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A cooperative framework of learning automata and its application in tutorial-like system

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ABSTRACT

A novel cooperative framework of learning automata (LA) is presented in this paper. In a system, where different LA can be integrated via the proposed framework, current *State of Learning* (SoL) index is advocated to evaluate the learning status of individual LA. Based on that learning status, individual LA will adaptively choose an appropriate interaction strategy at cooperative learning phase. Theoretical analysis demonstrated that this index is able to preserve the ε-optimal feature of independent learning automata. Experimental simulations validated that this cooperative framework is effective in improving learning speed of a variety of LA embedded in this framework. Then, we also present an application of the proposed cooperative framework in tutorial-like systems. Compared with existing method, our cooperative framework based method outperforms in both speed and accuracy.

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1. Introduction

Learning automaton (LA), a promising field of artificial intelligence, is a kind of self-adaptive finite state machine that interacts with a stochastic environment. LA is able to track the optimal action even provided with probabilistic wrong hints. Learning automata are very suitable for learning to control an agent by letting it interact with a well-defined environment. When the information is incomplete or the environment is noisy, LA is significantly superior to other methods. A wide range of learning automata applications are published in areas and some latest such as dynamic resource allocation [1], event patterns tracking [2], recommender systems [3], complex networks [4], function optimization [5], and so on [6–14].

While applications of LA are flourishing, the relatively slow rate of convergence become the bottleneck of LA applications been further investigated. On improving the convergence rate of LA, a plenty of techniques have been introduced: *estimator* [15], *discretization* [16], *generalization* [17] and *stochastic estimator* [18]. There are a number of different learning automata algorithms that incorporating these techniques: DPri [19], DGPA [17], SEri [18], LELA [20] and DGCPA [21] to name but a few. The maturity of single LA theory provides a solid basis for aforementioned applications.

Recent years, however, a number of ensemble methods, such as bagging, boosting, random forests, mixtures of experts, and swarm theory have been proposed in the field of machine learning, known as ensemble learning. Ensemble learning is a aggregation of base learners with the goal of improving accuracy and speed. Likewise, in some specific applications, a team of LA should be employed to solve one learning problem. These LA can be organized in a myriad of structures, such as parallel structure [22], hierarchical structure [23–26] and even networks of LA [27]. Frameworks that combine multiple LA together also show new features and potentials to speed up learning process. In [22], the author proposed a general procedure that suitable for parallelizing a large class of sequential learning algorithms on a shared memory system(demonstrated in Fig. 1). A variety of learning algorithms have shown speed improvement through parallelization. Hierarchical sturcture(demonstrated in Fig. 2) was first introduced in [23] to reduce the number of updatings to be made at each instant, which will lead to slow convergence on obsolete computers when the number of actions is large. Later it is further developed by incorporating estimator-based automaton in [25]. Thathachar show us the way how learning automata can constitute a feed-forward network in his book [27], just like a nerual network. All of these structures are utilizing collaborative intelligence to solve sophisticated problems more effectively and more efficiently. This motivate us to explore the possibility for a prospective framework for ensemble of different LA algorithms. Therefore, a cooperative framework that combines multiple LA algorithms, which allows each learning member communicate with others to enhance its own performance, is proposed in this paper. The ultimate goal is to

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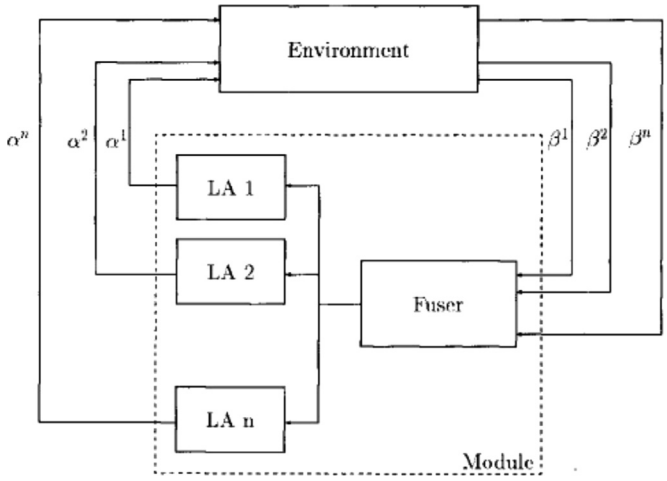

Fig. 1. module of learning automata [22].

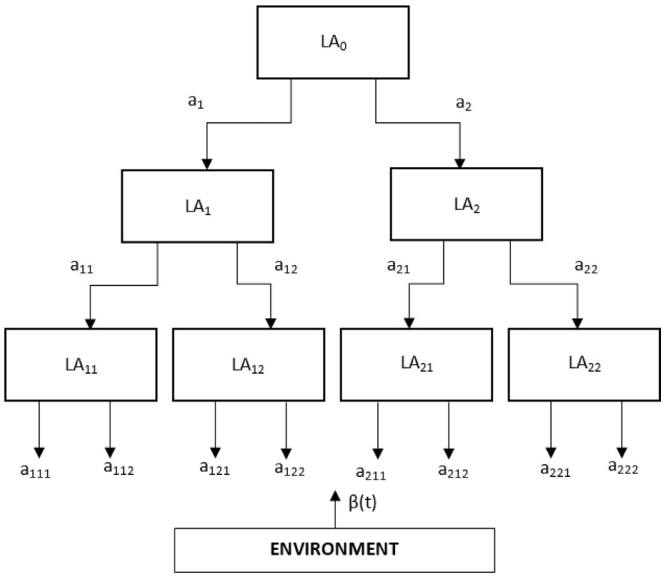

Fig. 2. A hierarchical learning automaton interacting with a stochastic environment [23].

accelerate learning speed without compromising accuracy by the cooperation of LA.

From another perspective, the combination of tutorial-like systems [28] and learning automata (LA) has been a new study direction in the recent decade. Researchers endeavor to simulate components in tutorial-like systems using appropriate learning models. What to teach (domain model [29,30]), who to teach (student model [31,28]) and how to teach (teacher model [32,33]) are the main concerns in tutorial-like systems. Oommen and Hashem have done some excellent pioneering works [31,28–30,32,33] in using LA to model different components of tutorial-like sysyem.Oommen and Hashem [28] first present the student model using LA, then a student–classroom interaction model [34] is built upon it. LA are used as student simulators in [28] which attempt to model the behavior of real-life student in tutorial system. The long-term goal of the literature is that if the tutorial-like system can understand how the student perceives and processes knowledge, it will be able to customize the way by which it communicates the knowledge to the student to attain an optimal teaching strategy. In [34], Oommen and Hashem further developed the paradigm of tutorial-like system, by allowing students to be a member of a classroom of students, which implies that the student

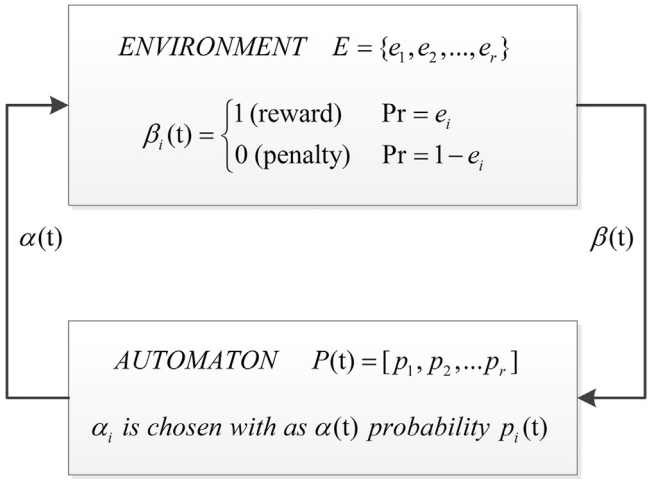

Fig. 3. Block diagram of *learning automaton and environment* interactions.

of the classroom can not only learn from the teacher(s) but also learn from any of his fellow students. Experimental simulation shows that the new philosophy can improve the learning speed of a weak student up to 73%. However, this model enhances speed at the cost of accuracy. In this paper, we use the proposed cooperative LA model to simulate the interaction model among students.

The contributions of this paper are listed as follows:

1. This paper proposed a new cooperative framework of learning automata. A system consists of different LA can benefit from this framework.
2. Current State of Learning (SoL) index is presented to evaluate the learning performance of individual LA. Theoritic analysis demonstrated that this index is able to preserve the ε-optimal feature of learning automata.
3. Experimental simulations verified that the proposed framework is effective in improving learning speed of a variety of LA.
4. Modeling student–classroom interaction in tutorial-like system is presented as a successful application of the cooperative framework.

The rest of this paper is organized as follows. Section 2 introduces basic concepts of LA, as well as background of tutorial-like systems. In Section 3, a cooperative framework of learning automata is proposed, analyzed and experimentaly verified. Application in tutorial-like system has been conducted to further demonstrate the significance of the proposed cooperative framework in Section 4. The last section concludes this paper.

2. Fundamentals

In this section, we would like to introduce the basic concepts of the learning automata firstly, including the definition of automaton and the stochastic environment with which the automaton interacts, and a brief introduction of tutorial-like systems is given then.

2.1. Learning automaton (LA)

Learning automaton is an autonomous system that interacts with the environment and adaptively adjusts it behavior [16] towards being maximal rewarded. A block diagram illustrating how automaton interacts with environment is given in Fig. 3.

Environment, the aggregate of external influences of learning process, can be depicted as $\langle A, B, E\rangle$. Automaton, the learning

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