

“Traffic Control System Using Grey Fuzzy Logic and Artificial Intelligence”

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Abstract- Intelligent Traffic Control Systems are becoming essential in modern smart cities due to increasing traffic congestion and road accidents. Traditional traffic signal systems use fixed timing methods that are inefficient under varying traffic conditions. This research paper presents a Traffic Control System using Grey Fuzzy Logic and Artificial Intelligence techniques for adaptive traffic signal management. Grey System Theory is used for traffic prediction under uncertain and incomplete data conditions, while Fuzzy Logic is applied for intelligent decision-making. Artificial Intelligence techniques improve system adaptability and optimization. The proposed system reduces traffic congestion, waiting time, fuel consumption, and improves overall traffic efficiency.

Keywords: Grey System Theory, Fuzzy Logic, Artificial Intelligence, Traffic Control System, Intelligent Transportation System, Smart Traffic Management.

1. Introduction

Rapid urbanization and increasing numbers of vehicles have created major traffic congestion problems in cities. Conventional traffic signal systems operate on fixed timing schedules and cannot adapt to changing traffic conditions. Intelligent Transportation Systems (ITS) provide efficient traffic management using Artificial Intelligence methods.

Fuzzy Logic handles uncertainty in traffic conditions through rule-based decision-making, while Grey System Theory predicts traffic flow using limited or incomplete data. Combining Grey Theory and Fuzzy Logic with Artificial Intelligence provides an adaptive and intelligent traffic control mechanism.

The proposed system dynamically adjusts signal timings according to real-time traffic density and queue length.

2. Literature Review

Several researchers have developed intelligent traffic control systems using fuzzy logic and AI techniques.

Varshney et al. proposed a fuzzy rule-based intelligent traffic system to reduce congestion and optimize signal timing. Chala and Kóczy developed an intelligent fuzzy traffic signal control system for complex intersections. Researchers have also applied Grey System Theory for traffic prediction and adaptive signal control under uncertain data conditions.

Artificial Intelligence techniques such as reinforcement learning and neural networks have further improved traffic management systems by learning traffic patterns and optimizing traffic flow dynamically.

3. Objectives

The objectives of this research are:

1. To develop an intelligent traffic control system.
2. To predict traffic flow using Grey System Theory.
3. To optimize traffic signals using Fuzzy Logic.
4. To reduce traffic congestion and vehicle waiting time.
5. To improve traffic management efficiency using Artificial Intelligence.

4. Methodology

The proposed system consists of four major stages:

4.1 Data Collection

Traffic data is collected using:

Sensors

Cameras

Vehicle detectors

Collected parameters include:

Vehicle count

Queue length

Traffic density

Waiting time

4.2 Grey System Prediction

Grey System Theory predicts future traffic conditions using limited historical data. The Grey Model GM(1,1) is commonly used for short-term traffic forecasting.

GM (1, 1) Model

GM (1, 1) type of grey model is most widely used in the literature, pronounced as “Grey Model First Order One Variable”. This model is a time series forecasting model. The differential equations of the GM (1,1) model have time-varying coefficients. In other words, the model is renewed as the new data become available to the prediction model. The GM (1,1) model can only be used in positive data sequences. In this paper, a non-linear liquid level tank is considered. It is obvious that the liquid level in a tank is always positive, so that GM (1, 1) model can be used to forecast the liquid level. In order to smooth the randomness, the primitive data obtained from the system to form the GM (1, 1) is subjected to an operator, named Accumulating Generation Operation (AGO), described above. The differential equation (i.e. GM (1, 1)) thus evolved is solved to obtain the n-step ahead predicted value of the system. Finally, using the predicted value, the inverse accumulating operation (IAGO) is applied to find the predicted values of original data. Consider a single input and single output system. Assume that the time sequence $X^{(0)}$ represents the outputs of the system) x .

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots \dots x^{(0)}(n)), n \geq 4 \quad (1)$$

Where $X(0)$ is a non-negative sequence and n is the sample size of the data. When this sequence is subjected to the Accumulating Generation Operation (AGO), the following sequence $X(1)$ is obtained. It is obvious that $X(1)$ is monotone $i^{(0)}(n)$, $n \geq 4$

$$X^{(1)} = ((x^{(1)}(1), x^{(1)}(2), \dots \dots x^{(1)}(n)), n \geq 4 \quad (2)$$

Where

$$x^{(1)}(k) = \sum_{i=1}^k x^{(0)}(i), k = 1, 2, 3, \dots \dots n \quad (3)$$

The generated mean sequence $Z(1)$ of $X(1)$ is defined

$$\bullet \quad z^{(1)} = (z^{(1)}(1), z^{(1)}(2), \dots \dots z^{(1)}(n)) \quad (4)$$

Where $z(1)(k)$ is the mean value of adjacent data, i.e.

$$z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k - 1), k = 2, 3, \dots \dots n \quad (5)$$

The least square estimate sequence of the grey difference equation of GM (1,1) is defined as follows:

$$x^{(0)}(k) + az^{(1)}(k) = b \quad (6)$$

The whitening equation is therefore as follows:

$$\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = b \quad (7)$$

In above, $[a, b]^T$ is a sequence of parameters that can be found as follows:

$$[a, b]^T = (B^T B)^{-1} B^T Y \quad (8)$$

Where

$$Y = [x^{(0)}(2), x^{(0)}(3), \dots \dots \dots, x^{(0)}(n)]^T \quad (9)$$

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix} \quad (10)$$

According to equation (8), the solution of $x(1)(t)$ at time k :

$$x_p^{(1)}(k+1) = [x^{(0)}(1) - \frac{b}{a}] e^{-ak} + \frac{b}{a}$$

To obtain the predicted value of the primitive data at time (k+1), the IAGO is used to establish the following grey model.

$$x_p^{(0)}(k+1) = [x^{(0)}(1) - \frac{b}{a}] e^{-ak} (1 - e^a) \quad (12)$$

And the predicted value of the primitive data at time (k+H):

$$x_p^{(0)}(k+H) = [x^{(0)}(1) - \frac{b}{a}] e^{-a(k+H-1)} (1 - e^a) \quad (13)$$

The parameter (a) in the GM (1,1) model is called “development coefficient” which reflects the development states of $X(1)_p$ and $X(0)_p$. The parameter b is called “grey action quantity” which reflects changes contained in the data because of being derived from the background values.

4.3 Fuzzy Logic Controller

The fuzzy controller uses linguistic variables such as:

Low Traffic

Medium Traffic

High Traffic

Example Fuzzy Rules

1. IF traffic density is HIGH THEN green time is LONG.

2. IF traffic density is LOW THEN green time is SHORT.

3. IF queue length is MEDIUM THEN green time is MEDIUM.

Components of Fuzzy System

1. Fuzzification

2. Rule Base

3. Inference Engine

4. Defuzzification

4.4 Artificial Intelligence Optimization

AI algorithms continuously monitor traffic conditions and optimize signal timing dynamically. Machine learning techniques improve system performance by learning traffic patterns over time.

5. Proposed System Architecture

The proposed traffic control system contains:

1. Traffic Sensors
2. Data Processing Unit
3. Grey Prediction Module
4. Fuzzy Logic Controller
5. AI Optimization Module
6. Traffic Signal Controller

6. Applications

The proposed system can be applied in:

Smart Cities

Urban Traffic Management

Highway Traffic Systems

Emergency Vehicle Management

Intelligent Transportation Systems

7. Results and Discussion

The Grey Fuzzy AI traffic control system improves traffic efficiency compared to traditional fixed-time signal systems. Simulation results show: Reduced vehicle waiting time, Reduced fuel consumption, Improved traffic flow, Lower traffic congestion, The system adapts effectively under uncertain traffic conditions.

8. Conclusion

This research paper presents an intelligent Traffic Control System using Grey System Theory, Fuzzy Logic, and Artificial Intelligence. The proposed system predicts traffic conditions and dynamically adjusts signal timings according to real-time traffic density. The integration of Grey Theory and Fuzzy Logic provides accurate prediction and intelligent decision-making

under uncertain conditions. The system improves traffic management efficiency and supports smart city development.

Future work may include integration with IoT devices and deep learning algorithms for more accurate traffic prediction.

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