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Abstract. Complex control systems that operate in not entirely predictable environment have to deal with this environment in an autonomous manner using adaptability, the ability to predict environmental changes, and to maintain their integrity. Elements of the system must be able to find a new solution in a dynamic way. In this paper, we present the modeling of a traffic lights' control system using a multivalent system. This is a large-scale distributed system, consisting of autonomous and rational traffic light agents, in which there is no centre imposing an outcome. Multiagent system brings another kind of organization of the distributed control. The information is distributed over the agents. The behavior of the other agents is incorporated into the making decision process of the agent. We apply different control algorithms in our multiagent simulation environment and show that using multiagent systems in dynamic and unpredictable environment the control will be adoptable.

Keywords—control system; agent; dynamic environment; modeling.

1. Introduction

Multiagent system technology is viewed as a novel and promising software building paradigm. A complex software system can be treated as a collection of many small-size autonomous agents, each with its own local functionality and properties, and where interaction among agents enforces total system integrity. Intelligent autonomous agents are capable of sensing, acting, communicating and realizing task solution. Some of the benefits of using intelligent autonomous agent in distributed control systems are efficiency, robustness, reliability, scalability, flexibility, development and reusability, low cost. Nowadays, multi-agent system technology is being used for a wide range of control applications including scheduling and planning [1], diagnostics [2], condition monitoring [3], distributed control [4], hybrid control [5], congestion control [6], system restoration, market simulation [7], network control [8], and automation. Distributed control multiagent system approaches have been used in various domains, air traffic management where the aircraft competing for air space, systems of public roads where motor vehicles may appear as agents, which compete in the space-time for use of the road.

Multiagent system is exploited in two ways [9]: as an approach for building flexible and extensible hardware/software systems, and as a modeling approach. We note an interesting link between the desirable properties of intelligent control systems for complex autonomous systems and the behavior of agent-based systems. Many benefits are derived from the characteristics of the agents reactivity, proactiveness, and social ability.

This article focuses on the advantages of the use of agents in building control systems and their use for modelling the behaviour of complex control systems that operate in dynamic environments. We raise the hypothesis:

Are Agents capable to structure control problems and organize individual solutions? Is it appropriate to use multi-agents system in modeling a distributed system, which operate in dynamic and unpredictable environment?

In the following section, we prove that agents are able to work together - they can divide problems in subproblems, make the allocation of these subproblems, they are able to resolve individual problems, share these solutions among them, and combine them into complete solution. We develop a multiagent controller system for traffic lights, which is adaptive according to traffic flow. We show that multiagent systems provide a platform for building control system and simulating control problems.

Agents should not be considered simply as a technology [10] also as a modeling approach that can be exploited to represent some system properties that are not simply described as properties or functionalities of single system components but sometimes emerge from collective behaviors. Adaptive solutions can emerge at runtime through the interaction between autonomous individuals and from the task and environment requirements, which might not be fully accessible at the beginning of the problem.

This article focuses on the use of multiagent systems for modeling a decentralized distributed and intelligent control system for traffic lights. This system is based on the concept of autonomous agent. It aims to emphasize the fact that, in such systems the solution is not fully known since in the design phase, it is constantly changing. Intelligent behaviour of the system is achieved as autonomous agents interact among them. These interactions produce feedback, which regulates the system. Such an approach of multiagent systems in the distributed control make them suitable to realize the control in dynamic and unpredictable environment.

2. **Are agents capable to structure control problems and organize individual solutions?**

Control problems cannot be solved in a single step, a good portion of them are complex problems. Complex control problems can be defined in terms of partial control problems and their interdependencies.
A general projection method for the design of multi-controllers consists in local controllers; control algorithms that are operational only in specific parts of the operating regime of the device [11]. During the multi controller design, the designer must deal with aspects of integration, in order to determine when to activate or inactivate a local controller, initialize and finalize the state variables of local controllers and combine control actions of local controllers.
This model is based on a supervisor that integrates local controllers and handles aspects of central integration. From the design perspective, a supervisor who coordinates all controllers in a centralized manner may be not a good option. Although supervisory architecture solves the problems of coordinating a community of local controllers, in general it is not an open solution. Adding, removing or changing the local controllers can not be done without redesign the supervisor. This is due to the separation of control algorithm and characteristic of the operating regime accompanying initialization and finalization functions of local controllers.
A complex control problem is viewed as a set of partial control problems and a set of relationships that exist between partial control problems. Van Breemen developed a method based on the concept of decentralized integration and multiagent system [12].
Agents theory, suggests a different organization, to include all the functions in an autonomous entity [10]. Thus define a controller agent. A controlling agent is a controller that operates locally, autonomous enough, it includes of a control algorithm (in the form of a modification and calculation function), a description of the operating regime, initializing and finalizing functions, and an interface to coordinate the behaviour of it in order to handle the dependencies between controller agents [12].
Agents qualities make them suitable as tools for analysis and design of control systems in a dynamic environment. An agent is a software entity that perceives and acts in its environment and is autonomous in this environment. Its behaviour depends in part on its experience [13]. As an intelligent entity, an agent operates flexibly and rationally in a variety of environmental circumstances [15], [16]. As an entity that solves a problem it becomes usable for solving complex problems. Any partial problem can be solved through a special agent. As an interactive entity, an agent may be affected in its activities by other agents. Dependencies between the partial problems will be interpreted as dependencies between agents.

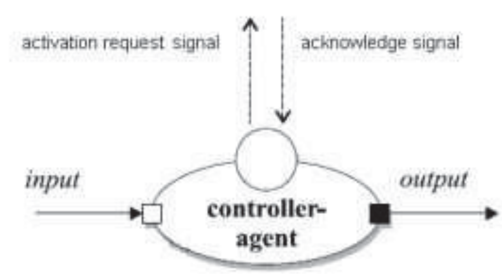

Figure 1 . The architecture of a controller – agent

The focus of an agent based model is on the purpose, functions, communication and coordination [14], - that means, a model based on the agents is related with the structural aspects of a problem. Through modelling individual solutions of the partial control problems with agents and treatment of relations between them through coordination, comprehensive solution becomes a multiagent system.

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3. An agent-based control system for trafic light control.

A view of the traffic grid is presented in figure 1. Every traffic light will be an agent. Electromagnetic sensors will be used to keep track of the number of motor vehicles in each artery.

Figure 2. A view of the traffic grid

The purpose of a traffic light agent is to ensure each motor vehicle a green light as soon as that need this service. This is a rational behavior of a single agent. This behavior will result irrational in multi-agent system's viewpoint. The multi-agent system's goal is to serve in time not only an artery but all the motor vehicles in all arteries. So, in the design of a traffic control system we must take into account interactive decision between agents.

Clearly, what an agent should do depends on what the other agents do. Multi-agent decision making is the subject of game theory. The theory tries to understand the behavior of interacting agents under conditions of uncertainty, and is based on two premises. First, that the participating agents are rational. Second, that they reason strategically, that is, they take into account the other agents' decisions.

The control mechanism has to increase the utility of the whole system by maximizing the cooperation and minimizing the conflicts between traffic light agents. Stefan Lammer and Dirk Helbing [15] in "Demanddriven service" concept, fig 3, define that "a green time starts after a critical number of vehicles has accumulated, which can be served during the green time with maximum rate. Fluctuations in the arrival process are compensated by variable service intervals". This is a good rule in which we can base the interactions between the agents in the same crossroad, that will increase the "satisfaction" of the whole system.

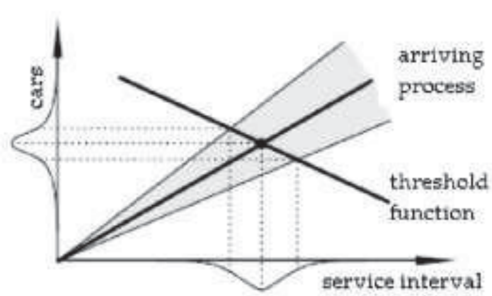

Figure 3. Diagram of "Demand-driven service"

Semaphore agent architecture is based on behavior. Each agent must be equipped with three modules which relate to three levels of behaviors:

Control module ensures that all decisions do not put the traffic light in the same intersection in incoherent situations.

Decision module is the level that allows the agent to decide what to do, based only on local information. Message module is responsible for the communication with the other agent, so that agents are able to take their actions in a distributed manner. Coordination can be regarded as the process by which the individual decisions of the agents result in good joint decisions for the group.

Traffic lights agents play a role in stabilizing the traffic. Although unconscious on the state of other junctions, traffic lights agents perform a global coordination.Traffic flow serves as a carrier of information, transforming system of agents in a decentralized control system, Fig. 4.

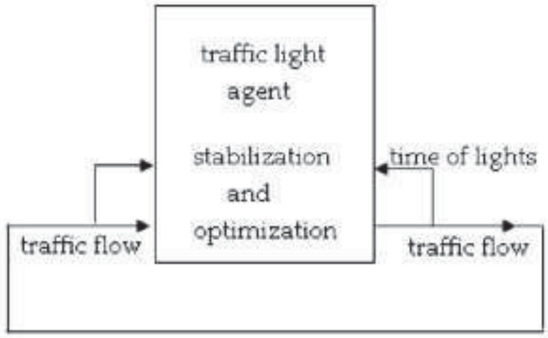

Figure 4. Multi-agent system for traffic lights control - a closed loop control system

Traffic light agent's algorithm

Based on the specifics of an intersection and diagram of "Demand-driven service", we assign a threshold value (threshold_value), as well as a minimum length of service with the green light (θ) to each traffic light.

During the time that the traffic light agent is red. It calculates in cyclic manner k_i = (product of the number of cars with the time that the agent traffic light
is red).

If this product (k_i) is greater than threshold_value. Red light agent makes request to neighboring agent for the green light service. If the green service time of neighboring agent is greater than minimum time (θ)

Agent passes green service to neighboring agentelse, the situation remains the same. State diagram for the traffic light junction are presented in Fig.5.

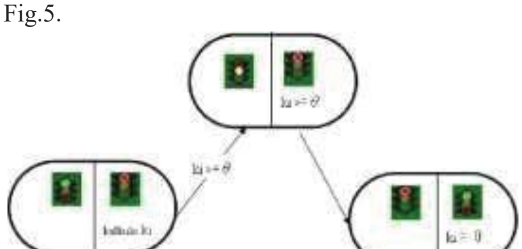

Figure 5. State diagram for the traffic light junction

If there is one or a few machines, they will stop for a long time before a red light.This gives other cars time to join them. As more cars join the group, they will wait less time in front of a red light. If there are enough cars, the red light will turn green before coming vehicles reach the intersection, generating a green wave upon request. Group of cars moving along. improves traffic flow, compared to the homogeneous distribution of cars, because there are large empty areas between groups, which can be used by groups in neighboring artery with less interference. This simple mechanism achieves self-organization [16].

4. Simulation results

Let's return again to the hypothesis set at the beginning of this article. Let's prove that multiagent systems are suitable for distributed control in dynamic and unpredictable environments. Simulation allows us to observe the dynamic behavior of the system and enables us to understand the global behavior at times, even to understand the solution.

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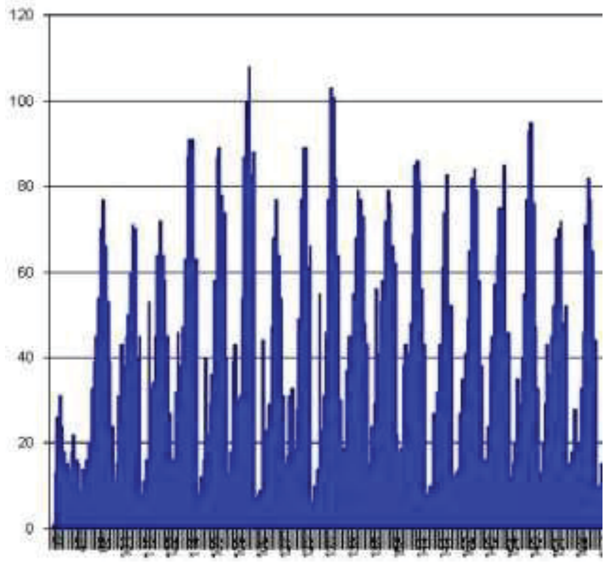

Figure 6. The average waiting time of cars for “green wave” algorithm in traffic lights control

We simulate the traffic control process and then observe how the traffic flow changes by applying "green wave" algorithm, Fig 6, as well as the "selforganizing" algorithm of Gersherson, Fig.7, in traffic lights control.
The graphical results of our simulation show that, the average waiting time of cars in intersections when we use selforganizing algorithm in decentralized multiagent control system is smaller than in the case of “green wave” control algorithm. Also, the traffic is stable.

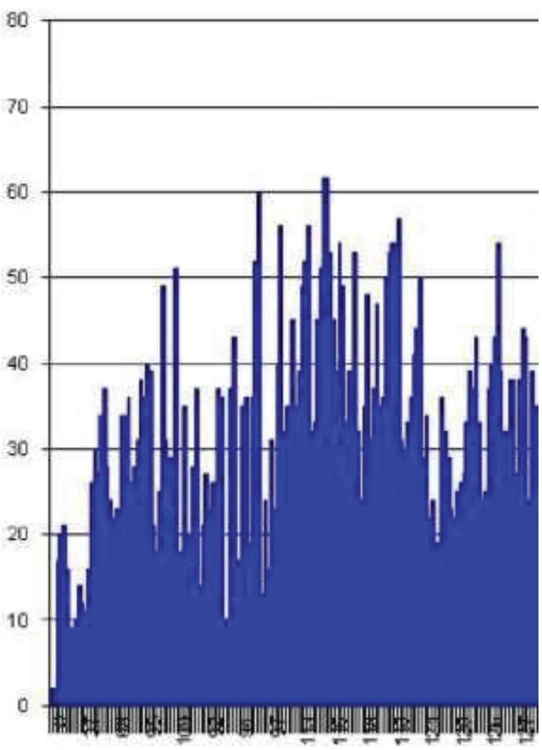

Figure 7. Average waiting time of vehicles for selforganizing algorithm in traffic lights control

Results and discussion

Simulation shows that a multiagent system is an attractive concept to model specific types of distributed unpredictable problems. Multiagent system for traffic control is adaptable according to the traffic flow. The multiagent system face unpredictable environment autonomously using: adaptibility, the ability to predict changes and maintain their integrity against fluctuations that occur without losing the purpose and function. So, such a system is self-organized to achieve a solution. Agents of the system are able to find a new solution in a dynamic way. Multiagent systems are suitable for modular, decentralized and complex applications, satisfying the demand for autonomy and flexibility to find a solution, the ability to communicate between them, sharing and integrating the tasks, resources and information.

Conclusions

Agents platform is suitable for distributed systems. Since agents are modular, the implementation of a multi-agent system is simpler than the implementation of a full centralized system.
Through simulating and modeling the behavior of traffic lights control system, we show that a decentralized multiagent system behaves as an intelligent traffic control system. This system intelligently adapts to traffic flow. The simulating results show that agents are able to work together; they are suitable to be used in the design of distributed systems that operate in dynamic and unpredictable environment. A multi agent system in traffic lights control behaves as a self-organizing system; It produces the necessary information that regulates the system.

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