Stepwise Genetic Fuzzy Logic Signal Control Under Mixed Traffic Condition

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Adaptive traffic signal control typically feeds the real-time traffic data, collected by the sensors, into a build-in controller to produce the timing plans. Thus, it can provide signal-timing plans in response to real-time traffic conditions. Numerous adaptive signal control models have been proposed, especially, fuzzy logic control (FLC) based signal control models are popular. Most of FLC-based signal control models subjectively preset logic rules and membership functions without an optimal learning algorithm. Adjusting the combination of logic rules and membership functions very often requires tremendous efforts, but there is no guarantee to obtain good control performance. Genetic algorithms (GAs) have been proven suitable for solving both combinatory optimization problem (e.g., selecting the logic rules) and parameter optimization problem (e.g., tuning the membership functions). Employing GAs to construct an FLC system with learning process from examples, hereafter termed as genetic fuzzy logic controller (GFLC), can not only avoid the bias caused by subjective settings of logic rules or membership functions but also greatly enhance the control performance.

Most previous GFLC studies, however, have employed GAs either to calibrate the membership functions with preset logic rules, to select the logic rules with given membership functions, or to learn both logic rules and membership functions iteratively. Thus, the applicability of that GFLC is very likely reduced. However, to simultaneously or sequentially learn of logic rules and membership functions may require a rather lengthy chromosome and large search space, resulting into poor performance, a long convergence time and unreasonable learning results (i.e. conflicting or redundant logic rules, irrational shapes of membership functions). To avoid these shortcomings, this paper proposes a stepwise evolution algorithm to learn both logic rules and membership functions. At each learning process, the proposed algorithm selects one logic rule which can best contribute to the overall performance controlled by previously selected logic rules. Such a selection procedure will be repeated until no other rule can ever improve the control performance. Therefore, the incumbent combination of logic rules is the optimal learning results.

To facilitate the learning process of the stepwise GFLC-based signal control model, the cell transmission model (CTM), a mesoscopic model proposed by Daganzo (1994, 1995), is used to evaluate the performance of learned logic rules and membership functions. In addition, the conventional CTM was designed for pure traffic, which is not applicable for many Asian urban streets where mixed traffic of cars and motorcycles is prevailing. Thus, this study also proposes mixed traffic cell transmission models (MCTM) to replicate the behaviors of mixed traffic.

To validate the proposed SGFLC model, case studies on the signal control of isolated intersection and sequential coordinated intersections are conducted, respectively. For the case of isolated intersections, the results show that in terms of total vehicle delay, the SGFLC model performs best in comparing to pre-timed signal control and queue length-based adaptive control models. In the case of sequential intersections, the results consistently show that the SGFLC model performs best, no matter which coordinated signal system (i.e. progressive, alterative, and simultaneous) is operated.

Key words: Adaptive Signal Control, Genetic Fuzzy Logic Controller, Stepwise Learning Algorithm, Mixed Cell Transmission Model

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