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Computer aided fixture design - A case based approach

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Abstract: Automated fixture design plays important role in process planning and integration of CAD and CAM. An automated fixture setup design system is developed where when fixturing surfaces and points are described allowing modular fixture components to get automatically select for generating fixture units and placed into position with satisfying assembled conditions. In past, various knowledge based system have been developed to implement CAFD in practice. In this paper, to obtain an acceptable automated machining fixture design, a case-based reasoning method with developed retrieval system is proposed. Visual Basic (VB) programming language is used in integrating with SolidWorks API (Application programming interface) module for better retrieval procedure reducing computational time. These properties are incorporated in numerical simulation to determine the best fit for practical use.

1. Introduction

The function of fixtures is to locate and constrain a workpiece during a machining operation. A machining fixture can be classified to have two basic functions: (a) To locate the component at correct position in relation to cutting tools; (b) To hold the component firmly in order to prevent motion during the machining. Fixtures find application in machining, welding, assembly, inspection, and other operations. Machining fixtures directly influence the productivity, machining quality, and the cost of machined parts. So two samples of different densities are taken into consideration and tests are performed to obtain their exact material properties and numerical simulation is done.

The procedure of fixture design is complex and experienced based, so deign of modular fixtures requires over 10 years of practical experience, and furthermore, there is no intensive solid theory to bolster it. In a large portion of the cases, machining installations are planned and produced by experimentation approach. Consequently, Computer Aided-Fixtures Design (CAFD) is answer for the complex fixture design types. Further automated CAFD frameworks have turned out to be more useful since the CAM activities for assembling have enhanced quickly in late decades. Fully automated CAFD framework enables the user-end to characterize the attainable apparatus design together with, finding techniques and clipping instruments and format for a given component. Various methodologies have been utilized for this reason by application of CAD programming.

This paper proposes another installation plan technique in light of a case-based reasoning (CBR) approach incorporated with SolidWorks API. At first, different CAFD methodologies are studied to clear up the requirement for the advancement of the CAFD approach. Case-based thinking has so far observed effective application in the period of apparatus format arranging, i.e. characterizing of the finding and clipping surfaces for a predefined design conspire. It relies on upon surveying the

closeness between the cases. CBR includes recovering, and systemizing the past cases of fixture design on a component in library as database all together that they can be reviewed, promptly reused or possibly adjusted when user need few alterations. Essentially to take care of a plan issue, a CBR approach must have the capacity to perceive the best coordinated case among the current cases in information base to the present outline prerequisite by a proper case recovery framework. At that point, the user can select the recovered case to meet the plan prerequisites in the new outline issue if necessary. The primary objective of CBR process is to locate the most comparative workpiece with the number of workpieces existing in the database. This similitude estimation framework is called CBR method.

However, the current CBR based fixture design approach faces a great difficulty in converging to single ideal solution for a given problem because of clichés in case-retrieval strategy. Majority of the systems end up giving more than one part for fixture design solution. It is then up to the designer to select the optimum one. Further improving the accuracy of case retrieval will reduce the number of selected fixture designs that will be suggested. Hence, there is an opportunity to improve the case retrieval of CBR-based CAFDs if we can study and have a better similarity function in order to determine similar fixture design among many fixtures stored in the database.

2. Literature Survey

Various studies and research have been done in field of automated modular fixture for past few years. Many authors have experimented with various numerical models to design a successful retrieval system. Number of new theories and concepts has been put forward to address obstacles in systems architecture design.

A new method for computer aided fixture design is CBR approach [1,3]. Based on developed model, it was implemented using software on standalone system. Similarity assessment and retrieval of solid models play a crucial role in reusing number of solid models [2]. He used multi-resolution skeleton model to achieve similarity using database management system (DBMS) and successfully implemented. Scale-space technique can obtain features that are invariant compared to global structure of model [11]. On integrating CAD package it was found that solution obtained was very crucial in feature identification. Algorithms to determine existing parts in a database that are similar to query part provided by user [4]. Reduced feature vectors on each feature was applied, analysed and compared with the same of query part to obtain acceptable results in form of similar parts. CBR and RBR approach for automating modular fixture by combing these two methods [2]. With help of software 3D user interface was provided incorporating the above mentioned methods. A new fixture layout using CBR approach. The method was impended on large database having different attribute [9]. The result was found satisfactory as it provided in majority of the cases. Automated method for assembling modular fixtures using SolidWorks API. A plug-in code was generated to create entire new module of fixture design within SolidWorks GUI. An attempt to improve the effectiveness of case based reasoning system by finding similarity between symbolic features has been made [5, 6]. Similarities between parts are derived based on machining features and size using numerical model. The results obtained are found to be astonishingly accurate. A method for improving the search method in database for fixture design using similarity method to compare the similarity between the parts [6]. Focus was on fixture design, working principles, and pertinent proposed approach [6]. Several AI models techniques have been studied to use optimum method for evaluating all stages of CBR system with high accuracy. An Internet-enabled fixture design system was also implemented that utilizes Case-Based Reasoning paradigm derived from instances based on previous solutions of similar problems[7, 8].

3. Methodology

3.1 CBR Model

CBR is type of comparison based method on similarity. It is created in the artificial intelligence field environment. It is able to process the new problems using past experiences encountered by the system on which this method is employed. Hence, it requires a database to be constructed where past problems encountered are stored with their relevant solutions, and then, the new cases as confronted issues can be classified by deciding the best-coordinated case from the database. So, CBR method works by giving solution as solution of similar stored cases. To design a CBR-based system, the crucial areas which affect the performance of the whole process, are the right case characterisation (i.e. indexing method), similarity function (retrieval strategy) and arrangement of the number of cases in database. In case of fixture design, a CBR technique ought to be capable of distinguishing the best coordinating case among the current cases in database to the target design requirement by utilizing a legitimate ordering and recovery methodology. Then, the system allows the designer to modify the retrieved workpiece and the related fixture to meet the design necessities in the new design problem. The general steps of a typical CBR fixture design system are expressed in Figure 1.
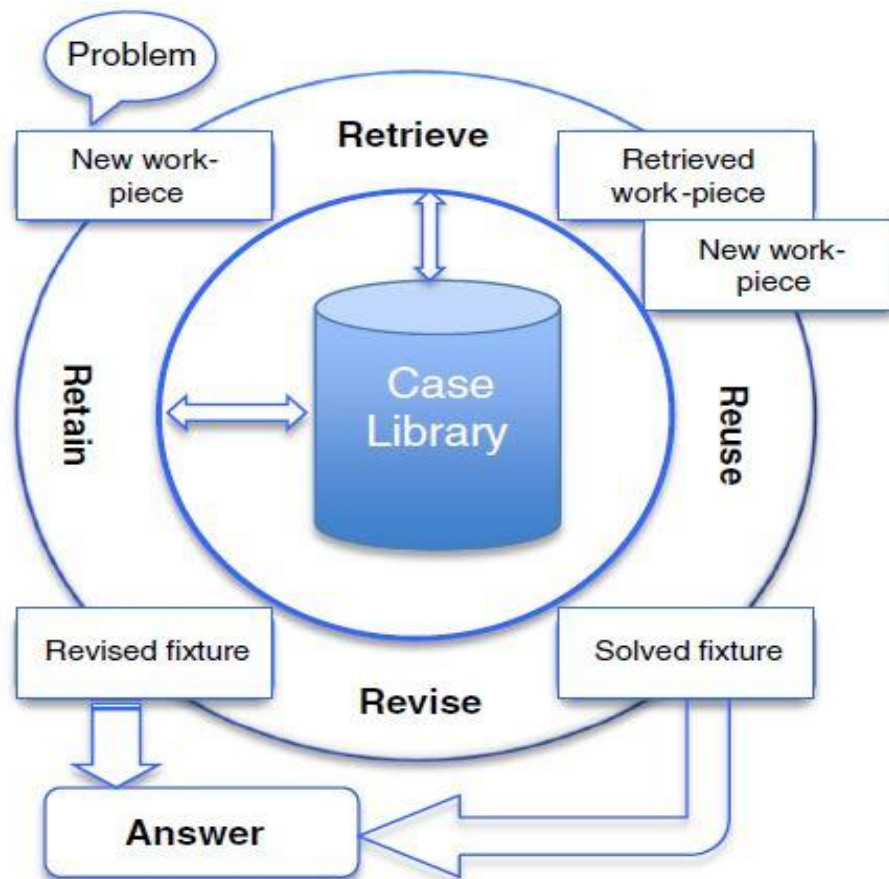
Figure 1. General steps in CBR
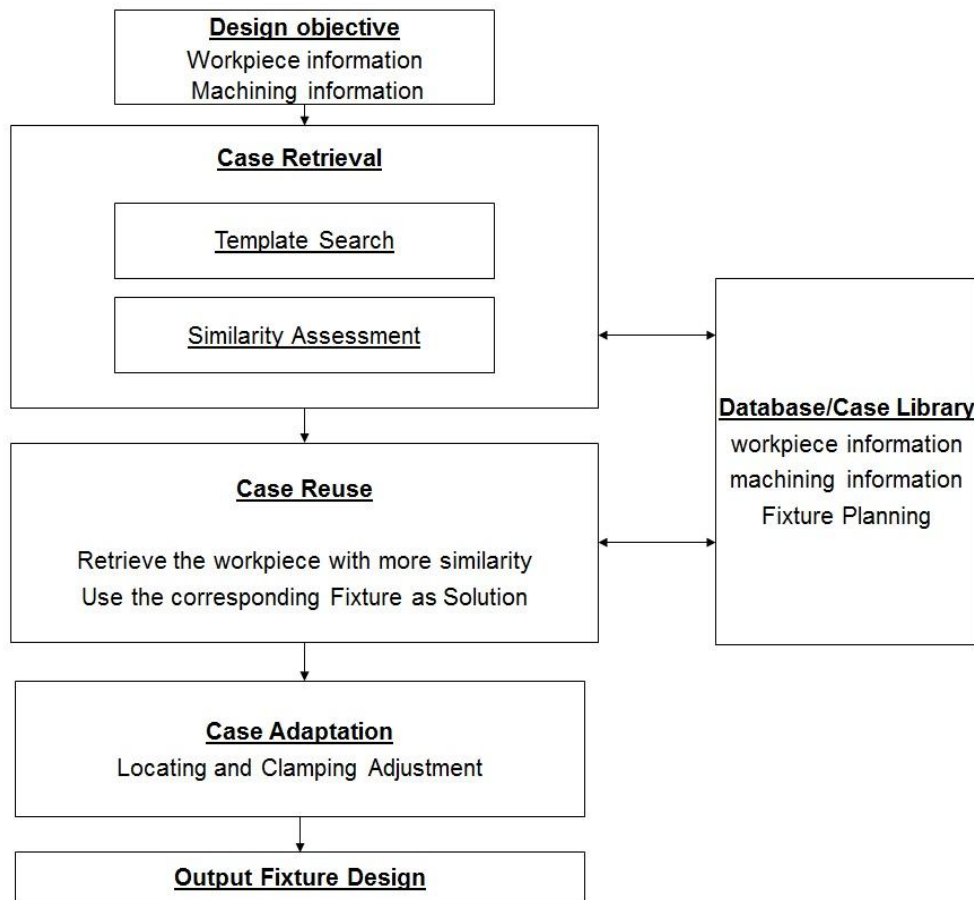
Figure 2. CBR based fixture design algorithm

3.1.1 Indexing

The purpose of indexing is to determine the relation of feature of previous cases in database with the existing case. Case indexing is an important part of CBR method as insufficient indexing may lead to case inseparability. Case retrieval is concerned with finding a related case in the database that is exceptionally impacted by indexing approach.

The proposed methodology can be broken down into two sub steps, first is the main searching process in the database and second to find the solution for the query part based on the result obtained in the first step. Based on this, the method demand to have database inform of two subcategories, that is workpiece information, machining information in one group while solution of workpiece (fixturig solution) in the second.

Therefore the key processes in indexing can be said as going through the database in first steps to obtain optimal results and based on the result obtained, second step to provide ideal fixture solution. Based on this we can define various feature parameters required to differentiate and provide similarity ranking.

3.1.2 Template Search

In this research, template search as the initial step of this CBR retrieval stage is to maintain a strategic distance from repetitive similarity calculations between superfluous in the database. The objective of

template search is to verify and to reduce computational search time removing unwanted, irrelevant cases for next step [10]. For example if the query part is prismatic, then it will remove all cylindrical and semi cylindrical part from of consideration. Hence only filtered cases containing required specific attributes will proceed for further evaluating methods.

In our approach the key parameters of workpiece attributes are Workpiece Type, Workpiece Size, Machine Type, Axis of Machining, and Machining Operation. These are the most basic attributes of component to be machined defining its basic characteristics. Hence the above listed five parameters have crucial impact on template search method. In this we have not considered more number of attributes to filter the cases as it may lead to conflicts in filtering process thus giving insufficient or no filtered cases.

3.1.3 Similarity assessment
The filtered cases from template search will be further evaluated in this method. Since the total numbers of selected cases are much less as compared to that of present in the database, Computational time for similarity assessment reduces drastically. The main goal of this method is to locate the most comparative case in database which is the fundamental target of all CBR-based fixture design applications.

In our approach, similarity assessment has been simplified in two main steps. The first step is dimension similarity of the two components (i.e. between query component and case component from database) using the Eq.1 while the second step is to evaluate these cases for machining similarity. This is basically achieved by using Distance function equation as mentioned in Eq.2. This study has been restricted to only prismatic parts.

$$\text{Sim}(p_i,q_i) = -\frac{|g(p_i)-g(q_i)|}{\max(p_i,q_i)} + 1 \qquad\qquad \text{Eq.1}$$

$$d(P,Q) = \frac{\sum_{i=1}^{n}\text{mind}(p_i,q_i)}{n} + w_{fm}\frac{|f_{mP}-f_{mQ}|^2}{\text{AVG}(f_{mP},f_{mQ})^2} + w_{fd}\frac{|f_{dP}-f_{dQ}|^2}{\text{AVG}(f_{dP},f_{dQ})^2} + w_s\frac{|s_P-s_Q|^2}{\text{AVG}(s_P,s_Q)^2} \qquad \text{Eq.2}$$

$$d(p_i,q_i) = (1-\delta(p,q))[w_v(v_p-v_q)^2 + w_\varepsilon(\varepsilon(p)-\varepsilon(q))^2 + w_c(n(p)-n(q))^2] + w_T\delta(p,q) \qquad \text{Eq.3}$$

$$\text{Sim}(P,Q) = \frac{\sum_{i=1}^{n}w_i \times \text{sim}(p_i,q_i)}{\sum_{i=1}^{n}w_i} \qquad\qquad \text{Eq.4}$$

In the above equations, $p_i \epsilon P$, $q_i \epsilon Q$, f_{mP},f_{mQ} indicates number of milling features while f_{dP},f_{dQ} indicates number of drilling features of respective parts. v_p and v_q are the normalised volume of feature, $\varepsilon(p)$ and $\varepsilon(q)$ are the machining tolerances and $n(p)$, $n(q)$ are the cardinality values. w_v, w_ε, w_c are the weighing factors. For simplification purpose machining tolerances are neglected, weighing factors are assumed to be equal to 1 and $(p,q)=0$.

The first step of dimension similarity uses dimensions of component to find the similarity between two parts. Here outermost dimension of two parts to be compared are used for evaluation. Hence as the difference of two increases, similarity index decreases. In the second part machining similarity is defined by considering the number of drilling and milling features. It also takes into account the normalised volume of feature along cardinality. Finally Eq. 4 gives the overall similarity by adding all the similarities obtained. The result obtained is used to rank the components in database for finding the most similar one.

3.1.4 Reuse and Adaptation
The most similar parts obtained from case retrieval are then displayed to user to select the most appropriate cases of all. The selected case gives its corresponding fixture solution stored in database. Based on this user can perform further case adaptation such as adjusting the clamp and locator as

required. If the new fixture arrangement is found valid then the system retain this new case in database. This is done so as to provide solution if similar problem is encountered in future.

4. Case study

CBR method via a case study is illustrated stepwise as follows.

Step 1. Input the test workpiece

Input the test workpiece for which the fixture is to be designed. A prismatic part named test workpiece is utilized as a case study and shown in Figure. 7. Run the feature extraction command where it automatically recognizes the features of workpiece. A pop up window appears which asks for the workpiece and machining information and this information is used for the template retrieval.
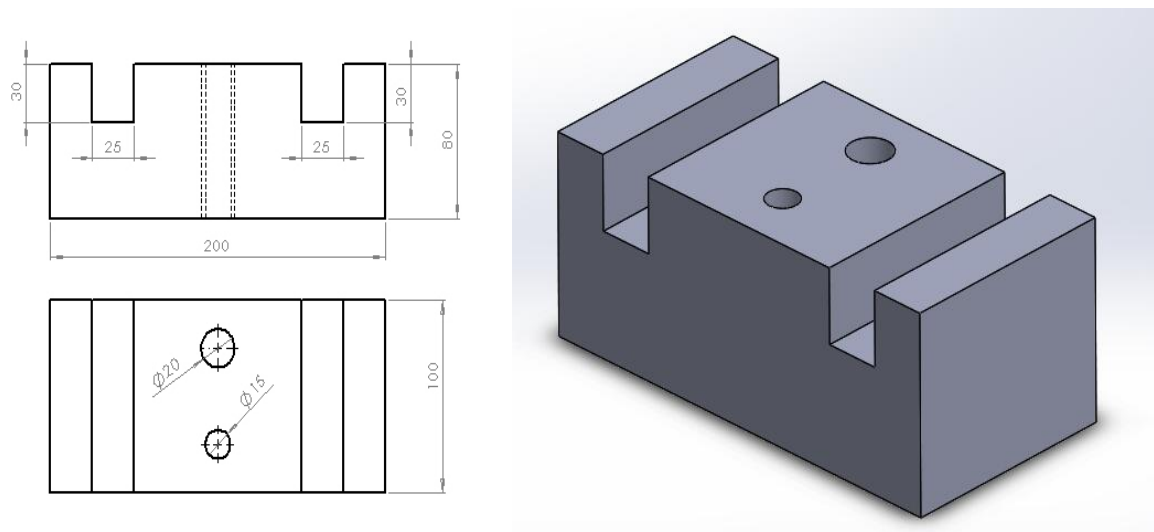
**Figure 3.** Test workpiece used for case study
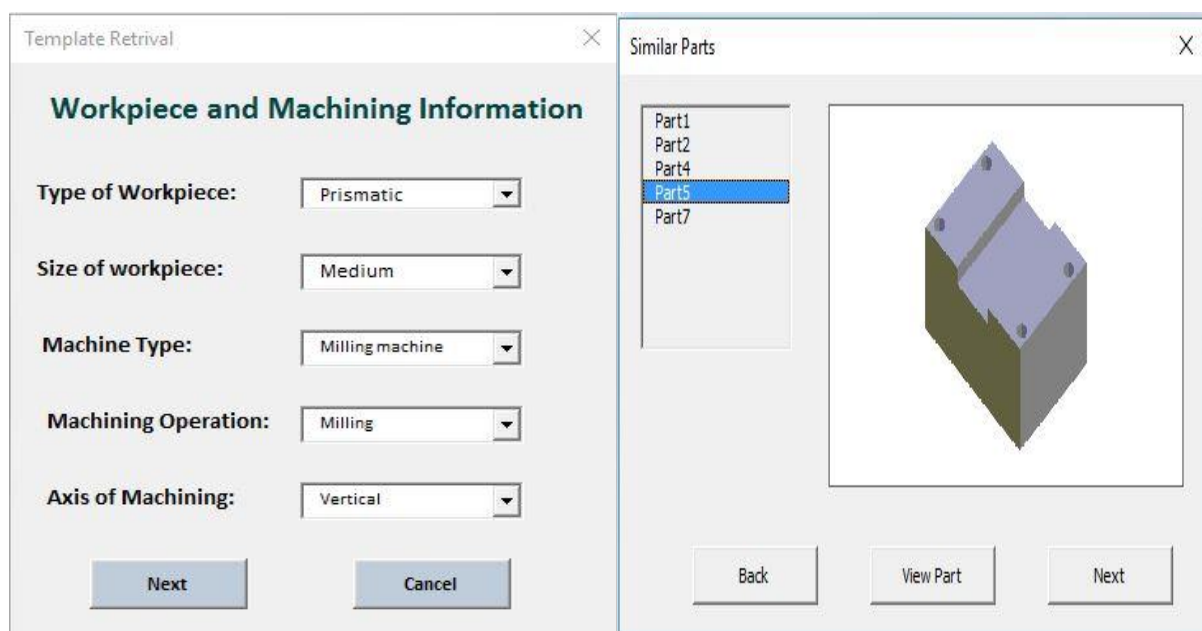
Figure 4. First Retrieval stage- Template Retrieval

Step 2: Indexing and retrieving similar workpieces
First retrieval stage: A few key attributes for template retrieval step are used to distinguish workpieces with the same attributes. The attributes are used for this step are (i) workpiece type, (ii) size of workpiece, (iii) machine type, (iv) axis of machining, and (v) machining operation. First pop up user-form allows user to select these attributes for query part. In our case study, the query part is prismatic, Size of workpiece is Medium, Machining type as milling machine, Machining operation is milling, Axis of machining as vertical. After this stage, five parts from the database are filtered out and displayed to user in second user-form. It also allows user to open CAD file of selected parts by using view command option in user form. Parts in database which do not have attributes in mutual with the test workpiece are omitted. Then, the selected five parts are sent to the next stage as the key step to determine the solution among them concerning fixture design criteria.

Step 3: Similarity assessment
The similar workpiece found in the template retrieval stage are used in this stage. This stage is the important part of the process, which gives the most similar workpiece as the solution by similarity assessment method. After template retrieval a pop window appears which ask for the dimensions such as length, width, breadth, slot and hole dimensions of the test workpiece and these are used to find out the individual similarity between the test workpiece and workpiece from the database which are found similar in the first stage.
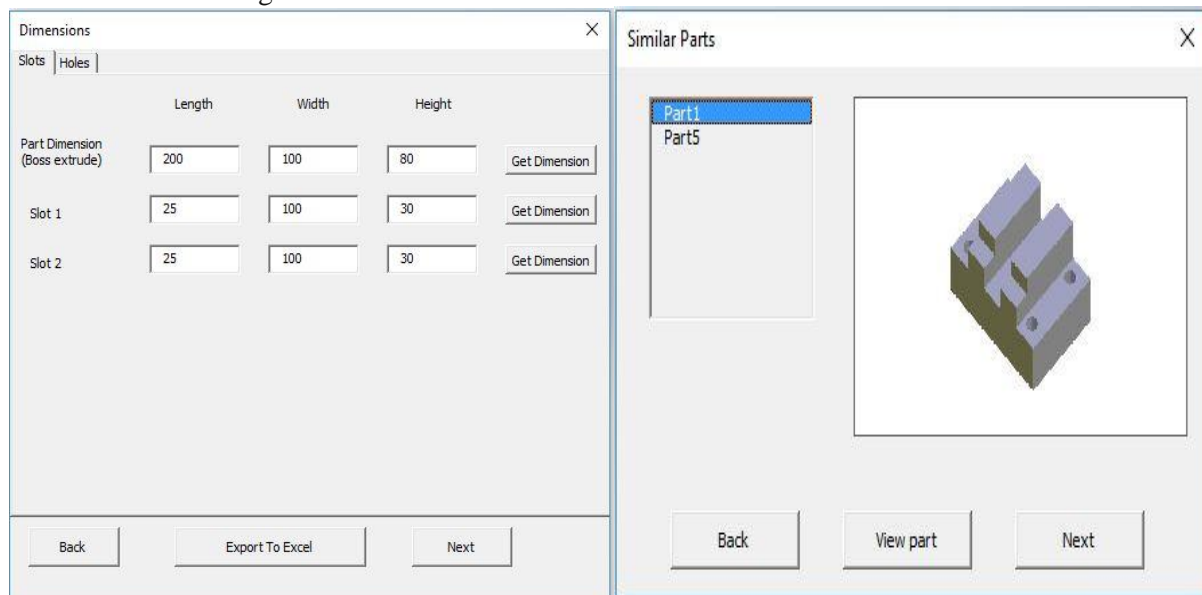

Figure 5. *Second Retrieval Stage- Similarity assessment*

Step 4: Fixture design reuse
Based on the proposed method, the workpiece rank ordering is done within database and their fixture designs, which are also stored in the database. So, the most similar part is one in the ranking list having larger value of similarity equation. Similar to previous case it also allows user to view the part. Further on clicking next, it gives fixture solution of corresponding part with its image at right.
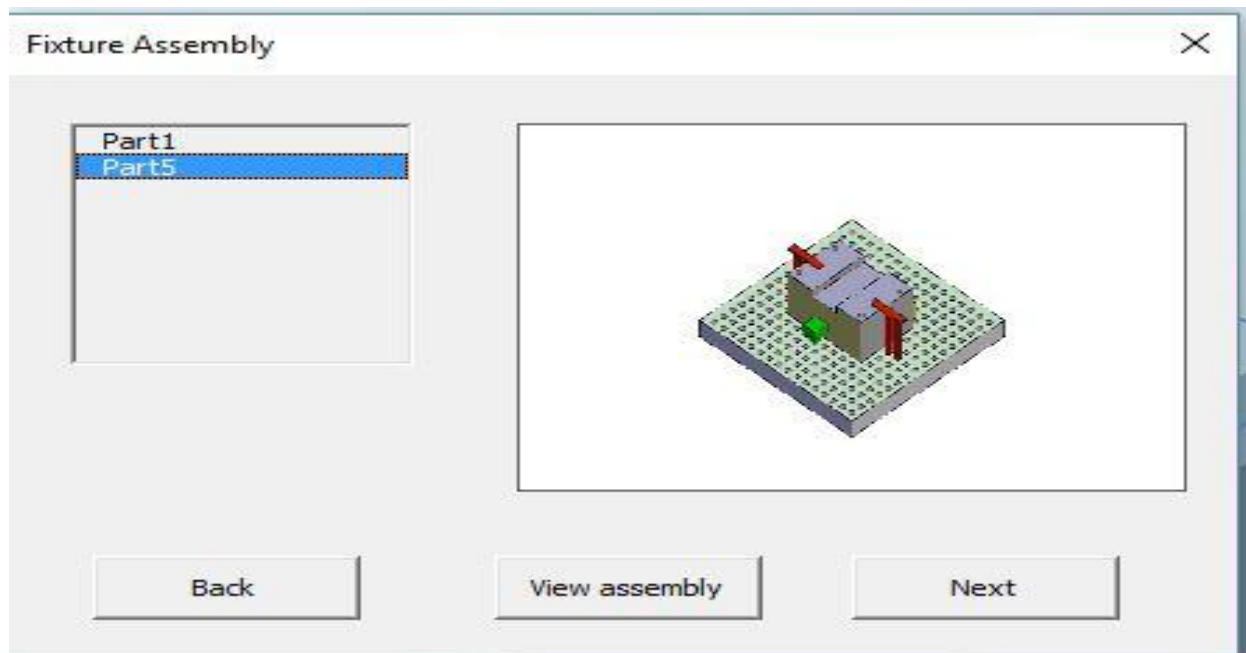
Figure 6. Fixture solution for reuse

5. Conclusion

A CBR method is developed and implemented successfully for machining parts. Implementation is done with the help of SolidWorks API using macros. In this research attempt is made to increase efficiency of CBR system by improving the accuracy of fixture indexing, Template Search, Case Retrieval process. Indexing proposed in this paper is such that the effect of part inseparability is made negligible in database. As a result of which the implemented method works successfully for prismatic parts. The dimension similarity and feature similarity equations instigated in retrieval stage of CBR method provide optimal solutions over its predecessor methods. However this method provides solution based on the data available in its database. In case of query part not having similarity with none of the parts stored in database, this method does not provide valid solutions. In such circumstances, various other methods such as Rule based reasoning can be used.

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