Genetic Algorithm Aided Optimization of Hierarchical Multiagent System Organization

(Extended Abstract)

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ABSTRACT

In this paper, we propose a genetic algorithm aided optimization scheme for designing the organization of hierarchical multiagent systems. We introduce the hierarchical genetic algorithm, in which hierarchical crossover with a repair strategy and mutation of small perturbation are used. The phenotypic hierarchical structure space is translated to the genome-like array representation space, which makes the algorithm genetic-operator-literate. Our experiments show that competitive structures can be found by the proposed algorithm. Compared with traditional operators, the new operators produced better organizations of higher utility more consistently. The proposed algorithm extends the search processes of the state-of-the-art multiagent organization design methodologies, and is more computationally efficient in a large search space.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search – *heuristic methods.*

General Terms

Algorithms

Keywords

Genetic Algorithm, Hierarchical Crossover, Multiagent Systems, Organization Design, Representation, Tree Structures.

1. INTRODUCTION

In the last few years, there has been a growing interest in the organization design of a multiagent system (MAS), since various organizations employed by a system with the same set of agents may have different impacts on its performance. Previous studies [1], [4] suggested the use of a utility as the quantitative measurement of the system performance to automate the process of organization design.

Among all kinds of organizations, the hierarchical structure is one of the most common observed in multiagent systems. Due to the difference in the depth and width of the hierarchy, the number of organization instances increases exponentially with the number of agents. Although many methodologies for organization modeling have been proposed, few of them present an effective way to search for an optimal organization instance.

Recently, evolutionary based search mechanisms have been used to help the design of MAS organizations [5], [2], [3]. These techniques show a promising direction to deal with organization search of hierarchical multiagent systems, as exhaustive methods become inefficient and impractical in a large search space.

This paper proposes a genetic algorithm (GA) approach to optimize hierarchical multiagent systems. We design novel crossover and mutation operators to make the algorithm suitable for organization evolution and thereby ensure competitive performance. Experiment of the algorithm is carried out with the information retrieval (IR) model [1] which exhibits numerous possible organizational variants.

2. ORGANIZATION REPRESENTATION

We propose an array representation of hierarchical MAS organizations. It converts s set of hierarchical trees into a fixed-length array with integer components. The representation is not limited to describing a single tree, or just binary trees. The number of subordinates of each node need not be a constant. Unbalanced trees, in which leaf nodes are not on the same hierarchical level, can also be depicted using this representation.

We assume that the number of leaf node agents is fixed and that the upper bound of the level number is determined. Let N be the total number of leaf nodes, so that the they can be numbered as 1, 2, …, N respectively from left to right. Let M be the maximum tree depth (i.e. maximum height of the structure). The organization of a hierarchical MAS can be outlined by:

$a_1 a_2 a_3 \ldots a_{N-1}$

where a_i is an integer between 1 and M, denoting the level number where leaf nodes i and i+1 start to separate. An example with seven leaf nodes (N=7) is illustrated in Figure 1. (Agent

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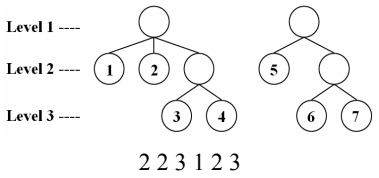

Figure 1. An organization and its array representation.

nodes are displayed as circles in the figure. Leaf nodes are numbered.)

The representation is compatible with genetic operators such as one-point, two-point or uniform crossover. Bit-wise mutation can also be applied to this representation.

3. CROSSOVER AND MUTATION OPERATORS

To speed up the evolution and increase the chance of getting a desired structure with higher utility, we propose a novel crossover operator, hierarchical crossover, specially designed for optimizing tree-structured organizations. The operator, based on the representation described in Section 2, contains a swap of sub-organizations and a repair strategy to keep the number of total leaf nodes constant.[1]

In addition to the crossover operator, we use the mutation of small perturbation. It is different from bit-wise mutation in that the digit can only increase by 1 or decrease by 1 with equal probability. In the cases of the boundaries, if the perturbed digit is out of bounds, the original value is restored.

4. EXPERIMENT

We examine the algorithm in the IR system [1]. We compare the proposed algorithm, called hierarchical genetic algorithm (HGA), with the standard GA using one-point crossover with bit-wise mutation (SGA1) and two-point crossover with bit-wise mutation (SGA2) to show the benefits of the newly introduced operators. We evaluate the algorithms in terms of the accuracy and the stability of search, which are described by average percentage relative error (APRE) and success rate (SR) respectively. We investigate the test cases of 12, 14, 16, 18, 20, 22, 24, 26, 28, and 30 database agents. The maximum height of the structures is set to be 4. All cases involve 10 independent runs.

From Table 1, we can see that the accuracy of HGA is better than SGA1 and SGA2 in 9 out of the 10 cases. Regarding the search ability, HGA also has an advantage over SGA1 and SGA2 in the majority of the test cases. The superiority of HGA is more pronounced in larger-scale organizations which contain more than 20 database nodes.

Moreover, HGA uses much fewer evaluations compared to other methods such as ODML [1]. For example, number of evaluations needed for HGA in the 30-database case is 200,000, where as ODML will have to evaluate 3,788,734,984 candidates. This saves a great amount of computation burden, as the calculation of utility functions can be very computationally expensive.

Table 1. APRE and SR

No. DBs	SGA1		SGA2		HGA	
	APRE	SR	APRE	SR	APRE	SR
12	0.1103	0.5	0.1122	0.5	**0.0370**	**0.8**
14	0.0090	0.8	0.0460	0.7	**0**	**1**
16	0.0966	0.7	0.0869	0.8	**0**	**1**
18	0.0940	**0.8**	**0.0372**	**0.8**	0.0505	**0.8**
20	0.1150	**0.5**	0.3076	0.1	**0.0749**	0.3
22	0.2037	0.1	0.3085	0	**0.0031**	**0.9**
24	0.3376	0.2	0.4914	0	**0.0406**	**0.9**
26	0.1556	0.4	0.3494	0.1	**0**	**1**
28	0.2104	0.2	0.5307	0	**0.0067**	**0.9**
30	0.2470	0.2	0.4825	0.1	**0**	**1**

5. CONCLUSION

We have proposed a novel genetic algorithm based approach to solve the problem of designing the best organization in hierarchical multiagent systems. Complementary to existing methodologies that emphasize on the pruning of the search space, our algorithm uses a bio-inspired evolutionary approach to lead the search to promising areas, and is thus suitable for optimizing multiagent systems with a great variety of possible organizations where designer expertise alone is not enough or hard to acquire.

6. ACKNOWLEDGMENTS

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