A Control Method of Traffic Flow Based on Region Coordination

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Abstract. Urban traffic system is a complex and time-varying nonlinear system. Control of traffic flow requires the use of intelligent control technology. This paper researches a coordinated control method of regional traffic flow based on Multi-Agent technology. This paper also researches the framework of the control system of the Multi-Agent regional traffic flow, Agent architecture, and optimization and coordination method among Agents. By comparing with the real-time control system of traditional urban traffic flows, this system has the following advantages: the system is collective intelligence through all kinds of traffic Agents integrated together and finishes the task of traffic flow control making full use of their respective advantages.

Introduction

Urban traffic is a road network composed of a large number of roads and crossroads, which constitutes a typical regional system. Regional system consists of a limited number of interconnected subsystems, which can be called region. When the traffic flow is managed and controlled, the traffic flow in the region is required to be smooth. Countries around the world have attached great importance to the increasingly serious traffic problems, and a lot of manpower and material resources have been applied to research for the management of road transportation systems and control technology. And there are a wide variety of traffic control methods and systems, which play a huge role in alleviating traffic congestion. Mature and extensive application of computer technology has promoted the development of artificial intelligence technology, and the artificial intelligence technology has good nonlinear approximation capability and does not rely on precise mathematical model to coincide with the broad framework of intelligent transportation systems. Therefore, it has attracted a lot of researchers who have attempted to use intelligent computing means to seek solutions for traffic control [1]. In recent years, as for the inherent flaws and limitations of traditional traffic control system, domestic and foreign scholars have introduced such practical technology such as fuzzy control in artificial intelligence, artificial neural networks, genetic algorithms, Agent and other practical technologies and applied to the field of traffic engineering [2,3] . Within the regional traffic coordination control method, Agent control method is more advantageous. This paper focuses on the research for Agent control method and its application in the regional coordination control traffic flow.

Agent Technology

An Agent has a sensory ability, problem solving skills and ability to communicate with the outside world, it can also practice logically and physically separate systems in parallel and coordinate to achieve problem solving, and it is also an entity with active capacity devised from decision-making or the operation of the control tasks in the whole process, which has such characteristics as reactivity, autonomy, initiative, mobility, sociality and so on [4].

A Multi-Agent system(MAS) is an organized, orderly agent groups which work together in a particular environment. Each Agent can complete their tasks according to the environmental information and can also cooperate with each other to complete a specific task. A MAS based control system is different from the distributed control system. The former regards the controller as intelligent Agents which have autonomy and collaborative initiative capacity, and the intended target will be achieved through the communication and task sharing with related other Agents [5,6].

MAS Based Regional Traffic Control Architecture

Urban traffic flow system is a distributed, nonlinear and time-varying stochastic systems, and there is a great difficulty in its real-time control and optimization, which not only requires real-time optimization and controll when the control system is stable, but also requires some adaptive and intelligent control. Just the MAS has equipped with distributed processing and coordination technology and is suitable for solving such complex problems.

System Structure. The structure of MAS based urban traffic flow control system is shown in Fig. 1. Regional Intelligent coordinated control system often uses a multilevel hierarchy structure[7], every level consists of Agents with similar function and structure, which mainly include: region Agent, sub-region Agent and crossroad Agent.

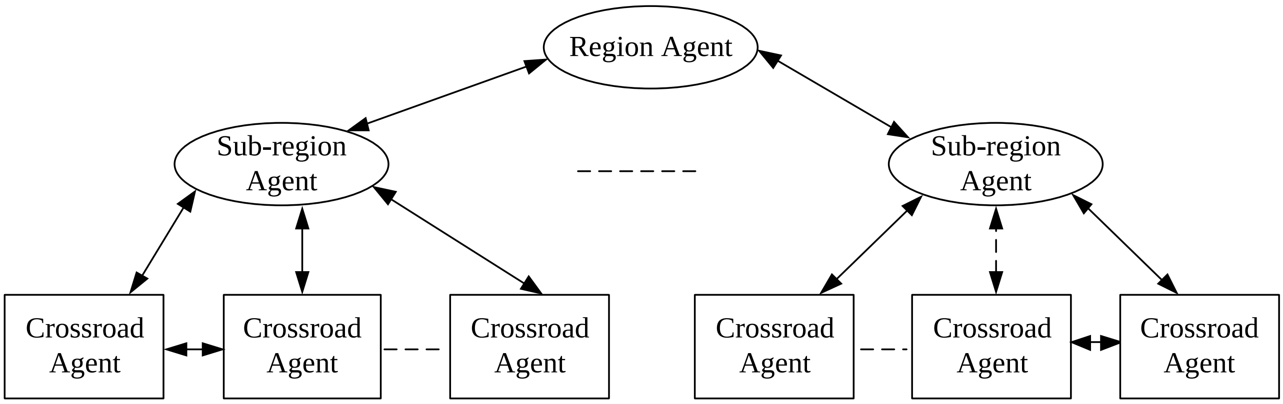

Fig. 1 MAS Based Regional Traffic Control Architecture

When the local traffic conditions change, time allocation of crossroad Agents is adjusted according to the communication module and coordination mechanisms among interrelated crossroad Agents. When the coordination among the interrelated crossroad Agents can not be achieved to obtain the desired control effect, crossroad Agent will send a request to the sub-region Agent, and then the sub-region Agent will coordinate the crossroad Agents in the sub-region to achieve satisfied control effect by certain strategies and optimization. When the sub-region Agent can not effectively solve the traffic problem, it will send traffic state information and coordination requests to the region Agent through information dissemination module to solve problems in larger region. This approach can not only autonomously make decision-making in the local region to achieve real-time adaptive control, but also adjust regional traffic in the macro region to maintain ideal traffic state.

Crossroad Agent Structure. Each crossroad Agent is an entity that can operate independently, which also can achieve the toally optimal control through coordination between Agents, and its basic structure is shown in Fig. 2.

In Fig. 2, the perception system achieves collection and processing of traffic information; knowledge base stores control regulation of traffic signal, traffic rules, information (such as road length, number of lanes, lane type and saturation flow, etc.) among this crossroad and the adjacent crossroad provides basic data for the learning machine and a basis for decision making module.

Traffic flow information, control plans and intermediate data and feedback information from the learning machine in the learning process are all stored in the memory unit.

The coordination module is responsible for data exchange for internal modules and data updates of knowledge base, at the same time having communication and coordination with the adjacent crossroad Agent and sub-region Agent and affecting the knowledge base and control decision module to form a final control strategy for controlling traffic lights.

Coordination and Optimization among Agents

In the intelligent coordination and control system of urban traffic, the decision-making of an Agent not only tends to influence that of the other Agent, but also is affected by other Agent decisions. The single crossroad Agent must consider the control situation of own crossroad and that of the other crossroads. When a single crossroad Agent cannot solve the current problems, it is necessary to resort to other adjacent Agents. This requires coordination among the sub-region Agent to make the global optimal. The system uses reinforcement learning method for each Agent to optimize and applies game theory to coordinate adjacent Agent.

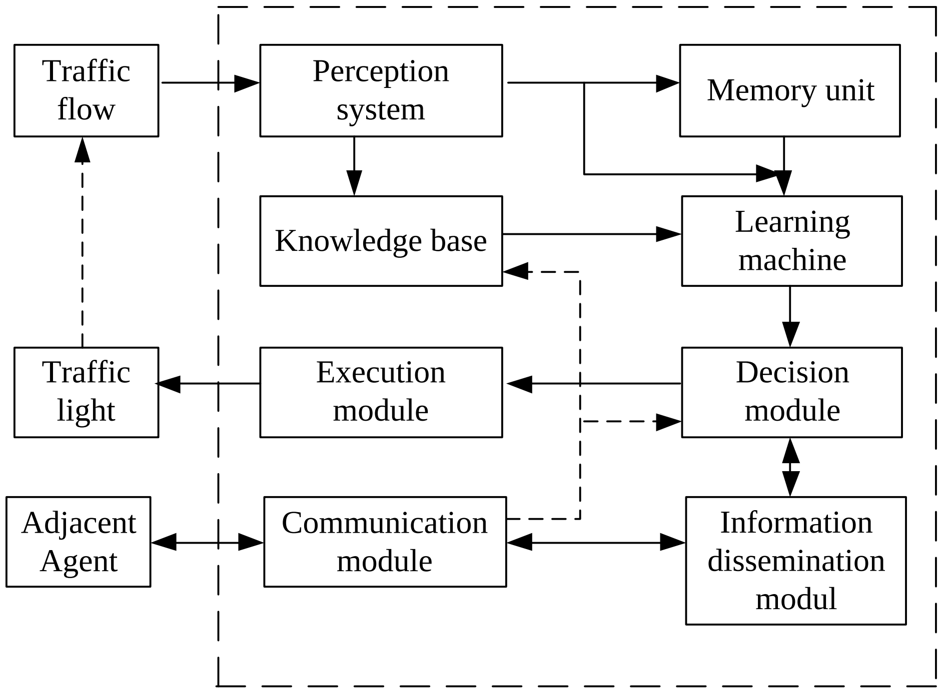

Fig. 2 Structure of the Crossroad Agent

Reinforcement Learning in Local Optimization. An urban transportation system is time-varying dynamic systems, traffic light controller needs to decide what action to be taken to adapt to traffic flow dynamic change according to the information collected from its own sensors. This is a local optimal control problem and reinforcement learning is very suitable for solving such a problem.

The Reinforcement Learning (RL) is also known as intensive learning, which has attracted a lot of attention in the field of intelligent control. The RL system is shown in Fig. 3. RL regards learning as the process of probing and evaluation, the learning machine selects an action to affect the specific circumstance, and states of the corresponding will change after affected by the above action and will produce a reinforcement signal r which is sent back to the learning machine. If the signal is reward signal, r is positive value and if it is punishment signal, r is negative value [8].

Learning machine will select the next action based on reinforcement signal and the current state of the circumstance. The principle of choice is to suffer an increase in the probability of positive reinforcement.

Circumstance itself is controlled by some complex dynamic process, which is non-stationary or some time-varying dynamic process. So selecting the action not only needs to rely on reinforcement signal r and but also the current state of the circumstance. The learning machine requires achieving some kind of association mapping between the state space of the circumstance and the output action space, and the optimal mapping is to get the maximum expected value of r [9].

Coordination Approach Based on Game Theory. In the traffic control system, all the crossroad Agents and region Agent share a common global goals and their own local targets which make the traffic smooth in the global region and the crossroad traffic or regional traffic smooth as much as possible. The crossroad Agents, the sub-region Agents and the region Agent will interact and influence mutually. Therefore, each Agent's decision-making is bound to be affected by the strategy selection of other Agents, a certain degree of conflict is bound to happen between Agents and therefore coordinating among Agents is quite necessary. The system uses the game theory to coordinate the Agents. Game theory is the theory of studying the conflict and cooperation between rational subjects, which studies how the subject's behavior influences each other and how the subject make their behavior choices and behavior decision in the interaction [10].

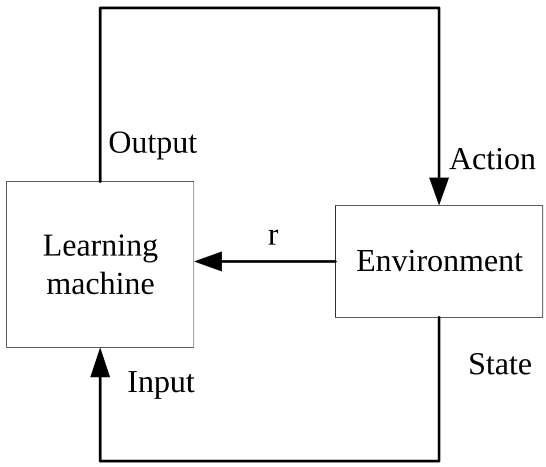

Fig. 3 Structure of Reinforcement Learning

Coordinating Model. In urban traffic, the capacity of existing roads is fixed, but the increase of vehicles will lead to conflicts among crossroads. An Agent's decision will influence other Agents' decision; meanwhile, it is also affected by other Agent decisions. Therefore, an Agent decision-making process should consider other possible strategies taken by other Agents to determine their own strategy. Each Agent can have a full understanding of other Agents' characteristics through mutual communication, and this determines that the coordination process between Agents is the game process based on complete information.

Coordination Algorithm. The coordination algorithm is as the following:

Step 1: If the number of queuing vehicle in a crossroad exceeds the threshold value, the crossroad Agent will sends a coordination request to the adjacent crossroad Agents.

Step 2: The adjacent crossroad Agent will responds to the request and look for the Nash equilibrium.

Step 3: If Nash equilibrium exists, each Agent controls the intersection in accordance with the Nash equilibrium, and then the coordination is completed; if there is no Nash equilibrium, a coordination request is necessary to be sent to the region Agent.

Step 4: Region Agent will responds to the request and carries out game coordination for the crossroad Agent to seek Nash equilibrium; if Nash equilibrium does not exist, a coordination request is necessary to be sent to an adjacent region Agent.

Step 5: The adjacent region Agent will respond to request and conducts game coordination to seek the Nash equilibrium; if Nash equilibrium does not exist, automatic coordination of the system fails and it requires manual intervention strategies.

Conclusions

The paper has conducted a research for the coordination control method of the regional traffic flow on the basis of the Multi-Agent technology. The framework of a traffic flow control system, the structure of an Agent, coordination and optimization methods between Agents have been discussed. By comparing with the real-time control system of traditional urban traffic flows, this system has the following advantages: the system is collective intelligence through all kinds of traffic Agents integrated together and finishes the task of traffic flow control making full use of their respective advantages.

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