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**EM7136 Forecasting Techniques (2024-2025 Fall)**

**Final Exam Project**

**1.** Time series and ACF plots of the training data set:

Time series: ACF:

A graph with lines and numbers

Description automatically generatedA graph of a number of lines

Description automatically generated with medium confidence

**2.** Patterns: Trend and Multiplicative Seasonality

**3.** The length of seasonality: 12

**4.**

**4.1.** Smoothing parameters and initial states for Holt-Winters’ Additive Method:

* Smoothing parameters: alpha = 0.2851 beta = 1e-04 gamma = 1e-04
* Initial states: l = 23.8468 b = 0.1126

s = 3.3925 -0.7698 -0.2478 -0.5372 1.3739 0.5058 0.6965 0.4639

-0.9532 -0.8327 -1.8106 -1.2811

**4.2.** Smoothing parameters and initial states for Holt-Winters’ Multiplicative Method:

* Smoothing parameters: alpha = 0.1895 beta = 0.0777 gamma = 3e-04
* Initial states: l = 23.9559 b = 0.1234

s = 1.1159 0.9738 0.9925 0.9795 1.0474 1.0193 1.0252 1.0158 0.9648

0.9706 0.9386 0.9566

**4.3.** Decomposition plot of Additive Decomposition:

A graph of different types of additive time series

Description automatically generated with medium confidence

**4.4.** Decomposition plot of Multiplicative Decomposition:

A graph of multiple times

Description automatically generated

**4.5.** Adjusted R Square for the regression model:

* Adjusted R-squared: 0.9518

**4.6.** ANOVA table for the regression model:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Residual Std. Error** | **Degree of Freedom** | **Multiple**  **R-squared** | **F-Statistic** | **P-Value** |
| 0.7886 | 70 | 0.9593 | 127 on 13 and 70 DF | < 2.2e-16 |

**4.7.** Table of coefficients for the regression model:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Estimate** | **Std. Error** | **t value** | **Pr(>| t |)** |  |
| **Intercept** | 26.6288609815 | 0.3962951 | 67.195 | < 2e-16 | \*\*\* |
| **t** | 0.1056342519 | 0.0143689 | 7.352 | 2.84e-10 | \*\*\* |
| **tsq** | 0.0002730588 | 0.0001637 | 1.668 | 0.0998 | . |
| **D1** | -4.5398561508 | 0.4233761 | -10.723 | < 2e-16 | \*\*\* |
| **D2** | -5.0659698093 | 0.4230604 | -11.975 | < 2e-16 | \*\*\* |
| **D3** | -4.1497724424 | 0.4227787 | -9.815 | 8.62e-15 | \*\*\* |
| **D4** | -4.2912640502 | 0.4225282 | -10.156 | 2.09e-15 | \*\*\* |
| **D5** | -2.9333017755 | 0.4223066 | -6.946 | 1.57e-09 | \*\*\* |
| **D6** | -2.7330284755 | 0.4221124 | -6.475 | 1.12e-08 | \*\*\* |
| **D7** | -2.7904441501 | 0.4219449 | -6.613 | 6.28e-09 | \*\*\* |
| **D8** | -2.0484059422 | 0.4218041 | -4.856 | 7.03e-06 | \*\*\* |
| **D9** | -3.9354852804 | 0.4216908 | -9.333 | 6.51e-14 | \*\*\* |
| **D10** | -3.6088250218 | 0.4216066 | -8.560 | 1.70e-12 | \*\*\* |
| **D11** | -4.1684251664 | 0.4215537 | -9.888 | 6.36e-15 | \*\*\* |

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

**5.** Forecasts:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***h*-month ahead forecasts** | **Method** | | | | |
| Holt-Winters’ Additive | Holt-Winters’ Multiplicative | Additive Decomposition | Multiplicative Decomposition | Regression |
| 1 | 32.53498 | 32.59782 | 32.53513 | 32.09545 | 33.04077 |
| 2 | 32.11816 | 32.16675 | 32.08701 | 31.57959 | 32.66698 |
| 3 | 33.20878 | 33.45512 | 33.24932 | 32.88234 | 33.73605 |
| 4 | 33.20101 | 33.44198 | 33.15120 | 32.83458 | 33.74798 |
| 5 | 34.73084 | 35.40977 | 34.76559 | 34.63825 | 35.25991 |
| 6 | 35.07620 | 35.93608 | 35.12441 | 35.03582 | 35.61469 |
| 7 | 34.99839 | 35.93050 | 35.00199 | 34.97079 | 35.71233 |
| 8 | 35.97918 | 37.12358 | 35.81291 | 35.91325 | 36.60998 |
| 9 | 34.18077 | 34.90810 | 34.44118 | 34.19414 | 34.87905 |
| 10 | 34.58297 | 35.56738 | 34.61598 | 34.40647 | 35.36240 |
| 11 | 34.17373 | 35.08485 | 34.25051 | 33.90802 | 34.96005 |
| 12 | 38.44874 | 40.42478 | 38.50517 | 39.14311 | 39.28626 |

**6.** Forecast accuracy:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Error measures calculated on the test set** | | | **Suggested method (X)** |
| **Method** | **RMSE** | **MAE** | **MAPE** |
| Holt-Winters’ Additive | 2.200817 | 2.019479 | 6.322902 |  |
| Holt-Winters’ Multiplicative | 2.930234 | 2.753893 | 8.523486 |  |
| Additive Decomposition | 2.220343 | 2.045033 | 6.4008 |  |
| Multiplicative Decomposition | 2.060765 | 1.883484 | 5.855402 | **X** |
| Regression | 2.798223 | 2.656369 | 8.283659 |  |