Proceedings of the 13th Annual
International Conference on Industrial Engineering
Theory, Applications and Practice
Las Vegas, Nevada
September 7-10, 2008

# EXPLORATION OF OPTIMIZATION TECHNIQUES FOR THE MACHINE SEQUENCE PLANNING (OPEN SHOP AND JOB SHOP) WITH MULTIPLE PRECEDENCES: A REAL SCENARIO

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**Abstract:** This paper presents the application of common heuristics, random search and evolutionary algorithms with representation of random keys and permutations in order to compare as techniques of optimization for the machine sequence planning in a real scenario considering multiples precedence. The results indicate a compromise that the user must take between the quality of the solution and the processing time.

## 1. INTRODUCTION

In general, the problematic of machine sequence planning is a difficult problem to solve. The complexity of the problem can been seen from the fact that in a general job shop when n jobs go through m machines there are $(n!)^m$ possible schedules, hence if n=20 y m= 10 then the number of schedules is $7.2651 \times 10^{183}$

These problem increases on complexity when the jobs has subjobs and that each one also has multiple precedence and must be scheduling in different machines. So the application of the correct technique for the solution comes to the question to answer.

We propose these optimization techniques assuming that can help us to solve our problem:

- Dispatching rules are policies or rules that prioritize all the jobs that are waiting for processing on a machine. They use as the criteria for ordering the jobs the processing time or due time
  Some of the main priority rules are:
  - FCFS – First Come, First Served. The jobs are processing by the sequence they arrived
  - SPT – Shortest Processing Time. The jobs are scheduling by ascending order of processing time
  - EDD – Earliest Due Date. The jobs are ordered by ascending delivered due date
  - CR- Critical Ratio. This planning requires to consider the coefficient of the processing time between remain time until deliver date (Nahmias, 1997)
- The Optimization Techniques of Local Search as:
  - Hill Climbing starts with a random (potentially poor) solution, and iteratively makes small changes to the solution, each time improving it a little. When the algorithm cannot see any improvement anymore, it terminates. Ideally, at that point the current solution is close to optimal, but it is not guaranteed that hill climbing will ever come close to the optimal solution.
  - Random Search is based on iteratively improving an assignment of the variables until all constraints are satisfied. Typically modify the value of a variable in an assignment at each step. The new assignment is close to the previous one in the space of assignment. (Russell, & Norvig, 2003)
- Evolutionary algorithms are a new paradigm to optimize combinatorial problems and find an optimum sequence. Genetic Algorithms (GA) simulate adaptive process of natural systems and to develop artificial systems that retain features of natural system. GAs simulates the genetic state (chromosomes) of a population of individual using recombination operators (crossover and mutation). Crossover exchanges genetic material between two parents and mutation flips a bit in a chromosome. Each individual is evaluated and fitness assigned in proportion to the value of the objective function for the individual. New individuals created by these operators are selected on the basis of their fitness for the next generation. (V. Oduguwa, A. Tiwari, R. Roy, 2005)


ISBN # 97809654506-6-9

## 2. MACHINE SEQUENCE PLANNING WITH MULTIPLE PRECEDENCE

Job shop problem J || Cmax is NP-hard if either $m \geq 3$ or $n \geq 3$ where m represents the amount of machines end n represents the amount of jobs. (Pinedo, 2002)

Considering the previous theorem that Michael Pinedo has demonstrated, we decide apply as a reference to these paper the next real scenario:

- Total of articles = 9
- Amount of each article = 10
- Subjobs = 116 (n)
- Amount of different machines or workstations = 5
- Amount of machines or workstations = 23 (m)

This real scenario is the machine sequence planning with multiple precedence that it is used at the Training Center of Grupo Deacero at Complejo Industrial Saltillo, where groups of 10 workers produce the 9 different articles of variety complexity using drills, lathes and millings conventional machines during 15 weeks.

A graphic representation of the real scenario is explained in the next figure:

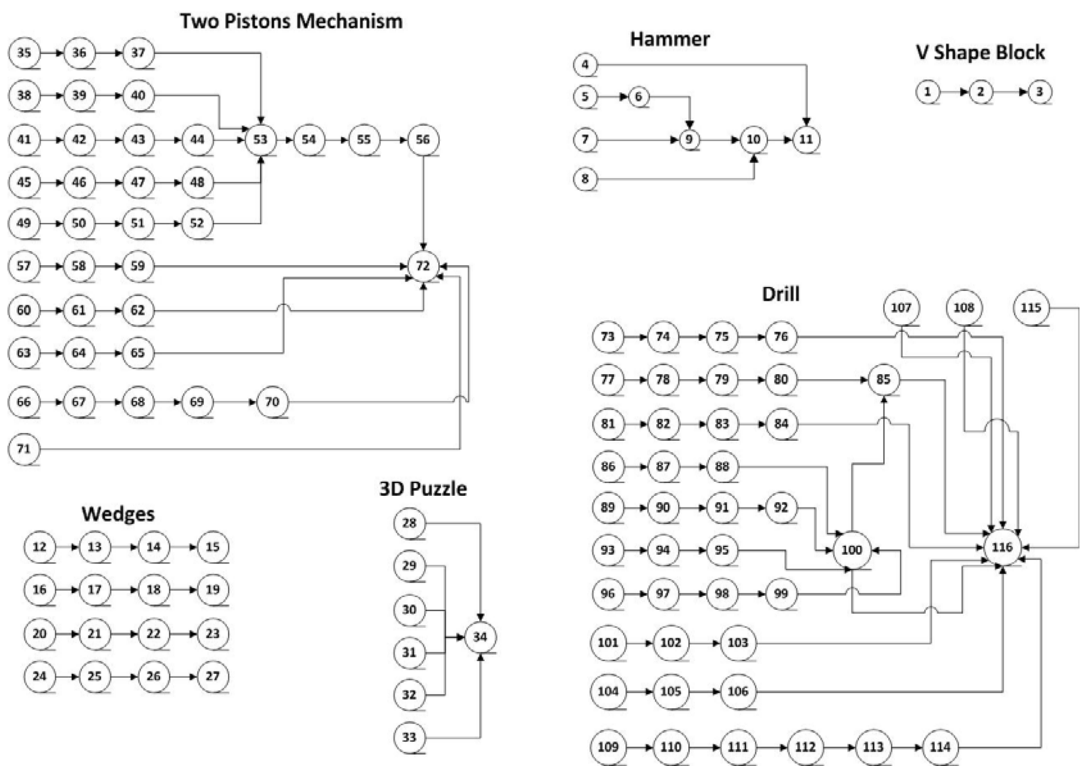


Figure1. Sequence Diagram

The description of the machine sequence planning for this case of study has the follow characteristics and processing times:

Table 1 Real Scenario

| Job | Sub Job | Type of Machines | Precedence | Processing Time |
|---|---|---|---|---|
| V Shape Block | 3 | 1,3,5 | 1 | 34.18 |
| Hammer | 8 | 2,3,5 | 2 | 111.60 |
| Wedge3 | 4 | 1,3,4,5 | 1 | 18.72 |
| Wedge5 | 4 | 1,3,4,5 | 1 | 20.95 |
| Cuña6 | 4 | 1,3,4,5 | 1 | 15.53 |
| Cuña8 | 4 | 1,3,4,5 | 1 | 16.95 |
| 3D Puzzle | 7 | 3,5 | 6 | 59.30 |
| Two Pistons Mechanism | 38 | 1,2,3,4,5 | 6 | 194.66 |
| Drill | 44 | 1,2,3,4,5 | 10 | 183.54 |

## 3. APLICATION OF OPTIMIZATION TECHNIQUES: DISPATCHING RULES, LOCAL SEARCH AND GENETIC ALGORITHM

There are different techniques for the problem solution of the scheduling jobs and the combinatorial optimization; however we decide to apply three different alternatives: dispatching rules (heuristics), local search and genetic algorithms.

This selection of techniques was in order to generate a point of reference about improves that offers the application of the Genetic Algorithms versus other conventional techniques. Genetic algorithms (GA) are the most used evolutionary algorithms. GA was developed by Holland (1975) and has grown as the most used paradigm to solve optimization problems (i.e. Mitsuo Gen, 2000).

The general procedure for Genetic Algorithms was applied: evaluation of the individuals, selection of the best individuals (in a deterministic or stochastic way), crossover, and mutation of individuals (Goldberg, 1989; Mitchell, 1993).

The population sequence begins with random solutions usually with low performance and high diversity. The evolutionary procedures (evaluation, selection, crossover and mutation) are applied in a cyclical way. Solutions of better performance are obtained and the diversity is lost. This is a more intelligent way to search solutions than “trial and error” procedure. (Torres, 2007)

For the real scenario that this paper presents, the problem representation used a 116 items vector with the restriction that even on the combinatorial sequence it is important considers multiples precedence so this situation increases the complexity for an optimal solution.

Then we apply a comparative between the dispatching rules techniques using heuristic as first come - first serve, shortest and longest processing time, earliest and latest due date, besides local search optimization as random search and hill climbing to finally use the genetic algorithms with representation of random keys and permutations

The comparative was made on two phases:

- First, doing a comparative between different heuristics and we find that the best solution was Shortest Processing Time (SPT) and with that result we validate Michael Pinedo Theorem that said WSPT dispatching rule is the optimal (Pinedo, 2002)
- Second, we apply random search, hill climbing and genetic algorithms with representation of permutations to the same scenario and we find that CX Cycle Crossover was the best crossover operator (Goldberg ,1997)

## 3. EXPERIMENTAL RESULTS

With a better understanding of the variables for the machine sequence planning and the different optimization techniques, we decided to generate a trial of 10 pieces of each job and also we considered three different runs for each crossover operator and procedure of local search in order to have a better reference in the comparative.

The results that we obtained are:

Table 2 Optimization Techniques Comparative

| Optimization Techniques | Crossovers Procedures, Rules | Completion Time (hrs) | Difference in Hours | % Effectiveness |
|---|---|---|---|---|
| GA | CX | 79.51 | - | - |
| | INTER | 80.05 | 0.54 | 0.68% |
| | PMX | 85.43 | 5.92 | 7.44% |
| | ERX | 89.58 | 10.07 | 12.67% |
| Local Search | Hill Climbing | 89.84 | 10.33 | 12.99% |
| | Random Search | 97.25 | 17.74 | 22.31% |
| Dispatching Rules | SPT | 101.87 | 22.36 | 28.12% |
| | LCFS | 113.29 | 33.78 | 42.48% |
| | FCFS | 129.64 | 50.13 | 63.04% |
| | LPT | 129.66 | 50.15 | 63.07% |

These comparatives allows to appreciate the advantages that we get with the Genetic Algorithms on the real world of manufacturing where the problems are usually large scale, highly dimensional, non linear and highly uncertain involving interaction with engineers and highly skilled operators that control the process plant. These problems are also characterized by chaotic disturbances, randomness and complex non linear dynamics. (D.B Fogel, 2000)

## 4. CONCLUSIONS

The dispatching rules (heuristics) demonstrated to converge quickly and to show a non-optimal solution when the machine sequence planning has multiple precedence.

However, the application of the evolutionary algorithms with representation of permutations offers an advantage on 13% better than the local search technique hill climbing and a 28% better than optimal heuristic (SPT). In addition, against the worse heuristic, we achieve to reduce the scheduling time in a little more than 50 hours with the best GA, for this case of analysis the dispatching rule was the Longest Processing Time (LPT) and the crossover operator was the Cycle Crossover.

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