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Soft Computing Approaches in Traffic Control Systems: A Review

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Abstract

Handling congestion in urban traffic through next generation artificial intelligence techniques is an important research area. Various models and approaches have been developed using soft computing techniques to tackle with this problem. Major soft computing approaches for this purpose are Fuzzy Approaches, Neural Network and Genetic Algorithms, Petri Nets and many more. Also, multi-agent systems are highly applicable in this approach. This paper is an effort towards revisiting such approaches in developing modern traffic control systems.

Keywords: Fuzzy Logic, Multi-agent Systems, Urban Traffic Control System.

1. Introduction

Many urban traffic control systems to deal with the congestion at the intersection in urban traffic have been developed. The major requirements of the developed system are, the signal must not allow the ambiguous movement to the traffic and it must be transparent that how/when the representation of signal shown to be changed. Two other aspects to be handled are to take decisions about signal indication sequence in the control system to make the system well optimized and development of control logic for signal generation.

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This paper has been divided into 6 sections. Section 2 revisits the fuzzy techniques in the development of traffic control systems. Various simulation based approaches are revised in section 3 and different cognitive/learning approaches are discussed in section 4. Section 5 consists of other approaches.

2. Approaches based on Fuzzy Techniques

Traffic signal control system is not efficient controlling congestion in urban areas. A model based multi agent fuzzy system with three levels of control is proposed in [1].To control traffic at an intersection; parameters used are intensity of traffic, recommendations from near about intersections and a knowledge repository which gives information about data at any particular time. A traffic observer is used to deliver data to data management component according to which the decision making layer makes the decision.

A two stage fuzzy clustering algorithm can be used by the prediction module to predict the effect of most intersections on a specific intersection as shown in [2]

Type 2 fuzzy logic based multi-agent integrated architecture having distributed type nature has been proposed in [3] for reducing the traffic congestion in urban areas. PARAMICS simulator has been used.

Dynamic nature of the traffic in urban areas has caused heavy congestion in urban areas. A signal control system using multi agents is proposed in [4] with an aim to reduce the congestion.

Urban traffic is difficult to control because of its dynamic nature with vehicle types, speeds, length, flow rates etc. An Adaptive fuzzy algorithm is proposed which is integrated with multi agent approach as shown in [5]

A multi-agent system using geometric fuzzy system is proposed in [6]. GFMAS efficiently handles dynamicity and outperforms other traffic control algorithms such as GLIDE and HMS.

A fuzzy neural network based traffic control system is designed in [7] wherein a coordination system is used. Each junction and coordination is treated as agents. Particle swarm optimization is used to optimize the queue length.

To handle congestion in urban traffic an Intersection Agent (AI) hardware platform is developed in [8], An intersection agent is designed for coordination which uses fuzzy control strategies. Thus, a multi agent coordination algorithm is developed.

3. Simulation based approaches

Computer traffic simulation can be used to understand traffic flow and develop traffic control strategies.

In [9] traffic simulation with microscopic vision is designed which follows the concept of multi-agent systems. The whole concept is implemented in MS C++.

A multi agent based simulation approach is proposed in [10]. This approach uses Object- Z and state chart formal languages.

Past historical real world data and dynamic simulated data can be used to forecast traffic. Based on this an online simulation framework is proposed in [11] which integrates real traffic data along with multi-agent approach.

To control simulated vehicles, reactive agents can be used. Using microscopic traffic simulator, an approach is developed in [12] wherein vehicles are controlled by driving agents with different behaviour settings.

In [13] a multi agent based simulation tool is developed which includes the factors, such as opportunistic behaviour of an individual causing norm violations and anticipation of critical situations by individuals.

An approach named HUTSIG is derived from a microscopic traffic simulator HUTSIM in [14]. It is based on fuzzy inferences using multi agents and simulating real traffic data.

Queue models can be used for simulating traffic agents such as travellers and traffic signals as proposed in [15].

Traffic signal control can be made efficient by utilizing the signal phase transition time. In [16] a multi agent based simulation model is designed using Repast S on java platform. Its used to enhance the system capacity at the intersections.

Simulating driver's behaviour is difficult because of its uncertainty. A simulation model named DRACULA is proposed in [17] which integrates reasoning capabilities with multi agent based approaches to simulate the driver's behaviour.

4. Cognitive / Learning based approaches

For minimizing the waiting time of the commuters in the queues, signals of the adjacent intersections are coordinated. In [18] multi agent coordination is done using RMM (recursive modelling method). To update the knowledge base and selecting the correct model for other agents, Bayesian learning is used along with.

For adapting the changing network conditions an urban traffic control system is designed in [19]. Multi agent based approach integrated with fusion technology is proposed. Reinforcement learning is used for coordination of traffic signal control network.

Pre-timed controllers cannot adapt to the dynamic changes in traffic flow. Agents need to communicate directly to learn the system behaviour. Machine learning algorithms can be used by agents to learn the traffic control policy as proposed in [20].

A multi agent traffic handling method which is based on reinforcement learning is proposed in [21] to adapt the dynamicity of traffic flow.

In [22] traffic signal control problem is solved by designing a hierarchical multi agent system where multi stage online learning process is implemented. Agent learning is based on reinforcement learning, learning rate and weight adjustment and fuzzy relation updates.

A decentralized strategy is proposed in [24] wherein individual agents are responsible for each intersection. Sensors are placed at each intersection to gather information and decisions are influenced by opinions of other agents.

Urban areas require their traffic signal controllers to adapt according to the traffic situations. In [25] a Q-Learning based approach is proposed wherein the average queue length is used as estimation parameter by the controller agents. Results show better performance as compared to fixed time controllers.

An approach supporting coordination between neighbouring intersections and supporting Q- Learning is proposed in [26]. This approach gives an optimal control policy for multi- intersections environment and also reduces the average delay time.

A distributed control approach for controlling traffic is used where for every intersection a local agent acts as the traffic signal controller. Based on this two models are proposed in [27]. In first model, agents update their knowledge using multistage online learning process and accordingly take decisions. Second model uses perturbation stochastic approximation theorem with fuzzy neural networks. PARAMICS simulation program is used proving the efficiency of proposed models.

Online reinforcement learning can be used by multi agents for computing the green time. In [28] sensors are used at each intersection to compute green time on the basis of historic traffic patterns and information from agents of adjacent intersections. Proposed approach results in reduced mean time delay.

In [29] Green Light District (GLD) vehicle traffic simulator is used adding reinforcement learning like cooperation among the adjacent agent controllers. This results in minimized time, reduced rate of accidents and maintaining threshold speed for lowest fuel consumption.

5. Other approaches

To solve the congestion problem, coordination among the control strategies is required. An approach named Intelligent Traffic Control System (ITCS) is proposed in [30]. It is based on coordinated-agents that help managing the current traffic flow. Upon occurrence of any incident, each affected agent interacts with each other to take an optimal control action.

Urban Traffic Control (UTC) system can be made effective by use of autonomous intelligent agents. In [31] a UTC system is designed and it has signal and authority agent making it adaptable to real time traffic conditions.

For the overall network performance improvement, global information about whole network is required. For this a higher level agent is appointed as shown in [32] which communicates with the decentralized traffic light controlling agents.

Traffic operators need to take the best control measure corresponding to the prevailing traffic situation. For this, they need to predict the possible outcomes of these control measures. A multi agent based simulation approach is proposed in [33] which allows on line, real time evaluation of the traffic situation.

To resolve the disturbances in the transportation system, a multi agent based regulation process is proposed in [34]. It also uses evolutionary algorithms to optimize this regulation process.

802.11p is standard for wireless access tin vehicular environments (WAVE) which allows communication among cars and other roadside systems. An agent based simulator is proposed in [35] that can simulate communication between cars.

In [36] a multi agent based system is proposed for urban traffic management. It consists of following types of agents: segment, crossing, section and central decision agent which share information for a group decision to make an efficient traffic management system.

As per the demands of the traffic environment mobile agent technology can be used. [37]shows how these mobile agents can be reconfigured according to required traffic conditions.

In [38] multi agent technology is used along with genetic algorithms to improve the urban traffic control system. It involves optimization of the timing schemes at traffic intersections.

A hierarchical multi-agent architecture is proposed in [39] where each agent is responsible for any one task such as collection of data, pre-processing of data and decision making. A policy based management model is proposed to develop an intelligent algorithm for coordination among the agents. It aims at reducing the average size of the queue, average waiting time and travelling time.

6. Conclusion and Future Scope

Fuzzy Logic, Multi Agent Systems, various learning/cognitive approaches are utilized to develop modern traffic control system for handling the congestion by traffic overflow. This paper reviews the approaches developed in this context.

In future, the authors would be interested towards the development of urban traffic control system using satellite and global positioning based systems.

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