KI Service Zentrum by Hasso-Plattner-Institut

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Time Series Forecasting

1.7 Statistical Methods I

Exponential Smoothing

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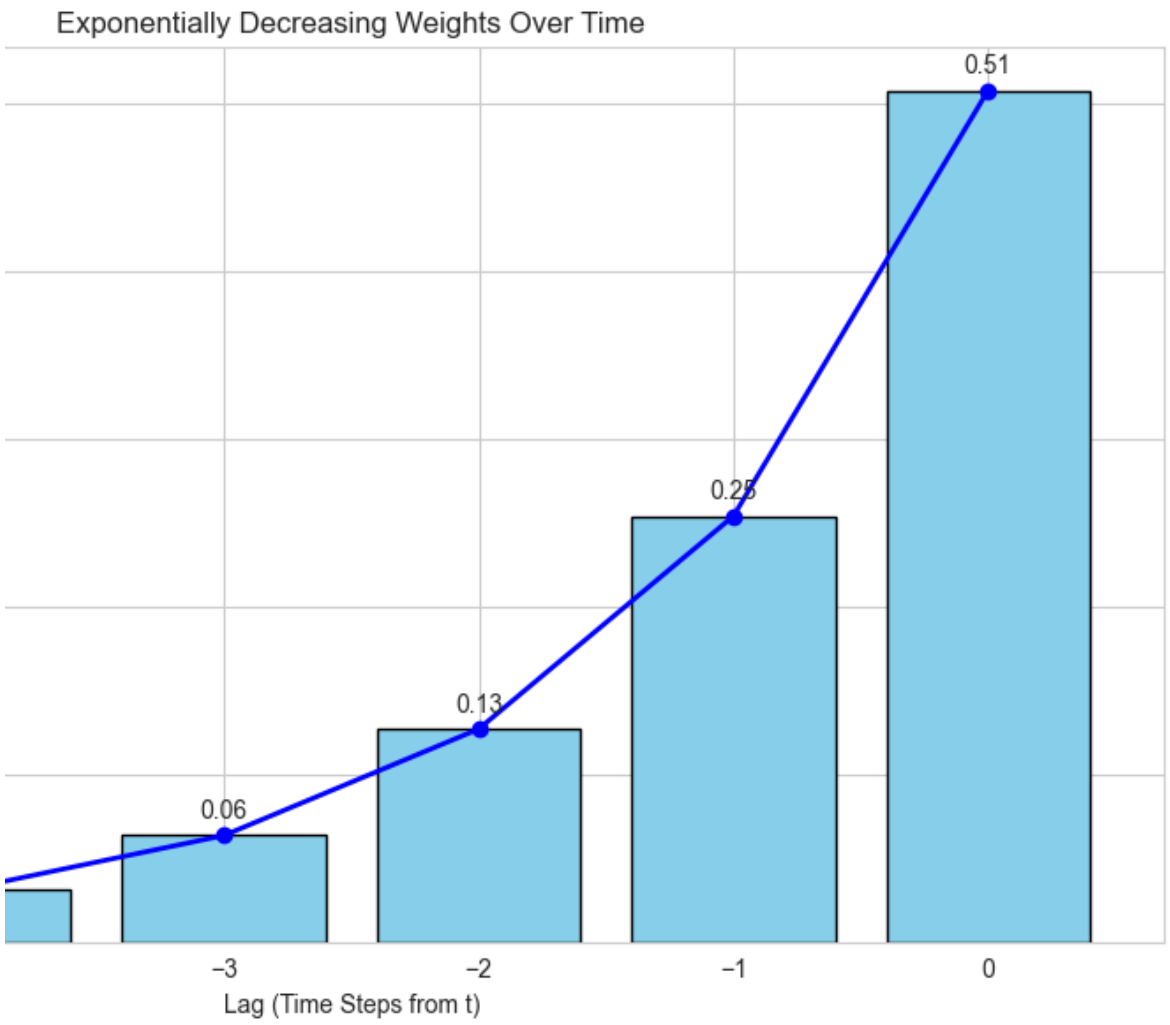
What we'll cover in this video

- What is Exponential Smoothing?
- When and Why to Use It
- Three Key Methods
  - Simple Exponential Smoothing (SES)
  - Holt's Linear Trend Method
  - Holt-Winters Method

What is Exponential Smoothing

- A time series forecasting technique that creates smooth estimates by filtering out random variation
- Places exponentially decreasing weight on older observations, giving priority to recent data
- Helps uncover the underlying signal in noisy datasets, like trends or level shifts
- A foundation for more advanced models that handle trends and seasonality



Simple Exponential Smoothing (SES)

- Best for stationary data — no trend, no seasonality
- Gives more weight to the most recent observation
- Controlled by a smoothing parameter α (alpha), where:

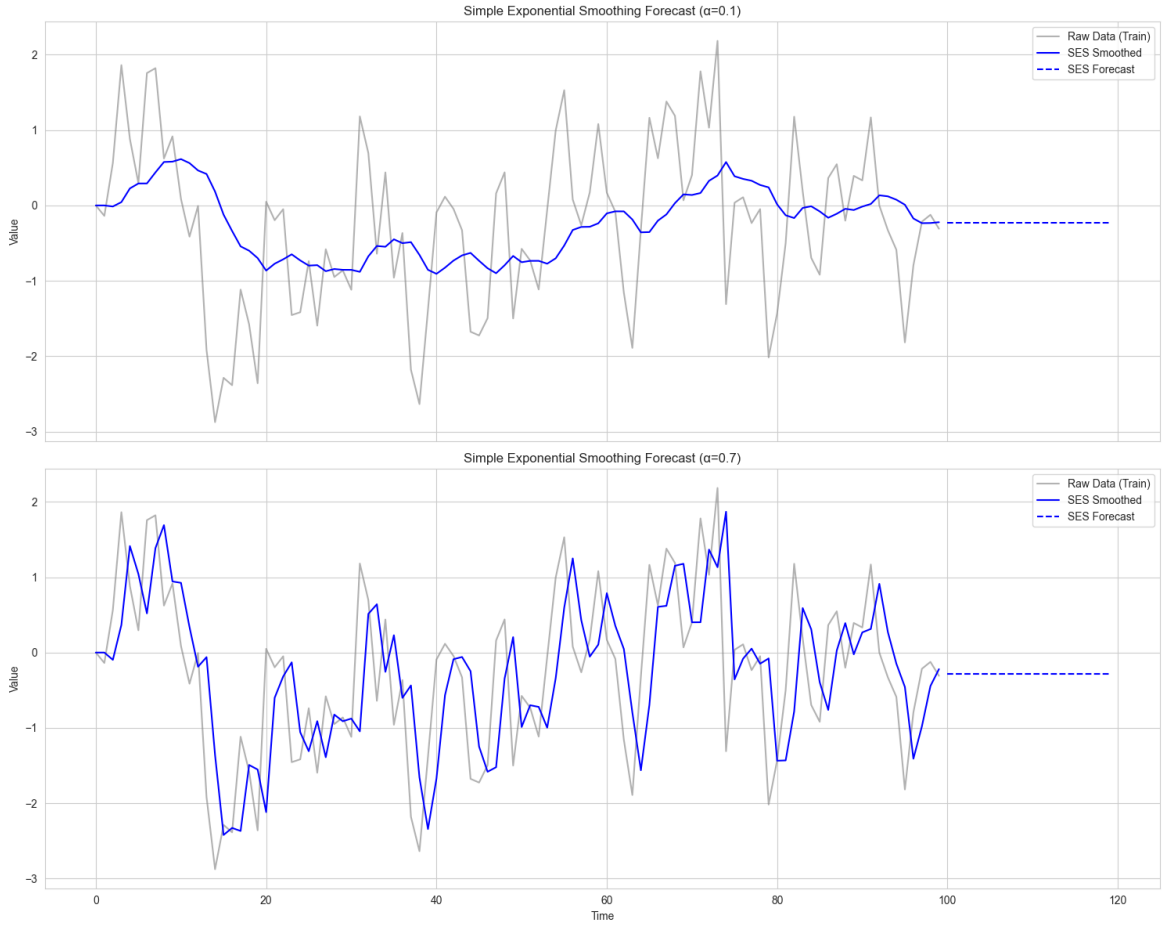
$$0 < \alpha < 1$$

- Forecasting Equation

$$f_t = \alpha\, y_{t-1} + (1-\alpha) f_{t-1}$$

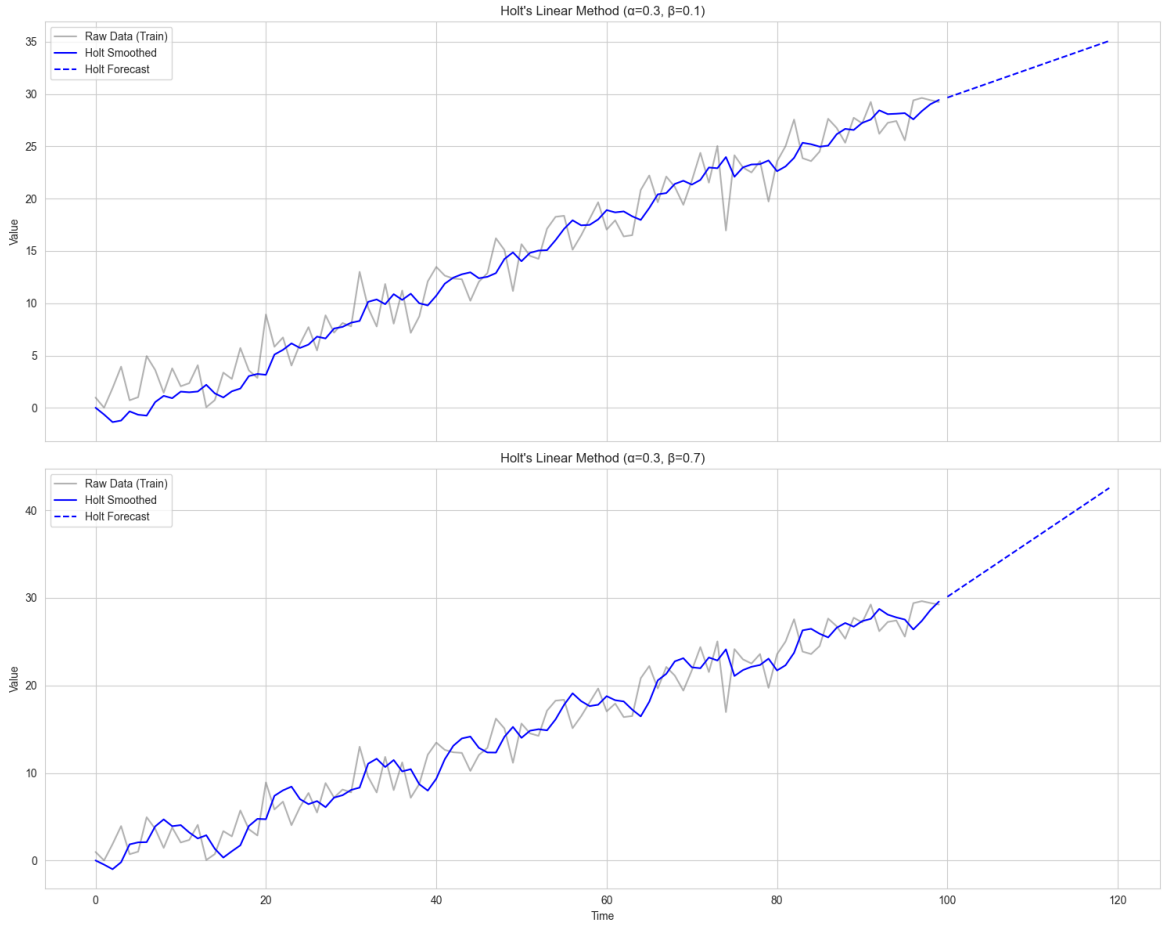
forecast = weighted average of latest actual value and previous forecast

- If $\alpha = 1$, the forecast equals the last observed value (naive forecast, no smoothing)



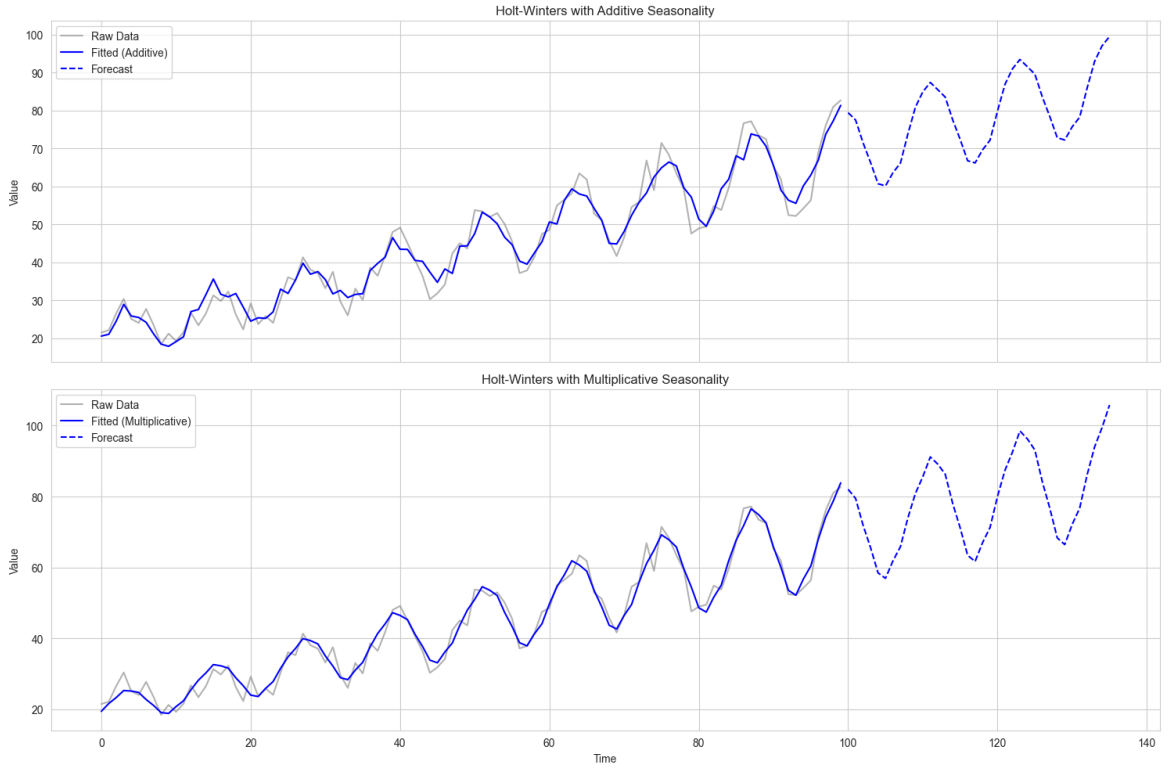
Holt’s Linear Trend Method

- Extends SES to handle linear trends
- Separates the forecast into two components:
  - **Level**: the baseline value
  - **Trend**: the rate of change over time
- Suitable for data with consistent upward or downward movement
- Equations
  - Level: $\ell_t = \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1})$
  - Trend: $b\_t = \beta(\ell_t - \ell_{t-1}) + (1-\beta)b_{t-1}$
  - Forecast: $f_{t+h} = \ell_t + h \cdot b_t$



Holt-Winters Method

- Extends Holt's method by adding seasonality
- Ideal for data with repeating patterns (e.g., months, quarters, days)
- Three components:
  - **Level** — baseline value
  - **Trend** — direction of change
  - **Seasonal** — repeating pattern
- Two Variants:
  - **Additive**: Seasonal variation stays roughly constant
  - **Multiplicative**: Seasonal variation grows or shrinks with the level



What we‘ve learnt

- Exponential Smoothing is a family of methods for time series forecasting that gives more weight to recent observations.
- SES is best for data with no trend or seasonality.
- Holt’s Method adds a trend component for data that consistently increases or decreases.
- Holt-Winters Method includes both trend and seasonality:
  - Additive: for constant seasonal effects
  - Multiplicative: for seasonal effects that change with the level