Research of Intelligent Control of Traffic Signal

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Abstract. At present, in the field of intelligent control of traffic signal, most of scholars at home and abroad use fuzzy control and intelligent algorithm, such as genetic algorithm, ant colony optimization, particle swarm optimization, multi-agent, artificial neural networks, fuzzy method etc. This paper summarizes and analyzes these algorithms, points out the problems and shortcomings in the present research, puts forward the direction and trend in the future research. These works have certain directive significance to the research and development of intelligent control of traffic signal.

Introduction

With the rapid development of economy, the amount of urban motor vehicles grows fast. This causes a series of problems, such as traffic congestion, environmental noise, air pollution, energy consumption etc. It is the truth that there are too many motor vehicles, but the key problem is the backward control mode of traffic signal in our country. In our country, most of traffic signals are controlled by the fixed-timing mode. This mode has been unable to meet the current needs of the urban traffic. There are frequent occasions when there is not any car in the green light direction and there are too many cars in the red light direction. Some traffic signals are controlled by the mode of different scheme in different periods of time. This mode is better than the fixed-timing mode. But this mode also has some shortcomings. When the amount of cars in each direction fluctuates fast, the control effect of this mode will become bad.

Therefore, scholars at home and abroad are devoted to the research of intelligent control of traffic signal. Scholars try to realize the real-time adaptive control of the traffic light. Because traffic flow has characteristics of randomness, nonlinear and complexity, it is very difficult to set up an accurate mathematical model. Therefore, in recent years, most of scholars are researching using fuzzy control and intelligent algorithm to realize intelligent control of traffic light. The intelligent algorithms widely used include genetic algorithm, ant colony optimization, particle swarm optimization, multi-agent, artificial neural networks etc. This paper summarizes and induces these algorithms, analyzes the advantages and shortcomings of each algorithm, and points out the problems in the present research and the direction in the future research.

Intelligent Algorithms used in the Control of Traffic Light

Genetic Algorithm(GA). GA is a computational model which imitates the process of biological evolution. This process is achieved by genetic selection and natural selection.

Chen Xiaofeng and Shi Zhongke put forward the four-phase dynamic control model of traffic signal. They use GA to optimize two targets of green light duration and signal cycle length meanwhile [1]. Li Ruimin and Lu Huapu from Tsinghua University combine the GA and fuzzy control theory, put forward the fuzzy control model of traffic trunk line based on GA [2]. Zhang Dingxue from Huazhong University of Science and Technology introduces predation search strategy into standard GA,
combines GA and particle swarm optimization, and puts forward the control model based on the improved GA and particle swarm optimization.

GA is a typical heuristic random searching method, and has strong robustness. So it can be used for the optimization of complex systems, such as the control of traffic light. Compared with traditional optimization algorithms, GA has many unique and significant advantages. The object processed by GA is code set of parameters, not parameters themselves. During the searching process of GA, it is not necessary that the function is continuous or derivative. Through recombination of excellent genes, GA can deal with the very complex optimization problem. GA is high parallel, so its searching efficiency is very high.

Even though GA has many advantages, there are some shortcomings of GA. GA is prone to premature phenomenon, that means the solution searched by GA is local optimal solution, not global optimal solution. This is the most difficult problem to solve of GA. In addition, there is not a general method in GA to calibrate the fitness value. When GA is near the end of searching, it swings near the optimal solution. So the convergence speed of GA is slow. To solve these problems of GA, researchers put forward some improved methods as follows:

1) The fitness value calibration. Adjust the fitness value of individuals to avoid that population is dominated by the extraordinary individual and the searching process swings near the optimal solution.
2) Elitist selection strategy. Retain some elite individuals into the next generation directly to avoid that some good solutions are destroyed.
3) Adaptive cross and variation probability of genes. Adjust cross and variation probability according to the fitness value of individuals, so that the excellent genes will not be destroyed and the algorithm will not become a blind and random searching process.
4) Niched Genetic Algorithm. Divide individuals of each generation into several kinds, let them evolve in different living environment. This improved method makes the algorithm search all over the solution space to find more optimal individuals. This method avoids that the individuals which have high fitness value bloom in the later evolution. So the algorithm will not stop at the local optimal solution.

Ant Colony Optimization (ACO). ACO is a probabilistic method to search optimal path in graph. Research suggests that ant colony optimization has many good characteristics.

Wen Yu and Wu Tiejun put forward the real-time rolling control model of urban traffic light based on ACO. They use ACO to search optimal phase sequence of traffic light of each intersection, and analyze the algorithmic complexity. The simulation experiment shows good performance [4]. He Jiajia uses ACO to achieve multi-objective optimization, and puts forward the signal control model of single intersection and traffic trunk line [5].

ACO has characteristics as follows:
1) Characteristic of self-organizing. Self-organizing is a process from disorder to order. In the beginning of searching process of ACO, individual artificial ants search solution in disorder. After a period of evolution, through information hormone, artificial ants tend to the optimal solution spontaneity.
2) Distributed computing. The searching process of each ant is independent. Ants communicate only through information hormone. So ACO can be seen as a distributed multi-agent system. ACO searches the solution independently from lots of positions of the solution space. So the algorithm is reliable and has strong global searching ability.
3) Positive feedback. Positive feedback makes the differences at the beginning expand constantly, and leads the searching process to the optimal solution.
4) Robustness. Compared with other algorithms, ACO is undemanding to the initial population, and its searching process does not need manually adjustment. In addition, parameters of ACO are less, and are simpler to set.

Particle Swarm Optimization (PSO). PSO is a new evolutionary algorithm developed in recent years. The algorithm starts from a random solution, searches the optimal solution iteratively. The
algorithm also evaluates the quality of solution according to fitness value. However compared with genetic algorithm, PSO is simpler. PSO does not have cross and variation operation. PSO searches global optimal solution by following the current optimal solution.

Qu Gaofeng and Chen Shuyan set up the signal timing control mode to minimize time delay and number of stops. They solve the model by PSO. The result shows that PSO is feasible [6]. Fu Shaochang and Huang Huixian introduce variation operator into adaptive PSO to improve the individual and global extremum point, set up the discrete control model of traffic light. The simulation shows that the improved PSO can solve local convergence problem and improve control effect of traffic light [7]. Xing Guangcheng puts forward the four-phase and multi-target control model of traffic light using the improved PSO [8].

PSO has characteristics of high precision and fast convergence, and is simple to carry out. However the traditional PSO also has some shortcomings. Scholars at home and abroad put forward some improved methods as follows:

1) Introducing inertia weight. Inertia weight can balance global searching ability and local searching ability of the algorithm.
2) Introducing binary encoding. Traditional PSO is a searching algorithm based on continuous real space. Through introducing binary encoding, PSO can solve discrete binary problem. So PSO can be used to solve combinatorial optimization problem in many projects.
3) Introducing convergence factor. Introducing convergence factor can ensure the convergence of the algorithm and improve local searching ability of the algorithm. So the algorithm has higher convergence speed.
4) Combining with selection strategy. Through selection strategy, PSO can select better area and weed out worse area. So the resources can be allocated more reasonably.

**Multi-agent System.** Multi-agent system is a set consisting of multiple agents. The target of multi-agent system is dividing large complex system into some small systems which are simple to manage. These small systems can communicate and coordinate each other. Multi-agent system has characteristics of autonomy, distribution and coordination, and abilities of self-organization, studying and reasoning. Multi-agent system is robust, reliable and effective.

Burmeister introduces the idea of using multi-agent system in traffic in 1997 [9]. Goldman puts forward the incremental complementary learning intersection controller based on multi-agent system [10]. Based on game theory and multi-agent system, Gao Haijun, Yu Guojun and Li Zhenlong put forward the control model and algorithm of urban traffic [11]. Liu Hongxiu puts forward a coordination method based on multi-agent system. This method can adapt traffic environment which changes in real-time, overcome the disadvantage of high cost of communication in traditional coordination method [12].

Because of distribution of traffic, multi-agent system is very suited for traffic control. Multi-agent system has some advantages in traffic control:

1) Multi-agent system uses the “bottom-up” design method which accords with formation rule of traffic.
2) The hierarchical structure of multi-agent system accords with distribution of traffic.
3) Autonomy and adaptability of multi-agent system accord with intelligent features of traffic.

**Artificial Neural Network(ANN).** ANN is a nonlinear and adaptive information processing system composed of lots of processing units. ANN bases on the researching results of modern neuroscience, tries to process information through imitating processing and memory way of brain.

Li Xiuping gives a method of intersection traffic signal control with online self-learning ability based on neural network [13]. Zhang Kang puts forward the concept of “traffic blocking parameters”, uses fuzzy neural network to train the rule of traffic signal control. The simulation results show that the control effect is improved significantly [14].

ANN has abilities of nonlinear description and adaptive learning. So through training, ANN can approximate any nonlinear relationship. Because ANN has ability of learning, ANN applies to complex multi-phase intersections. ANN can process large amounts of information concurrently.
Meanwhile ANN has fault-tolerant ability of parallel distributed processing. However ANN has some
disadvantages. The convergence speed of ANN is slow. ANN is easy to converge to local extreme. In
view of the above shortcomings, some researchers combine ANN and genetic algorithm. They
optimize weight value and threshold value of ANN through selection, cross and variation operation of
genetic algorithm. Thereby they can get more reasonable network structure and improve learning
speed of ANN [15].

**Fuzzy Control.** Fuzzy control is a control method based on fuzzy mathematics. Fuzzy control does
not need acquiring complex relationship of model or setting up precise mathematical model. Fuzzy
control applies to systems which are very complex or difficult to describe. So fuzzy control applies to
the control of strong random urban traffic.

Chen Hong and Chen Senfa from Southeast University distinguish critical and non-critical traffic
flow, put forward a two-phase fuzzy control method [16]. Zhao Chen and Hu Fuqiao from Shanghai
University of Communication put forward the four-phase fuzzy control model [17]. Hong Wei from
Xi’an University of Communication considers mutual influence between intersections of traffic trunk
line, puts forward the fuzzy coordination control method of traffic trunk line [18]. Lv Zongtao gives a
bi-system control method for the intersection traffic signal based on fuzzy control [19].

Fuzzy control is robust and adaptive, and has fault-tolerant ability. However fuzzy control lacks
systematicness. Therefore, if we want to control the traffic signal better, we should combine fuzzy
control and adaptive control technology and artificial intelligence.

**Conclusions**

Intelligent control imitates the way of thinking of human brain to solve problems, has strong ability of
approximating nonlinear relationships. Intelligent control does not rely on precise mathematical
model. In dealing with the complex and uncertain problems, intelligent control has incomparable
advantages with traditional control methods. Urban traffic is very random, nonlinear and discrete. So
intelligent control is very suitable for traffic signal control, has good control effect. But from the
analysis of all kinds of intelligent algorithms, we can see that there are some disadvantages of each
intelligent algorithm. Therefore, current and future research trend is the combination of various
intelligent algorithms. Researchers use characteristics of each intelligent algorithm to achieve
complementation and thus improve control effect.

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