In the name of God

Fuzzy Sets and Systems course

Project 1:

Fuzzy Time Series Forecasting Assignment

Fall 2025

Fuzzy Time Series Forecasting Assignment

Assignment Overview

In this assignment, you will implement and analyze a Fuzzy Time Series (FTS) forecasting model using both First-Order FTS (FOFTS) and High-Order FTS (HOFTS). You will work with two different datasets to understand how fuzzy logic can be applied to forecasting problems and evaluate the model's performance under different conditions. This assignment will give you hands-on experience with fuzzy logic systems, time series forecasting, and experimental analysis of these models. The focus is on both theoretical understanding and practical implementation skills.

Theoretical Background

Fuzzy Time Series (FTS)

Fuzzy Time Series is a forecasting method that uses fuzzy set theory to handle linguistic uncertainty in time series data. Unlike traditional statistical methods, FTS models can work with vague, imprecise data and provide interpretable rules.

High-Order FTS (HOFTS)

The key innovation in HOFTS is the use of multiple previous time steps to predict the next value. While first-order FTS uses only the immediate previous value ($F(t-1) \rightarrow F(t)$), high-order models use a sequence of previous values ($F(t-k), F(t-k+1), ..., F(t-1) \rightarrow F(t)$). This allows the model to capture more complex temporal patterns.

Model Components

1. **Universe of Discourse**: The range of possible values for the time series
2. **Fuzzy Sets**: Linguistic variables that partition the universe (e.g., "Low", "Medium", "High")
3. **Membership Functions**: Define how crisp values belong to fuzzy sets (triangular, trapezoidal or gaussian)
4. **FLRGs**: Derive Fuzzy Logical Rule Groups
5. **Defuzzification**: Converting fuzzy outputs back to crisp predictions

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Implementation Details

Core Algorithm Steps

1. **Data Preprocessing**
   - Load and prepare time series data
   - Split into training and testing sets (80% train, 20% test)

2. **Fuzzy Set Creation**

- Define universe of discourse
- Choose a partitioning strategy
- Choose a membership function type (triangular, trapezoidal, Gaussian, bell-shaped, etc.)

3. **Fuzzification**
   - Convert crisp values to fuzzy set memberships
   - For each value, find the fuzzy set with maximum membership
4. **FLRG Generation**
   - Create relations from historical patterns: $(t-1) \rightarrow (t)$
   - Build First Order relations (order = 1)
   - Build Higher Order relations (order ≥ 2)
5. **Forecasting**

Assignment Tasks

Dataset 1: Mackey-Glass Time Series

- **Characteristics**: Chaotic, non-linear, widely used in forecasting benchmarks
- **Task**: Predict future values using historical patterns

Dataset 2: Number of specimens-Influenza A-Influenza B cases

- **Task**: Forecast total number of specimens, those detected with influenza Type A and number of those detected with influenza Type B

Experimental Procedure

1. **Parameter Tuning**: Conduct systematic experiments with order and number of partitions
2. **Performance Metrics**: For each configuration, calculate:
   - **RMSE** (Root Mean Square Error)
   - **MAE** (Mean Absolute Error)
   - **MAPE** (Mean Absolute Percentage Error)

Report Requirements

Your report must be clear, well-structured, and sufficiently detailed so that others could reproduce your FTS model based solely on your documentation. The report should include the following sections:

Executive Summary

- Brief overview of findings and best configurations

Methodology

- Explain your partitioning strategy and the type of membership function you chose and why you chose it.

- Explain the process of membership function creation in details.
- FLRG generation process.
- FLRGs

Results & Analysis

Performance Analysis

1. **Best Configuration Analysis**
2. **Performance Metrics**
3. **Comparison between First Order and Higher Order**

Deliverables

1. **Complete Source Code**
2. **Comprehensive Report** including all sections above
3. **Visualizations**:
   - Time series plots with predictions
   - Error metrics across parameter space
   - Devise an interface that user enters ***n*** **historical data** and get the **next predicted** data.

Appendix Requirements

A. Best Model Configurations for each dataset

B. Final FLRGs

C. Plots of membership functions (fuzzy sets) for each dataset

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Upload file format

Create a zip file containing all the necessary deliverables. The name of the zip file should be according to the following format. (Firstname_Lastname_StdNumber.zip)

Note: DO NOT use any pre-implemented fuzzy time-series libraries; you must implement all methods from scratch.