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A CRITICAL REVIEW ON COMPUTER-AIDED PROCESS PLANNING USING FEATURE BASED DESIGN & GENETIC ALGORITHM

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ABSTRACT

For the past three decades, computer-aided process planning (CAPP) has attracted a large amount of research interest. A huge volume of literature has been published on this subject. Today, CAPP research faces new challenges owing to the dynamic markets and business globalization. Thus, there is an urgent need to ascertain the current status and identify future trends of CAPP. Covering articles published on the subjects of CAPP in the past 13 years or so, this article aims to provide an up-to-date review of the CAPP research works, a critical analysis of journals that publish CAPP research works, and an understanding of the future direction in the field. First, general information is provided on CAPP. The past reviews are summarised. Discussions about the recent CAPP research are presented in a number of categories, i.e. feature-based technologies, genetic algorithms. Research on some specific aspects of CAPP is also provided. Discussions and analysis of the above methods are then presented based on the data gathered from the Elsevier's Scopus abstract and citation database. The concepts of 'Subject Strength' of a journal and 'technology impact factor' are introduced and used for discussions based on the publication data.

Keywords— CAPP; machining process; features; planning; operation

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1. INTRODUCTION

The use of computer technology for process planning was initiated four decades before. Since then, there has been a large amount of research work carried out in the area of computer-aided process planning (CAPP). One of the reasons for this is the role of CAPP in reducing throughout time and improving quality [1]. CAPP is the application of the computer to assist process planners in the planning functions. It is considered as the key technology for computer integrated manufacturing (CIM). It consists of the determination of processes and parameters required to convert a block into a finished part/product [2]. The process planning activities includes interpretation of design data, selection, and sequencing of operations to manufacture the part/product, selection of machine and cutting tools, determination of cutting parameters, choice of jigs and fixtures, and the calculation of the machining times and costs [1, 3].

There are two basic approaches to CAPP: variant and generative [4]. From these two basic approaches, the variant approach continues to be used by some manufacturing companies. Nowadays, the trend is toward a generative approach [1,5].

1.1 VARIANT APPROACH

Also called as retrieval approach, it uses a group technology (GT) code to select a generic process plan from the existing master process plans developed for each part family and the edits to suit the requirements of the part [6]. The variant approach is commonly implemented with GT coding system. Here, the parts are segmented into groups based on similarity, and each group has a master plan. The advantages of this approach is the ease of maintenance, but the lack of an on-time calculation of manufacturing process and quality of the process plan still depend on the knowledge of a process planner and it still requires manual inputs for the establishment of the mass data into manufacturing processes [3]. Figure 1 shows the variant approach to CAPP.

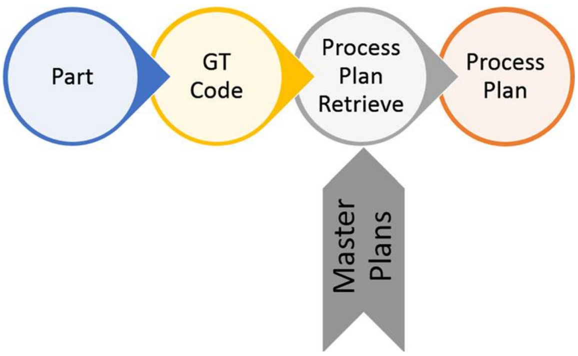

Fig. 1 Variant CAPP approach

1.2 GENERATIVE APPROACH

In this approach, a process plan for each component is created from scratch without human intervention. These systems are designed to automatically synthesize process information to develop a process plan for a part. These systems contain the logic to use manufacturing database and suitable part description schemes to generate a process plan for a particular part [3, 4]. Generative approach eliminates disadvantages of the variant approach and bridges the gap between the computer-aided design (CAD) and computer-aided manufacturing (CAM). The bottleneck of this approach is the difficulty in obtaining useable features and the difficulty in representing, managing, and utilizing human expertise. Figure 2 shows the generative approach to CAPP.

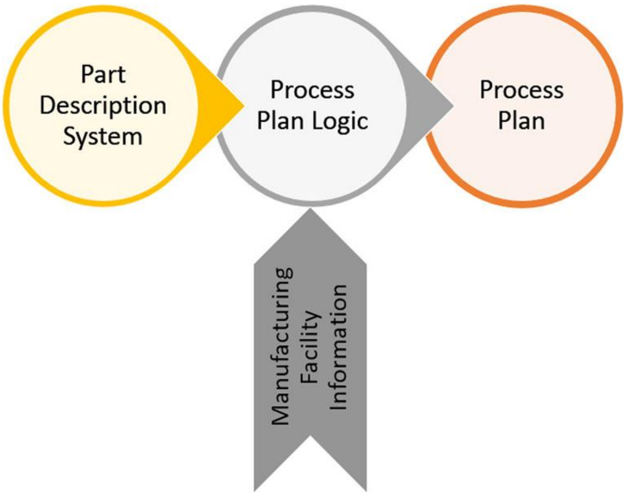

Fig. 2 Generative CAPP approach

2. GENETIC ALGORITHM

In GA the candidate solution is represented by a sequence of numbers known as chromosome or string. A chromosome's potential as a solution is determined by its fitness function, which evaluates a chromosome with respect to the objective function of the optimization problem under consideration. A judiciously selected set of chromosomes is called a population & population at a given time is a generation. The population size remains fixed for generation to generation and has a significant effect on performance of GA. GA's operates on a generation and consist of three main operations: -

1. Initialization:Randomly generate a population, which satisfies all the (manufacturing) constraints.
2. Fitness Evaluation: Calculate the fitness value for each string from precedence cost matrix (PCM).
3. Reproduction:Selection of copies of chromosome proportional to their fitness value.
4. 4.Crossover:An exchange of sections of chromosomes.
5. Mutation:A random modification of chromosome.

The chromosome resulting from these operations, often known as offspring or children, from the next generation's population. The process is repeated for a desired number of generations, usually up to a point where the system converges to a significant well performing sequence. to be carefully structured and coded. Agent-based approach offers some unique functionality for distributed product design and manufacturing. The fact that process planning for a complex part can be broken down into smaller planning

3. CAPP Survey

The importance of CAPP in a manufacturing facility cannot be underestimated. One of the reasons for this is that it provides a link between design and manufacturing and reduces the time and cost and improves the quality [7]. The CAPP area has been greatly developed in the last three decades. In this section, a snapshot of the past and current survey in the field of CAPP is presented by dividing it into two: Sections 3.1 and 3.2. The aim of this section is to provide a comprehensive review on CAPP technology: past work is discussed in the Section 3.1, whereas the Section 3.2 presents the survey of the last 10 years based on work of the above-stated methods/technologies of CAPP.

3.1 PREVIOUS REVIEW IN CAPP

The idea of developing a process plan using computers was presented by Niebel [8] in 1965. In 1984, Harold presents the first review article on CAPP in which scholars discussed about the approaches and strategies for structuring manufacturing methods and data development for the development of a generative type-automated planning system. That article also outlines the anticipated development of a "common language of geometry" to relate a part to the process and development of CAD/CAM systems that incorporated CAPP [9]. In 1988, Ham and Lu presents an assessment of CAPP status and appropriately stated that the direction of future research lies on the integration of design, manufacturing, and the use of artificial intelligence (AI) technologies [10]. In the following year, the most significant survey of that time was accomplished by Atling and Zhang, which indicated that the difficulty in the integration of CAD with CAPP is due to the lack of common methods to represent geometric entities. In this survey, the author also recognized AI technologies as a crucial technology in the development of an effective process planning system and also pointed out the importance of the learning systems and identified an ideal approach to integrate all the information involved in production of a part into a single database. The authors also highlighted the issue of interfacing between CAPP and CAM and other computerized production systems such as NC tool path, MRP, production simulation, etc. [11]. In the same year, a survey of the 128 systems of CAPP was in print by Gouda and Taraman, which highlights the four types of CAPP systems: variant, semi-generative, generative, and expert process planning system [12].

In the year 1993, a survey was conducted by ElMararghy in which the issues of quality and evolving standards are addressed. That survey also included the major development thrust in CAPP, evolving trends, challenges, integration of design, and production planning [13]. In the same year, Eversheim and Schneewinf suggest that the future of CAPP development is an extension to assembly planning, function integration with NC programming, use of AI methods in decision making, and use of database sharing for data integration with CAD [14]. In year 1995, an overview of the techniques and the role of process planning was discussed by Kamrani et al. That article also highlights the critical issues and the characteristics associated with evaluation and selection of a CAPP system [15]. In the following year, a comprehensive review on CAPP was published by Leung, in which the author observed that solid modeling in CAPP systems is not as adequate as anticipated, hence the revitalization of variant process planning systems. The scholars believed that it is logical that future process planning systems be built on intelligent system architectures with AI techniques [16]. In 1997, an 8-year survey (1990– 1997) was in print by Cay and Chassapis, which provides an overview of manufacturing features and feature recognition techniques with CAPP research [17]. In the following year, a review was presented by Marrie et al., which covers the literature from 1989 to 1996. In that article, the advantages and disadvantages of the systems were discussed with the generative approach highlighted [18]. After a 10- year gap, Xu et al. presented an article which provides a comprehensive review on CAPP technologies developed for machining since the 1990s, but mostly after 2000. In that article, the researchers provided an up-to-date review of the CAPP research works, a critical analysis of journals that published CAPP research works, and an understanding of the future direction in the field [19]. In 2014, Yusof et al. presented an article which provides provide a comprehensive survey on CAPP based on features, knowledge, artificial neural networks, genetic algorithms (GA), fuzzy set theory and fuzzy logic, Petri nets (PN), agent, Internet, standard for the exchange of product data (STEP)-compliant method, and functional blocks (FB) method/technologies for last 12 years (2002–2013). The aim of this paper is to provide an up-to-date survey with graphical representation for easy understanding of the past, present, and future of CAPP [20].

3.2 CURRENT STATUS OF CAPP

In this section, the entire work is presented in two subsections; first subsection is composed of a 6-year survey and second subsection is composed of a 7-year survey based on above mentioned methods and presents the entire survey into graphical representation for easy understanding.

3.2.1 Survey of 2002-2007

1. Feature based- In year 2002, [21] suggest a methodology to extract user-specific features from generic features. This is achieved by specifying patterns for these specific features. [22] also did a work on feature-based technology and developed a generative CAPP system for prismatic parts. The scholars have divided the system into three modules:the first concerns with feature extraction, while the second and third concern with the setup planning, machine selection, cutting tool selection, cutting parameter selection, and generation of process plan sheet. Later in year 2003, a generic CAPP support system (GCAPPSS) was proposed by [23], which invokes a set of algorithms that enable feature extraction, recognition, coding, classification, and decomposition. In year 2004, Gonzalez and Rosado presented an internal feature model for process planning by using STEP AP224 features to represent information around the machining features for process planning without the use of geometric entities [24]. Later in year 2005, Woo et al. integrate three feature recognition methods: graph matching, cell-based maximal volume decomposition, and negative feature decomposition to develop a hybrid feature recognizer for machining process planning [25]. In year 2006, Hou and Faddis investigated the integration of CAD CAPP/CAM based on machining features [26]. In the same year, Wang et al. presented a different approach as a part of their distributed process planning (DPP) system [27]. In this system, a two-layer hierarchy is considered to separate the generic data from those that are machine specific in DPP. Machining process sequencing is treated as machining feature sequencing within the context. In year 2007, Lee et al. developed a projective feature recognition algorithm that outputs features that can be directly used for process planning [28].

2. Genetic algorithms In year 2002, Li et al. presents a hybrid generic algorithm-simulated annealing (GA-SA) approach to solve the optimization problem of process planning for prismatic parts [29]. In year 2005, a fuzzy inference system for choosing appropriate machines was introduced [30]. In addition, the load for each machine is balanced by using the GA based on the capability information, which is measured by a reliability index. Afterward, a GA was developed to search for an optimal process plan for single and distributed manufacturing systems [31]. In the same year, Vidal et al. presented an algorithm based on operation cost optimization [32]. In this approach, the authors talked about the problems of manufacturing route selection in metal removal processes. The authors developed a system for cutting-process parameter selection for milling operations.

In the same year, the developed system was extended for high-speed machining [33]. Later in year 2006, Bo et al. reconstructed generic algorithms based on the analysis of various constraints in process route sequencing, including the establishment of coding strategy, evaluation operators, and fitness function [34]. In the same year, Henriques developed a nonlinear, uni-criterion, and multivariable optimization model for the integration of process and production planning [35]. The developed model generates schedule according to performance measures. Later, [36] presents a method which utilizes the application of a newly developed ant colony algorithm search technique for the quick identification of the optimal operation sequence by considering various feasibility constrains.

3.2.2 Survey of 2008-2014

1. Feature based In year 2008, Babic et al. presented a survey on three major feature reorganization problems: extraction of geometric primitives from a

CAD model, defining a suitable part representation from feature identification, and feature pattern matching/recognition [37]. In year 2010, Abu and Md Tap presented an approach to feature recognition using a rule based on different characteristics specific to each feature such as the total number of faces, edges, etc. [38]. The authors have implemented the approach by using graphic interactive programming (GRIP) and uni-graphics solid modeler. Later in year 2011, Garcia et al. introduced a method which utilizes feature-based modeling for defining a preprocess plan. A preprocess plan defines the required capabilities on a high level. This method of feature reorganization offers both geometric and nongeometric information [39]. In year 2012, Yu et al. presented a CAPP method for rotational parts based on case retrieval [40]. In this approach, the authors had proposed a method which combines feature and characteristics of part information. This method was proposed to achieve reuse process characteristics for manufacturing process information models. In the same year, Behra et al. developed feature detection algorithms in STL part specification [41]. Developed algorithms were able to detect 33 different features of geometry, curvature, location, orientation, and process parameters within an expert CAPP system for SPIF. Later in year 2013, [42] proposed a method of features coding for prismatic parts. The authors highlighted the use of developed method in process planning environment.

2. Genetic algorithm In year 2009, Salehi and Tavakkoli- Moghaddam presented an approach to divide the planning into preliminary and detailed planning stages and applied generic algorithms for process planning in both stages [43]. In year 2011, Taiyong proposed an algorithm based on the Pareto genetic algorithm for the cutting parameter selection and optimization to solve the decision-making problems of the cutting parameters in CAPP systems [44]. In the same year, [45] presented an approach for manufacturing analysis based on generic algorithm and fuzzy combination.

In this approach, the authors utilize generic algorithms for result optimization. In the following year, Ouyang and Shen present a STEP-NC-oriented process planning optimization based on a hybrid genetic algorithm to solve the nonlinear process planning problem [46]. The hybrid algorithm was proposed by integrating a search of operation precedence graph with genetic algorithm. Fan andWang presented multiobjective decision and optimization of process routing based on a genetic algorithm [47]. In this approach, the decision space of process routing based on process constraints was constructed with improved search efficiency of generic algorithm. In the same year, Liu and Qiao proposed a genetic algorithm for operation sequencing in process planning [48]. In this approach, an iterative generic algorithm based on constraint matrixes was developed for the optimization of manufacturing features and operations. The authors concluded that the iterative generic algorithm is proved to be superior on traditional simple generic algorithms in terms of shortening operation sequence time. In year 2013, an algorithm was developed to enable concurrent process planning and scheduling environment in manufacturing of tuned parts by [49]. The developed algorithm is based on GA, which performs strategic resource optimization for process planning development and also handles unplanned events. In the same year, Petrovi´c et al. utilize GA for the development of optimization agent in a multiagent-based system for the integration of process planning and scheduling [50].

4. DISCUSSIONS AND CONCLUSION

CAPP plays an important role in the CIM systems, and it eliminates the gap between CAD and CAM integration. Therefore, the need of CAPP is always there in CIM systems. In this article, an attempt is made to provide a survey carried out on CAPP based on features, GA methods/technologies in the past and present.

From this survey, it has been found that most of the CAPP work carried out on machining manufacturing resolve the problem issues of operation, tool and machine selection and sequencing, feature extraction, reorganization, interpretation and representation, knowledge integration, representation, acquisition and sharing, setup planning, energy consumption, linear and nonlinear planning, integration of product and manufacturing data, intelligent tool path generation, optimization problems, intelligent decision making and sharing of knowledge, integration of process planning and scheduling, etc.

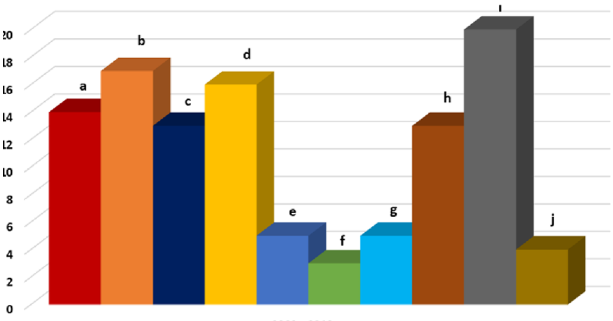

Fig. 3 Graphical representation of 2002–2014 survey:
(*a*) feature based (*d*) genetic algorithm

This paper present a survey of CAPP of the last 13 years based on two established techniques. From this study, it is found that during the 2002–2007 period of time, there was a pretty balanced work on feature-based, genetic algorithm techniques. Whereas during the 2008–2014 period, hybrid technique utilization was increased to some extent as compared to the 2002–2007 period. However, the rest of the techniques are almost utilized at the same rate. Figure 3 shows the overall status of CAPP research based on stated methods. For more clarification, Fig. 4 presents the complete method vise status of the present survey in terms of percentage.

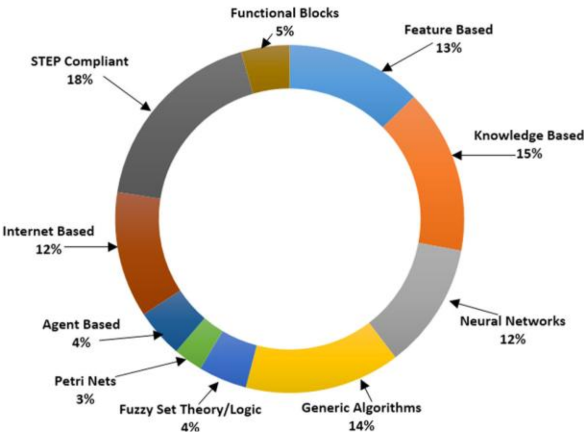

Fig. 4 Graphical representation of 2002–2014 survey

From this survey and graphical representations, it has been identified that the generic algorithm, feature-based methods had been used in the majority of CAPP works as compared to hybrid methods. However, the Hybrid feature based Genetic Algoritm method is still new as compared to other works and considered to be a new direction for CAPP.

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