Guiding Disassembly Sequence Planning Based on Improved Fruit Fly Optimization Algorithm

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Abstract: How to improve the efficiency of guiding disassembly sequence is the main research contents of augmented reality maintenance. To furnish the disassembly sequence to the system efficiently, assembly disassembly hybrid hierarchical graph model is established based on interference matrix between the assembly parts. The assembly's disassembly mathematical model is build and a newly fruit fly optimization algorithm combined with genetic algorithm is used to solve the best path. Finally, an example based on augmented reality guiding system is analyzed in detail to show that the method is appropriate and efficient, the method has offered guidance to the research of augmented reality disassembly guiding system.

Introduction

With the fast growth of virtual reality technology, augmented reality [1] has got a fleetness develop. Compared with traditional maintenance mode, the guiding maintenance based on augmented reality has the advantages of lower cost, higher maintenance efficiency and more simple maintenance process. The application of Augmented Reality allows maintenances that even with no rich experience to rapidly complete disassembly and repair under the guidance of the equipment system. Guiding disassembly is the core of guiding maintenance. It is based on the maintenance in the process of operating disassembly sequence planning, intelligence transports relative guidance information. The research of Disassembly sequence has become an important content of augmented reality system. The nature of the assembly maintenance's induced disassembly issues is the optimization problem of part's disassembly sequence, the important goal is how to search the solution space quickly and efficiently, and get a better induction program.Existing research in product disassembly AND / OR graph or other based on graph theory basic topology model apply such as simulated annealing algorithm [2], genetic algorithm [3], PSO [4], ant algorithm [5]etc. to generate the sequence of disassembly automatically according to the disassembly optimization goals. Xiaohong Zhang, Shiqi Li [6] product disassembly hybrid graph model and use the ant colony algorithm to design the search space which satisfy contact relationships and non-con-tact priority relationships is to obtain the optimization or near optimization disassembly sequence. Junfang Xue, Changhua Qiu [7], on the basis of the relationship of disassembly precedence constraints on products, propose and build the level of disassembly information and graph model of target part, and propose an improved PSO to achieve search and optimization for the program of disassembly. Compared with fruit fly optimization algorithm [8], these algorithms incur much larger amount of calculation. But, the fruit fly optimization algorithm has the gaps of poor stability and local optimum. Based on augmented reality technology to disassembly sequence planning problem, this paper builds the mixed hierarchical assembly graph according to the requirements of maintenance to the target part and the assembly of parts disassembly precedence constraints, and makes use of the cross mode of the genetic algorithms, combines fruit fly optimization algorithm [9] and genetic algorithms [10] to optimize disassembly sequence online, this method ,which is adopted to solve the problem of poor stability and local optimum in fruit fly optimization algorithm, is verified and analysis in augmented reality disassembly system .

Improved Fruit Fly Optimization Algorithm

Fruit Fly Optimization Algorithm(FOA) is an optimization based on the foraging behavior of drosophila after particle swarm algorithm and ant colony algorithm were proposed, which was made by Panchao Wen, a teacher from Taiwan. It can find the most concentrated smell fruit fly along with the iteration which use mainly the advantage between drosophila olfactory and visual senses and other species, which can collect a variety of odors into the air.

According to the disadvantage of FOA, combining with the characteristics of the fruit fly in search of food, the improved algorithm can be summarized as the following steps.

（1）Producing the position of a fruit fly population randomly. The position was expressed by coordinates (X_axis, Y_axis).

（2）Imparting the individual random searching direction and distance to find the food use the drosophila olfactory, and then, when drosophila searches for food, adop the cross mode of the genetic algorithms.

（3）Acting the reciprocal of the distance between the current position and the origin position as a flavor concentration judgment value.

（4）Substituting the determination value of the flavor concentration into the taste of the flavor concentration determination function, typically called optimized function, researching the concentration of taste of the drosophila individual position.

（5）Finding the taste of the fruit fly population in the highest or lowest concentration of fruit flies according to the optimization objective of the function.

（6）Drosophila groups flying toward optimal flavor concentration, and retain x, y coordinate values.

（7）Iterating and finding the optimal solution, repeating the above steps. The termination condition is the number of iterations.

This algorithm is simple, efficient, and able to escape local minima until find a global optimal solution. Application in augmented reality can save time of the algorithm and make efficient induction of the operator.

Establish Disassembly Induced Model

Disassembly induced model of the assembly contains various parts of the model and the mate-relationship model among the parts. Parts of the model include name of parts, type of parts, and location of parts in the assembly. Mating constraints among the parts includes two aspects: constraint type and reference elements. Constraint type include fit, alignment，insertion, tangency, etc. Reference elements refer to the geometrical elements such as point, line, surface, the coordinate system, etc. consulting in assembly. Establishing an assembly disassembly induction model is to establish the structural model which can describe information of product components, assembly relations, product-level, assembly feature and constraint, etc. The method to establish disassembly induced model includes mainly undirected graph, directed graph, mixed graph, disassembly Petri nets [11], demolition matrix and other methods. This paper use disassembly matrix method, which is based on undirected graph and directed graph.

Removing Interference Matrix. In dismantling inducible system, firstly, in order to establish the priority to dismantle product components, we determine the set of assembly parts $P\{p_0, p_1, \cdots, p_{n-2}, p_{n-1}\}$, where n is the total number of parts. According to the assembly of information among the assembly components including a mating type, mating parameters, mating direction to obtain bearing assembly disassembly direction for each part. For example, insert type with the demolition of the direction along the axis, laminating, etc. with the demolition of the direction tangent to the corresponding normal direction of the plane. Detaching direction finally obtained assembly set, $S\{s_0, s_1, \cdots, s_{n-2}, s_{n-1}\}$ denote the corresponding parts of the detachment direction. Construct interference matrix I (n × n) for each detaching direction: start from the first part, and let each parts move along the dismounting direction established above, if the parts interfere with the remaining parts, then set the interference matrix to number 1, whereas set to number zero.

$$I = \begin{bmatrix} 0 & p_0 p_1 & \cdots & p_0 p_{n-1} \\ p_1 p_0 & 0 & \cdots & p_1 p_{n-1} \\ \vdots & \vdots & 0 & \vdots \\ p_n p_0 & p_n p_1 & \cdots & 0 \end{bmatrix} \tag{1}$$

When i=j, the default is 0

Removing the Establishment of A Mixed Hierarchical Graph. Demolition is the process to separate the parts out of the product If the parts of the product or sub-assembly is defined as a point, then mixed image is the graphics to connect those points through directed edges and undirected edges. The assembly constraints between the parts or sub-assemblies are expressed by directed edges and undirected edges. Removing hybrid graph [9] is expressed as: $G = \{VF, E, DE\}$, where G for hybrid graph, VF for parts; E for undirected edges ,which indicates the interference between parts; DE for directed edges, which expressed there is no interference between parts but a priority relationship . Based on the demolition mixed graphs, they constitute demolition mixed hierarchical graph after a hierarchical process. The so-called hierarchical layer [12] is the collection of those parts which start from the root part and can be reached synchronized. For example, in Fig.1, vertices 1,2,3,4,5,6 are parts; Vertices 3 to 5 are undirected edges, which represents that parts 3 and 5 have interference; point 1 to point 3 are directed edges, indicating part 1 removal before part 4.

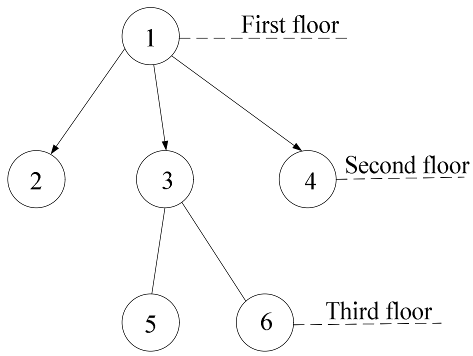


Fig.1 Remove the mixing hierarchical graph

Scanning each row of the interference matrix I, if the i-th row elements all equal to 0, p_i represent a detachable part, whose direction to detach is the direction s_i represents, while consider such parts as w-th (in this case w = 1) layer of the demolition mixing hierarchical graph, and save the part p_i as one of the nodes of w-th layer. Finally, the collection $P'(p_i'\cdots)$ of detachable parts was generated after scanning all matrices I. Continue traverse other lines of the matrix interference, if the element in the direction of v_i between the part p_j and disassembled parts is one, indicating that the demolition of parts p_j should be performed after the part p_i, so a directed real edge between the node p_j and p_i should be added, which point p_j to p_i. At the same time, get the (w + 1)-th layer nodes and generate the set of detachable parts $P'(p_j'\cdots)$. Then set the p_i' column of the matrix I to zero, i.e., the current part p_i does not constitute a constraint to other parts. Using this method as described above until all the elements in the matrix are zero. Then removing hybrid hierarchical graph has established.

Building Disassembly Sequence Optimization Model. The optimal for Disassembly sequence goals to reach the highest efficiency disassembly sequence for part .In disassembly model, identify the optimal disassembly path for target part in the process, that affect the efficiency of disassembling factors [13] are: The number of changing using tools and direction of operations. For each disassembly sequence, at the same conditions, each part individually removable time is homologous, so this paper establish the disassembly evaluation function will not consider the basic time of single part. Removing evaluation function as follows:

$$\begin{aligned} &P(x_{i-1},x_i)=\alpha\cdot f\ (x_{i-1},x_i)+\beta\cdot \mathrm{g}\ (x_{i-1},x_i) \\ &P=\sum_{i=1}^{n}P(x_{i-1},x_i) \end{aligned} \tag{2}$$

In formula (2), $f_{\mathrm{direction}}(x_{i-1},x_i)$ is the changing direction of parts x_{i-1} and x_i functions, α is the direction of transformation penalty factor; $\mathrm{g}_{\mathrm{tool}}(x_{i-1},x_i)$ is the tools transform function of disassembly parts x_{i-1} and x_i, β is the penalty factor of converting disassembly tool. $f_{\mathrm{direction}}(x_{i-1},x_i)$ and $\mathrm{g}_{\mathrm{tool}}(x_{i-1},x_i)$ is defined as follows:

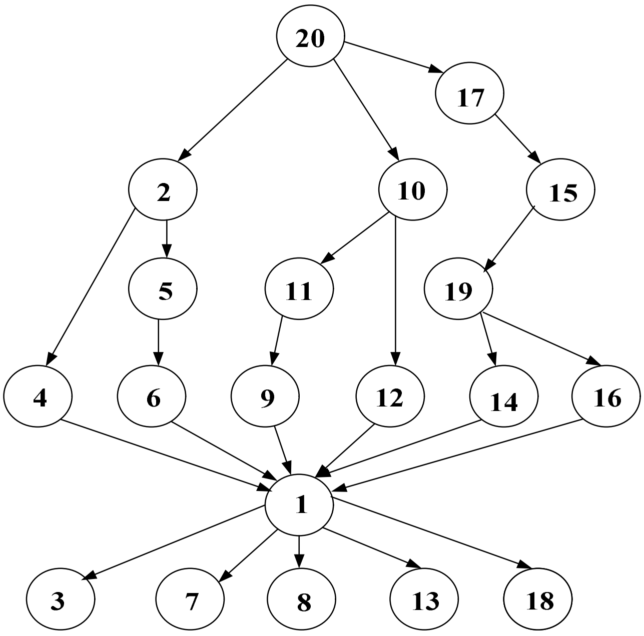
$$\mathrm{g}_{\mathrm{tool}}(x_{i-1},x_i)=\begin{cases}1 & \text{part } x_{i-1} \text{and } x_i \text{the same tools}\\ 0 & \text{part } x_{i-1} \text{and} x_i \text{different tools}\end{cases} \quad f_{\mathrm{direction}}(x_{i-1},x_i)=\begin{cases}1 & \text{part} x_{i-1} \text{and} x_i \text{the same direction}\\ 0 & \text{part} x_{i-1} \text{and} x_i \text{different direction}\end{cases} \tag{3}$$

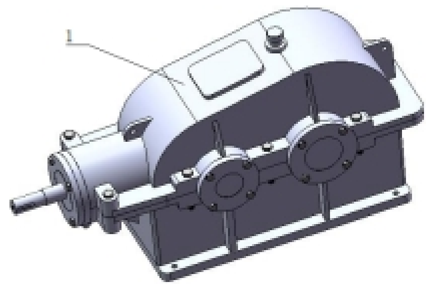
Disassembly Sequence Optimization

In this paper, we adopt the drosophila optimization algorithm to optimize disassembly sequence. And we use pure string to represent the drosophila position vector, for example, n-dimensional vector $X=(x_1,x_2,\cdots x_n)$ is used for expressing the drosophila position and every elements of vector indicates different parts, while the order of elements indicates the order of disassemble. For instance, (x_1,x_3,x_4,x_2) shows that the disassembling order of this assembly is x_1-x_3-x_4-x_2。The dimension of drosophila initial position changes with the change of the targeted parts. When drosophila searches for food, we adop the cross of the genetic algorithms. For example, parents are $P1(x_1,x_2,|x_3,x_4,|x_5)$ and $P2(x_5,x_3,|x_1,x_4,|x_2)$, and the junction is 2and 4, thus the result of junction is $S1(x_1,x_2,x_1,x_4,x_5)$ and $S2(x_5,x_3,x_3,x_4,x_2)$. We adopt above assessment function as the decidable function of concentration of flavor. Algorithm flow chart is shown as Fig.2.

Case Study

Solve the Optimal Disassembly Sequence. We adopt Improved fruit fly optimization algorithm to conduct optimal disassembly sequence planning, and use dismantle time as the objective function , calculate the optimal route demolition. Fig.3 is a model of the gearbox assembly, and Table 1 is the parts list of assembly





(a)

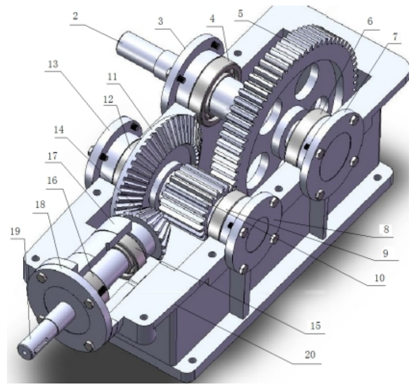


Fig.2 Improved fruit fly algorithm flow chart

(b)

Fig.3 Gearbox model assembly

Table 1 Transmission Parts List

NO.	Part Name	NO.	Part Name	NO.	Part Name	NO.	Part Name
1	Cover	6	Bearing 2	11	Large bevel gear	16	Bearing 6
2	Axis 1	7	Cover 2	12	Bearing 4	17	Shaft sleeve
3	Cover 1	8	Cover 3	13	Cover 4	18	Cover 5
4	Bearing 1	9	Bearing 3	14	Bevel pinion	19	Output shaft
5	Large gear	10	Gear shaft	15	Bearing 5	20	Foundation

First, according to previously described methods, we obtain the mixed hierarchical graph of gearbox disassembling in Fig.4.

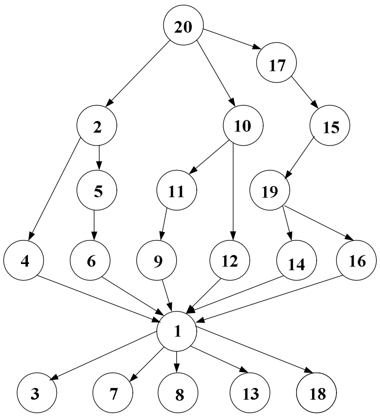


Fig.4 Transmission disassembling hybrid hierarchical graph

In this paper, the value of α and β among objective function respectively take 0.2 and 0.7.we write the corresponding algorithm program by MATLAB. What is shown in Fig.5 is the convergence properties of genetic algorithms, and Fig.6 shows the convergence properties of drosophila optimization algorithm. By the results, the fitness of function value is 5.1. At the beginning and end of the MATLAB program, we add tic and toc to calculate the run-time of program. the genetic algorithm spends 0.528440 seconds; drosophila optimization algorithm is 0.235640 seconds. The result shows that the operation speed of drosophila optimal algorithm is faster than the genetic algorithm, which can shorten the reaction time, achieve human-computer interaction better. The following is the disassembly sequence generated by drosophila optimization algorithm: 3-8-18-13-7-1-4-6-5-2-12-9-11-10-16-14-19-15-17-20。

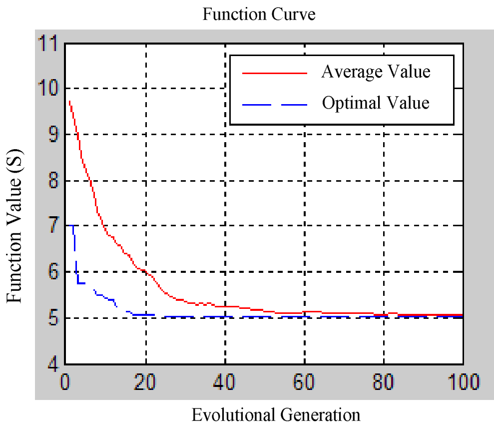


Fig.5 Genetic algorithm converges characteristic diagram

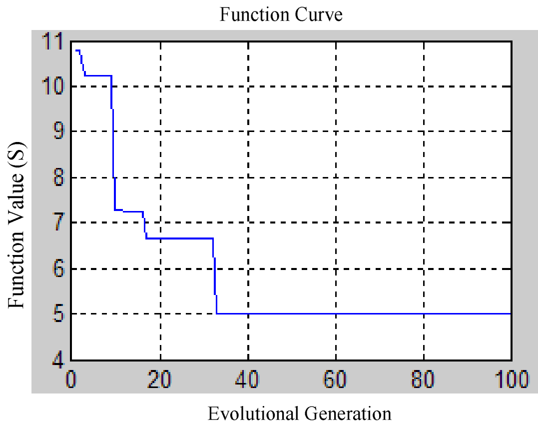


Fig.6 Improved fruit fly algorithm converges characteristic diagram

Augmented Reality Induced Disassembly System. In this paper, induced disassembly system [14] based on augmented reality is developed by software platform of Microsoft VC ++. NET, and the program is written by ARTooKit. Generated optimal disassembly sequence is transmitted to the system, which can assist personnel with operations. Fig.7 shows animation demonstration of the disassembling operation of parts.

We can conclude from the results of experiments that disassembly sequence described planning method in the text is reliable and effective, in a certain extent, it is able to guide the operator to carry out the gearbox removal operation step by step, which fundamentally realizes the original target.

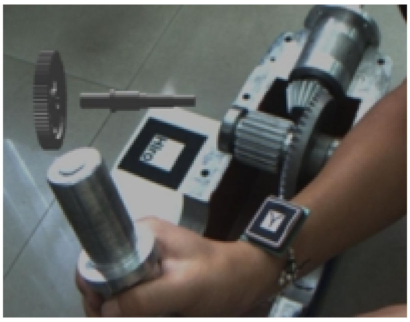


Fig.7 Induced disassembly animations

Conclusions

This paper, which has investigated disassembly sequence problem in induced disassembly system based on augmented reality, has reasonably used drosophila optimization algorithm combined with genetic algorithm on the basis of the reasonable establishment of evaluation function to improve the speed of the system reflects, and brought up more online operations in favour of operating personnel and the system, improved efficiency and the system instances also confirm that this method has certain practical significance for the improvement of the system.

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