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Control of technical object on the basis of the multi-agent system with neuroevolution and student-teacher of-line learning

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Abstract. This paper presents algorithm for generating neuroevolutionary multi-agent system that allows agents to learn from high-quality activities. Dissimilar traditional learning algorithms proposed algorithm combines student-teacher of-line learning and teaching agents based on sufficient activities producing by any agent in its subculture. The simulation studies demonstrated that the proposed algorithm is effective at rapidly generating near-optimal control agents.

Introduction

This research formalizes problem of technical object's control solving by multi-agent system with neuroevolution and student-teacher of-line learning. Unlike existing single-agent and team-search problems in proposed algorithm the agents collaborate through knowledge of other agents during the dynamic changes in the technical system [1]. Neuroevolution is evolution of neuronets, has arisen as a powerful approach to fulfilling intelligent activities for agents. Evolved networks take a number of simulated or real sensor signals as input, and generate a nonlinear mapping to outputs that define control signal. Recurrent neuronets integrate information over time, and generate output signals robustly under random perturbations and partially observable as opposed to standart value-function based reinforcement learning methods have trouble. Therefore, automatic design methods utilizing intelligent techniques [2-6] such as neuroevolution are effective in fulfilling intelligent agents. NeuroEvolution of Augmenting Topologies (NEAT [1]) is a method for evolving neuronets that adjusts both the topology and the weights as part of the learning process. NEAT has been shown to be successful in several open-ended design domains. Student-teacher techniques can be fulfilled in different ways. We are implemented of-line learning.

Nowadays around 70% of electric power is consumed by electric drives. Therefore, we are considering induction motor as an example of common technical system.

1. Model of the technical object's control on the basis of the multi-agent system with neuroevolution and student-teacher of-line learning

The multi-agent system consists of autonomous control agents evolved through neuroevolution and student-teacher of-line learning. Each control agent represents artificial neuro-controller. Fulfilling an operation of adding and pruning neurons and adjusting weights, NEAT evolves genomes that interpret as networks. The agent's success in control of technical

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system defines its fitness. Every generation reproduced networks with the highest fitness, while those with the lowest fitness are unlikely to do so. Therefore, NEAT provides genetic diversity through speciation and supports innovation through explicit fitness sharing. Fig.1 presents the proposed algorithm for generating the multi-agent system with neuroevolution and student-teacher of-line learning.

```
Input: generations; maxTimesteps
population ← InitializePopulation()
g ← 0
t ← 0
loop
        while g < generations do
        subcultures ← FormSubcultures(population)
                while t < maxTimesteps do
                        for each subculture in subcultures do
                                for each agent in subculture do
                                        s ← ReceiveAgentInputs()
                                        a ← GetResponse(agent; s)
                                        r ← TakeAction(a)
                                        agent.memory ← UpdateMemory({s; a; r})
                                end for
                                for each agent in subculture do
                                        if Acceptable(agent.memory) then
                                                for all observer in subculture do
                                                        Train(observer, agent.memory)
                                                end for
                                        end if
                                end for
                        end for
                        t ← t + 1
                end while
                population ← SelectAndReproduce(population)
                g ← g + 1
        end while
end loop
```

Figure 1. The proposed algorithm for generating the multi-agent system with neuroevolution and student-teacher of-line learning

During the generating the multi-agent system with neuroevolution and student-teacher of-line learning individuals within the population were ranked depend on the weighted sum of the fitness parameters. The experiment was conducted to measuring the performance of a monocultural algorithm of the multi-neuroagent search in Darwinian and Lamarckian evolutionary paradigms. There are two main categories of the genetic inheritance paradigms in evolution: Darwinian and Lamarckian. During Darwinian evolution, genomes are fixed and any knowledge or qualities shared during their lifetimes are not passed on to their offspring at birth. Unlike, in Lamarckian evolution an agent's genome adjusts as it learns during its life, and these changes are passed on to each of its offspring. In the context of neuroevolution, this corresponds to whether the changes in each agent's neuronet weights, as a result of social learning, are propagated to their genome at the end of the generation. Also experiment was conducted to compare the performance of the proposed algorithm for generating the multi-agent system with neuroevolution and student-teacher of-line learning with Darwinian, Lamarckian and simple neuroevolutionary algorithms.

2. Simulation and results

All the simulations for this study are implemented in MATLAB, Simulink. Figures 2 to 4 illustrate the simulation's results. Figure 2 shows the results of applying a monocultural algorithm of the neuroevolutionary multi-agent search to the induction motor's control in both the Lamarckian and Darwinian algorithms. The aforementioned algorithms quickly converged, but performance Darwinian algorithm better than Lamarckian. For on-line evolution Darwinian algorithm is likely to be preferred to Lamarckian in dynamic environments such as induction motor's control because adaptation is important. The adaptation is necessary for agents to control induction motor during the dynamic changes in the technical system and generate control signal robustly under random perturbations and partially observable.

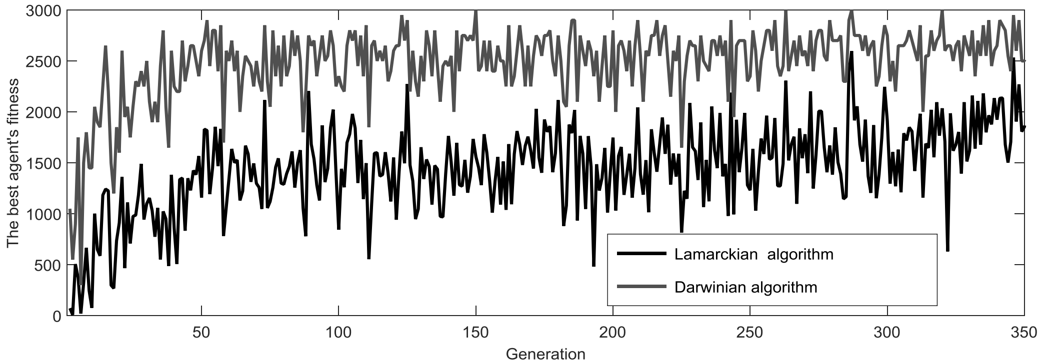

Figure 2. Plot of the performance Darwinian algorithm and Lamarckian algorithm respectively

Figure 3 shows the results of applying the proposed algorithm for generating the multi-agent system with neuroevolution and student-teacher of-line learning to the induction motor's control. Ultimately, in all aforementioned cases performance of the proposed algorithm converges to a higher score than that of simple neuroevolution, Darwinian and Lamarckian algorithms (Figure 3).

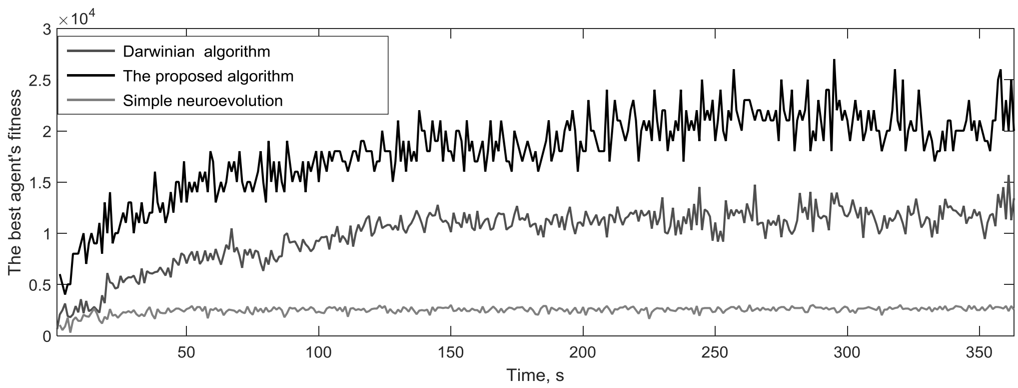

Figure 3. Plot of the performance Darwinian algorithm, the proposed algorithm for generating the multi-agent system with neuroevolution & student-teacher of-line learning and simple neuroevolution algorithm respectively

The proposed algorithm through evolution of recurrent neuronet generates a more effective intellectual model of the induction motor's control, as compared with the standard control model based on PI controller (Figure 4).

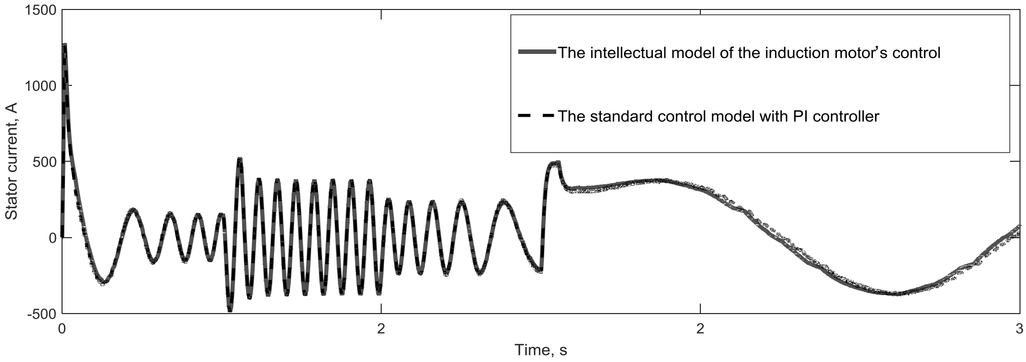

Figure 4. Plot of the control signal provided by the intellectual model of the induction motor's control and the standard control model with PI controller respectively

Extensive simulation studies on Simulink model have been carried out on different initial conditions, different disturbance profiles and variation in induction motor's control system parameters. It shows consistent performance has been achieved for the proposed algorithm on the basis of the recurrent neuronet with good stability and robustness, as compared with Darwinian, Lamarckian and simple neuroevolution algorithms.

3. Conclusions

This paper presented the algorithm for generating the multi-agent system with neuroevolution and student-teacher of-line learning that enables control agents to learn from high-quality activities. Unlike traditional social learning algorithms that follow a student-teacher model, proposed algorithm combines student-teacher of-line learning and teaching agents based on sufficient activities producing by any agent in its subculture. Extensive simulation studies demonstrated that consistent performance has been achieved for the proposed algorithm on the basis of the recurrent neuronet with good stability and robustness, as compared with Darwinian, Lamarckian and simple neuroevolution algorithms. The proposed algorithm generates a more effective intellectual model of the induction motor's control, as compared with the standard control model based on PI controller.

References

[1] Stanley K O and Miikkulainen R 2004 Competitive coevolution through evolutionary complexification *Journal of Artificial Intelligence Research* **21** pp 63-100
[2] Engel E A 2012 Solving control problems, decision making and information processing by fuzzy selective neural network *Information Technology* **2**
[3] Kovalev I, Zelenkov P, Ognerubov S, Bahmareva K, Denisova E 2015 The efficiency analysis of the automated plants *IOP Conference Series: Materials Science and Engineering* **70 (1)**
[4] Engel E, Kovalev I V, Kobezhicov V 2015 Intelligent control of non-linear dynamical system based on the adaptive neurocontroller *IOP Conference Series: Materials Science and Engineering* **94 (1)**
[5] Kovalev I V, Kovalev D I, Zelenkov P V, Voroshilova A A 2015 The pseudo-Boolean

optimization approach to form the N-version software structure *IOP Conference Series: Materials Science and Engineering* **94 (1)**

[6] Engel E, Kovalev I V, Karandeev D 2015 Energy-saving technology of vector controlled induction motor based on the adaptive neuro-controller *IOP Conference Series: Materials Science and Engineering* **94 (1)**

[7] Kovalev I, Zelenkov P, Ognerubov S 2014 The Efficiency Analysis of Automated Lines of Companies Based on DEA Method *Lecture Notes in Economics and Mathematical Systems* **675** pp 107

[8] Kovalev I V, Zelenkov P V, Ognerubov S The practical approach to the reliability analysis of the software architecture of a complex company control system *IOP Conference Series: Materials Science and Engineering* **94 (1)**