COURSE SPECIFICATION DOCUMENT

Academic School/Department:	Science, Innovation & Technology
Programme:	Mathematics and Data Science
***FHEQ* Level:**	6
Course Title:	Time Series Analysis and Forecasting
Course Code:	MATH 6103
Total Hours	160
Timetabled Hours:	45
Guided Learning Hours:	15
Independent Learning Hours:	100
Credits:	16 UK CATS credits 8 ECTS credits 4 US credits

Course Description:

This course introduces students to the fundamentals and advanced techniques of time series analysis and forecasting. Students will learn how to model, analyze, and forecast time-dependent data using both statistical and machine learning approaches. The course will cover classical time series models such as ARIMA, exponential smoothing, and state-space models, as well as more advanced techniques including neural networks and Long Short-Term Memory (LSTM) models. The emphasis will be on practical applications in various fields, including finance, economics, and environmental sciences, using real-world datasets and computational tools like Python and R.

Prerequisites:

70 credits, MATH 4101 Probability and Statistics.

Aims and Objectives:

Aims:

- To provide students with a deep understanding of time series data and the challenges of analysing time-dependent data.
- To equip students with the tools and techniques necessary for forecasting and analysing time series using statistical and machine learning models.
- To develop students' ability to critically evaluate time series models and apply them to real-world forecasting problems.
- To enhance students' proficiency in using software tools for implementing time series analysis and forecasting.

Objectives:

- Teach students to differentiate between various time series models and understand their appropriate applications.
- Develop skills to pre-process time series data, detect patterns, and select suitable models for analysis.
- Enable students to assess the performance of forecasting models and interpret the results in practical contexts.
- Provide practical experience with tools and libraries used for time series analysis, including Python (statsmodels, pandas) and R (forecast, tseries).

Programme Outcomes

L6 AI, AII, BIII, CII, DIII

A detailed list of the programme outcomes is found in the Programme Specification. This is maintained by Registry and located at:

https://www.richmond.ac.uk/programme-and-course-specifications/

Learning Outcomes:

By the end of this course, students will be able to:

1. Understand the characteristics of time series data and identify key components such as trend, seasonality, and noise.
2. Implement advanced forecasting techniques, such as state-space models and machine learning models like LSTMs.
3. Evaluate and compare the performance of different forecasting models using appropriate error metrics (e.g., MAE, RMSE, MAPE).
4. Use Python and R to manipulate time series data, develop forecasting models, and visualize the results.
5. Identify and address challenges such as non-stationarity, seasonality, and autocorrelation in time series data.
6. Analyse the limitations and assumptions of different time series techniques and make informed choices when building models.

Indicative Content:

- Overview of time series data and its applications.
  Components of time series: trend, seasonality, cyclicality, and noise.
- Time Series Decomposition
  Additive and multiplicative models.
- Stationarity and Data Transformations
  Concept of stationarity in time series.
- Autocorrelation and Partial Autocorrelation
  Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF).
- ARIMA Models
  Introduction to Autoregressive Integrated Moving Average (ARIMA)and Seasonal ARIMA (SARIMA)
- Exponential Smoothing Methods
  Simple Exponential Smoothing (SES).
- State-Space Models and Kalman Filters
  Introduction to state-space models.
- Machine Learning for Time Series Forecasting
  Overview of machine learning approaches for time series.
- Advanced Neural Networks and LSTMs
  Introduction to Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM) networks.
- Model Evaluation and Selection
  Model diagnostics and residual analysis.
- Handling Anomalies and Missing Data in Time Series
  Practical approaches to clean and pre-process time series data.
- Multivariate Time Series Analysis
  Introduction to multivariate time series.
- Real-World Applications and Project Presentations
  Case studies of time series forecasting in finance, retail, climate science, etc.
  Ethical considerations in time series forecasting (bias, fairness).

Assessment:

This course conforms to the University Assessment Norms approved at Academic Board and located at: https://www.richmond.ac.uk/university-policies/

Teaching Methodology:

This course will be delivered face to face through a combination of lectures and interactive sessions. In addition to classroom activities, there are guided learning elements that are tutor led and arranged through Blackboard. These activities can be asynchronous online sessions, flipped classrooms, set readings with discussion boards or set guest lectures for example. Set activities are monitored by the instructor to ascertain student engagement. Students are encouraged to prepare for class and to play an active part, to raise questions, following-up ideas and interact with a wide range of provided material.

Indicative Text(s)

Box, G.E. P., Jenkins, G. M., Reinsel, G. C., and Ljung, G. M. (2015) *Time Series Analysis: Forecasting and Control.* 5th edn. Hoboken, New Jersey: Wiley.

Chatfield, C. and Xing, H. (2019) *The Analysis of Time Series: An Introduction with R*. 7th edn. New York: CRC Press.

Hamilton, J. D. (2022**)** *Time Series Analysis*. USA: Princeton University Press.

Hyndman, R. J., and Athanasopoulos, G. (2018). *Forecasting: Principles and Practice.* 2nd edn. Australia: OTexts. Available at: https://otexts.com/fpp2/ (Accessed: November 2014).

Journals and Articles:

Journal of Time Series Analysis: A leading journal covering the latest research in time series analysis.

Statistics: A Journal of Theoretical and Applied Statistics. Available at: Statistics: A Journal of Theoretical and Applied Statistics (Accessed: November 2014).

Statistical methods and applications. Available at: Statistical methods and applications (Accessed: November 2014).

Journal of Computational and Graphical Statistics: Focuses on computational techniques and methodologies applied in data science.

Online Resources:

Forecasting: Principles and Practice (Hyndman & Athanasopoulos)
Online Textbook.

Statsmodels Documentation (Python Library for Time Series Analysis). Available at: https://www.statsmodels.org/stable/tsa.html (Accessed: November 2024).

Kaggle – Time Series Analysis Datasets and Competitions. Available at: https://www.kaggle.com/datasets/shenba/time-series-datasets (Accessed: November 2024).

R Forecast Package Documentation. Available at: https://www.rdocumentation.org/packages/forecast/versions/8.23.0 (Accessed: November 2024).

See syllabus for complete reading list.

Change Log for this CSD:

Nature of Change	Date Approved & Approval Body (School or LTPC)	Change Actioned by Academic Registry
First Edition	November 2024	