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Procedia Engineering 15 (2011) 3689 – 3693

Procedia Engineering

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Advanced in Control Engineering and Information Science

A multi-agent evolutionary algorithm for connector-based assembly sequence planning

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Abstract

Some Evolutionary algorithms for connector-based ASP have been researched. But those algorithms have lots of blind searching because individuals have little intelligence in making use of geometry and assembly process information of product assembly body. To improve individuals' intelligence, A multi-agent evolutionary algorithm for connector-based ASP (MAEA-ASP) is presented which is integrated with the multi—agent systems. learning、competition and crossover -mutation are designed as the behaviors of agent which locate lattice-like structure environment. Experimental results show that MAEA-ASP can find an approximate solution faster compared with other evolutionary algorithms.

Keywords: Assembly sequence planning; Evolutionary algorithm; Learning; Competition; Cooperation;

1. Introduction

In the past few years, significant work has been done to develop artificial intelligence (AI) or soft computing techniques applicable to the ASP problem. Some approaches have been developed to connector-based ASP. Hwin-En Tseng and Rone-Kwell proposed a novel means of means of generating assembly sequences using the connector concept[1]. ZhouPing et al suggested a connector-based hierarchical approach to assembly sequence planning for mechanical assemblies[2]. H.-E. TSENG* and C.-E. TANG proposed A sequential consideration for assembly sequence planning and assembly line balancing using the connector concept[3]. Tseng, H. -E. suggested Guided genetic algorithms for solving a

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doi:10.1016/j.proeng.2011.08.691

larger constraint assembly problem[4]. In the above EA, individual is encoded as a permutation order of parts, but each individual has many parts whose position can't satisfy basic constraint conditions. Let's take fig.1 for example. Such as any permutation including "bc" sequence is an impossible solution in fig.1 because b and c is not adjacent. It is also to say that traditional EAs will generate a great deal of infeasible solutions in the evolution process which results in inefficiency of the solution-searching process. To improve individuals' intelligence, A multi-agent evolutionary algorithm for connector-based ASP (MAEA-ASP) is presented which is integrated with the multi—agent systems.

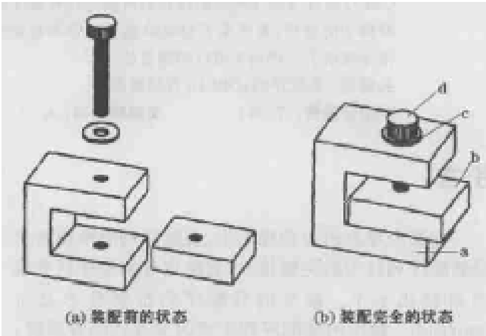


Fig.1 a. the status before assembly
b. the status after assembly

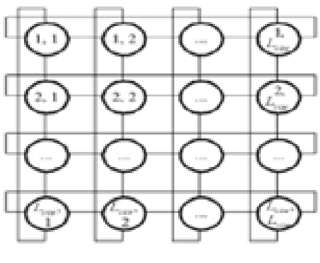
2 MAEA for connector-based ASP

2.1 Environment of agents

According to [5], an agent is a physical or virtual entity that essentially has the following properties:(a) it is able to live and act in the environment;(b) it is able to sense its local environment;(c) it is driven by certain purposes and (d) it has some reactive behaviors. Multi-agent systems are computational systems in which several agents interact or work together in order to achieve goals.

In the paper，the environment is organized as a latticelike structure, which is similar to literature [5].

Latticelike structure definition: All individuals live in a latticelike environment L. The size of L is Lsize×Lsize，where Lsize is an integer. Each individual is fixed on a lattice-point and can only interact with the neighbors. Suppose that the individual located at (i, j) is represented as Li,j, i,j=1,2,…,Lsize，then Neighborsi,j are defined as follows:



$$Neighbors_{i,j} = \{L_{i',j}, L_{i,j'}, L_{i'',j}, L_{i,j''}\}$$

$$\text{Where } i' = \begin{cases} i-1 & i \neq 1 \\ L_{size} & i = 1 \end{cases}, \quad j' = \begin{cases} j-1 & j \neq 1 \\ L_{size} & j = 1 \end{cases}$$

$$i'' = \begin{cases} i+1 & i \neq L_{size} \\ 1 & i = L_{size} \end{cases}, \quad j'' = \begin{cases} j+1 & j \neq L_{size} \\ 1 & j = L_{size} \end{cases}$$

Fig.2 The lattice model of individuals enviorment

The lattice can be represented as the one in fig.2. Each circle represents an agent, the data represent the agent's position in the lattice, and two agents can interact with each other if and only if there is a line connecting them.

In the agent lattice, to achieve their purposes, Individuals will compete with others so that they can gain more chance to produce offsprings. Since each Individual can only sense the local environment, the behaviors can only take place between the individual and the neighbors. A individual interacts with the neighbors so that information is transferred to them. In such a manner, the information is diffused to the whole agent lattice. As can be seen, the model of the agent lattice is closer to the real evolutionary mechanism in nature than the model of the population in traditional EAs.

2.2 Three Evolutionary Operators for Agents

To achieve its purpose, Competition, learning and crossover-mutation three evolutionary operators is designed for agents. Learning operator realize the behaviors of making use of knowledge. Crossover-Mutation operator realize cooperation among agents. Competition make better agent get more chance to survive.

2.2.1 Competition

In this operator, the energy of an agent is compared with those of the neighbors. The agent can survive if the fitness is maximum; otherwise the agent must die, and the child of the one with maximum fitness among the neighbors will take up the lattice-point.

Suppose that the competitive behavior is performed on the agent Li,j located at (i, j), and Maxi,j is the agent with maximum fitness among the neighbors of Li,j, namely,Maxi,j∈Neighborsi,j and ∀Individual∈Neighborsi,j,then Individual(E)≤Maxi,j(E). If Li,j(E) ≤Maxi,j(E), then Maxi,j generates a child agent, Childi,j, to replace Li,j,; otherwise Li,j is left untouched. Where Individual(E) and Maxi,j(E) denotes the corresponding agents. In fact, Childi,j is generated by exchanging a small part of Maxi,j, and is equivalent to performing a local search around Maxi,j. The purpose of the competitive behavior is to eliminate the agents with low energy, and give more chances to the potential agents.

2.2.2 Leaning

Agents have knowledge which is related to the problem that they are designed to solve. In fig.1, the adjacent relationship of ‘b’ and ‘c’ is knowledge. In the fig.5(c), Precedence graph of connectors for electric fan is knowledge。Agent check its connector-based asp from start to end , if there exits two adjacent parts which are x1 and x2 whose relationship is not accord with Precedence graph of connectors,then Minimum conflict decoding is used to improve its energy。

2.2.3 Crossover-Mutation

Parent A(a, b, c, d, e, f, g, h, i, j, k,
Parent B(a, f, d, b, e, c, g, h, j, i, k, l, m)
Offspring1(a, d, b, e, c, f, g, h, j, i, k, l, m)
Offspring2(a, b, c, d, e, f, g, h, j, i, k, l, m)
Offspring3(a, d, b, e, c, f, g, h, j, i, k, l, m)
Offspring4(a, f, b, c, d, e, g, h, j, i, k,
Offspring5(a, f, d, b, e, c, g, h, i, j, k,
Offspring7(a, *c, e, b, d,* f, g, h, j, i, k, l, m)
Offspring6(a, f, b, c, d, e, g, h, i, j, k, l, m)
Offspring8(a, f, *e, d, c, b,* g, h, j, i, k, l,

Figure. 3. An example of reversal operator based on

We find the effect of crossover and mutation presented by K. Katayama and H. Sakamoto for combinatorial optimization problems is very good. The crossover method is called a complete subtour exchange crossover (CSE-X) [6]. We present a reversal operator based on CSE-X to increase individuals’ varieties. It is illustrated in fig. 3. Offspring7 and offspring8 are the offspring of parent A and parent B with the reversal operator based on CSE-X.

2.3 The flow of MAEA for connector-based ASP

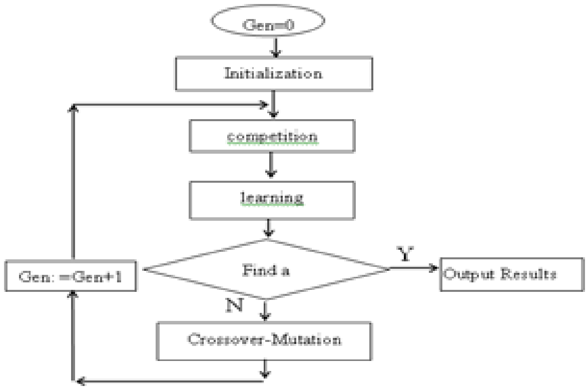


Fig.4. Flowchart of MAEA-ASP

3 Experimental results

The electric fan consists of 38 parts. According to the principle of connector settings,25 connectors can be specified. Figure.5(a) illustrates the parts of the electric fan; figure.5(c) shows the precedence graph for the fan connectors. In this example, In terms of the engineering data, the combination type, assembly tools, and assembly direction are equally important. These data is same as reference[4]. The energy of agent is equal to the fittness of individual. The number of agents is set 9. Under this condition, two algorithms implement ten tests for comparison. The results are shown in table 1 and fig.6.

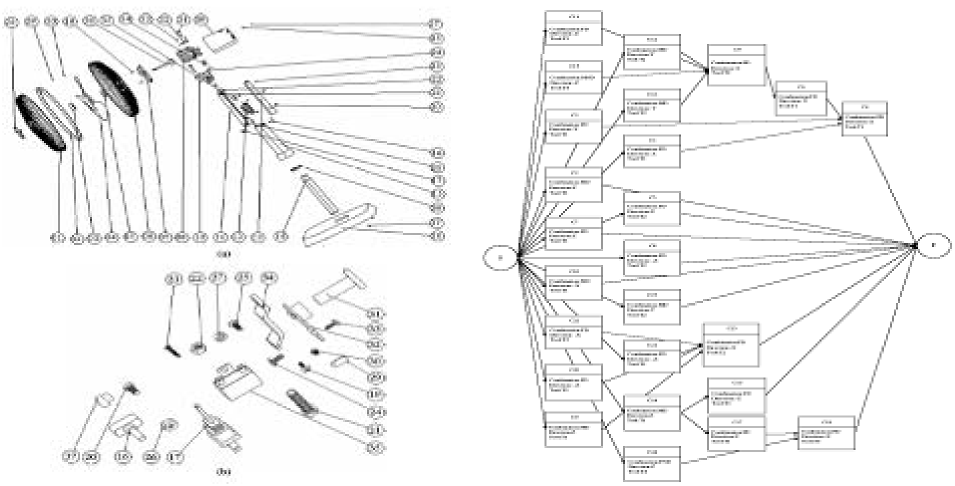


Figure 5. Electric-fan parts: (a) exploded drawing and (b) enlarged scale drawing for small parts in (a).
(c) Precedence graph of connectors for electric fan.

Table1 A comparison among three EAs (fan)

Method	Average runtime	Average fitness	MaTimum fitness
T-GAs	2.808	16.133	16.667
G-GAs	3.951	18.285	18.333
MAEA-ASP	0.38	18.426	19.139

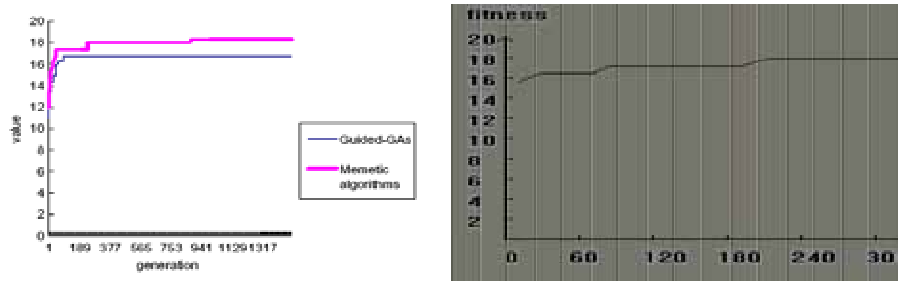


Fig 6 (a)Convergence plot of electrical fan. (b) Convergence plot of MAEA on fan.

Figs. 6 display the part drawing and the connector-precedence graph, respectively. The results of comparison for Guided-GAs and MAs can be found in Table 1. From the results of Guided-GAs in Table 1, the average computation took up3.951s , the average fitness value was18.285, and the aximum fitness value was 18.333. Furthermore, the average computation time of MAEA engaged 0.38s, the average fitness value was18.426, and the maximum fitness value was 19.139. Fig. 6 presents the convergence diagrams of these two algorithms. The critical point here indicates that if we sacrifice a little computation time for achieving more superior solution quality, the MAEA is undoubtedly a preferable selection for assembly planning decision.

4. Conclusion

In this paper, a new algorithm to solve connector-based algorithm is proposed to combine multi-agent systems and evolutionary algorithms. The experiment results show that algorithm has a faster speed in finding solutions.

5. Acknowledgements.

This work has been supported by National Natural Science Foundation of China(Grant NO.61063039,No. 50865003,No. 60963010, NO.60903079) and the Guangxi Provincial Natural Science Foundation ,China (No. 2011GXNSFA018156, No. 0832006Z).

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