CHAPTER 2

LITERATURE REVIEW FOR OPTIMIZATION OF OPERATION SEQUENCING PROBLEM IN CAPP

2.1 INTRODUCTION

In any CAPP system, selection of machining operation sequence is one of the most important activities for manufacturing a part as per the technical specification and part drawing. Any fixed sequence of the operations that is generated in a process plan cannot be the best possible sequence for all the production periods or for the criteria such as quality and machine utilization. Thus an aim should be to generate feasible operation sequences, which have to be pruned by the criteria in order to determine the best sequence of operations for the prevailing production environment. Manned methods, mathematical programming methods as well as computer based methods have been used to determine the process plan. Regardless of which method is used, the operation sequence problem is inevitable. This problem arises due to type of operations involved, part features to be produced and blueprint tolerances to be satisfied. The order in which the operations are performed will influence setup depends cost and non-cutting time. Operation sequencing is a complex task, which highly exhibits combinatorial nature.

As the operations sequencing problem involves various interdependent constraints, it is rather difficult to formulate and solve this problem using integer programming and dynamic programming methods alone. Although large number of CAPP systems has been reported in the literature, only a few have considered the optimization of operation
sequencing and determination of alternative optimal sequence of operations for prismatic components after analyzing the technological and feasible constrains. Recently some research areas such as feature recognition or feature extraction from CAD file, application of AI techniques like GAs, Particle Swarm Optimization (PSO), Simulated Annealing (SA), Ant Colony Optimization (ACO), Artificial Neural Network (ANN) and Hybridization of AI techniques are gaining more attention among the researchers. In this chapter, views of various researchers are discussed regarding the use and capabilities of above mentioned techniques in the chronicle order in which they were developed. An attempt is made to explore various techniques used for operation sequencing.

2.2 INTELLIGENT CAPP SYSTEM DEVELOPMENT

Weill et al. (1982) intended to give a comprehensive picture of the actual knowledge in the field of CAPP systems and possible areas of computer application in process planning. A systematic review of typical existing systems is performed with an effort to classify systems according to their basic characteristics and attempted to establish a precedence relationship matrix by the computer for any part based on certain constraints.

Gu and Zhang (1993) presented an approach for automatic generation of machining sequences in an object-oriented automated process planning system. The automatic generation of the machining sequence is embedded in the process planning activities. Sequencing of machining operations is carried out in three phases of planning: initial planning, set-up planning, and final planning. The developed prototype of an object-oriented process planning system for cellular manufacturing systems integrates complete information and associated knowledge about all three aspects of process planning, the part model, the manufacturing facility model and the process plan model.
Irani et al. (1995) explored in depth the integration of a machinist’s concept of manufacturing precedence among part features with a complete and explicit graph representation for alternative process plans. Demonstrated a strategy for CAPP in the single machine case using a feature precedence graph to represent the relative costs of setup changes required for any two consecutive operations. The least cost optimal process route was identified by Hamilton path of precedence graph. Further they compared Latin multiplication method with Kernighan heuristic for randomly generated alternative plans.

Jasthi et al. (1995) discusses the need for modeling the process plan, and proposed a framework for process plan internal representation for the effective integration of CAPP and CAM functions. Implementation in GIFTS - a CAPP system for rotational parts - is also discussed.

Marri et al. (1998) discussed the state-of-the-art of CAPP systems developed during the period 1989-1996. The discussion focuses on the general aspects of the systems, such as, functions, working steps, approaches of implementation, and methodologies of knowledge representation, programming language, and architecture of the system. Also suggested that architecture and constraints for machining operations should be considered while developing a CAPP system with integrated facility for process planning and cost estimation. Further concluded that intelligent CAPP systems will play a vital role in the modern manufacturing industry in future.

A systematic approach for automated setup planning in CAPP was introduced by Hong-Chao Zhang and Enhao Lin (1999). The concept of hybrid graph, which can be transferred into directed graph by changing any two-way edge into one-way edge, is studied. Tolerance relations are used as critical constraints for setup planning. The hybrid-graph theory, accompanied by matrix theory, is used to aid computerizing.
Sadaiah et al. (2002) attempted to design and develop a generative CAPP system for prismatic components and named PSG-CAPP. This CAPP system has been divided into three modules. The first module is concerned with feature extraction. The second and third modules deal with planning the set-up, machine selection, cutting tool selection, cutting parameter selection, and generation of process plan sheet. The whole CAPP system is developed using Visual Basic 6.0 as front end and Oracle 7.3 as back end. The SolidWorks98 plus has been used for modeling, and feature extraction has been implemented using a program written in Visual Basic 6.0. The developed CAPP system is linked with CAD module and it extracts the majority of features automatically prior to process planning. The developed CAPP system has been tested with aerospace components. A case study has been included to highlight the potential of the CAPP system. Also suggested that the feature recognition module of the CAPP system must be further developed in order to recognize complex features. Also, the operation-sequencing problem is to be optimized for different criteria such as minimum cost. Further it can be observed that an AI technique can be applied for solving the similar problems.

Gonzalez and Rosado (2004) focused on information system for representing the product for internal CAPP use with generality and flexibility characteristics. The application domain of the model proposed is the assignment of processes and machines in machined parts.

In order to solve the isolation and the unilateral sequence integration between CAPP and PPS, Liu Min (2004) proposed a integrated system of CAPP and PPS based on distributed and dynamic process planning aiming for single-piece, small-lot and made-to-order production and then systematically builds the integrated model. Further constructed the function model, which includes the designing layer, the part planning layer, the shop
planning layer and the scheduling layer in detail, according to the requirement for the rationalization of resource utilization, process design and plan scheduling.

Honghee Lee (2004) generated a process plan based on the sequences of the feature groups and features. The planning with the individual features is very complicated, feature groups are formed for effective planning using the nested relations of the features of a part, and special feature groups are determined for sequencing. When multiple machines are required, efficient machine assignment is performed. A series of heuristic rules are developed to accomplish it.

Lau et al. (2005) realized that the efficiency of process planning systems still needs significant improvement due to the problems of design data loss or design data misinterpretation. An attempt has made to introduce an intelligent computer-integrated system for reliable design feature recognition in order to achieve automatic process planning. Moreover, it describes a rule-based computer-integrated system for recognizing features of components stored as STEP format, analyzing the design files and designing manufacturing processes. The significance of this research is that the product designs with dissimilar formats from various CAD systems can be interconnected and automatically coded for multiple manufacturing purposes. It presents an effective method named rule-based reasoning for creation of optimal process plans for metal cutting.

Utilization of feature method for representations of the construction and the technological process elements is a key factor for integration of design and technological process planning CAD/CAPP integration model. The availability of alternative process plans plays the main role in the CAPP/PPS system integration. Grabowik et al. (2005) described a methodology for integration of CAD/CAPP/PPS systems.
Xionghui et al. (2007) proposed a practical solution for a bi-directional integration of CAD and CAPP on the platform of commercial CAD systems. The techniques such as feature recognition and conversion, feature parameter and constraint extraction, feature tree reconstruction, technical information processing, process planning, automatic process drawing marking and 3D material stock CAD model generating are discussed. The extracted features and their related technical information and knowledge are encapsulated together with the geometry-oriented CAD model to form an integrated product information model to facilitate effective integration with the downstream activities.

2.3 OPTIMIZATION TECHNIQUES DEVELOPMENT

Kirkpatrick et al. (1983) reviewed the central constructs in combinatorial optimization and in statistical mechanics and then develops the similarities between the two fields. They showed how Metropolis algorithm for approximate numerical simulation of the behavior of a many-body system at a finite temperature provides a natural tool for bringing the techniques of statistical mechanics to bear on optimization. Application of this technique to partitioning, component placement and wiring of electronics systems have presented. Travelling salesman problem has considered to test the robustness of SAT.

Feng-Tse Lin et al. (1993) presented a stochastic approach called the annealing-genetic algorithm for solving combinatorial optimization problems. This approach incorporates GA into SA to improve the performance of SA.

Ulrich (1994) demonstrated that the performance of simulated annealing strongly depends on the annealing schedule. An attempt has been made to optimize the annealing schedule.
Mandira and Uday (1997) applied GA and SA to the problem of optimal link enhancement, which is an Non deterministic Polynomial (NP) complete combinatorial optimization problem in the topological expansion of computer communication networks and showed that simulated annealing outperforms genetic algorithm on this problem.

Prasad et al. (1997) reports the development of an optimization module for determining process parameters for turning operations as part of a personnel computer based generative CAPP system. Improved mathematical models are formulated by modifying the tolerance and work-piece rigidity constraints for multi-pass turning operations. The formulated models are solved by the combination of geometric and linear programming techniques.

Cai and Zhou (1997) examined the problem of sequencing a set of jobs on a single machine, where each job has a random processing time and is associated with a known job-dependent weight, with the objective to minimize the expectation of the weighted variance of job completion times. Established the NP-completeness of this problem, and further show that the problem under some compatible conditions is NP-complete in the ordinary sense and introduced the concept of a W-shaped solution for the problem and find that an optimal W-shaped sequence exists under the compatible conditions.

A method incorporating a combination of expert system and mathematical programming is proposed by Kim and Suh (1998) to produce an optimal operation sequence to minimizing the non cutting time. Also precedence, tolerance and alternative operations are taken into consideration as constraints. The mathematical method performs grouping and sequencing simultaneously and the expert system preprocesses the procedure by eliminating infeasible solution sets and clustering the operations according to
the tool commonalities. A prototype CAPP system was also developed using an object oriented expert system shell.

Hildegard and Gerhard (1998) have used SA to the Order Spread Minimization Problem in the process of planning industrial cutting operations and it can be looked upon as a generalization of the Traveling Salesman Problem (TSP), it has to be classified as NP-complete. SA appears to provide solutions which - in terms of solution quality - are equivalent to previous work reported. Claimed that SA provides significantly improved solutions at the expense of a moderate increase in computing times.

Rui-Rong Wu and He-Ming Zhang (1998) have employed object-oriented technology to represent set-up planning knowledge and generate alternative set-ups which can respond to the dynamic manufacturing resource and facilitate the CAPP / production planning systems (PPS) integration. Based on fuzzy-set theory, a fuzzy evaluation function is proposed to produce optimal set-ups. Combined with a real project, a setup planning system is developed to generate alternative and optimal set-up plans for the machining of prismatic parts.

Klaus Neumann and Jurgen Zimmermann (1998) presented polynomial heuristic procedures for NP-hard stochastic scheduling problems with identical parallel machines and objective functions where stochastic precedence constraints are given by special acyclic networks. To develop appropriate heuristics for scheduling problems with uniform parallel machines and more general objective functions needed further studies.

Ronald et al. (2001) conducted empirical research on heuristics. The toughest technical challenges are finding (or generating) suitable test instances, and assessing how close heuristic algorithms come to optimal. No investigation can hope to produce useful results if these matters are not
addressed early and intensively. The rest of the procedures for conducting, analyzing and reporting empirical results can usually be boiled down to fairness and common sense. Formal statistics may help some analyses, but a well-conceived graph can do just as well. If adequate thought and effort is devoted to understanding what the research is about, what results are hidden in the experimental outcomes, and how these findings can be fairly and effectively communicated, every study can contribute something to the critical but still underdeveloped science of heuristic algorithms.

Mitsunori et al. (2002) dealt with the two problems in SA. One is the long computational time of the numerical annealing, and the solution to it is the parallel processing of SA. The other one is the determination of an adaptive mechanism for changing the temperature. The multiple SA processes are performed in multiple processors, and the temperatures in the SA processes are determined by a genetic algorithm for a TSP problem.

The classical version of SA is based on a cooling schedule. Generally, the initial temperature is set such that the acceptance ratio of bad moves is equal to a certain value. Walid Ben-Ameur et al. (2004) proposed a simple algorithm to compute a temperature which is compatible with a given acceptance ratio. Then, the properties of the acceptance probability are showed this function is convex for low temperatures and concave for high temperatures. Also provided a lower bound for the number of plateaux of a SA based on a geometric cooling schedule and many numerical experiments are reported.

Balram Suman (2004) used four SA based multi-objective algorithms to solve multi-objective optimization of constrained problems with varying degree of complexity along with a new algorithm. The algorithm uses a strategy of Pareto dominant based fitness in the acceptance criteria of SA and is improved.
Based on the various constraints in process route sequencing and the astringency of GA, the GA was reconstructed by Zhang Wei Bo (2006), including the establishing of the coding strategy, the evaluation operator and the fitness function. The natural number is adopted in coding strategy, the “elitist model” and the “tournament selection” are adopted as selection operators, the nonconforming sequential searching crossover operator is used and the inconsistent mutation operator is adopted, the fitness function is defined as a formula of the sum of compulsive constraints with each weighing, and these constraints are used as the control strategy for GAs in the searching process. By using GAs in the optimization, the optimal or near-optimal process route is obtained.

To solve the job-shop scheduling problem (JSSP) more effectively an immune GA was proposed and presented by Xiao-Dong and Cong-Xin (2007) via combining the immune theory and the GA. A modified precedence operation crossover was also proposed to improve the performance of the crossover operator. On the other hand, the “shortest processing time” principle was selected to the vaccine and the design method of the immune operator was given at the same time. Finally, the performance was validated by applying to benchmark problems.

2.4 PROCESS PLANNING BY HEURISTIC TECHNIQUES

John and Royce (1996) presented an approach for operation sequence coding that permits the application of GA for quick determination of optimal, or near-optimal, operation sequences for parts having varying complexity. This approach provided better results over existing techniques by utilizing common sequencing constraints to guide the coding process resulting in a reduction of the solution search space. These improvements enhance the efficiency of determining near-optimal operation sequences for complex parts.
within a time frame, which is ideal for a real-time dynamic planning environment.

A generic prototype process planning system has been developed by Gu et al. (1997) for the machining of prismatic parts. Reported a fuzzy model that uses the concept of `feature manufacturability’ to evaluate feature priorities and identify important features. The model is created by means of the construction of parametric fuzzy membership functions and fuzzy objective functions. These functions, based on neural networks methodologies, enable the evaluation of the complexity of features in a part description model and the manufacturing capability in an environment description model simultaneously. After feature prioritization, operation sequencing of the important features can be carried out first within a much smaller search space and the operations of the less important features can be arranged easily due to reduced constraints.

Zhang et al. (1999) described a process planning approach that integrates the tasks of routing and sequencing for obtaining a globally optimal process plan of a part concurrently considering the selection of machines, tools, TADs for each operation-type and sequence among operations, together with the constraints of precedence relationship, conditional precedence relationship, and validity of operation-methods. A simulated annealing based algorithm was developed to search for global optimal solution in the planning model and found that the method is quite effective.

Larry et al. (1999) presented production planning multi-resource generalized assignment problem to allow splitting individual batches across multiple machines, while considering the effect of setup times and setup costs, then given different formulations and suggest adaptations of GA and SA and Lagrangian relaxation approach.
Dereli and Huseyin (1999) introduced optimization modules of a process planning for prismatic parts using GA, which has been developed to provide a complete CAD/CAM integration, for shop floor use that can be used by an average operator and to produce globally optimized process plans and part programs. The developed GA-based optimization would be possible to increase machining efficiency by the use optimal cutting parameters, sequence of operations, and positioning sets on tool magazines, and to contribute to the success of the manufacturing industry. This will lead to increased utilization of CNC machine tools and will probably enhance the performances of future process planning systems.

Bhaskara et al. (1999) demonstrated the application of GA as a global search technique for a quick identification of optimal or near optimal operation sequences in a dynamic planning environment. Feasible sequences are generated from the feature precedence relationship based on the precedence and geometrical tolerance constraints. A novel initialization scheme for representing the genetic code and a new crossover operator are designed to retain the local operation precedence for each form feature. Since sequences can be obtained quickly, this approach can actually be used by the process planner to generate alternative feasible sequences for the prevailing operating environment.

Ma et al. (2000) described an approach that models the constraints of process planning problems in concurrent engineering. An algorithm based on SA has been developed to search for the optimal solution. Several cost factors including machine cost, tool cost, machine change cost, tool change cost and set-up change cost can be used flexibly as the objective function. Precedence relationships among all the operations required for a given part are used as the constraints for the solution space.
Qiao et al. (2000) presented a study of using GA method to select the machining operation sequence for prismatic parts. Process planning rules including precedence rules, clustering rules, adjacent order rules and optimization rules are considered and are encompassed quantitatively in the fitness calculations for alternative operation sequences. Claimed that GA proves effective for machining operation sequencing of prismatic parts, by incorporating various production environment considerations into process planning.

Dong et al. (2001) considered the Operation-Sequencing Problem (OSP) in process planning with the objective of minimizing the sum of machine, setup and tool changing costs. Four simulated annealing and two Tabu search algorithms have been suggested to obtain optimal or near-optimal solutions within a reasonable amount of computation time. Application of the suggested search heuristics has been illustrated. To compare the six search algorithms, computational experiments were done on randomly generated test problems and results concluded that the Tabu search algorithms perform better than the simulated annealing algorithms on overall average. Also, the test results show that the Tabu search with the interchange method performs the best among the suggested algorithms. Furthermore, the computation times were reasonable so that it can be used to solve most practical problems.

Dereli et al. (2001) developed a system software to optimize the cutting parameters for prismatic parts based on an artificial intelligence tool called GA. It was implemented using C programming language.

Keung et al. (2001) address the problem of Job scheduling and machine assignment on a flexible machining workstation equipped with multiple parallel machines in tool-sharing environment using GA. Attempted to model the problem with the objective of simultaneously minimizing both
the number of tool switches and number of tool switching instances. Further, a set of realistic constraints has been included for the investigation.

Dong et al. (2004) suggested a tree-structured precedence graph to represent the precedence relations and alternative operations in process planning. Based on the graph, the entire problem is decomposed into two sub problems: operation selection and operation sequencing. Then, three iterative algorithms are suggested to solve the two sub problems for obtaining optimal / near optimal solutions. The algorithms are illustrated using an example part, and to show the performances of the proposed algorithm, computational experiments were done on randomly generated test problems. The results show that the algorithms suggested work well for the test problems. In addition, the two heuristics gave near-optimal solutions with much shorter computation times.

Jain and Gupta (2005) developed a meta-heuristic to solve operation sequencing problem, which tries to minimize the total change over cost taking in account the related technological constraints among operations, using ACO technique. The precedence relationships among features are analyzed to generate a Precedence Relationship Matrix (PRM). This method highlights various technological constraints to be considered while sequencing and minimize the total change over cost. A computer code has been developed which will help the end users in determination of optimal sequences for a given part.

Li et al. (2005) presented application of genetic algorithm to CAPP in distributed manufacturing environments. In a distributed manufacturing environment, factories possessing various machines and tools at different geographical locations are often integrated to achieve the highest production efficiency. When jobs requiring several operations are received, feasible process plans are produced by those factories available. These process plans
may vary due to different resource constraints. Therefore, obtaining an optimal or near-optimal process plan becomes important. Presented a GA, which, according to prescribed criteria such as minimizing processing time, could swiftly search for the optimal process plan for a single manufacturing system as well as distributed manufacturing systems.

Guo et al. (2006) modeled the complicated operation sequencing as a combinatorial optimization problem, and modified PSO algorithm has been employed to solve it effectively. To explore the search space comprehensively and to avoid being trapped into local optima, several new operators have been developed to improve the particles movement, forming a modified PSO algorithm. Comparison has been made between the result of the modified PSO algorithm along with GA and the SA algorithm. The developed PSO can generate satisfactory results in optimizing the process planning problem.

Vijay Pandey et al. (2006) made an attempt to develop Operation Sequencing Rating Index (OSRI) which is the weighted sum of four indices: setup changeover index, tool changeover index, motion continuity index and loose precedence index. Owing to the combinatorial nature of the problem, the SA based algorithm has been employed to determine the optimal/near-optimal operation sequence by maximizing OSRI. In this methodology, a perturbation scheme named as modified shifting scheme has been devised to generate a feasible neighborhood sequence that minimizes the search space and helps the algorithm to escape from local optima. A new approach for temperature variation in the SA algorithm is also incorporated, and reduction in temperature is assumed to be parabolic. The advantage and effectiveness of the methodology in terms of its algorithmic implementation have been verified on four test parts.

Rainer and Sonke (2006) considered heuristics for the well-known resource-constrained project scheduling problem. Based on the computational
results discussed features of good heuristics. While recombining merely existing ideas occasionally seems to be less creative than developing new ideas, some of the integration efforts have put well–known techniques into a new and promising context, and the results have often been encouraging emphasized the value of new methodologies. Comparisons might motivate researchers rather to improve the benchmark results with recombination or modifications of existing approaches than to develop new and innovative ideas.

Fu-Qing Zhao et al. (2006) presented a fuzzy inference system in choosing alternative machines for integrated process planning and scheduling of a job shop. To overcome the problem of un-utilization machines, sometimes faced by unreliable machine, an improved PSO have been used to balance the load for all the machines

Andreas et al. (2006) presented a stochastic method based on the differential evolution algorithm to address a wide range of sequencing and scheduling optimization problems.

Krishna and Rao (2006) presented an application of ACA as a global search technique for the quick identification of the optimal operations sequence by considering various feasibility constrains. A couple of case studies are considered from the literature for comparing the results obtained by the method and a considerable reduction in computational time has been reported.

Guang et al. (2007) presented a GA-based synthesis approach for machining scheme selection and operation sequencing optimization for obtaining global optimal process plans based on the combinations of different machining schemes selected from each feature. The memberships of alternative machining schemes for each feature derived from fuzzy logic
neural network are used for machining scheme selection. Obtained process plans increase the competitiveness of the part and also provide the production scheduling with more flexibility.

For process planning and scheduling in a job shop, a unified representation model and a SA based approach have developed by Li and McMahon (2007) to facilitate the integration and optimization process. Performance criteria, such as makespan, the balanced level of machine utilization, job tardiness and manufacturing cost, have made the algorithm adaptive to meet various practical requirements.

Agent technology has been considered as a promising approach for developing process planning systems and optimizing process plans in a distributed environment. Zhang and Xie (2007) directs agent technology used to CAPP and discusses issues in traditional approaches.

Mwinuka (2007) provides a scientific approach for the sequencing of features based on maximizing the stiffness of the intermediate component. In the case of intersecting feature volumes, preference is given to a feature with a lower machining cost. This scientific approach is embedded within a flexible environment in which heuristic rules can be constructed from a rich vocabulary covering geometric and technological attributes, without the need for additional programming.

Dashora (2008) a psycho-clonal-algorithm-based approach has been proposed to solve optimally the operation sequencing problem and comparing its performance with other established meta-heuristic approaches. The psycho clonal algorithm works in a hierarchy, executes its search through the mechanism of hyper mutation (inverse mutation and pair-wise interchange), receptor editing, and explores the search space thoroughly by maintaining a tradeoff between local and global search.
Chu et al. (2008) presented a formal graph representation scheme for stamping operation sequencing for sheet metal progressive dies and a graph theoretic method for automatic determination of stamping operation sequence.

Li et al. (2008) developed a new method using an evolutionary algorithm, called genetic programming and is presented to optimize flexible process planning. Comparison has been made for this approach with genetic algorithm.

A generic goal programming model was proposed by David et al. (2008) to the operational scheduling of the continuous coal handling and blending processes when considering multiple, and sometimes conflicting, objectives.

Rami Musa and Frank Chen (2008) introduced and solved the dynamic throughput maximization problem using simple greedy sorting algorithm, SA algorithms and two ACO algorithms. Numerical examples have been solved to compare the performances of the proposed algorithms. Claimed that ACO algorithms generally outperform the other algorithms.

Michael Andresen, et al. (2008) presented two iterative algorithms, namely a SA and a GA to solve problem of, scheduling n jobs on m machines in an open shop environment. For the SA algorithm, several neighborhoods are suggested and tested together with the control parameters of the algorithm. For the GA, new genetic operators are suggested based on the representation of a solution by the rank matrix describing the job and machine orders.

Joshi et al. (2008) presented setup planning and operation sequencing using neural network and GA for prismatic components to develop a CAPP system.
Hu et al. (2008) introduced process sequence optimization based on constraint matrix and GA was used to obtain the optimal process sequence.

An attempt in the direction of building a systematic approach for process planning based on process knowledge customization has been presented by Huan-Min Xu (2009). The outcomes of this study lay the foundation for process planning in future rapid process preparation, but realized that the overall problem is far from solved.

Wang et al. (2009) reported a PSO-based optimization approach for the process planning problem. Due to the nature of discrete problem domain and the continuous nature belonging to the original PSO, a novel solution representation is made to suit the PSO in the application of process planning. Moreover, local search is incorporated and interweaved with the PSO evolution to improve solution quality. A case study was used to demonstrate its effectiveness. Further numerical experiments with different problem size was studied and compared with other optimization approaches.

A novel SA algorithm was developed to produce a reasonable manufacturing schedule within an acceptable computational time for a hybrid flow shop scheduling with parallel identical machines to minimize the make span by Mirsanei (2009). Developed SA uses a well combination of two moving operators for generating new solutions. The obtained results are compared with those computed by Random Key GA and Immune Algorithm.

The integration of process planning and scheduling problem has been developed as a combinatorial optimization model, and a PSO algorithm, has been modified and applied to solve it effectively by Guoa et al. (2009). Initial solutions are formed and encoded into particles of the PSO algorithm. The particles “fly” intelligently in the search space to achieve the best sequence according to the optimization strategies of the PSO algorithm.
Meanwhile, to explore the search space comprehensively and to avoid being trapped into local optima, several new operators have been developed to improve the particles’ movements to form a modified PSO algorithm. Case studies have been conducted to verify the performance and efficiency of the modified PSO algorithm. A comparison has been made between the result of the modified PSO algorithm and the previous results generated by the GA and the SA algorithm, respectively, and the different characteristics of the three algorithms are indicated. Case studies show that the developed PSO can generate satisfactory results in both applications.

Mojtaba and RezaTavakkoli (2009) developed a preliminary and detailed planning, implementation of compulsive and additive constraints, optimization sequence of the operations of the part, and optimization selection of machine, cutting tool and Tool Approach Direction (TAD) for each operation using GA, simultaneously in CAPP.

Vasan and Srinivasa Raju (2009) deal with the application SA, simulated quenching (SQ) and real-coded genetic algorithms (RGA) to a case study of Mahi-Bajaj Sagar Project, India, to maximize the annual net benefits subjected to various irrigation planning constraints for 75% dependable flow scenario. It is concluded that SA, SQ and RGA can be utilized for efficient planning of any irrigation system with suitable modifications.

A multi objective GA with local search was presented by Liu Dayou (2009) to find the Pareto optimal solutions for an advanced planning and scheduling problem in manufacturing supply chain. Proposed algorithm makes use of the principle of non-dominated sorting, coupled with the use of a metric for normalized crowding distance. Local search technique is used to improve the efficiency and the algorithm was compared with two other multi objective GAs from the literature.
Eswaramurthy and Tamilarasi (2009) presented an application of the global optimization technique called Tabu search combined with the ACO technique to solve the job shop scheduling problems (JSSP). The neighborhoods are selected based on the strategies in the ant colony optimization with dynamic Tabu length strategies in the Tabu search.

Sequencing interdependent analysis components in order to reduce the execution time has been addressed by multidisciplinary design optimization. Optimized sequencing of analysis components in multidisciplinary systems has studied by Shaja and Sudhakar (2009).

PisutPongchainerks (2009) introduces three heuristic algorithms for solving JSSP with multi-purpose machines, and open-shop scheduling problems. All these algorithms are based on the PSO algorithm, and generate solutions that belong to the class of parameterized active schedules via their specific decoding procedures. Comparison of the benchmark test results of the proposed algorithms with those of existent algorithms reveal that the proposed algorithms perform better in some instances.

Vishwa et al. (2010) addressed simultaneous optimization of interrelated manufacturing processes problem with an integrated approach for single stage multifunctional machining system and identifies the best part sequence available in the part-mix. A mathematical model has been formulated to minimize the broad objectives of setup cost and time simultaneously.

Udhayakumar and Kumanan (2010) proposed a non-traditional optimization technique, ACO algorithm to generate an active schedules and optimal sequence of job and tool that can meet minimum makespan for the flexible manufacturing system.
Xiwu et al. (2010) developed a new directed graph approach to describe the precedence constraints to generate many optimal or near-optimal setup plans and provide more flexibility required by different job shops.

Young et al. (2011) demonstrated a GA approach based on a topological sort (TS) -based representation procedure for effectively solving precedence constrained sequencing problems (PCSPs). Showed that GA approach is a good alternative in locating optimal sequence for various types of PCSPs.

Mohammad and Farhad (2011) presented a special case of the general shop called partial job shop problem. The problem is formulated as a mixed integer programming model. A scatter search algorithm combined with Tabu search and path re-linking is used to tackle this problem with makespan criterion. The computational experiments are performed on some problem instances. The results are compared with a lower bound and the effectiveness of the algorithm is shown.

In order to ensure the feasibility of the process plans, the Constraint Matrix and State Matrix are used in ACO algorithm to show the state of the operations and the searching range of the candidate operations. Xiao-jun Liu (2011) used two prismatic parts to compare the ACO algorithm with Tabu search, SA and GA. The computing results show that the ACO algorithm performs well in process planning optimization.

Optimization of sequence of the operations of the part, and optimization of machine selection, cutting tool and TAD for each operation using the intelligent search and genetic algorithm has simultaneously developed by Mojtaba and Ardeshir (2011).
SajadKafashi (2011) presented GA approach to a generative system process plan for a given part. The proposed approach and optimization methodology analyses constraints such as TAD, tolerance relation between features and feature precedence relations to generate all possible setups and operations using workshop resource database. Based on technological constraints, the GA algorithm approach, which adopts the feature-based representation, simultaneously optimizes the setup plan and sequence of operations using cost indices. Case studies results showed that the developed system can generate satisfactory in optimizing the integrated setup planning and operation sequencing in feasible condition

2.5 HYBRID ALGORITHMS FOR CAPP OPTIMIZATION

Cordon et al. (2002) introduced a relevance feedback process for extended fuzzy information retrieval systems in world wide web search engines based on a hybrid evolutionary algorithm combining simulated annealing and genetic programming components.

Wong et al. (2003) developed a prototype solution procedure using a hybrid fuzzy genetic approach named as Fuzzy Process Planning System [FPPS] to optimize the manufacturing cost under uncertainty. The system has demonstrated possibility of using fuzzy set theory to handle process selection and sequencing under uncertainty. In FPPS, the optimal local operation sequence for a feature derived by a hybrid fuzzy expert system-GA approach

Ganesh and Punniyamoorthy (2005) proposed a modified single objective evolutionary program approach, namely GA, SA, and hybrid genetic algorithms-simulated annealing (GA-SA) for optimization of continuous time production plan problems. The results are compared with each other and it was found that the hybrid algorithm performs better. The proposed algorithm consists of two phases, where GA is used in the first phase and SA is used in
the second phase. Merging of these two powerful algorithms has the strength of both global and local search. The results obtained from GA and hybrid GA-SA algorithms are encouraging over SA.

Combined with the advantages of GA and SA, Shu and Zheng (2006) brought forward a parallel genetic simulated annealing hybrid algorithm and applied to solve task scheduling problem in grid computing. It first generates a new group of individuals through genetic operation such as reproduction, crossover, mutation, etc, and then simulated anneals independently all the generated individuals respectively. When the temperature in the process of cooling no longer falls, the result is the optimal solution on the whole. From the analysis and experiment result, it is concluded that this algorithm is superior to GA and SA.

To solve integrated Resource Selection and Operation Sequences problem in Intelligent Manufacturing System, a new two vectors-based coding approach has been proposed by Haipeng et al. (2006), to improve the efficiency by designing a chromosome containing two kinds of information, i.e., operation sequences and machine selection. Using such kind of chromosome, adapted multistage operation-based GA to find the Pareto optimal solutions. Moreover a special technique called left-shift hill climber has been used as one kind of local search to improve the efficiency of algorithm. Experimental results of several problems indicate that, proposed approach can obtain best solutions.

Sequencing of interacting prismatic machining features for process planning to determine machining precedence constraints by a set of defined knowledge-based rules, grouping machining features into setups based on tool approaching directions, and sequencing features within each setup through geometric reasoning using a hybrid technique has developed by Zhenkai and Lihui (2007).
A sequential hybrid approach at the macro level is proposed for process planning and process re-planning by Ahmed and Hoda (2007). Initially, the part family’s master plan is retrieved, followed by application of modeling tools and solution algorithms to arrive at the plans reconfigurable, is presented and compared. Random-based evolutionary SA algorithm has been tailored for re-planning.

Kunlei et al. (2009) modeled process planning problem using a hybrid genetic simulated annealing algorithm to optimize it. A part taken from literature used as an experiment to verify the performance of the hybrid GASA algorithm. The model can generate alternative optimal or near-optimal solutions for a prismatic part with better computation efficiency compared with single GA and single SA. The limitation of this approach is that optimization of the algorithm parameters needs further consideration.

Tamilarasi and Ananthakumar (2010) developed a new method for solving JSSP using hybrid GA with SA. This method introduces a reasonable combination of local search and global search for solving JSSP.

Process planning and scheduling are two most important functions in the manufacturing system. A new hybrid algorithm based approach has been developed by Xinyu Li et al. (2010) to facilitate the integration and optimization of these two systems. To improve the optimization performance of the approach, an efficient genetic representation, operator and local search strategy have been developed. Experimental studies have been used to test the performance of the proposed approach and to make comparisons between this approach and some previous works.

Bing et al. (2011) presented a hybrid PS-ACO algorithm. The pheromone updating rules of ACO are combined with the local and global search mechanisms of PSO. On one hand, the search space is expanded by the
local exploration; on the other hand, the search process is directed by the
global experience. The local and global search mechanisms are combined
stochastically to balance the exploration and the exploitation, so that the
search efficiency can be improved. The convergence analysis and parameters
selection are given through simulations on TSP. The results show that the
hybrid PS-ACO algorithm has better convergence performance than GA,
ACO and max-min ant system under the condition of limited evolution
iterations.

Voratas and Siriwan (2011) presented a two-stage GA for multi-
objective JSSPs to minimize makespan and total weighted earliness, tardiness.
The algorithm is composed of two Stages: Initial stage applies parallel GA to
find the best solution of each individual objective function with migration
among populations. In Stage 2 the populations are combined. The evolution
process of Stage 2 is based on Steady-State GA using the weighted
aggregating objective function. The algorithm developed can be used with
one or two objectives without modification.

A novel hybrid Tabu search algorithm with a fast public critical
block neighborhood structure is presented by Jun-Qing Li et al. (2011) to
solve the flexible job shop scheduling problem with the criterion to minimize
the maximum completion time. First, a mix of four machine assignment rules
and four operation scheduling rules has developed to improve the quality of
initial solutions to empower the hybrid algorithm with good exploration
capability. Second, an effective neighborhood structure to conduct local
search in the machine assignment module is proposed, which integrates three
adaptive approaches. Third, a speedup local search method with three kinds of
insert and swap neighborhood structures based on public critical block theory
is presented.
2.6 CONCLUSIONS FROM LITERATURE REVIEW

CAPP is concerned with determining the sequence of individual manufacturing operations required to produce a product as per technical specifications given in the part drawing. Any sequence of manufacturing operations that is generated in a process plan cannot be the best possible sequence every time in a changing production environment. As the complexity of the product increases, the number of feasible sequences increases exponentially and there is a need to choose the best among them.

A survey on the application of various artificial intelligence approaches in CAPP and their potential advantages and their shortcomings are discussed. Many optimization problems from the manufacturing systems are very complex in nature and quite hard to solve by conventional optimization techniques, so that an efficient search is required to explore the large solution space of valid operation sequence under various interacting constraints. Reported literature reveals that many techniques such as GA, SAT, PSO, ACA have been applied to solve the problem of operation sequencing in CAPP with the objective of

- Minimizing optimal cost
- Less computational time
- Obtaining optimal feasible sequences

To determine the optimal process plan automatically for a prismatic part in CAPP is an intractable with difficulties in the following aspects.

1. The geometric relationships between features in a prismatic part are complicated, and the explicit heuristic rules for sequencing the operations corresponding to the features are deficient.
2. In CAPP the evaluation criteria coming from some aspects, such as minimum usage of expensive machines and tools, minimum number of setups, minimum number of machine and tool changes, and achieving good manufacturing practice, are also conflicting in certain cases.

To carry out the different decision processes considering the evaluation criteria simultaneously is imperative to a globally optimized solution. However, it is usually difficult for some reasoning approaches.

3. In a part, there usually exist several alternative process plans that can achieve the predetermined optimization objective. To generate and provide the alternative optimal plans can help process planners make a reasonable decision according to the workshop environment and fixture conditions. However, in the existing approaches, few contributions have been made towards this direction.

Also, exploration of alternate optimal sequence is a highly competitive task where conventional meta-heuristics fails. Moreover, certain meta-heuristics yield an optimal solution which is not a global one. Recent works include hybridization of meta-heuristics in view to elucidate the above mentioned setbacks.

From the literature survey, the Table 2.1 demonstrates the different approaches attempted by various researchers to obtain optimal feasible sequences for CAPP to the industrial case studies for the past three decades, which are considered for further study in this research work.

However, application of a hybrid meta-heuristic algorithm using GA and SAT incorporating Solution Space Reduction Technique (SSRT) to obtain optimal sequence for CAPP has not been addressed. In this research work an attempt has been made for developing an efficient search technique to obtain feasible optimal solution with a minimal computational time.
Table 2.1 Techniques used to obtain optimal feasible sequences

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</table>

CV – Conventional method; LMM - Latin multiply method; BF – Branch and Fathoming

2.7 CONTRIBUTION OF THESIS

Although few hybrid algorithms are available, each and every algorithm has its own limitations even after different investigations were made to modify the various parameters of the algorithm in micro level to obtain optimal minimum solution. Hence the possibility of reduction in solution space, if any, should be thoroughly investigated and then should be incorporated in the algorithm. The main objective this research is focused towards the reduction of solution space, which is intern, reduces the complexity of the NP-complete problem, rather than searching the huge solution space.

In this research, a hybrid genetic algorithm (GA) and simulated annealing (SA) approach has been developed to determine sequencing operations for a prismatic part in an optimization procedure. This research work uses a precedence graph based on various manufacturing constraints, generates a precedence cost matrix using production rules and applies Genetic
algorithms, simulated annealing technique and Hybrid S-GENSAT algorithm to arrive at optimal or near optimal operation sequences for a CAPP.

GA, which is carried out in the first stage, generates good process plans. Based on these plans, SA is executed to search locally for alternative optimal or near-optimal process plans. A constraint based SSRT algorithm is proposed to reorganize the initially generated process plans in the GA and SA into a feasible domain.

Computational experiments are performed on the proposed algorithm and have verified its learning capability in guiding the search towards better quality solutions. The performance of the hybridized S-GENSAT is tested on five researched benchmark problems and has shown promising results. In addition, the hybridized S-GENSAT has outperformed several of the more established solution techniques in solving OSP. The details are presented in the following chapters.