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Research Article

A Case-Based Reasoning Method for Remanufacturing Process Planning

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Remanufacturing is a practice of growing importance due to its increasing environmental and economic benefits. Process planning plays a critical role in realizing a successful remanufacturing strategy. This paper presents a case-based reasoning method for remanufacturing process planning, which allows a process planner to rapidly retrieve, reuse, revise, and retain the solutions to past process problems. In the proposed method, influence factors including essential characteristics, failure characteristics, and remanufacturing processing characteristics are identified, and the local similarity of influence factors between the new case and the past cases is determined by nearest neighbor matching method, and then the vector of correction factor for local similarity is utilized in the nearest neighbor algorithm to improve the accuracy and effectiveness of case searching. To assess the usefulness and practicality of the proposed method, an illustrative example is given and the results are discussed.

1. Introduction

Remanufacturing, as a specific type of recycling, makes the fact that the used durable goods can be repaired to a condition like new realized [1]. By means of remanufacturing, most of the used machinery parts can be repaired to a condition like new with warranty to match, which not only alleviates environmental contamination, but reduces energy consumption and professional labor used in production [2]. Using remanufacturing of an engine as an example, the process can save 55 kg steels, 8.3 kg aluminum, and 113 kWh electric powers and reduce emissions of 565 kg CO_2, 6.09 kg CO, 1.01 kg NO_x, 3.985 kg SO_x, and 288.725 kg solid waste [3].

Optimal remanufacturing process often leads to improved product/component quality, enhanced remanufacturing rate, reduced capital investment cost, and better utilization of company resources. Due to its significance, remanufacturing process planning has received increasing attention. Tian et al. (2013) presented chance constrained programming models for disassembly cost to deal with the uncertainty of disassembly process due to a variety of unpredictable factors [4]. Kernbaum et al. (2009) presented an approach for the design, evaluation, and implementation of IT-equipment remanufacturing processes in a given facility [5]. Kin et al. (2014) analyzed the conditions of the core components to determine an optimal remanufacturing process sequence for these components [6]. Song et al. (2011) presented a new method based on constrained ordinal optimization for remanufacturing process planning [7]. Denizel et al. (2010) considered remanufacturing process planning when inputs have different and uncertain quality levels and provided a numeric study to generate insights into the nature of the solution [8, 9]. Undoubtedly, these studies provided very useful guidelines for remanufacturing process planning. Compared to manufacturing, remanufacturing process exhibits a high level of uncertainty due to stochastic returns of used products/components and their uncontrollable quality, and the uncertainty has a great impact on many levels in planning and control for remanufacturing [10]. For example, differences in the failure characteristics, historical information, and other characteristics, even with the same failure mode of the same parts, may lead to different remanufacturing processes. Therefore, how to create a reasonable remanufacturing process plan to rapidly ensure that remanufacturing production can be run smoothly has become one of the focuses and difficulties in remanufacturing researches.

To conquer this problem, many techniques have been proposed. For instance, Li and Tang (2011) proposed a GERT (graphical evaluation and review technique) based analytical method for remanufacturing process planning, which takes into account the quality uncertainty of incoming used components [11]. Jiang et al. (2014) presented a quality function deployment (QFD) and fuzzy linear regression-based method for remanufacturing process plan selection to make full use of experts' experiences and knowledge [12]. Cao et al. (2010) constructed a decision-making framework model based on manufacturing system engineering theory to formally describe the attributes of the decision-making objects in the remanufacturing process planning [13]. However, these researches mentioned earlier only considered one aspect of complex remanufacturing process optimization and neglected connections between the new case and the existing knowledge generated during the complex process planning of previous part remanufacture [14]. It is of extreme importance in improving the process efficiency, quality, and costs of producing these like-new products [15].

As an alternative solution to the problem, CBR is proposed for the remanufacturing process planning, making full use of existing experiences and knowhow generated from previous remanufacturing practices. CBR has been successfully applied in some remanufacturing fields to allow a process planner to retrieve, reuse, revise, and retain the solution to past problems [16]. Veerakamolmal and Gupta (2002) developed a CBR approach for automating disassembly process planning [17]. Ghazalli and Atsuo (2009) suggested an AHP-CBR based evaluation system for remanufacturing process to support automobile product design [18]. Ghazalli and Murata (2011) integrated an analytical hierarchy process (AHP) with case-based reasoning (CBR) to evaluate the product end-of-life (EOL) and develop an evaluation system for remanufacturing [19]. These researchers have achieved good progresses. However, the existing CBR methods lack an effective way to solve the problem of remanufacturing process which is more complicated in the way that (1) differential in quality and composition of returned products make remanufacture a production of large variety and small volume and (2) remanufacturing process is not necessarily fixed but rather is adapted to the condition of actual products to be remanufactured. Such situations, if not addressed properly, may lead to loss and inaccuracy of process information when cases are searched [20]. In addition, though there are several types of algorithms that could be employed in the process, that is, nearest neighbor retrieval, artificial bee colony [21, 22], and validated retrieval, yet scope of application of the nearest-neighbor retrieval is the most widely. Therefore, an improved case-based reasoning is paramount to identify remanufacturing influence factors to deal with the quality and composition of returned products and utilize a vector of correction for local similarity through considering the problem solving goals to improve the accuracy of case searching.

Motivated by the foregoing discussion, this paper presents a new CBR based method for remanufacturing process planning, so as to improve the efficiency and accuracy of case searching. In the proposed approach, influence factors including essential characteristics, failure characteristics, and remanufacturing processing characteristics are identified, and the local similarity of influence factors between the new case and the past cases is determined by nearest neighbor matching method. Then a vector of correction factor is applied in all the local similarities to evaluate the global similarity. Through this method a remanufacturing process plan can be selected quickly and effectively from a large database with a lot of cases. Finally, the method is verified via a lathe bed remanufacturing example.

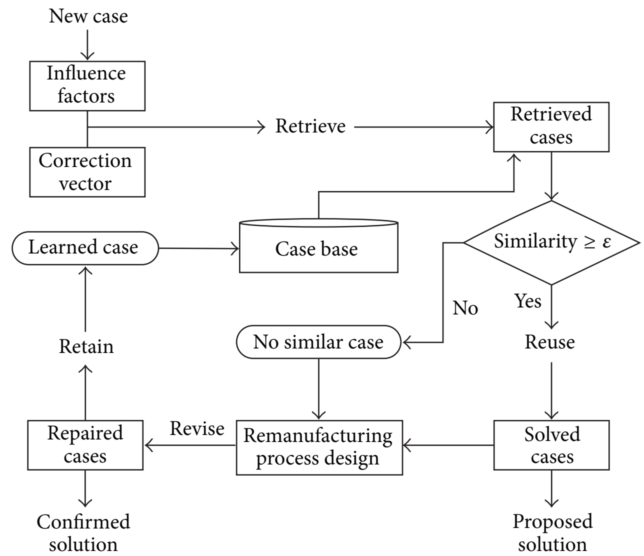

Figure 1: Framework of proposed CBR system for remanufacturing process planning.

2. Framework of Proposed CBR System for Remanufacturing Process Planning

Remanufacturing process planning is one of the most important operational decisions in remanufacturing because it directly affects the success rate of remanufacturing, as well as cost and quality. There is a need for an intelligent method which can develop a reasonable remanufacturing process plan. CBR method is proposed as an alternative solution approach. The use of CBR for solving a new problem involves (1) retrieving previous cases, (2) using the cases, (3) revising the proposed solution, and (4) storing the new experience in the case base. The flowchart of remanufacturing process planning with case based reasoning method is shown in Figure 1.

In the proposed CBR system, influence factors including essential characteristics (material characteristics and shape size), failure characteristics (failure symptoms, failure location, and failure degree), and remanufacturing processing characteristics (precision characteristics, surface hardness, and roughness factors) are identified firstly by analyzing the hierarchy structure of used products, a vector of correction factor for local similarity between corresponding influence

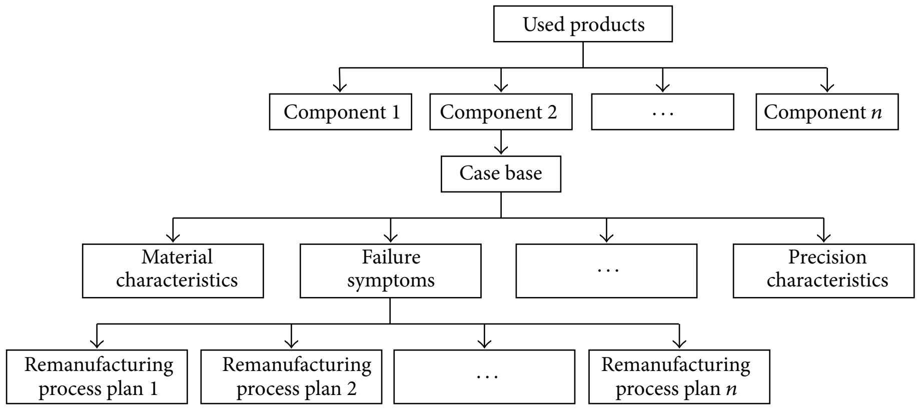

Figure 2: Hierarchy structure of influence factors and their corresponding remanufacturing process plans.

factors is used to reflect the problem solving goals, and then the vector is applied in the nearest neighbor algorithm to retrieve previous cases that have similar process condition to the new problem in order to select the useful features from the database. If the global similarity between the new case and the past ones is greater than the threshold value ε, the information and knowledge related to the case/cases may be reused to solve the new problem; otherwise, the remanufacturing process plan should be designed as a new case. Finally, the proposed solution and the new experience generated are also stored at a certain organizational hierarchy structure in the case base.

2.1. Identification of Remanufacturing Influence Factors. In remanufacturing process, changes in some representative factors (e.g., damage degree) may cause corresponding changes in process parameters, eventually resulting in different remanufacturing process plan, for instance, if used lathe guides in slight wear, the remanufacturing process is grinding → chrome plating → remanufactured parts testing; if used lathe guides in moderate wear, the remanufacturing process is grinding → cold welding → remanufactured parts testing. Therefore, it is necessary to identify remanufacturing influence factors for suitable remanufacturing process plan decision. In order to identify remanufacturing influence factors effectively, a hierarchy (product—components—influence factor—repair method) structure is presented, as shown in Figure 2.

With several decompositions of the used product, influence factors including essential characteristics, failure characteristics, and remanufacturing processing characteristics are identified. Changes in these factors could lead to corresponding changes in the process parameters that result in a different remanufacturing process plan. For example, four failure symptoms of used lathe bed [23] and different remanufacturing process methods for the used lathe spindles are shown in Figure 3.

2.2. Calculation of Local Similarity. Once influence factors of the new case are identified, the global similarity between the new case and the past ones during the phase of retrieval needs to be computed. This crucial operation can be realized with the local similarity. In this paper, the local similarity is determined by the nearest-neighbor matching method, which can gather all the local similarities to evaluate the global similarity and deal with different types of values: numeric, linguistic, and enumeration for the presented example. With the local similarities available, the global similarity can be calculated by

$$\operatorname{Sim}(X, Y) = \sum_{i=1}^{n} w(c_i) \operatorname{Sim}\left(c_i^X, c_i^Y\right), \tag{1}$$

where X and Y are the new case and source case, respectively; n is the number of influence factors. c_i^X and c_i^Y represent the ith factors of X and Y, and $w(c_i)$ is the associated weight of this factor c_i. $\operatorname{Sim}(X, Y)$ is the global similarity between the new case X and the source case Y. $\operatorname{Sim}(c_i^X, c_i^Y)$ is the local similarity between c_i^X and c_i^Y.

According to the composition of the problem influence factors in the remanufacturing process planning, the factors can be divided into three types (numerical factors, linguistic factors, and enumeration factors) combined with the corresponding areas. Each type corresponds to a calculation method for the local distance.

For numerical factors, such as precision characteristics, surface hardness, surface parallelism, and surface roughness, the local similarity is calculated by

$$\operatorname{Sim}\left(c_i^X, c_i^Y\right) = 1 - \frac{\left|c_i^X - c_i^Y\right|}{\max\left(c_i\right) - \min\left(c_i\right)}, \tag{2}$$

where $\max(c_i)$ and $\min(c_i)$ are the maximum value and the minimum value of factor c_i among all the cases.

For linguistic factors, the different values have no connection and can be considered independent. Their local similarities can be calculated by

$$\operatorname{Sim}\left(c_i^X, c_i^Y\right) = \begin{cases} 1, & c_i^X = c_i^Y, \\ 0, & c_i^X \neq c_i^Y. \end{cases} \tag{3}$$

In (3), the local similarity is 1 if two factors are identical; otherwise the local similarity is 0. Material characteristics,

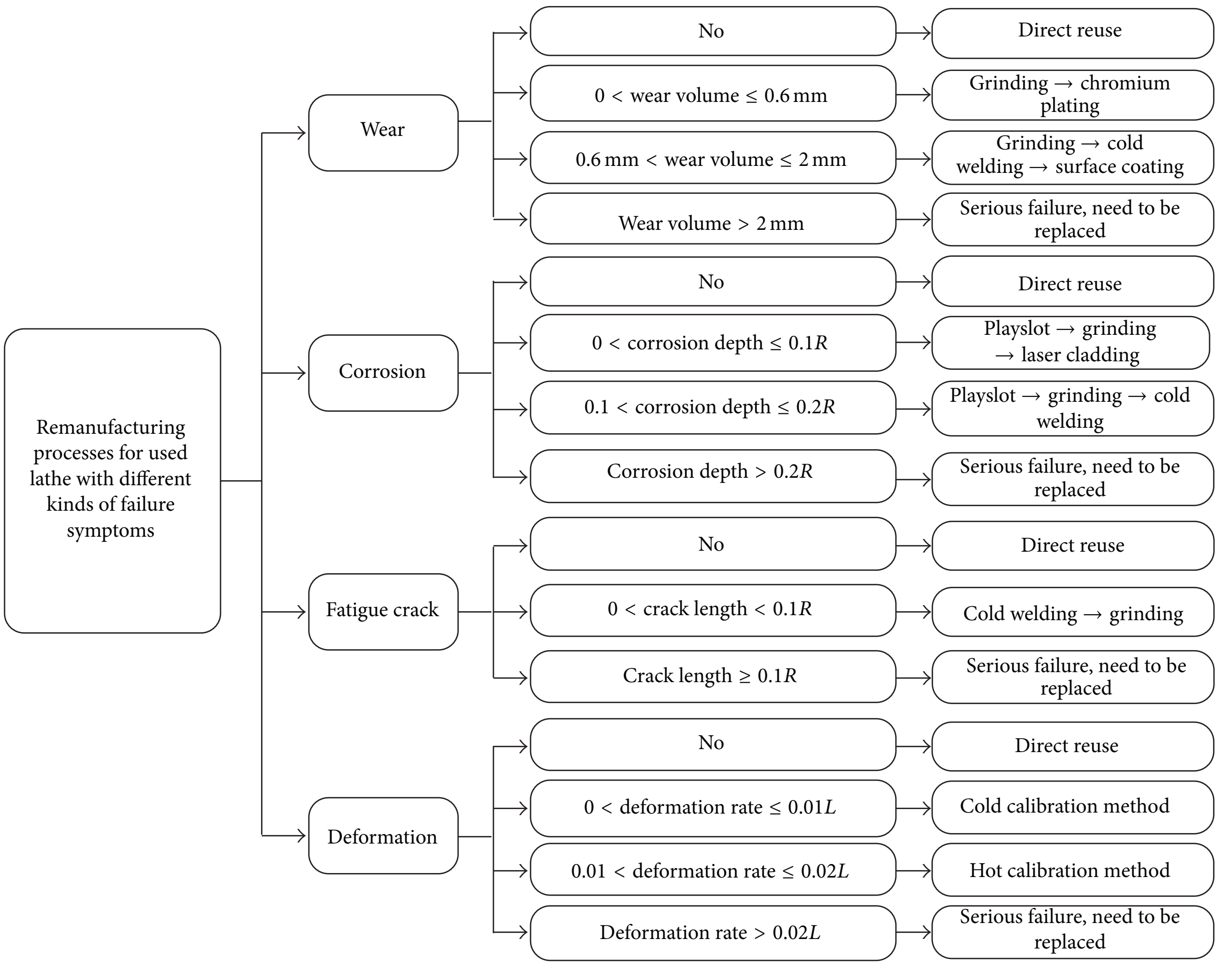

Figure 3: Remanufacturing process plans for used lathe spindles with various failure symptoms.

failure characteristics, failure location, and heat treatment are in the domain of the linguistic factors.

For enumeration factors, with arbitrary determination of discrete values of attribute local similarity is expressed as

$$\operatorname{Sim}\left(c_i^X, c_i^Y\right) = 1 - \frac{\left|c_i^X - c_i^Y\right|}{M}, \tag{4}$$

where M is the maximum assignment value of the factor enumeration c_i. For example, failure degree is described by the ambiguous words as {no, slight, moderate, serious} with the set $\{0.25, 0.5, 0.75, 1\}$, as shown in Table 1.

In order to fully consider the relative importance of the influence factors, analytic hierarchy process (AHP) is introduced to determine the appropriate weights for different factors. In AHP, a pairwise comparison matrix is created based on decision-maker inputs; the matrix is formed based on comparing the relative importance or preferences of two influence factors. In comparing two influence factors, experts compare every pair of influence factors and make a judgment of the importance of factor A relative to factor B. If factor A is judged to be far more important than factor B, the relative importance of A relative to B is set to 9 (the importance of B relative to A will be the reciprocal of this number, 1/9). A score of 1 refers to equal importance between the two criteria [24].

Table 1: The assignment values of different failure degrees.

Degree	No	Slight	Moderate	Serious
c_i	0.25	0.5	0.75	1

2.3. Case Retrieval of Goals-Oriented Problem Solving. Previous sections have identified the influence factors for remanufacturing process, and the local similarity and weighting scheme have been determined. However, similarity is not necessarily fixed but rather relies on people's priorities. That is to say, the similarity of the same parts may become not similar from a different viewpoint. In general, problem solving has its specific goals, which makes different factors have different emphases in the process of case retrieval, so as to affect the local similarity between factors, which affect the global similarity between two cases. With this in mind, a vector of correction factor for local similarity $P_k = (p_{1k}, p_{2k}, \ldots, p_{nk})$ is established to reflect the problem solving goals, where k is the target of problem solving, and n is the number of influence

Table 2: Vector of correction factor of local-similarity under goals of *CTQ*.

Influence factor	Correction vector		
	p_{iC}	p_{iT}	p_{iQ}
Precision characteristics	0.9	1.2	0.8
Failure symptoms	0.9	1.3	0.95
Failure degree	0.95	1.1	1.2
⋯	⋯	⋯	⋯

factors. The vector is applied in the nearest neighbor algorithm to improve the accuracy of case searching, and the global similarity can be calculated as

$$\mathrm{Sim}(X, Y) = \sum_{k=1}^{m} v_k \sum_{i=1}^{n} w(c_i)\,\mathrm{Sim}\left(c_i^X, c_i^Y\right) p_{ik}, \quad (5)$$

where v_k is the weight of the kth goal, p_{ik} is the correction factor of the local similarity of the ith factor between the new case X and the source case Y under the goal k, and m is the number of goals. $w(c_i)$ and v_k are determined by AHP. P_k (vector of correction factor for local similarity) is determined based on the current problem solving goals.

In remanufacturing process, determining the special problem solving goals (such as cost, quality, and time) to enable remanufacturing, so as to ensure the needs of the customer, is of primary importance [25]. Therefore, P_k is determined based on three goals including remanufacturing cost (C), remanufacturing cycle time (T), and remanufacturing quality (Q), as shown in Table 2.

3. Illustrative Example

As a typical electromechanical product, used lathes are of great potential for remanufacturing. The performance of remanufactured lathes can be the same as, or even better than, a new lathe. A remanufactured lathe may require only 40%–60% of the manufacturing cost of a new lathe [26]. To illustrate the proposed method for remanufacturing process planning, a company that remanufactures used C6132 lathes bed was considered. According to real circumstances, the repairable components of C6132 lathe bed include guide, saddle, and spindle. For example, the main failure of the guide is wear, the remanufacturing processes of guide are cleaning, surface repairing, and machining. The repairable guide can reach the standard of new guide requirements in shape, dimension, precision, and performance through these remanufacturing processes. The hierarchy structure of C6132 lathe bed is shown in Figure 4.

The repairable components need to go through some or all the remanufacturing operations before they can reach the same standard of the requirements for new lathe. These requirements can be described as influence factors that have important influence on the process planning. According to real circumstances, the remanufacturing process of this lathe bed is determined by 9 influence factors through analyzing its hierarchy structure including material characteristics (U), precision characteristics (P), failure symptoms (F), failure

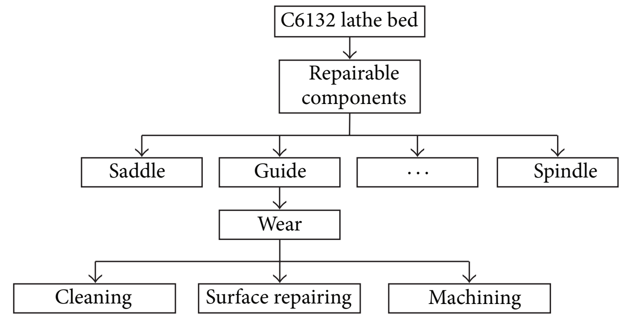

Figure 4: Hierarchy structure of C6132 lathe bed for remanufacturing process planning.

location (S), failure degree (D), heat treatment (H), surface parallelism (L), surface hardness (V), and the maximum machining diameter (R).

After the determination of the remanufacturing influence factors, the relative importance of the nine influence factors is determined through the discussion with the company which is captured using the AHP method. The importance weights of the influence factors are listed as shown in Table 3. Meanwhile, the enterprise recorded a number of processing cases for lathe bed (P_1, P_2, P_3, P_4), which feature property information is shown in Table 4. For example, the detailed information of case P_2 is shown in Table 5. Combined with the technological characteristics of C6132 lathe bed, feature property information of the new problem (P_w) is extracted as Table 6, and Table 7 shows the local similarity of influence factors for remanufacturing process.

Comparison procedure between problem-P_w and case-P_2 is shown in Table 8. The local similarity of each factor is calculated as in the following.

(i) In remanufacturing of lathe bed, "precision characteristics," "surface parallelism," "surface hardness," and "the maximum machining diameter" are numerically calculated using (2). Precision characteristics ranges are $(0, 8]$, surface parallelism ranges are $(0.01, 0.02]$, surface hardness ranges are $(40, 70]$, and the maximum machining diameter ranges are $(0, 320]$.

For lathe bed "surface hardness," known as the surface hardness of P_2, is 45HRC, the local similarity of surface hardness:

$$\mathrm{Sim}\left(c_i^X, c_i^Y\right) = 1 - \frac{\left|c_i^X - c_i^Y\right|}{\max(c_i) - \min(c_i)} = 0.833. \quad (6)$$

The local similarity of other factors can be obtained in the same way.

(ii) "Material characteristics," "failure characteristics," "failure location," and "heat treatment" are linguistically calculated using (3).

The local similarity of heat treatment is 1 because the two factors are identical.

(iii) "Failure degree" is an enumeration factor which can be calculated using (4).

Table 3: Importance weights of the influence factors.

Influence factors	U	P	F	S	D	H	L	V	R	Weight
U	1	5	3	2	4	7	6	8	9	0.286
P	1/5	1	1/3	1/4	1/2	3	2	4	3	0.223
F	1/3	3	1	1/2	3	5	4	6	7	0.145
S	1/2	4	2	1	3	6	5	7	8	0.112
D	1/4	2	1/3	1/3	1	4	3	5	6	0.085
H	1/7	1/3	1/5	1/6	1/4	1	1/2	3	4	0.061
L	1/6	1/2	1/4	1/5	1/3	2	1	3	5	0.043
V	1/8	1/4	1/6	1/7	1/5	1/3	1/3	1	2	0.028
R	1/9	1/3	1/7	1/8	1/6	1/4	1/5	1/2	1	0.017

Table 4: Feature property information of cases in the library.

Process cases	Influence factors								
	U	P	F	S	D	H	L	V	R
P_1	Cast iron	7	Surface scratch	Bed surface	Moderate	No	0.013	60	320
P_2	Cast iron	6	Rail wear	Bed surface	Slight	No	0.012	45	320
P_3	Cast iron	7	Rail wear	Bed surface	Slight	Quench	0.010	55	300
P_4	Cast iron	6	Surface crack	Bed surface	Slight	No	0.011	60	320
P_w	Cast iron	7	Rail corrosion	Bed surface	Moderate	No	0.012	55	300

Table 5: The detailed information of case P_2.

Serial number	Process name	Device ID	Device name	Device parameters	Fixture	Technical requirements	Remark
1	Cleaning	Q0008	Cleaning machine	(1) Water-soluble washing liquid 830LD, (2) maximum washing distance $d = 1850$ mm	Cleaning bracket	(1) Cleaning 6–8 times, (2) cleaning time 3.5–4 min	Handle with collision, cleaning fluid pollution under 2%
2	Grinding	M0006	Grinding machine	(1) Wheel rotational speed 2300 r/min, (2) coarse grinding allowance 0.25 mm, feed speed 2.1 mm/min	Grinding machine center frame	(1) Grinding way: cut mill, (2) grinding wheel dressing speed 0.1 m/min	(1) Grinding wheel code G80V60, (2) Injection for pressure 3 Mpa, fluid flow 18 L/min
3	Plating	D0019	Plating machine	(1) Electric net fluid TGY-1 voltage 10–14 v, (2) activation solution THY-5 voltage 12–15 v	Plating bath	—	—
4	Polishing	P0011	Polishing machine	—	Polishing machine bracket	Polished surface roughness to Ra 0.2 um or less	Polishing to technical cooperation requirements

Table 6: Feature property information of the new problem.

New problem	U	P	F	S	D	H	L	V	R
P_w	Cast iron	7	Rail wear	Bed surface	Moderate	No	0.010	50	320

Failure degree is described by the ambiguous words as {no, slight, moderate, serious}, as shown in Table 1. The local similarity between serious and moderate is

$$\text{Sim}\,(\text{serious}, \text{moderate}) = 1 - \frac{|1 - 0.75|}{M} = 0.75. \quad (7)$$

The global similarity between the problem P_w and the source case P_2 can be calculated as shown below.

According to the remanufacturing experience and experts' evaluation, the weights of goals of the lathe bed including remanufacturing cost (C), remanufacturing cycle (T), and remanufacturing quality (Q) are $[v_C, v_T, v_Q] = [0.3, 0.3, 0.4]$ as shown in Table 6. The global similarity

Table 7: Local similarity of influence factors for remanufacturing process.

Influence factors	Algorithm type	P_1	P_2	P_3	P_4
U	linguistic	1	1	1	1
P	Numeric	1	0.875	1	0.875
F	Linguistic	0	1	1	0
S	Linguistic	1	1	1	1
D	Enumeration	1	0.75	0.75	0.75
H	Linguistic	1	1	0	1
L	Numeric	0.7	0.8	1	0.9
V	Numeric	0.667	0.833	0.833	0.667
R	Numeric	1	1	0.9375	1

Table 8: Comparison procedure between problem P_w and case P_2.

Influence factors	P_w	P_2	p_{iC}	p_{iT}	p_{iQ}	Weight	Local similarity
M	Cast iron	Cast iron	1	1	1	0.286	1
P	7	6	0.9	1.2	0.8	0.223	0.875
F	Rail wear	Rail wear	0.9	1.3	0.95	0.145	1
S	Bed surface	Bed surface	1	1	1	0.112	1
D	Moderate	Slight	0.95	1.1	1.2	0.085	0.75
H	No	No	1	1	1	0.061	1
L	0.010	0.012	0.95	1.2	0.9	0.043	0.8
C	50	45	0.8	1.2	0.9	0.028	0.833
R	320	320	1	1	1	0.017	1

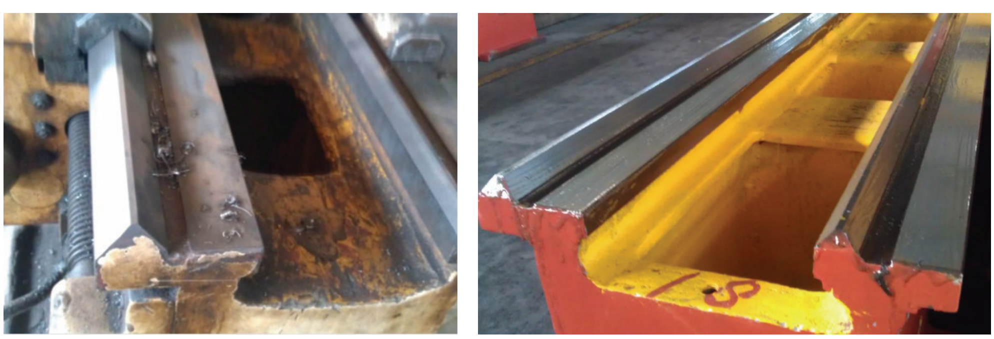

Figure 5: Comparison chart between before and after repair for the lathe guide.

between the problem P_w and the source case P_2 can be calculated using (5) as below:

$$\mathrm{Sim}(P_w, P_2) = \sum_{k=1}^{m} v_k \sum_{i=1}^{n} \mathrm{Sim}\left(c_i^{P_w}, c_i^{P_2}\right) \times w(c_i) \times p_{ik} = 0.9476. \tag{8}$$

Similarly, the global similarity between the problem P_w and the other cases can be calculated: $\mathrm{Sim}(P_w, P_1) = 0.8323$, $\mathrm{Sim}(P_w, P_3) = 0.9201$, and $\mathrm{Sim}(P_w, P_4) = 0.7769$. P_1, P_2, and P_3 are the satisfied cases under the condition that similarity threshold $\varepsilon = 0.8$. Eventually, the remanufacturing process planning of lathe bed would be completed based on P_2 which is the most similar case.

The remanufacture process used for the case P_2 was applied to repair the C6132 lathe bed. The used lathe before remanufacturing is shown in Figure 6. The guide (part model: C6132D and size: 2300 mm × 490 mm) is remanufactured through cleaning, surface repairing, and polishing to improve geometric precision guide. Comparison chart between before and after repair for the lathe guide is shown in Figure 5. Saddle (part model: C6132A1 and size: 645 mm × 615 mm) is remanufactured using grinding to recover precision, followed by quenching to increase the hardness and wear resistance. Spindle remanufacturing is remanufactured using the arc spraying technique to repair the surface wear and restore the machining precision of spindle.

With the remanufacturing processes of disassembly, clean, inspection and sorting, part reconditioning, machine upgrading and reassembly, the used lathe is restored into a new remanufactured lathe with similar and even better performance, as shown in Figure 7. As shown in Table 9, the comparison between the remanufactured lathe and

Table 9: Comparison of the remanufactured lathe with the standard of new lathe.

Items	Accuracy value	Outgoing quality standard of C6132	Accuracy of remanufactured C6132 lathe
Roundness (mm)		0.0085	0.008
Flatness (mm)		0.012	0.010
Pitch error		0.030	0.028
Surface hardness		55	50
Surface parallelism		0.030	0.025
Repeatability of positioning from feed (mm)	X axis	0.015	0.012
	Y axis	0.020	0.018

Figure 6: The used Lathe before remanufacturing.

Figure 7: The remanufactured new lathe.

the standard of new lathe shows that the remanufactured machine tool can satisfy the outgoing quality of the new machine tool.

In the above analysis, the proposed method has been used to obtain the optimal process for remanufacturing. Using this technique has enabled the inclusion of both remanufacturing influence factors and remanufacturing goals in the model, which has enhanced the accuracy and effectiveness of the model manifold.

4. Summary and Conclusions

Good remanufacturing process planning often leads to improved product/component quality, enhanced remanufacturing rate, reduced capital investment cost, and better utilization of company resources. This paper employs CBR to develop a reasonable remanufacturing process planning for part remanufacture. First, influence factors including essential characteristics, failure characteristics, and remanufacturing processing characteristics are identified. Then, the local similarity of influence factors between the new case and the past cases is determined by nearest neighbor matching, and a vector of correction factor for local similarity is utilized in the nearest neighbor algorithm to improve the accuracy and effectiveness of case searching. Finally, the usefulness and practicality of the proposed method were demonstrated using a lathe bed remanufacturing as an example.

The lathe bed example demonstrates the importance of considering remanufacturing influence factors and problem solving goals in the remanufacturing process planning. By utilizing a vector of correction factor for local similarity, remanufacturing process plan would be retrieved more accurately and efficiently than other approaches. The future work is developing a systematic method to identify remanufacturing influence factors under uncertain condition.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

[1] S. Bernard, "Remanufacturing," *Journal of Environmental Economics and Management*, vol. 62, no. 3, pp. 337–351, 2011.

[2] W.-W. Liu, B. Zhang, Y.-Z. Li, Y.-M. He, and H.-C. Zhang, "An environmentally friendly approach for contaminants removal using supercritical CO_2 for remanufacturing industry," *Applied Surface Science*, vol. 292, pp. 142–148, 2014.

[3] C. Li, Y. Tang, and L. Li, "A modeling approach to analyze variability of remanufacturing process routing," *IEEE Transactions on Automation Science and Engineering*, vol. 10, no. 1, pp. 86–98, 2013.

[4] G. D. Tian, M. C. Zhou, and J. W. Chu, "A chance constrained programming approach to determine the optimal disassembly sequence," *IEEE Transactions on Automation Science and Engineering*, vol. 10, no. 4, pp. 1004–1013, 2013.

[5] S. Kernbaum, S. Heyer, S. Chiotellis, and G. Seliger, "Process planning for IT-equipment remanufacturing," *CIRP Journal of Manufacturing Science and Technology*, vol. 2, no. 1, pp. 13–20, 2009.

[6] S. Kin, S. K. Ong, and A. Y. C. Nee, "Remanufacturing process planning," *Procedia CIRP*, vol. 15, pp. 189–194, 2014.

[7] C. Song, X. Guan, Q. Zhao, and Q.-S. Jia, "Remanufacturing planning based on constrained ordinal optimization," *Frontiers of Electrical and Electronic Engineering in China*, vol. 6, no. 3, pp. 443–452, 2011.

[8] M. Denizel, M. Ferguson, and G. G. C. Souza, "Multiperiod remanufacturing planning with uncertain quality of inputs," *IEEE Transactions on Engineering Management*, vol. 57, no. 3, pp. 394–404, 2010.

[9] M. Lage Jr. and M. G. Filho, "Production planning and control for remanufacturing: literature review and analysis," *Production Planning and Control*, vol. 23, no. 6, pp. 419–435, 2012.

[10] Y. Tang and C. Li, "Uncertainty management in remanufacturing: a review," in *Proceedings of the IEEE International Conference on Automation Science and Engineering (CASE '12)*, pp. 52–57, Seoul, Republic of Korea, August 2012.

[11] C. Li and Y. Tang, "A GERT-based analytical method for remanufacturing process routing," in *Proceedings of the 7th IEEE International Conference on Automation Science and Engineering (CASE '11)*, pp. 462–467, Trieste, Italy, August 2011.

[12] Z. Jiang, Z. Fan, J. W. Sutherland, H. Zhang, and X. Zhang, "Development of an optimal method for remanufacturing process plan selection," *The International Journal of Advanced Manufacturing Technology*, vol. 72, no. 9–12, pp. 1551–1558, 2014.

[13] H.-J. Cao, B.-T. Wang, F. Liu, and J.-Q. Ma, "Two-phase decision-making strategy for remanufacturing process planning," *Computer Integrated Manufacturing Systems*, vol. 16, no. 5, pp. 935–941, 2010.

[14] J. Gao, X. Chen, O. Yilmaz, and N. Gindy, "An integrated adaptive repair solution for complex aerospace components through geometry reconstruction," *The International Journal of Advanced Manufacturing Technology*, vol. 36, no. 11-12, pp. 1170–1179, 2008.

[15] T. Chen and R. Xiao, "A dynamic intelligent decision approach to dependency modeling of project tasks in complex engineering system optimization," *Mathematical Problems in Engineering*, vol. 2013, Article ID 398123, 12 pages, 2013.

[16] T. C. Kuo, "Combination of case-based reasoning and analytical hierarchy process for providing intelligent decision support for product recycling strategies," *Expert Systems with Applications*, vol. 37, no. 8, pp. 5558–5563, 2010.

[17] P. Veerakamolmal and S. M. Gupta, "A case-based reasoning approach for automating disassembly process planning," *Journal of Intelligent Manufacturing*, vol. 13, no. 1, pp. 47–60, 2002.

[18] Z. Ghazalli and M. Atsuo, "The development of the computer aided remanufacturing system (CARES) part I: software development (phase I) and a simulation study," in *Proceedings of the 5th International Workshop Computational Intelligence & Applications*, p. 181, IEEE SMC, Hiroshima, Japan, 2009.

[19] Z. Ghazalli and A. Murata, "Development of an AHP-CBR evaluation system for remanufacturing: end-of-life selection strategy," *International Journal of Sustainable Engineering*, vol. 4, no. 1, pp. 2–15, 2011.

[20] H.-D. Burkhard, "Similarity and distance in case based reasoning," *Fundamenta Informaticae*, vol. 47, no. 3-4, pp. 201–215, 2001.

[21] R. Xiao and T. Chen, "Relationships of swarm intelligence and artificial immune system," *International Journal of Bio-Inspired Computation*, vol. 5, no. 1, pp. 35–51, 2013.

[22] T. G. Chen and R. B. Xiao, "Enhancing artificial bee colony algorithm with self-adaptive searching strategy and artificial immune network operators for global optimization," *The Scientific World Journal*, vol. 2014, Article ID 438260, 12 pages, 2014.

[23] S. S. Sabade and D. M. Walker, "Evaluation of effectiveness of median of absolute deviations outlier rejection-based IDDQ testing for burn-in reduction," in *Proceedings of the 20th IEEE VLSI Test Symposium (VTS '02)*, pp. 81–86, 2002.

[24] Y.-B. Du, H.-J. Cao, F. Liu, P. Yan, and C.-B. Li, "Evaluation of machine tool remanufacturing scheme based on entropy weight and AHP," *Computer Integrated Manufacturing Systems*, vol. 17, no. 1, pp. 84–88, 2011.

[25] P. Goodall, E. Rosamond, and J. Harding, "A review of the state of the art in tools and techniques used to evaluate remanufacturing feasibility," *Journal of Cleaner Production*, vol. 81, pp. 1–15, 2014.

[26] Y. Du, H. Cao, X. Chen, and B. Wang, "Reuse-oriented redesign method of used products based on axiomatic design theory and QFD," *Journal of Cleaner Production*, vol. 39, pp. 79–86, 2013.