods

1. Benchmark methods
   1. Naïve Forecast
   2. Seasonal Naïve Forecast
2. Regression
3. Smoothing
   1. Moving Average
   2. Arima
   3. Simple Exponential Smoothing
   4. Double Exponential
   5. Holt-Winters Smoothing

Profile	No Seasonality	Additive Seasonality	Multiplicative Seasonality
No Trend			
Additive Trend			
Multiplicative Trend			

Simple exponential smoothing

Like MA, except use weighted average of all past values, instead of simple average in a window

Forecast at time t+1:

$$F_{t+1} = \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + \alpha(1-\alpha)^2 Y_{t-2} + \ldots$$

Equivalent to:

$$F_{t+1} = F_t + \alpha E_t$$

Smoothing parameter *α*

Simple exponential smoother corrects based on error

- If last period forecast was too high, next period is adjusted down
- If last period forecast was too low, next period is adjusted up

Amount of correction depends on value of *α*

- Value close to 1 > fast learning, close to 0 > low learning

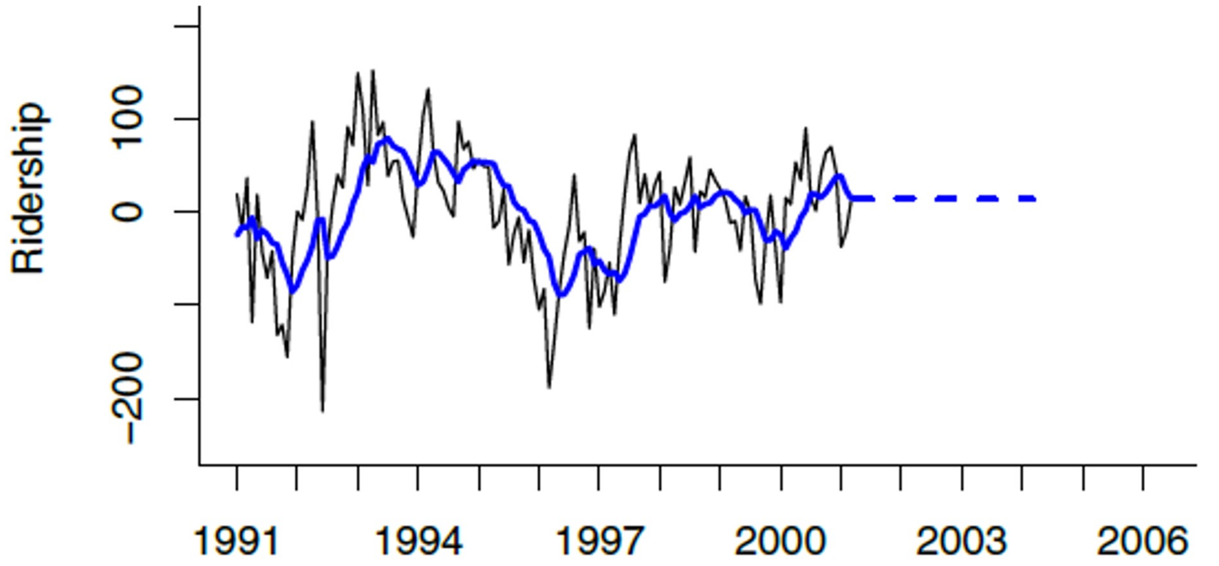
Output for simple exponential smoothing applied to residuals from regression model:

```
# get residuals
residuals.ts <- train.lm.trend.season$residuals

# run simple exponential smoothing
# use ets() with model = "ANN" (additive error (A),
# no trend (N), no seasonality (N))
# and alpha = 0.2 to fit simple exponential smoothing.

ses <- ets(residuals.ts, model = "ANN", alpha = 0.2)
ses.pred <- forecast(ses, h = nValid, level = 0)
```

y-axis is residual from regression model



Moving average and simple exponential smoothing can be used only when there is no trend or seasonality. When those features are present:

- One solution is to remove those components via regression
- Another is to use advanced exponential smoothing, which can capture trend and seasonality
- Double-exponential smoothing used for series with a trend

Double exponential smoothing

Incorporates trend

K-step ahead forecast is derived from the level (L) and trend (T) estimates at time t

Additive:

$F_{t+k} = L_t + kT_t$

Multiplicative

$F_{t+k} = L_t \times (T_t)^k$

where

$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1})$

$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$

Holt Winters exponential smoothing

- Extension of double exponential smoothing
- Incorporate both trend and seasonality

Holt Winters forecast for time t+k

Adds seasonality to double exponential

For M seasons (e.g. M=7 for weekly), forecast is

$$F_{t+k} = (L_t + kT_t)S_{t+k-M}$$

Where L = level, T = trend, S = season

Updating L, T and S

Like eq. for double exponential, except for seasonal adjustment term

$$L_t = \frac{\alpha Y_t}{S_{t-M}} + (1-\alpha)(L_{t-1} + T_{t-1}),$$

Like double exponential equation

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1},$$

Equation to update seasonal index

$$S_t = \frac{\gamma Y_t}{L_t} + (1-\gamma)S_{t-M}.$$

Holt Winters predictions:

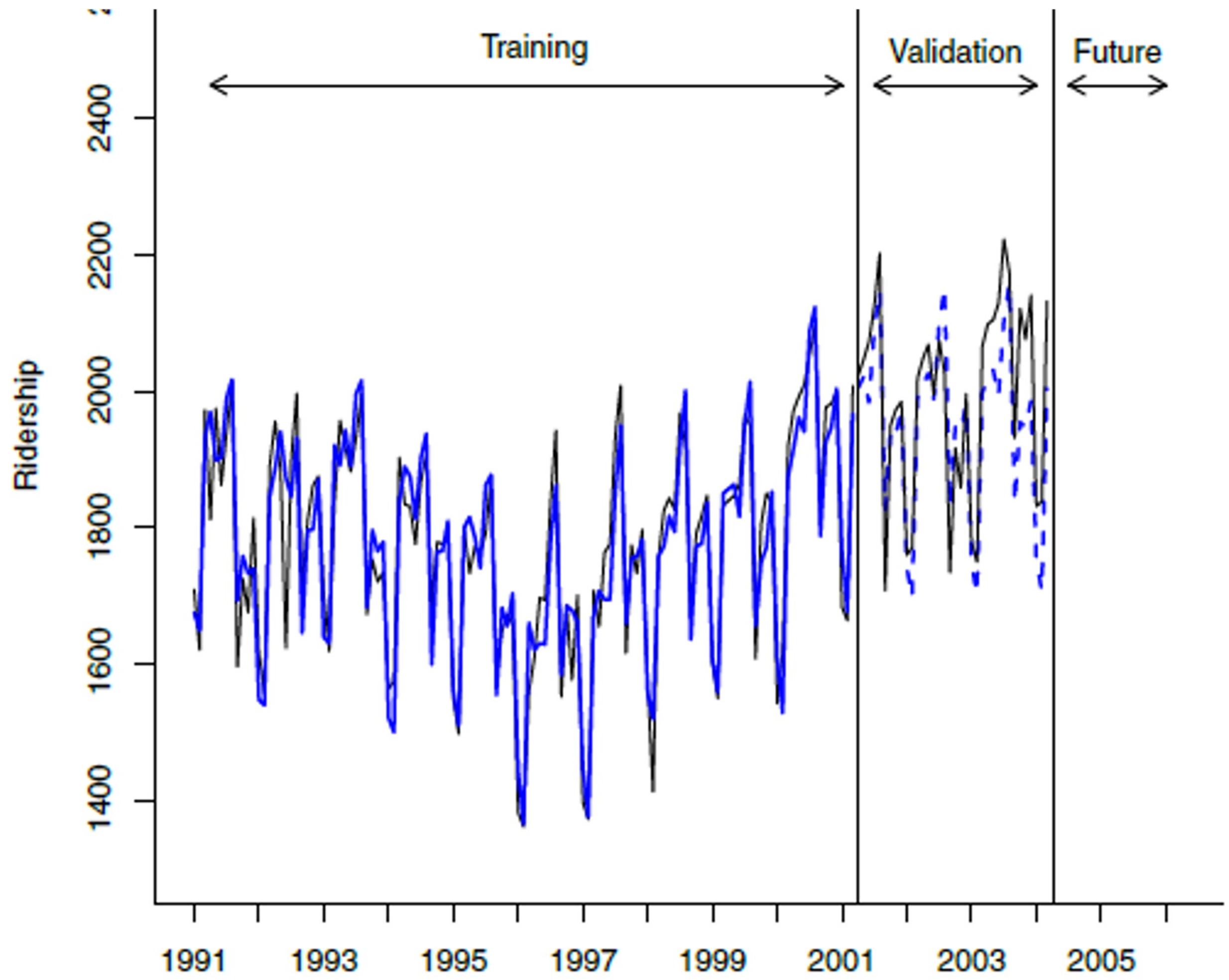
```
# run Holt-Winters exponential smoothing
# use ets() with option model = "MAA" to fit Holt-
# Winter's exponential smoothing
# with multiplicative error, additive trend, and
# additive seasonality.

hwin <- ets(train.ts, model = "MAA")

# create predictions

hwin.pred <- forecast(hwin, h = nValid, level = 0)
```

Holt-Winters Predictions

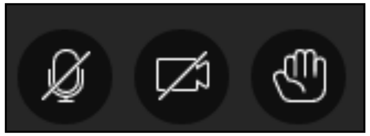


Summary

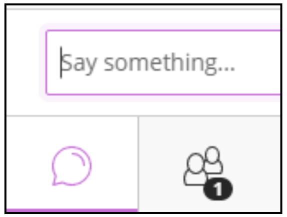
- Smoothing methods rely on local data, not mathematical structure
- Simple smoothing does not account for trend and seasonality, but can be combined with model-based forecasts to improve the forecast
- Holt-Winters smoothing incorporates seasonality and trend

Thanks for Attending

Q&A

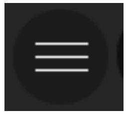


Audio questions: click on microphone button at the bottom of the screen



Text questions: enter it in the chat window

→ If you need to leave now, I would be grateful if you could complete the survey (a link is in the chat window)



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