Improved genetic algorithm for 3D printing multi-objective optimization task scheduling

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Abstract. For the 3D printing multi-objective optimization task scheduling problem, the problem model is established from the three aspects of related problem definition, constraint conditions, and objective function, which lays the foundation for subsequent research and solution.

1. Introduction

In order to better study the 3D printing multi-objective optimization task scheduling problem, this paper takes the shortest printing time and the lowest printing cost as the optimization goals, and establishes the 3D printing multi-objective optimization task scheduling problem model based on the 0-1 planning model. The task scheduling problem model in this paper is established on the basis of ignoring manual time, known printer printing speed and cost.

2. Definition of related issues

Suppose there are a total of M printer and N print tasks. The print speed of the i printer is v_i, the print cost is p_i, and the task volume of the j print task is l_j, so the time for the i printer to print the j subtask is for:

$$T = \begin{pmatrix} t_{(1,1)} & t_{(1,2)} & \cdots & t_{(1,N)} \\ t_{(2,1)} & t_{(2,2)} & \cdots & t_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ t_{(M,1)} & t_{(M,2)} & \cdots & t_{(M,N)} \end{pmatrix} = \begin{pmatrix} l_1/v_1 & l_2/v_1 & \cdots & l_N/v_1 \\ l_1/v_2 & l_2/v_2 & \cdots & l_N/v_2 \\ \vdots & \vdots & \ddots & \vdots \\ l_1/v_M & l_2/v_M & \cdots & l_N/v_M \end{pmatrix}$$

The cost of printing the j print task by the i printer is expressed as:

$$C = \begin{pmatrix} c_{(1,1)} & c_{(1,2)} & \cdots & c_{(1,N)} \\ c_{(2,1)} & c_{(2,2)} & \cdots & c_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ c_{(M,1)} & c_{(M,2)} & \cdots & c_{(M,N)} \end{pmatrix} = \begin{pmatrix} p_1/l_1 & p_2/l_1 & \cdots & p_N/l_1 \\ p_1/l_2 & p_2/l_2 & \cdots & p_N/l_2 \\ \vdots & \vdots & \ddots & \vdots \\ p_1/l_M & p_2/l_M & \cdots & p_N/l_M \end{pmatrix}$$

Task scheduling scheme matrix is expressed as:

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$$X = \begin{pmatrix} x_{(1,1)} & x_{(1,2)} & \cdots & x_{(1,N)} \\ x_{(2,1)} & x_{(2,2)} & \cdots & x_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ x_{(M,1)} & x_{(M,2)} & \cdots & x_{(M,N)} \end{pmatrix}$$

Among them, $x_{(i,j)}$ is a 0-1 decision variable, when $x_{(i,j)} = 1$ it means that the j print task is printed on the i printer, and when $x_{(i,j)} = 0$ it means the j print task is not printed on the i printer.

In this paper, the first task scheduling of the system is called primary scheduling, and each subsequent scheduling is called secondary scheduling. If it is a one-time scheduling, the setting time and warm-up time of each printer are different. If it is a second scheduling, the remaining tasks of each printer in the previous several task scheduling are different. As a result, after the task scheduling is completed, the time at which each printer can start printing is different. The time from the start of task scheduling to when the i printer can print a new task is called the printer's initial time TS_I, the initial time matrix can be expressed as:

$$T_s = \begin{pmatrix} TS_1 \\ TS_2 \\ \vdots \\ TS_M \end{pmatrix}$$

The time from when the j print task is scheduled to be ready for printing is called the initial time of the j print task, which can be expressed as:

$$tst_j = \begin{cases} \sum_{i=1}^{M} TS_i x_{(i,j)} + \sum_{i=1}^{M} \sum_{k=1}^{i-1} t_{(i,k)} x_{(i,k)} x_{(i,j)} & \sum_{i=1}^{M} \sum_{k=1}^{j} x_{(i,k)} x_{(i,j)} > 1 \\ \sum_{i=1}^{M} TS_i x_{(i,j)} & \sum_{i=1}^{M} \sum_{k=1}^{j} x_{(i,k)} x_{(i,j)} = 1 \end{cases}$$

The printing time tct_j of the j print task is mainly divided into the initial time tst_j and the processing time $t_{(i,j)}$ of the j print task on the i printer, which can be expressed as:

$$tct_j = tst_j + t_{(i,j)}$$

3. Restrictions

Since 3D printing has the characteristics of one-time molding, in general, each printing task can only be assigned to one printer, namely:

$$\forall j \in [1, N], \sum_{i=1}^{M} x_{(i,j)} = 1$$

Due to the limitations of printing materials, printing methods, printing accuracy, and size of space, only when the printing task is completely matched with the printer, the printing task can be printed on this printer. The matching value of the j print task and the print material of the i printer is $dc_{(i,j)}$, The value is the matching value of printing mode $df_{(i,j)}$, the matching value of printing precision $dj_{(i,j)}$, the matching value of space size $ds_{(i,j)}$, and the total matching value $dz_{(i,j)}$, namely:

$$\forall i \in [1, M], j \in [1, N], dz_{(i,j)} = dc_{(i,j)} \times df_{(i,j)} \times dj_{(i,j)} \times ds_{(i,j)} = 1$$

4. Objective function

After completing a task scheduling, the printing time matrix for each printer to complete the printing task assigned to the printer is expressed as:

$$T_1 = \begin{pmatrix} x_{(1,1)} & x_{(1,2)} & \cdots & x_{(1,N)} \\ x_{(2,1)} & x_{(2,2)} & \cdots & x_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ x_{(M,1)} & x_{(M,2)} & \cdots & x_{(M,N)} \end{pmatrix} \begin{pmatrix} t_{(1,1)} & t_{(1,2)} & \cdots & t_{(1,N)} \\ t_{(2,1)} & t_{(2,2)} & \cdots & t_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ t_{(M,1)} & t_{(M,2)} & \cdots & t_{(M,N)} \end{pmatrix} \begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{pmatrix}$$

The completion time of a printer refers to the time from the start of task scheduling to the end of the last printing task of the printer, including the initial time and printing time, so the completion time matrix of each printer is expressed as:

$$T_2 = T_1 + T_s = \begin{pmatrix} \sum_j t_{(1,j)} x_{(1,j)} + TS_1 \\ \sum_j t_{(2,j)} x_{(2,j)} + TS_2 \\ \vdots \\ \sum_j t_{(M,j)} x_{(M,j)} + TS_M \end{pmatrix}$$

The total printing time of the print task is the maximum of the completion time of all printers, so the total printing time of the completed print task is expressed as:

$$f_T(X) = max(T_2) = max \begin{pmatrix} \sum_j t_{(1,j)} x_{(1,j)} + TS_1 \\ \sum_j t_{(2,j)} x_{(2,j)} + TS_2 \\ \vdots \\ \sum_j t_{(M,j)} x_{(M,j)} + TS_M \end{pmatrix}$$

One of the goals of task scheduling is to make the total printing time the shortest, so the objective function of time optimization can be expressed as:

$$f_T = min(f_T(X)) = min \left\{ max \begin{pmatrix} \sum_j t_{(1,j)} x_{(1,j)} + TS_1 \\ \sum_j t_{(2,j)} x_{(2,j)} + TS_2 \\ \vdots \\ \sum_j t_{(M,j)} x_{(M,j)} + TS_M \end{pmatrix} \right\}$$

The total printing cost is the sum of the printing costs of all printing tasks on the corresponding printer, so the total printing cost can be expressed as:

$$f_C(X) = \sum XC = \sum \left(\begin{pmatrix} x_{(1,1)} & x_{(1,2)} & \cdots & x_{(1,N)} \\ x_{(2,1)} & x_{(2,2)} & \cdots & x_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ x_{(M,1)} & x_{(M,2)} & \cdots & x_{(M,N)} \end{pmatrix} \begin{pmatrix} c_{(1,1)} & c_{(1,2)} & \cdots & c_{(1,N)} \\ c_{(2,1)} & c_{(2,2)} & \cdots & c_{(2,N)} \\ \vdots & \vdots & \ddots & \vdots \\ c_{(M,1)} & c_{(M,2)} & \cdots & c_{(M,N)} \end{pmatrix} \right)$$

One of the goals of task scheduling is to minimize the total printing cost, so the objective function of cost optimization can be expressed as:

$$f_C = min(f_C(X)) = min\left(\sum_i \sum_j c_{(i,j)}\, x_{(i,j)} \right)$$

When completing the printing task, in order to meet the two optimization goals of time and cost at the same time, the n-norm weighting method is used to assign corresponding weights to the printing time optimization goals and the printing cost optimization goals, and the design based on the printing time and printing cost The objective function of the combined objective optimization mode can be expressed as:

$$H = min(H(X)) = min\left(\sqrt{\omega_1 \left(\frac{f_C(X) - f_C}{f_C} \right) + \omega_2 \left(\frac{f_T(X) - f_T}{f_T} \right)} \right)$$

Among them, is the comprehensive evaluation index value of printing time and printing cost, and the weights of printing time and printing cost are ω_1 and ω_2 respectively, among them $\omega_1 + \omega_2 = 1$.

5. Conclusion

The 3D printing multi-objective optimization task scheduling problem model established in this paper describes the problem in mathematical language, which facilitates subsequent research and solution.

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