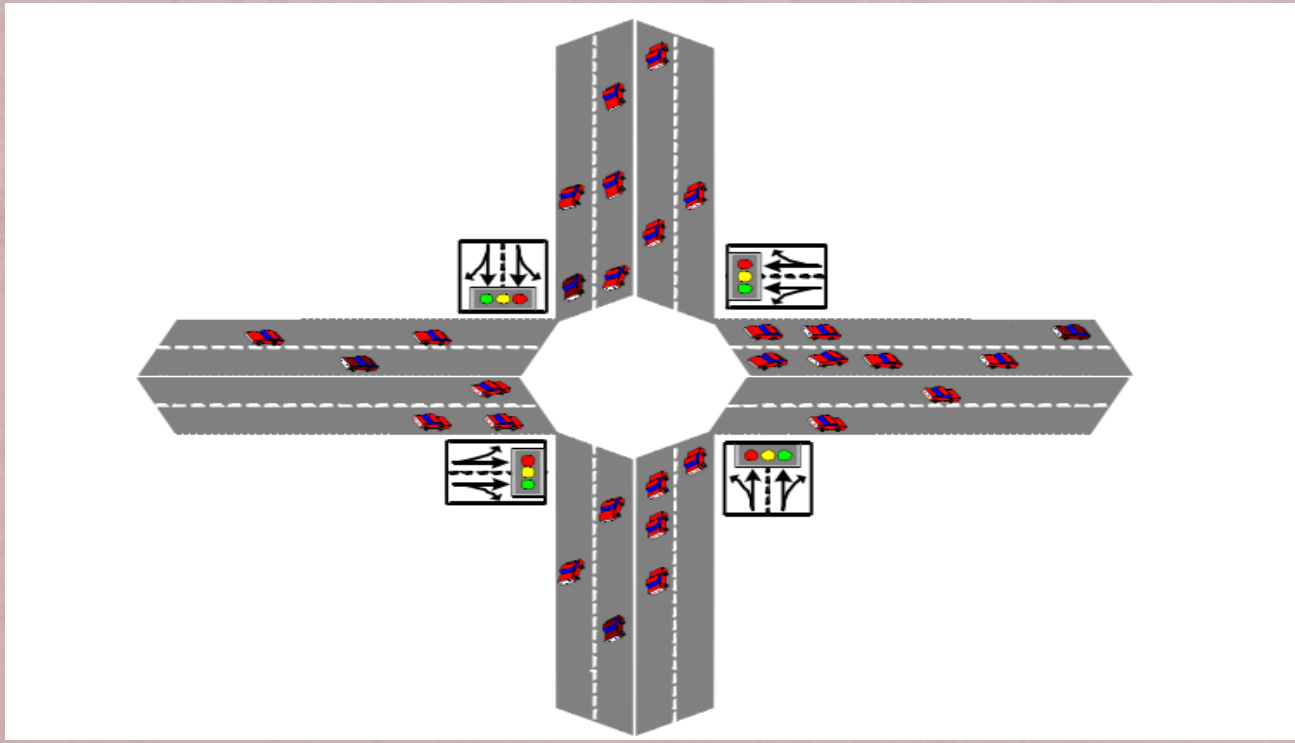
RESEARCH ON URBAN TRAFFIC SIGNAL CONTROL BASED ON MULTI-AGENT SYSTEM



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INTELLIGENT TRANSPORTATION SYSTEM (ITS)

The concept of Intelligent Transportation System(**ITS**)[1] ,was put forward on the first-time meeting of intelligence transportation on November ,1994, in Paris, then was adopted advanced computer technology, electronic sensor technology, artificial intelligence technology and modern telecommunication transmission technologies to transform the traditional transportation system, changes the original situation of passive transport in which makes the vehicles and roads intelligent in order to realize the safety and speedy road traffic environment, to achieve to alleviate road traffic congestion, reduces traffic accidents, improves the road traffic environment, saves the traffic energy, relieves driver's fatigue, etc..... ITS has become an accepted solve to the growing traffic problems.

INTELLIGENT TRANSPORTATION SYSTEM (ITS)

At present, In China has establised the ITS :

①Transportation Control System
②Transit Management System
③Transportation Surveillance System
④ Trasportation Information Dinamic Display System
⑤Transportation Dredge System
⑥Transportation Security Alarm System
⑦Electronic Payment System
⑧Traffic Accident Fast Reconnasissance Systme
etc...

INTRODUCTION OF URBAN TRAFFIC SIGNAL CONTROL SYSTEM (UTCST)TECHNOLOGY

1.The method traditional of traffic control:

The early traffic lights based on a “fixed with time”approach to implement automatic control. And in this way is played a small role only on traffic flow wasn’t great in early.As the traffic increasing, a single mode couldn’t met the demands then genera a multi-period control mode.

2.The method dynamic of traffic control:

To adapt the change of characteristics in traffic flow, the human has an idea: traffic control on-line: By the road vehicle detector on-line, real-time collection of traffic data, recognition with traffic model, and when the parameters of distribution obtained with the optimization problem, on-line to solve the problem that has the scenario of assigned-time, then controls the traffic signals within the region.

INTRODUCTION OF URBAN TRAFFIC CONTROL TECHNOLOGY (UTCT)

Example:

1. In Washington,1975s , installed a traffic control system. The system used a CYRANO(Cycle-free responsive algorithm for network optimization) , provided the software controlled the algorithm of assigned-time, it could make each cycle respond to change in the traffic conditions, period、offset as same as each control cycle of every intersection could be changed in response to the fluctuation of traffic demand.

2. An adaptive control system-- SCOOT(Split-Cycle-Offset Optimization Technique), which is actually an on-line traffic network system, It was realized to real-time detect traffic date by the vehicle detector, made use of the traffic model to optimize the signal parameters of assigned-time, and depended on the communication network and signal control machine other hardware devices to implement control. It most important feature of SCOOT was the vehicle detector which was installed in the intersection of the exit of the upstream intersection. Therefore, this traffic model was a short-term predicting model, with high accuracy.

INTRODUCTION OF URBAN TRAFFIC CONTROL TECHNOLOGY (UTCT)

3. The method of Intelligent Transportation System(ITS) traffic control:

The core of problem of artifical intelligence – research on agent technical. In that agent technical has many features as adaption, cooperation, reactivity ect., so an adaption urban traffic signal control system technology can be provided with some functions:

① adapted the variety of trasportation condition, such as occasionality of congestion, affairs, accident and trasportation demanding increment etc, have the adaptability, that is, the system would control in real-time and make the scenario of optimization assigned-time on-line;

② It would be made use of dynamic state of transportation distribute and control the signal ;

③ It would realize the traffic within route particular or the special vehicle controls in priority;

④ It has ability of learning, gradually raise to control function by learing which the operative had controlled ;

⑤ It has ability of error tolerant, even if would be happend malfunction detection or telecommunication but the system would not lose to control.

METHOD OF TRAFFIC CONTROL BASED ON AGENT

In the UTSCS，the traffic signal controller can be distributed on the different geography location, and between different signal controller exist benefits conflict, So it belongs to a typical problem distribute. The agent technique and multi-agent system theory can be applicated in area of UTSCS, provided new method and new thinking to solution of problem.

The model of urban traffic signal control based on multi-agent, combined with varity of scenario transportation of China, it was put forword the algorithm about in intersection traffic congestion and coordination of special events happend. [2]

It was constituted based on multi-agent completely distributed the frame of ubran traffic signal control system, and introduced a mechanism of learning to the agent of system, the first step built up the urban intelligent transportation system that has the characteristic of expert system, and can be continuously evolved the distributed .[3]

PART II

Introduction of Multi-Agent System and Application

BDI MODEL

Bratman [4] the earliest used the mode concept of --intention ,belief, desire to descript un agent system, so it was BDI model. He thought that the agent can't be directly drived only from the belief and desire as well as the planning of between the two, it has also an intention between the the desire and planning which based on belief. The belief is that the agent has knowledge of the surrounding environment, the desire to obtain from the belief,and the agents deduce the state of enviornment from their knowledge, the intention restricts the agent's action , is a subset of set of agent 's goal.

BDI model describes structure of agent that is composed of the state of belief the current desire, the set of goals,an intention,and the plan library.The plan library provides the the wide range of planning to complete goals and adapt the current situation, generates the behavior reasonable; the structure of intention chose to implement the planning needed, and according to the system of beliefs and goals chose the planning to complete functionally of system.

THE CONCEPT OF AGENT

The concept of minimum-agent that an'agent has the basic features that should be include: reactivity, autonomy, goal-oriented and aimed at enviroment, and then in accordance with application situation can be added others characteristics. For example, in multi-agent system , the agents must have capabilites of communication. [5]

In general, the agent is a kind of computational entity in a particular enviornment can play a role independently autonomy, and perceive enviornment, is possessed of reactivity, sociality, proactively. Specifically in said, the agent is entity of able to indpendently and continuously in the dynamically changing, there are others agents in enviornment running and could interact with the environment

THE CHARACTERISTICS OF AGENT

Generally speaking, the agent has the following characteristics:

1.Autonomy： the agents are autonomous, an agent can be implemented its own task in absence of interaction with the enviornment or a shortage of command from the enviornment, so it has a set of mechanisms to control its own behavior and internal state.

2.Reactivity： the agent can perceive changes in the environment, and can within a certain period of time makes an appropriate reaction from the environmental information.

3.Proactively/Goal-oriented ： the agents not only to reaction with enviornment change, and also in certain circumstances will take the initiative action, which the ability comes from the agent has its own strictly defined goals.

4.Reasoning/Learning/Adaptation： the agent improve their ability to adapt to enviornmental variation by learning, the agent are learning include the knowledeg of the problem domain and with the relationship between the the occurrence of other relevant agent’s information.

THE CHARACTERISTICS OF AGENT

5. Action/controlling： Any agent has a set of action, the agent adopts certain actions to change the enviornment or adapt the change in the environment, the agents have ability to control their environment to ensure implementation.

6. Role： the agent manifests insecurity、 risk、 trust 、honesty in the social activities.

7. Communication/Cooperation/Coordination: the group of agent should have a social property, that is, the agent can interact with other agents by means of the certain communication language.Enabling the agent to obtain except its own observations about other information of state in the system to coordinate and complete the task.

AGENT VS OBJECT

The agent and the objects are both in common, but there are very different. They all have the identification, the state, the action e the interface, but the agent compares with the object , the agent has the main differences :

(1) The agent is intelligent, has its own knowledge base and inference engine, but the object generally has not the intelligence.

(2) The agent can autonomy to decide whether take a respond the information from other agent, but the object must be act in accordance with the requirements of outside world. In other words , the agent system can be encapsulated behaviors, the object can only be encapsulated states, the behavior of an object depends on invocation from the method external .

(3) Among the agents communication use communication language which can be supported transfer to knowledge.

THE ARCHITETURE OF AGENT

The architecture of agent mainly refers to the agent system by which modules, how to interact information among them, the agent perceives information how to affect their behavior and internal state, and so how to use software or hardware realize the agent. According to agent whether the use of symbolic knowledge, Wooldridge [6] is divided into the arichitecture of agent 3 typies: Deliberative Agent(Cognitive Agent), Reactive Agent, and Hybrid Agent.

Deliberative Agent has state internal of active software,in different with specific knowledge domain,is possessed of knowledge represetation, problem solving representation, the enviornment represetation,specific communication protocol and so on. It includes explicit representation of the symbolic model, and its decision-marking process is realized through logical reasoning, pattern matching and symbolic operations.

DELIBERATIVE AGENT

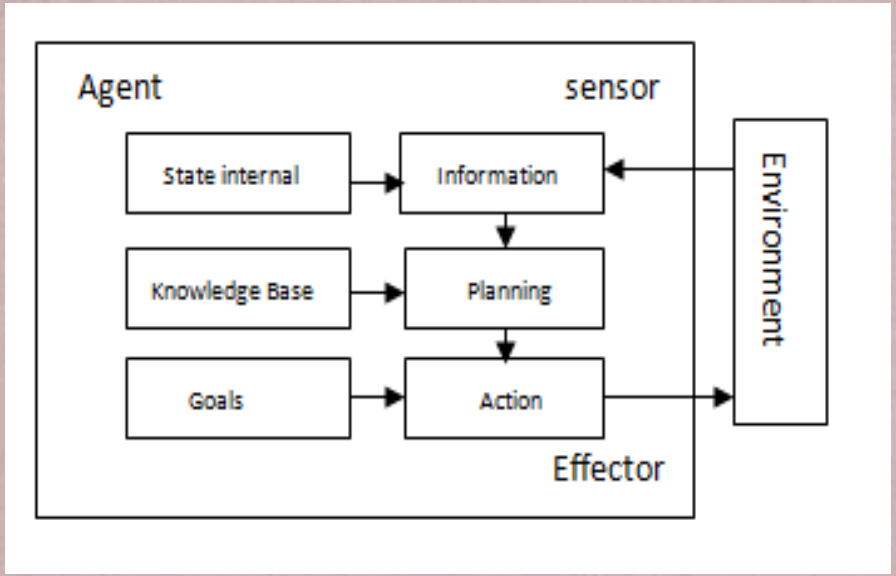
A typical architecture of deliberative-agent is Bratman proposed the structure of BDI model can be described by the following elements:

(1) A set of beliefs about the world;

(2) A set of desire(or goals) which the agent currently intends to achieve;

(3) A plan library, is used to describe how to achieve goals and how to change its belief;

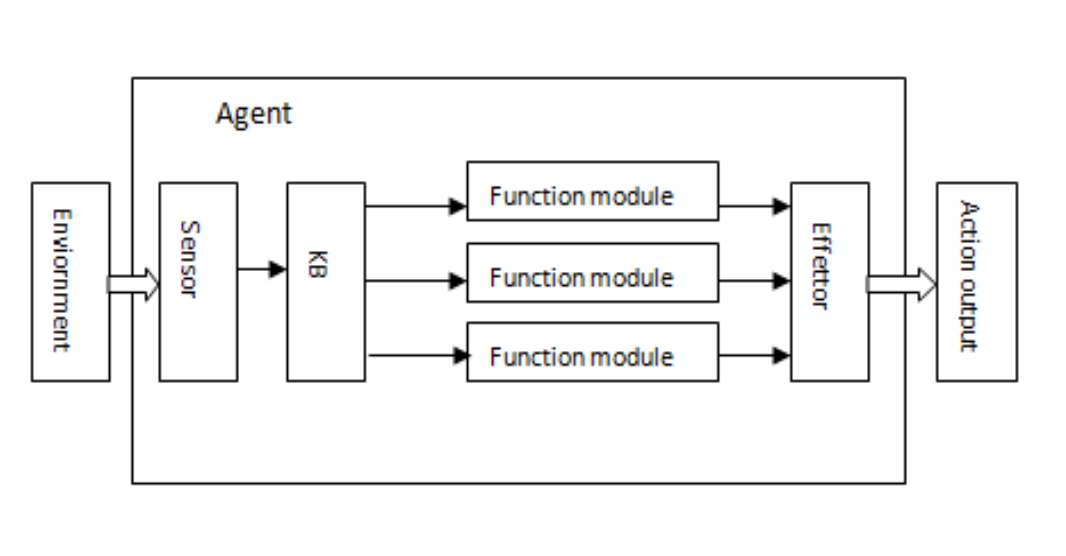
(4) An intention structure, describes the agent how to achieve its current goals , and how to change its beliefs according to real-time conditions.



ARCHITECTURE OF REACTIVE AGENT

The architecuture of reactive-agent came from the thought of Brooks[7], The agent doesn't depend on any sign, according to directly perceive produce action without planner, scheduler and so others links.

The architecture of reactive-agent and deliberative-agent is relative, not the actual model and planning, only exists a few simple patterns of behavior, rective-agent does not contain the symbols of the world model, neither use complex symbolic reasoning.



ARCHITECTURE OF MIXED-AGENT

The approach combined is in the agent system contains two (or more) subsystem: one is the deliberative-agent subsystem, containing the world model using symbols and use of traditional artificial intelligence proposed method is generated planning and the corresponding decision-marking; the other subsystem for the reactive-agent, directly taken to response in the environment of some emergency event.

MULTI-AGENT SYSTEM (MAS)

The multi-agent system is a set of agent which by a number of interactions and ongoing happened interation with the surrounding environment; among agents or between the agent and the environment through commucation, consultation and collaboration to coordinate complete problem which the individual agent can not resolve. The multi-agent system and single agent have the essential difference: MAS support commnucations among agents, so in mainly reseach the cooperation of agent autonomous.

(1)MAS assign to each agent to solving problem in different sub-problem, therefore the system has goold robustness and solution efficiency.

(2) In system each agent has the ability to parallel computing provides a new method of parallel computing;

(3) The composition of MAS each agent is modularity,can be esaily extended system requirement, so that the system has the extendability.

(4) The MAS relax to constrain for a centralized,sequential control, provide a decentralized control, response and mode of treatment.

(5) Since MAS assigned sub-task to the each agent , in favor of realizzation a single agent.

(6) The MAS can reduce the hardware and software costs, is faster approach solving the problem

The MAS using the method for solving the problem generally has the following characteristics:

(1) Each agent have only to solve the problem of incomplete information, need not have all capability to solve problem required,

(2) There is no global overall system control;

(3) The data of system is decentralized;

(4) The computing of problem is asynchronous.

THE ARCHITECTURE OF MULTI-AGENT

The architecture of MAS can be divided into 3 typies: Fullly autonomous, Master-slave and Problem-solving .

Fully autonomous : that is the mode of fully distributed organization, each agent has the autonomy to achieve their goals, among agents equal the status, without relation management and no-management, each other coodination is realized through the interaction between the behavior of agent. So every agent has the autonomy to achieve own goals.

Master-Salve: such a structure is more suitable for mode working in closely coordination where all of agent form an agent group. According to the scope of workng functions of the agent can be divided into management agent,function agent, application agent.

Problem-solving: this is a dynamic organizational structure in order to agent can together complete a task. The relationship among the agents is dynamic, once time the specific task is completed, this relation dissappeared, when a new task comes will form a new composition of the problem-solving structure by other agent .

LEARING IN MULTI-AGENT SYSTEM

The basic mechanisim of learning is tried to bring experiences from a case successful and unsuccessful applied to another the solution process of similar problem.During the agent interacts with the environment, it continually acquires knowledge to update their knowledge base, at the same time learning adapt to the environment changing.

The learning in MAS there are the following respects:

1. The agent would achieve to its own goals, an agent must learn to coordiante their behavior when it interacts with others, and thus to obtain maxmize the reward.
2. The agent can observe the behavior of other agent, constructs model for others, predicts the behaviore of others, enabling to take the optimal action based on the current situation.
3. How to take into account the relationship between learning and the agent communications. Among agents communication bring high costs for system, so agent can obtain other agent of knowledge and information by learning, thereby reducing unnecessary communications.

LEARNING IN MULTI-AGENT SYSTEM

The reinforcement learning (also known as evaluation learning), is an important machine learning methods, theory of reinforcement learning can apply to the multi-agent technology, it enables agent directly learning their state of internal models from the enviornment different in outside world, this can eliminate or decrease dependence on the model enviornment external , the agent can be based on previous experience to effectively take control action.

The reinforcement learning is an exploratory of learning problem, by means of the interaction with external world get the evaluation of feedback information, then the agent computs to learn how to implement appropriate action.

Q-learning algorithm is an implementation of reinforcement learning,its advantage is that do not have to estimate model of the enviornment, but rather directly optimization of an iterative computing Q-function. In Q-learning, agent's goal is not only immediate reward to maximize for the current state, but also to reward cumulative to maximize a period of time in the future.

COLLABORATION IN MULTI-AGENT SYSTEM

Types of the agent collaboration in MAS:

In accordance with the interdepedence of agent, for problem-solving of collaboration in MAS is divided into 4 categories following:

1.The horizontal collaboration: two type of cases, (1) the collaborative groups of each agent has not ability to solve the overall problem, the problem solves need to with collaboration of multi-agent; (2) in collaboration group of every agent be able to independently solve the problem, but if agent can be interaction to enhance the credibility of the solution.

2.The tree collaboration: high-level agent based on the result of low-level agent to solve the problem and make the final conclusion.

3.The cycle collaboration: in order to obtain the solution of problem, and different agent interdependence, they can reiprocation collaboration.

4.The hybrid collaboration: that the entire system in any level with the horizontal collaboration but in the whole is used the cycle collaboration , or the tree collaboration; or the overall the horizontal collaboration but with the partial in the tree collaboration o the cycle collaboration.

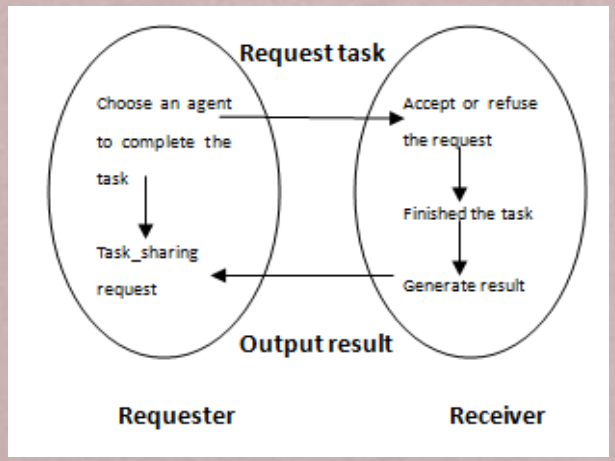
COLLABORATION IN MULTI-AGENT SYSTEM

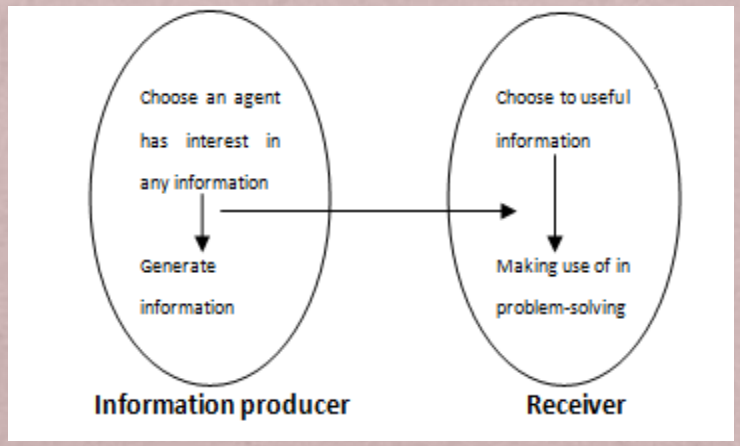
The form of agent collaboration in MAS:

The forms of collaboration in a certain sense which is in the form of distributed control, the forms of collaboration can be divided into the task sharing and the result sharing.

The Task Sharing refers to the multi-agent inter-cooperation, sharing of computational load of each sub-task, and when the task of agent is too heavy it can not complete, it can be decomposisted of task, so that other agent can undertake and complete the task. This form of control is Goal-Driven.

The Result Sharing refers to the agent transfers each other and makes use of differente points of view get to the partial results from the overall problem. This form of control is Data-Driven.





APPLICATION OF MAS IN UTSCS

As the traffic and transportation routes in the topology structure distrubuted is very suitable for multi-agent technology.

Burmerister [8]adapted multi-agent technology to realize the passenger management station, customers and station resepectively denote two types agents. The customer agent associates with the station agent, then it requests travle time and destrination, the station agent give the recommended trips.

Goldman[9] and others proposed methods of using incremental learing to coordinate the intersection of the two controllers.

There are some scholars proposed the distruibuted path to guide MAS, the system made use of coordiantion of mulit-agent technology, combining knowledge base on information in the transportation and path border search algorithm, establishing the mechanism description of a local world, accesso to information via radio and activate re-planning path, and to propose a plan to obtain the shortest path algorithm, resulting the best trajectory of vehicles,the system provide adivse for dirvers to avoid the car conflict in motion.

PART III

ARCHITETECTURE DESIGN OF URBAN TRAFFIC SIGNAL CONTROL SYSTEM BASED ON MULTI-AGENT

The intersection is the most basic node of urban traffic network,therefore the road network control bases on single intersection signal control .Using the agent technology for the each intersection signal control, it makes the controller of each intersection has the ability to draw up and complete their strategy of control, It not only can enhance the autonomy of controller of each intersection , but also among agents can exchange information and coordination through the intersection traffic control, so form of distributed traffic signal control based on agent.

URBAN TRAFFIC SIGNAL CONTROL(UTSC) AGENT FEATURES

Compare the traditional intersection traffic signal controller with the intelligent signal control agent,it has some advantage：

(1) To accept real-time information of traffic state at a certain time interval;

(2) To predict the trend (increasing/decreasing)of traffic flow in the short term;

(3) To obtain the information from adjacent intersection traffic state;

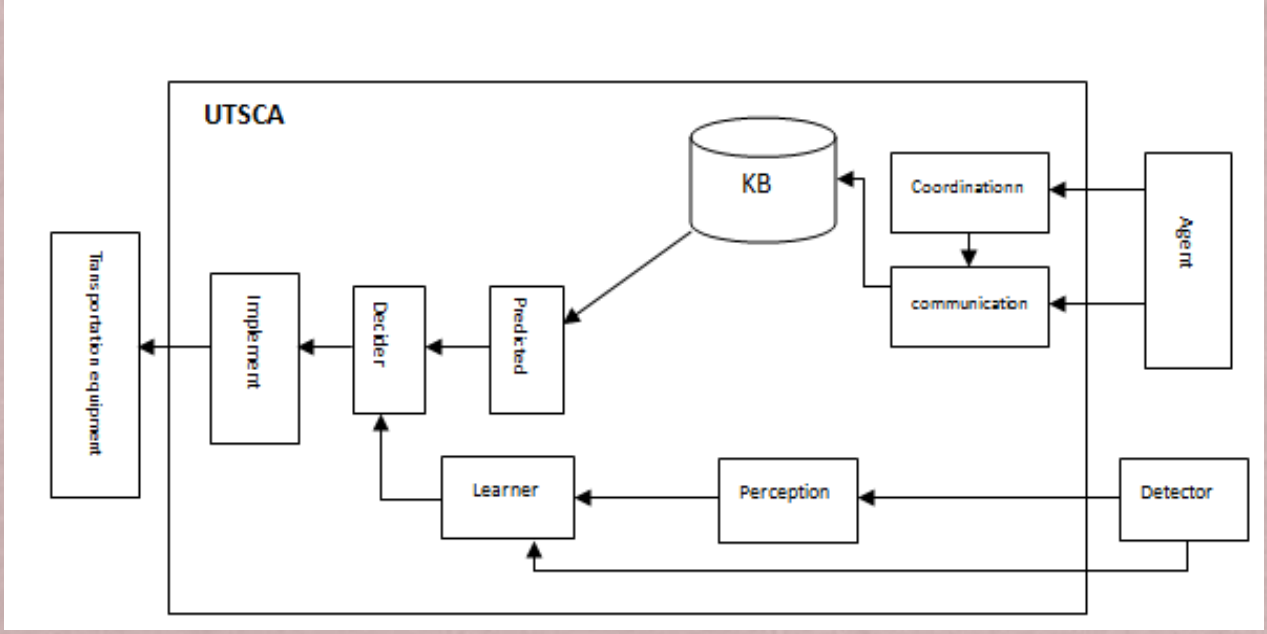
(4) For control the intersection,there is an accurate model, such as the maximum quality of traffic, the value of vehicles in every direction;

(5) To detect and deal with the fault which is happened the section controlled;

(6)To send important information about their own to other agent.

STRUCTURE OF UTSCS-AGENT

The single intersection of traffic signal control agent only effects on this single intersection. So the main function of the single intersection of traffic signal control agent is according to information of traffic state in real-time adopts the control dynamic strategies to control reasonable on traffic flow, meanwhile the agent communication information with adjacent intersetcion, coordination of control strategies. In accordance with task, the agent can be designed major parts: the decision-making device, learning device, coordination module, signal control regulations knowledge base .



1.Communication modules: to send and receive the request of control traffic flow and request of data among agents.

2.Signal control regulations knowledge base: to storage signal control regulations, the kowledge base can provide alternative scenario through communication with relevant the intersection traffic control agent.

3. Perceptron device : to collect information of traffic flow about intersection and the adjacent intersection, is provided uniform by the local intersetion of information collector device or data monitoring center,that is the basis for learner device to develop and control strategy.

4. Learner device : in according to the information received, as well as knowledge empirical or by learning to obtain information quantitative, for the behavior decision-making device provides basis for the strategy. When the controlling behavior acts on the traffic intersection of detector to provide information strengthen get value amended, depending on state of traffic state make again decision-making.

5.Prediction modules: traffic model can be built to simulate the situation of traffic flow in some time, to gain the corresponding predicted data.

6. Decision-making device: the result from the prediction module and learing modules, it would make the decision-making the optimal control parameter in next period of time.

7. Implementation device : according to the environmental interface provides the environmental information and the decision-making provides the control strategy , it would control the distribution of proper intersection’s offset of split in real-time.

THE WORKING PROCESS OF UTSCS BASED ON AGENT

Making use of traffic signal control agent realizes to the process coordination distributed can be described as:

1.The detection device of vehicle will detect the state of information through the perceptron device send to the learner,at one time the adjacent traffic signal control agent provides information related traffic for the learner.

2.The learner is according to the information received and knowledge relevant experience or by learing has obtained quantitative information to provide the strategy for decision-making.

3.The detector received the information which included the information of the adjacent intersection control agent , it makes the coordiantion and it will choose the rules corresponding from the knowledge base and according to the rules pass through prediction modules constitutes transport model to simulate the state of traffic flow provides the basis for decision-making.

4. The behavior of the decision-making device chooses behavior by means of learner and prediction module have provided information, and the device of implmentation controlls and executes this behavior.

5. After the control behavior acted on the traffic intersection, it will change the state of traffic intersection,when passes a certain period of time the vehicle detector to detect the state of intersection again, transmit these states to UTSC-agent, and computes the signal reinforced feeback to the learner, then leaner receives the signal amends this value, and again considers the state of traffic would to do decision-making.

6. The above process is reapted...

THE LEARING MODEL OF URBAN TRAFFIC SIGNAL CONTROL AGENT

Q-learning is a form of non-model reinforcement learning[10],it is a real-time, online learning methods, it does not need to construct the enviornment and to describe the precise mathmatical of task. So it must not tell the agent how to achieve the goals, just tell it what is the goal, through learning the agent can be gained the available information about the system state、action 、 reward and useful experience to hold a set of optimal strategies.

During the agent interact with the enviornment, supposes the enviornment is a finite-state. The agent perceives the basic state of enviornment $s(t) \in S$, where S is the space of state, any one of the basic state corrispondes to a set of basic action $A(s)$. The agent can choose an action: $a(t) \in A$， where A is the sample space of action, for a sequence discrete time t=0,1,2,3,....., the agent interacts with enviornment in each time step, the environment can feedback the numerical reward $r(t+1)$ for agent in the next time step then the agent can observe the next basci state $s(t+1)$.

Q-LEARNING METHOD

The agent's task is to learn an optimal decision-making process, the strategy is the mapping of action event probablity from a state of the environment to the agent. So, $Q(s,a): S \times R \rightarrow A$, it makes the agent in each state *s*, and accordance with certain action strategies to select the action appropriate to obtain expected cumulative discounted reward:

$$V^{Q}(S) = E_{Q}\{R_{t} | S_{t} = S\} = E_{Q}\left\{\sum_{k=0}^{\infty} \Upsilon^{k} r_{t+k+1} \middle| S_{t} = S\right\}$$

Where $\Upsilon \in [0,1]$ as the discount rate, $V^{Q}(S)$ named as the value of function during the strategie *Q* when the agent stays in the basic state *S*.

Q-LEARNING METHOD

In practice , the *Q* is the decision-making device . The optimal state value function explicits a state, according to a certainly strategy of action, the agent can obtain the maximum sum of expected cumulative discounted reward:

$$V^*(S) = \max (V^Q(S))$$

At this point, the strategy *Q* becomes the optimal strategy:

$$Q^* = \arg(\max(V^Q(S)))$$

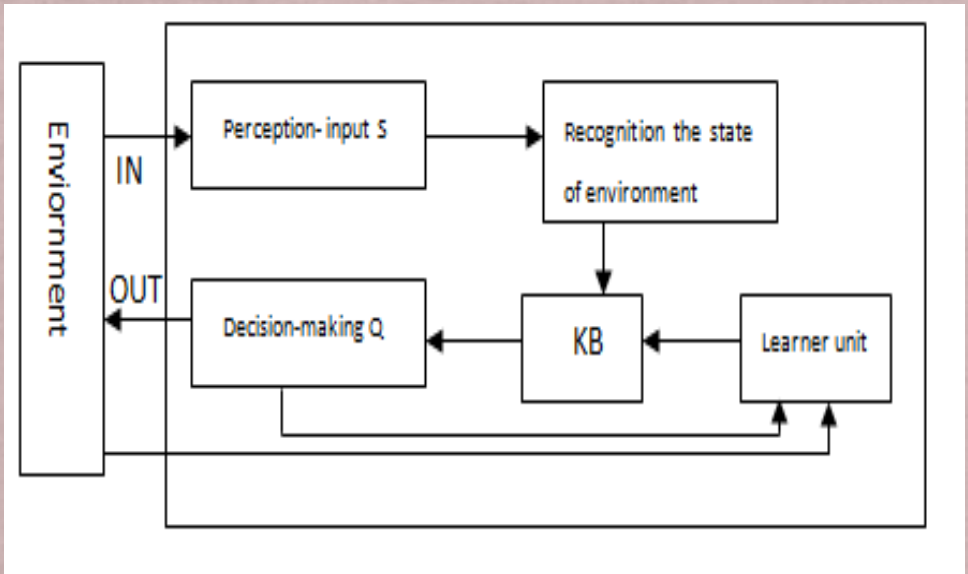
The purpose of reinforcement learning is to obtain such an action strategy. [11]

The Q-learing algorithm is the tipo of algorithms that it realizes of reinforcement learning . Therefore the elementary Q-learning algorithm can be described as:

1. Initializzation arbitrary *QL(s,a)*;
2. Initializzation the initial state *s*;
3. During the running every step,with the action strategy *Q* and the value table of *QL* to obtain the action *a* when the agent in the state *s* ;
4. To implment the action *a* observer reward *r* and the next state *s'*, then update the value table of *QL* .

THE LEARING MODEL OF URBAN TRAFFIC SIGNAL CONTROL AGENT

Due to the time-variant is very strongly in traffic flow and the change of traffic environment traffic is dynamic, it requires the traffic control system not only is capable of recognise the state but also should be able to have capacity of self-control for finding the optimal strategy as well as the capacity of self-adaptive for the enviornment change through the system online runs can obtain the best effect of control strategy corresponding to state of traffic in various conditions, after the enviorment changes it can be self-preception under the new enviornment it will control the strategy of re-learning and finding the optimal. The application conditions of Q-learning method coincide with actual traffic control system, therefore construct a basic structure for traffic signal control agent can be used the Q-learning method.



THE LEARING MODEL OF URBAN TRAFFIC SIGNAL CONTROL AGENT

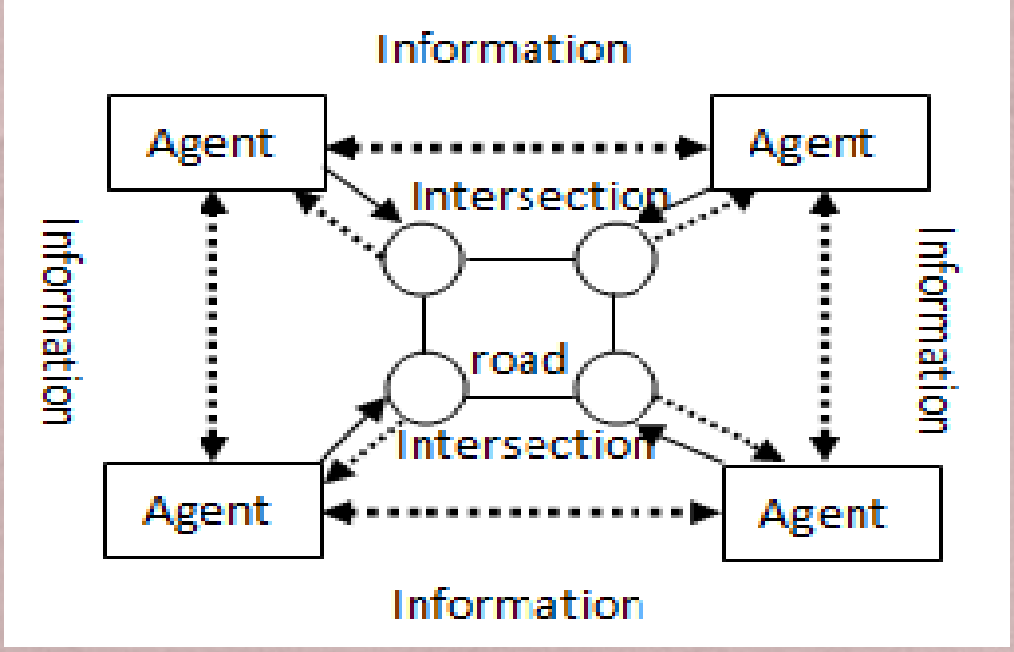
The state of enviornment *s* is a state of traffic in specified time interval,including the state of vehicles reached, the state of semaphore,etc... The knowledge base contains the alternative control strategy and knowledge of relevant experience; The learing unit according to the received information with relevant experience by learing to obtain quantitative information then evaluates an action given, for the decision-making device provides a basis for choice next behavior then selects this behavior , the devices of implementation controls this behavior.When the control behavior acted on the traffic intersection, it will change the state of traffic intersection, after a certain time interval, the vehicle detector detects the state of traffic intersetion sends to the traffic signal control agent and calculates a reward value, so which is the signal strengthening feedbacks to the learning unit,then the learning unit revises this value and depending on the state of traffic makes the decision again.

THE FRAMEWORK DESIGN OF UTSCS BASED ON MULTI-AGENT

The multi-agent traffic signal control system is composed of a number of single signal agent, each intersection signal control agent can be considered the adjacent other agent as part of the system enviornment, therefore how to distribute them in the multi-agent system and research the relatioship among them becomes the part of system design.[3]

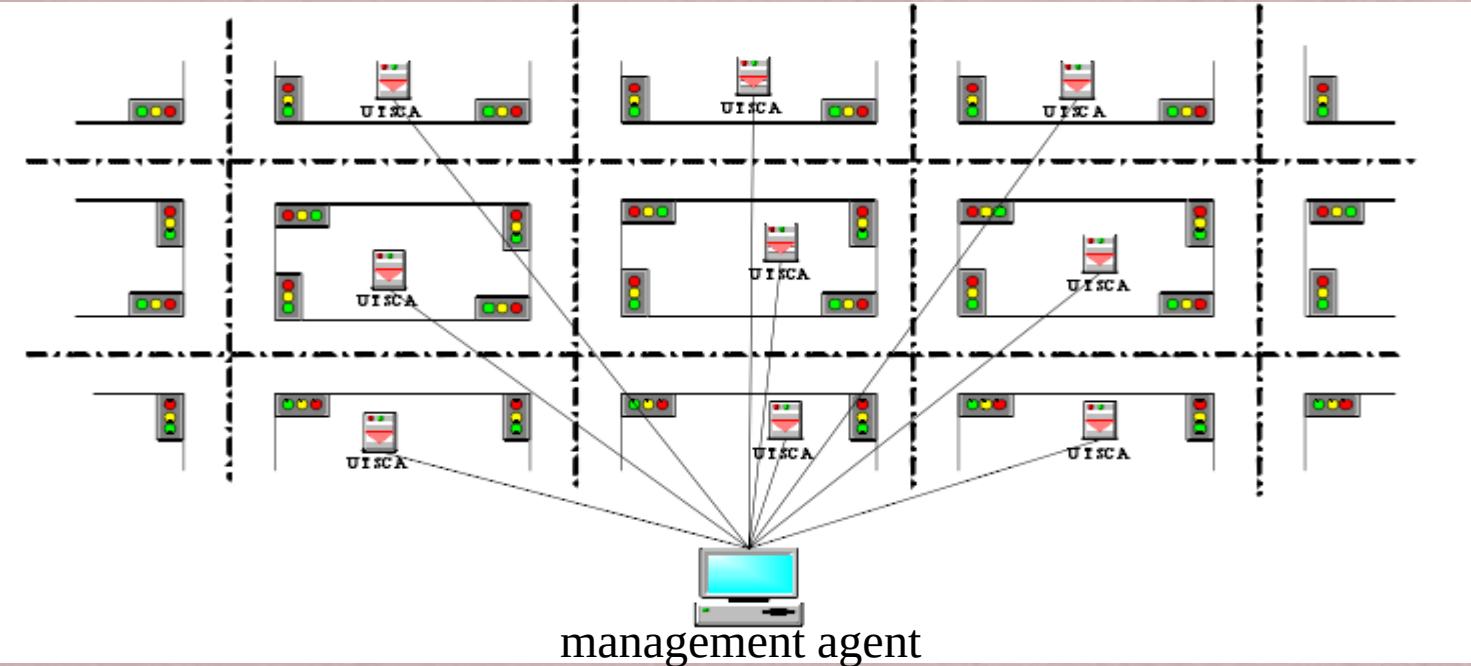
The multi-agent technology is applicated in UTSCS which is constituted by fully-distributed multi-agent architecture that each intersection controlled or node is an agent,they can with their own intelligence and capacity of autonomy to control every intersection, or they can cooridinate with the intersection the adjacent agent depending on the collaboration among themselves to control no need the regional control and a central controller.

The distributed control architecture has great flxeibility, given full play that the agent is autonomy, coordination, but the agent in itself has the capacity limited, the single agent often represents its own benefit to maximize, in the global problem somewhat inadequate, but also the agent requests itself more high.



DESCRIPTION STRUCTURE OF MULTI-AGENT SYSTEM

The UTSCS based on multi-agent, the whole structure of control system is the key to each agent's control domain. In order to reduce unnecessary communication among the agents and to ensure that the better effect of overall optimization, each signal control intersection control by an agent, in this way the traffic signal control agent sends information of the state traffic to management agent in real-time , each agent communicate and cooperate only with the adjacent intersection agent.



THA ADVANTAGES OF DISTRIBUTED CONTROL OF MULTI-AGENT

(1)Real-time: each intersection of UTSC agent is only responsible for control one intersection,whereas the siutation of single intersection is relative simple, Which is equivalent to simplify dealing with the problem complex of traffic control, each intersection of UTSC agent can be changed in response to traffic conditions in real-time,so it raise the system's capability of real-time response, to satisfy the complexity of needs for the traffic control system;

(2) Timeless:each intersection of UTSC agent can communicate and transfer the information, then enhancing the collaboration between the every intersection , to facilitate co-operation between the signals of intersection, thereby improving the comprehensive capacity between systems ;

(3) Reliability: each signal control agent can be worked independent, therefore the system will not be because of the individual agent's failure to stop running or to affect the operation fo the other intersection, and when the individual signal control agent failures in the system, the managners can come to understand information across human-machine interface from management agent, interferes manual and solving the problem in time.

(4) Flexibility: the management agent be able to interfere with the behavior of the traffic control agent in essential moment, based on experience to adjust the single intersection traffic control, in order to easy control for emergencies or special festivals and other special circumstances

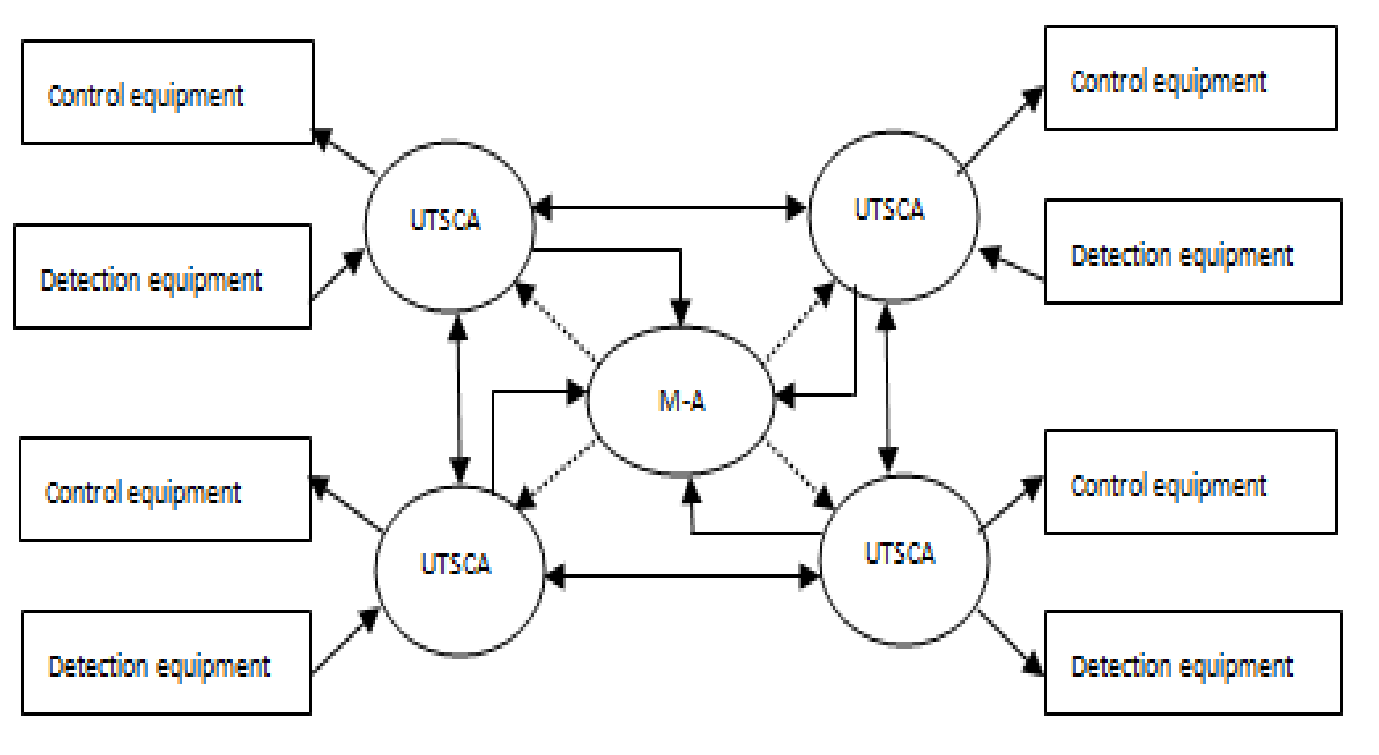
(5) Relativity: each intersection of UTSC agent has its own the intersection of structure and the state of traffic data when the agent makes decision for traffic control is more targeted.

(6) Extendability: because each agent is relatively decentralized independent in the system ,so the system can more easily be extended , rather than updating the entire system.

THE FRAMEWORK DIAGRAM OF UTSCS BASED ON MULTI-AGENTS

The framework diagram of UTSCS based on multi-agents:

Note: M-A -- management agent.



PART IV

The Coordination and Control of UTSCS based on Multi-Agent

In UTSCS based on multi-agent ,the system runs stabile operation is important that the interaction each of agent autonomous, the coordination each of intersection traffic signal control agent and the realization of the control strategy for the coordinated manner.

THE COMMUNCIATION AMONG THE TRAFFIC SIGNAL CONTROL AGENTS

In the UTSCS based on multi-agent, the communication is from each intersection signal control agent with the adjacent intersection signal control and between the management agent[12],in reality the transmission of information is by the action of interaction,so as to achieve the effect of optimal control of whole the transport network, the communication of the intersection traffic signal control in essence consists of 2 parts:

1.To deal with the received information (message);

2.During the process of running in the system at any time to generate and send the information necessary to the management agent and other agent.

In summary the communication between each intersection traffic signal control agent with the adjacent intersection can be divided into exchange of information and request of coordination two main forms.

THE CONTENT OF COMMUNICATIONS OF UTSCS

1. The exchange of information between the signal control agent means when the offset of each intersection signal control agent changed in the local intersection, it will present the latest information and the state of traffic send to the adjacent traffic signal control agent and management agent, in same time, every intersection traffic signal control agent will be received new information from the adjacent agent at any time.
2. The request of coordination between of signal control agent means when each intersection signal control agent occured any situation of traffic jams in local intersection, it will send some information of the current level of traffic jams and driving direction to the adjacent intersection traffic signal control agent which is related to the direction of the occurrence of traffic block,and to request the adjacent intersection traffic signal control agent would change the assigned-time of signl offest in order to postpone for the situation of congestion in local intersection.

THE CONTENT OF COMMUNICATIONS OF UTSCS

3. The commnication with the management agent means: on the one hand, the management agent bases on experience knowledge and received all of information which is transfered from the intersection traffic control agent,as a whole measuring to the strategy for each intersection traffic control agent. In the event necessary that it would send the instructions of control to agent which one it needed to change the strategy.

THE BRIEF COMMUNICATION LANGUAGE OF UTSCA

In the multi-agent system the interaction is realized among agents by means of the common language, comprehension common of the exchange knowledge and the realization the ability of exchange.

KQML(Knowledge Query and Mainpulation Language) is the communication language from a KSE(Knowledge sharing Effort) institution developed and had been continuously improving and perfecting that is a more mature autonomous asynchronous agent to share the knowledge and to realize collaborative proble-solving. The KQML is the message format,and also supports to share the message processing protocol in real-time between agent which aims to achieve knowledge interoperability among heterogeneous system and integration.

For the UTSCS based on mulit-agent that uses the distributed architecture, each intersection or subsystem has been given greater autonomy, the signal control agent is principal part, in the logic is equality, in the physically is dispersed,in the function is independent,every node is interconnected by passing message, in a common communication language makes the coordination and cooperation to complete their tasks.

THE MODE OF COMMUNICATION

The behavior among agents are autonomous, each node does not exist the strict relation interdependence, but they each other can passing message, in the different message types and different content will lead to different response to the message receiver.

Passing message uses mainly:direct communication e broadcoast communication:

Direct Communication: This is the current object-oriented software design adopts methods, among agents connect physically,through a set of pre-agreed format and rules passing message computing requests and handling the results, this message format such as TCP/TIP and so on , agent can directly send information to agent objective.

Broadcast Communications: The agent will send the message in the form of broadcast, when the message is longer if it adopts to use of direct communication will increase greatly load of the netword,but broadcast communications not need to mutliple copies of messages, therefore can be avoided to increase in netword load.

KQML

The message in form of mainly two kinds: One is the notification message, and the is the query message. The notification message initiative to inform certain information to the recipient; query message is the sender sent the message in order to obtain the state of information of other nodes.

The following any example:the communication of agent in UTSCS:

```
(Invite
   :sender key Agent
   :receiver neighboring Agent
   :context())
(Ask
   :sender
   :receiver
   :context())
(Request
    :sender
    :receiver
:context())(
 (Ensure
      :sender
      :receiver
      :context())
  (Response
       :sender
       :receiver
       :context())
```

KQML

1.sender: who sent the message

2.receiver: who will receive the message

3.Context: the content of message

In the traffic control system, the information transmitted among agents can be summarized as follows:

1.Request: for an agent requests the information to another agent.

2.Response: for an agent responds the request to another agent.

3. Ensure: for between agent to confirm the message precedent whether has been received .

THE COMMUNICATION OF MULTI-AGNET

The structural characteristics of UTSCS based on multi-agent, the communication of traffic control agent is mainly to between the adjacent intersection of agent and as well as to communication with management agent.When the intersection traffic signal control agent controlls the semaphore changes the colore, it must send the information to all its adjacent intersection traffic signal control agent, in order to decision-making applies to the latest information.

When the traffic control agent controlles the intersection occurred the accident and that the traffic was very crowded,in order to clear the traffic as soon as possible, the agent must to request the coordination with the adjacent intersection.

The request of coordination only for a specific adjacent traffic control agent , using the way of one-to-one direct communication.

THE PRIMITIVE OF KQML

The communication of intersection adjacent traffic control agent include:

The transformation of signal control the state of information and the request of coordination.The traffic control agent communicate with the adjacent intersection traffic control agent adopted to the basic communication primitive can be described follows:

(1) Send to the information of adjacent traffic control when the semphore changed the color : the primitive --inform

inform

(inform

sender: // the ID of traffic control agent who sent the message.

receiver: // the ID of traffic control agent who will receive the message.

content: // the content of message.

(action: // send a message to the appropriate message buffer of control agent

(description: // transmission of information cocerning the change of state traffic control agent;

(response: no)))

(2) When request the coordiantion to adjacent traffic control agent : the

primitive –request

(request

sender: // the ID of traffic control agent who send the request of coordiantion.

receiver: // the ID of traffic control agent who will receive the request of coordiantion;

content: // the content of message

(action : // send a message to the appropriate message buffer of control agent

(description: // send the request of coordination and adopt diverse ways corresponding to Q-values;

Response : // whether accept to the coordiantion, if it accepts then returns the result.

)))

The communication between the traffic signal control agent and the management agent is bidirectional.On the one hand, the management agent sends the control strategy to the traffic signal control agent ,it is principal controlled instruction; the other hand, the traffic signal control agent needs to send information about their proper the information the state of traffic signal,as well as will to feedback the effect after the implementation of control strategies.

(1) To send the information of the intersection to the management agent—the primitive inform

inform

(inform

sender: // the ID of traffic control agent who sent the message..

riceviver: // the management agent

content : // the content of the message

(action : // send a message to the buffer of management agent

(decription: // transmission of information concerning the state of change in traffic control agent.

Response: // no)))

(2) In the special case,the management agent send the control instruction to the traffic signal control agent : the primitive –order

order

(order

sender: // the management agent

receiver : // the ID of traffic control agent who will receive the message

content : // the content of the command to execute.

(action : // send a message to the appropriate message buffer of control agent;

(description: // send a command request

Response: // executes the command, and returns the results of implementation of task.)))

THE COORDINATION MODE OF LEARNING OF UTSCS BASED ON MULTI-AGENT

In the UTSCS based on multi-agent , using a model of distributed reinforcement learning, that in the control processing each intersection of traffic signal control agent the goal of learning is optimize the performace of the whoel the system, rather than the performance optimization of agent individual.[13]

Distributed multi-agent system that uses distributed reinforcement learing method computing in parallel can speed up the calculation processing. One of algorithm is distributed value function reinforcement learning[14],it only needs less the communication volume to get the value function of agent adjacent, during the processing of learning through method iterative , non affact the decision-making of agent adjacent,is most likly to obtain system performance optimization,so is a more effective scenario of distributed reinforcement learning.

THE COORDINATION MODE OF LEARNING OF UTSCS BASED ON MULTI-AGENT

In the distributed value function of reinforcement learning , each agent used the information of value function from the adjacent agent would update the value function:

$$V_i(x) = \max_{a \in A_i} \left(R_i(x,a) + \gamma \sum_j f(i,j) \sum_{x' \in X} P(x'|(a,x)) V_j(x') \right)$$

Where $V_i(x)$, is the value function of agent i in the state x , $f(i,j)$ is the value function agent$i$ depends on agent j in the average degree .

This function is substitued into the method of Q-learning , so

$$Q_i(x_i,a_i) \leftarrow (1-\alpha) Q_i(x_i,a_i) + \alpha_i \left(R_i(x_i,a_i) + \gamma \sum_j f(i,j) V_j(x_j) \right)$$

$$V_i(x_i) \leftarrow \max_{a \in A_i} (Q_i(x_i,a_i))$$

These two formulas are distributed Q-learning pricipal step iterative.

THE CONTROL PROCESS OF UTSCS BASED ON MULTI-AGENT

1.Each intersection traffic signal control agent deals with the data from the vehicle detector detected the information of intersention,at the same time, observes the belief of adjacent intersection traffic signal control agent and transmits in itself display the state of traffic send to the adjacent traffic signal control agent and the management agent, the above process, the belief of every the intersection traffic signal control agent has been updated.

2.Each intersection traffic signal control agent will send the belief itself and the set of perceiving the state as in form of a parameter to the respective learning device, the learner device based on multi-agent enviornment distributed learning model to select and evaluate the behavior , to obtain the optimal response mixed strategy in action jointed.

3.Every decision-making of intersection according to the signal control rules and experience should be selcted the strategy.

4. The implementation device controls the strategy then carry out it.

5. The learner device changes the environment by controlled behavior should revise the learning rate and making decision-making again.

6. The above procedure repeated...

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