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Utilizing CBR Method in Parameter Planning for FDM process of 3D printing

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***Abstract*— Currently the 3D printing machine utilizing fused deposition modeling (FDM) process is common in the market. Because of low cost and high accessibility, this machine has become one of the favorite tools for makers. However, there are many operational parameters needed to be determined before printing. Users with insufficient experience usually fail to produce high-quality samples in the end. In order to solve this problem, many slicing software, such as CURA software, are developed to assist in the setup of parameters. However, studies have shown that over-dependence on this software prevents users from accumulating experience to learn how to set up advanced parameters for 3D printing.**

In this study, we proposed to utilize the CBR method to help users to learn parameter setting by previous print experience. Initially, previous printing experiences of similar cases were reviewed. Then the new parameter setting was done by fine-tuning previous settings with the revise rule. After finishing each printing according to the new parameter setting, this setting was saved in the case library to improve this system.

***Index Terms*—3D printing, Fused deposition modeling (FDM), Case Based Reasoning, Cura 3D Printing Slicing Software.**

I. INTRODUCTION

3D Printing (3DP), or additive manufacturing, is a process to manufacture a three-dimension mold. The mold is formed by layering, which is controlled by the computer program of the 3DP machine. This technology was firstly proposed by Hideo Kodama [1]. The process of 3DP starts with the creation of a 3D diagram file. Then the printing area and pathway of each layer are set up by the specific computer software. Finally, the manufacture is completed layer by layer. Currently plastic, metal powder, resins, and chemical polymers are commonly used as the raw materials of 3DP [2].

Fused deposition technology (FDM), stereo lithography technology, inkjet printing technology, selective laser sintering, and electron beam laser sintering are five common 3DP processes nowadays [3]. Because of economic benefits, the best-selling 3DP machine uses FDM process. About the FDM, each layer is formed by extruding the material flow followed by immediate solidification. Filaments of thermoplastic materials, metal wires or other material are fed into an extrusion nozzle head of 3DP machine that heats the material and controls the material flow [4].

Many factors can determine the success of FDM-based 3DP, such as the user experience, the operation of machine during printing, environmental interference to the machine, and adhesion between the machine platform and the mold [5]. Especially the user experience influences most. Experienced experts can improve the printing quality quickly by finding out the key points. In opposite, beginners take time to discover the critical points for improvement.

In this study, case-based reasoning (CBR) is proposed to be utilized to help beginners set up the printing parameters of a FDM-based 3DP machine. By retrieving previous similar printing experience in a databank, users can know how to set up printing parameters, potential printing results, and possible solutions to improve the printing quality. This approach will help users to be more familiar with operating FDM-based 3DP machines and overcome the condition of no expert nearby.

II. METHODS

A. Introduction of CBR Method

Schank and Anderson firstly proposed this reasoning method [6]. In this method, previous case samples are collected in a case base. In order to manage with a new case, initially same or similar case samples are selected. Then the new case and selected case samples are compared. If the new case and the case sample is the same, the new case can be managed in the same way as the case sample experienced. If differences are found between the new case and the case sample, revise rules can be applied to adjust the management of the case sample to fit the new case. Usually in the case base, the details and solutions of each case sample is recorded [6]. The framework of CBR is shown in Figure 1, which includes four main steps: case retrieval, case reuse, case revise, and case retaining.

1) Case retrieval: The scope of case retrieval is to search for prior case samples similar to the case entered. Similarity will be evaluated for every case samples. During the process of retrieving, multiple case samples with the same similarity sometimes happen. In this situation, the weighting concept can be utilized to further focus on specific characters to highlight specific case samples with higher importance.
2) Case reuse: From the cases retrieved, corresponding solutions can be connected with each other or with other knowledge by the system. Usually the retrieved case samples cannot totally fulfill the requirement. Case explanation is then used to fulfill the requirement. In case explanation, it is necessary to determine which marker should be added, deleted or modified.

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3) Case revise: This step is also called case modification. Since there is usually difference between the new case and the retrieved cases, retrieved cases are needed to be modified. There are two ways for case revise. One is to modify retrieved cases by pre-existing rules. The other is by interchange with other case samples.
4) Case retaining: In this step, the solutions developed by previous steps and their application outcomes are stored into the case base. Whether the outcome is good or bad, all developed solutions will be stored. Good solutions can be reused in the similar case in the future. Bad solutions can improve the applicability by reasoning and adjusting.

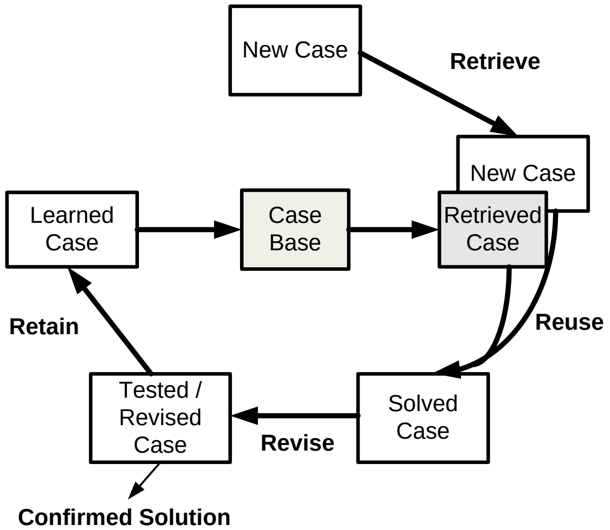

Fig. 1 The framework of CBR [6]

B. Application of CBR Method in Setting Parameters of 3DP Machines

Currently-used 3DP planning software enable users to set up parameters without limitation. This study uses Ultimaker Cura 3D Printing Software Edition 2.7. Recommend and Custom parameter settings are provided in the operation interface. Recommend parameters include infill, generate support, build plate adhesion and print material settings. Custom parameters are quality, shell, infill, material, speed, cooling, support, build plate adhesion and special modes settings. Setting of these parameters determines the time, cost, and quality of 3DP, which challenges beginners a lot.

However, by applying the CBR system, a large number of previous expert-created cases including parameter setting can be stored in the case base. Beginners can search for most suitable cases by case retrieval and then take parameter setting in these cases as reference. Finally the beginners can set up their own parameters by evaluating the printing outcomes and modification suggestions in previous cases.

In this CBR system, the diagram of the printing molding, complete printing parameter settings, printing outcome, and modification suggestions are recorded in every case. The information within one case is shown in Table 1. The index system which is used to link a suitable case from the case base is shown in Table 2. The features within the index system include the geometric description of the mold, the purpose of the mold, and the requirement for printing quality. Each case in the case base is categorized by the index system and has a code number. The current case base has collected a total of 50 print cases as a reasoning base. For example, in the case of Table 1, the code number is 72435.

The most suitable case can be found based on its similarity. The formula for calculating similarity is shown as Formula 1. The importance of each feature is set equal in this study (weightings are $w_1 = w_2 = w_3 = w_4 = w_5$) but users can also adjust the importance when needed. As mentioned earlier, beginners can set up parameters and then print the mold after using this CBR system. The complete information of this printing should be also edited as a new case and then stored in the case base to enhance the reasoning ability of the system.

$$\sum_{i=1}^{n} w_i \times sim_i\left(f_i^{\,I}, f_i^{\,R}\right) / \sum_{i=1}^{n} w_i \qquad (1)$$

The way to judge each similarity value is, if $f_i^{\,I} = f_i^{\,R}$ then $sim_i = 1$, else $sim_i = 0$. w_i is the weight of the i th index. i is the subscript for i th index. n is the number of indices. sim_i is the similarity of the i index between new case and previous case. $f_i^{\,I}$ is the value of index i of the new case. $f_i^{\,R}$ is the value of index I of the retrieved case.

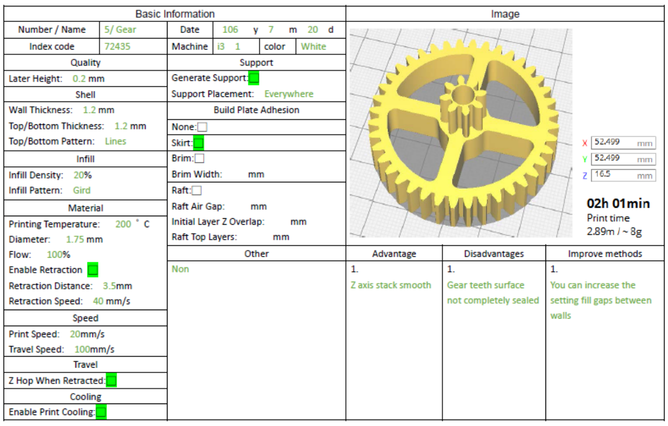

Fig.2 The information within a case

Table 1 The content of index system

Index	Illustration	Selection
1	The contact status between Print object and the platform	1. point contact (less than 5 points) 2. point contact (between 5 to 10) 3. point contact (more than 10 points) 4. line contact (less than 5 points) 5. line contact (between 5 to 10) 6. line contact (more than 10 points) 7. surface contact (less than 5 points) 8. surface contact (between 5 to 10) 9. surface contact (more than 10 points)
2	The degree of hollowness of the printed object	1. Non 2. less than 5 3. between 5 to 10 4. more than 10
3	The approximate shape of the	1. Square 2. Rectangular 3. Sphere

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	object	4. Cylinder 5.Cone
4	Application of the printed object	1.Not combined with other objects, No stress conditions 2.A combination of relations, but the force situation is minor 3.A combination of relations and the force situation is obvious
5	Print quality requirements of the object	1.Made in the shortest time 2.Time spent is more important than the print quality 3.Time is as important as quality 4.print quality is more important than the time spent 5.Highest quality as a priority

III. RESULTS AND DISSCUSSION

There is a new printing require as shown in Figure 3. This molding has surface contact to the platform, three hollow areas, body approximate to square, combination of relations and medium quality requirements. According to the description of the characteristics in the index system, the code number of it is 72223. Based on the similarity calculating, the most similar case retrieved from the system is case 12. The detail information of case is shown in Figure 4. The quality of printed results is good but with incomplete sealing of the top and bottom surface edges. The suggested modification is to increase the gap between walls. After consideration, the modification idea is taken and other parameters are following the case 12. The final print result is in the following Figure 5. Finally, this new case will become a new case and also be put into the case base to increase the capacity of the system.

From the printing results of the new case, the object quality has the advantage of smooth stack on the z-axis by using the printing parameters and suggestions for corrections in case 12. Unfortunately, the top and bottom surface edges are still not completely sealed. The recommended way to improve printing quality is to increase the setting that enables ironing. Therefore, when the CBR system recommends this case 12 as a print parameter setting next time, the user must consider in advance to increase the setting that enables ironing to avoid the problem of incomplete sealing on the top and bottom surface edges.

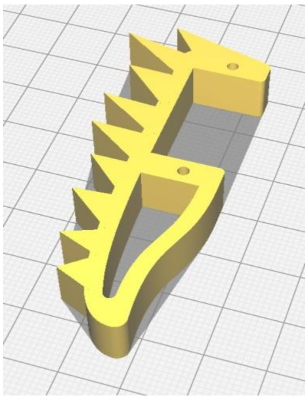

Fig.3 The diagram of new printing case

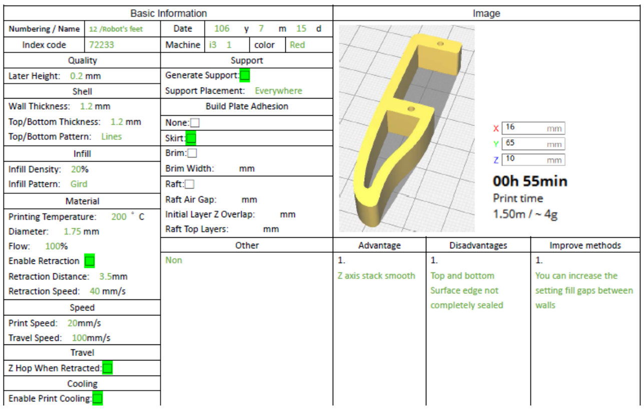

Fig. 4 The description of case number 12

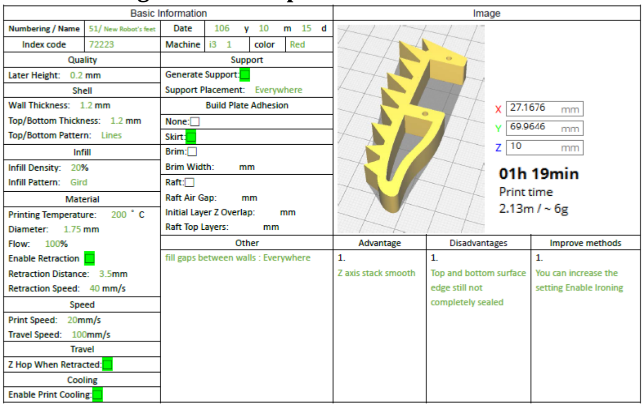

Fig.5 The description of new printing case

IV. CONCLUSIONS AND FUTURE WORK

According to our results, the parameters for 3D object printing by FDM process can be provided by the CBR method. In addition, the suggestion to improve printing quality, as shown in the case, can also help a lot. Users can decide by themselves to follow the suggestion or not to obtain better printing quality. Moreover, during the calculation of case similarity, the introduction of weight concept allows users to identify the geometric characteristics of the object that match some particular needs. The other characteristics with lower importance can then be managed by case correction methods or user experience.

There is still more work to do in the future. First of all, the cases in the case base should be gathered continuously to improve the power of this CBR system. In addition, the character description of the index system may be adjusted since the accuracy of searching most similar case may decrease as the number of cases increases. Besides, more way to adjust retrieved cases should be developed. In addition to the policy described above, the rules to adjust parameter settings will be added.

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