Global Jour. of Engg. & Tech.
Volum 2, Number 2 (2009) 237-242

SOLVING THE MACHINE SET-UP PROBLEM: A CASE WITH A UNIVERSITY PRODUCTION WORKSHOP

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Abstract : This paper defined and solved the machine set-up problem as a combinatorial optimization problem. Based on this, a PC-based software for solving the machine set-up problem was developed and adapted for an easy-to-learn-and-apply in a university Production Engineering workshop situation. The system stores pertinent data and has features for determining the optimal sequence of production and relevant information for operator's quick manual setting-up of machine. This approach to managing the workshop was compared to the existing approach of selecting parts randomly. The innovation was found to improve performance between 23 to 55%.

1.0 Introduction

Production Engineering workshops in Universities have become important centers for supplementary machine parts manufacture in some Third World countries. These are high mix-low volume machining environment, characterized by high machine set-up time operations [8,12,19]. Unfortunately, the Sequence Dependent Machine Setup Problem (MSP), like its identical twin, the travelling Salesman Problem [2, 6,7,9,11,16] is one of the class of difficult combinatorial optimization problems [10,13, 26]. An MSP solution procedure finds the sequence a set of N parts will be processed in order to minimize makespan (total machine set-up and processing times).

Despite attracting several researchers' attention in recent times [2,3,4,11,14,15,22,23], large-scale industrial applications have not been reported. One possible reason may be that the adoption and successful implementation of optimal procedures require application of scheduling theory. In most production environments, especially in developing countries, workshop operators may not be familiar with complicated scheduling theories [17,21,25].

Keywords : machine set-up problem, the traveling Salesman Problem, production workshop

Besides, manual solutions to the MSP are not feasible. For instance, it may take more than a lifetime to solve just one industrial problem with a regular size computer [1]. To date, industrial problem instances solved to optimality have been by super computers or massively parallel computer processors which are not available in developing economies [5,20]. Yet, there seems an urgent need to introduce innovative ideas to enable Production Engineering workshops in Universities to operate efficiently and profitably. This implies that the University workshop machine set-up problem has to be solved.

This study examines the possibility of developing easy-to-learn inexpensive made-in-Nigeria industrial software for optimally solving the machine set-up problem prevalent in University Engineering workshops. In particular, an attempt is made to suggest a set sequencing algorithm embedded in a PC-based user-friendly software capable of producing an optimal processing sequence of any workshop-size set of parts.

2.0 Methodology

2.1 Machine Set-up Sequencing Algorithm

The Set Sequencing Algorithm recently proposed [4,5,20] will be adopted as the solution algorithm because it is comparatively efficient [20].

In the Set Sequencing paradigm, a complete sequence of N parts is viewed as comprising a set of N matrix elements (links). Hence, set sequencing is defined as the transformation of a known sequence (S_{i-1}) to a new sequence (Si) by feasibly replacing a subset of its links (Lr) with equal number (M) of candidate links (Lc) using the recursive function :

$Va(S_i) = Va(S_{i-1}) + D(Lr, Lc\ M)$;

where $Va(S_i)$ and $Va(S_{i-1})$ are the respective sequence values and D(Lr Lc, M), the exact amount $Va(S_i)$ is changed by the replacement operation. Consequently, an alternative TSP (MSP) model, Minimize D(Lr, Lc, M), has been defined and shown to be equivalent to the traditional MSP formulation. At each iteration of the replacement operation, information from a computed NxN difference matrix is used to select replacers. The details of the set sequencing algorithm can be found in [5,20].

2.2 Machine Set-Up Problem Data Collection

To collect the set-up time data, a centre lathe machine located in the Technical Support Unit of the Faculty of Technology, University of Ibadan was used. It is a 400 volts, 5.2Amps, 50Hz 3-phase Harrison centre lathe machine. It has a bed length of 1.5 metres, carrying 3 Horsepower motor and four range of speeds: 58-1200, 40-800, 85-1700 and 125-2500 revolutions/min. An experienced operator was observed for some days and the sequence-dependent tasks in Table I recorded :

Table-1 : Sequence-Dependent Set-up Tasks of the Lathe Machine.

s/n	Operations	s/n	Operations
1	Set-up chuck on headstock	8	Teardown cutting tool on tailstock
2	Teardown chuck on headstock	9	Set-up taper turning attachment
3	Set-up cutting tool on toolpost	10	Adjust taper turning attachment
4	Teardown cutting tool on toolpost	11	Adjust speed
5	Set-up centre on tailstock	12	Adjust depth of cut
6	Teardown centre on tailstock	13	Adjust feed
7	Set-up cutting tool on tailstock		

Using time study procedure, the standard time required to perform each set-up task was then determined and presented in Table-2. Mshelia [18] carried out a similar study on standard times of some setup tasks on the lathe with similar results.

Collecting the MSP Matrix Entries As many distinct parts as found in the workshop were chosen for the study. Using the procedure outlined in [20] the 60X60 machine set-up time matrix for the sequence-dependent tasks $[S^d_{kij}]$ was formed.

Table-2 : Setup Time study Data

Setup Code	Set-Up Tasks	Standard Minutes
T1	Set-up Chuck on Headstock	0.78
T2	Teardown chuck on Headstock	1.15
T3	Set-up cutting tool on tool post	0.53
T4	Teardown cutting tool on tool post	0.29
T5	Set-up Centre on Tailstock	0.22
T6	Teardown Centre on Tailstock	0.23
T7	Set-up Cutting Tool on Tailstock	0.72
T8	Teardown Cutting Tool on Tailstock	0.47
T9	Set-Up Taper Turning Attachment (Swivelling of Compound slide)	0.85
T10	Adjust Taper turning Attachment	0.77
T11	Adjust Speed	0.33
T12	Adjust Depth of Cut	0.35
T13	Adjust Feed	0.69
T14	Adjust Thread Cutting Gear Levers	0.74

2.3 Computer Platform Used

The specification of the computer facility used is summarized below.

- Computer Processor; 667MZ Pentium III MMX processor;
- Computer Memory; 128Mb SDRAM; and
- Operating system; Microsoft Windows 98, window 2000 or window XP

2.4 Software Design

The MSP algorithm software is designed as a window based programme with a mouse and keyboard driven input/output Graphical User Interface. The software system is made up of three subsystems as shown in Fig-1. The three subsystems are as follows :

- The Graphical Interface (GUI);
- The Processing or analysing subsystem;
- The external file and data management subsystem.

The Graphical Interface (GUI)

The GUI is divided into three modules, which are the input module, the Help module and the Output module.

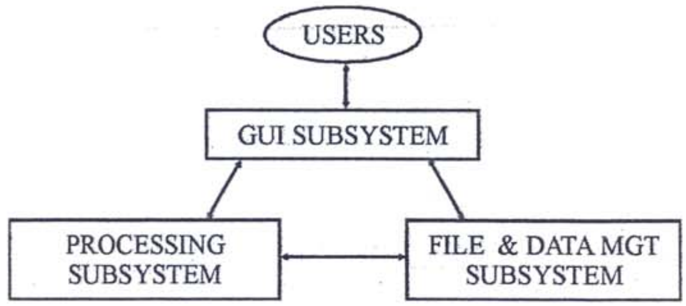

Fig-1 : The MSP Solution Software System

The Main interface And Application Scope

The MSP software interface is designed to resemble the familiar Microsoft based window interface. This is to take advantage of most users' familiarity with this type of interface (See Fig.-2) easy-to use by University students and computer-literate workshop operators. The operating data in the PC accessible by the software are the code number of each part commonly processed in the workshop; the machine set-up time data matrix; processing times and the machine set-up tasks for each part. On feeding the code numbers of a set of parts into the system, the optimal sequence and the associated makespan will appear on the computer monitor. When the code number of any of these parts is next fed into the system, the associated machine set-up tasks are indicated for the operator's action. Embedded in the software is how-to-use it self-teaching aspect for beginners.

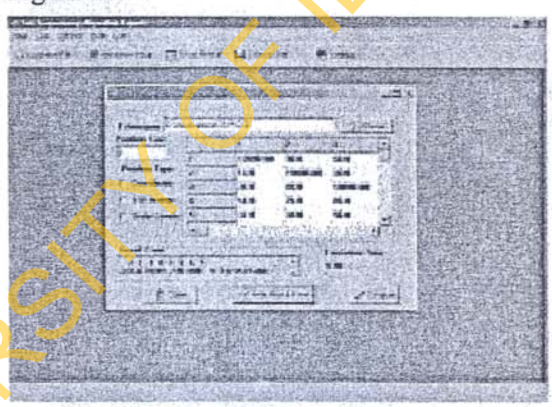

Fig.-2 : Input menu interface

2.5 Experimental Work

Given a set of parts for processing, the existing practice is that the operator randomly selects and processes a part, one after the other, until completion. Notice that this amounts to the random selection of processing sequence. Hence, from the sixty parts' data stored in the computer, thirteen problems with number of parts ranging between 10 and 30 were drawn randomly (includes the 60 parts problem). For each problem, the sequence by the existing approach was determined and the associated makespan computed. The makespan of the software solution was also determined and both compared by computing the percentage improvement. The results are presented in Table-3.

Table-3 : A comparison of the existing Workshop Approach and the Software Application.

S/n	No of Parts	Total Makespan (Minutes) Existing Approach	Software Application	Percentage Improvement
1	10	22.10	14.09	36.4%
2	16	38.69	26.01	32.8%
3	18	40.53	24.96	38.4%
4	20	46.74	30.46	34.8%
5	20	45.10	34.72	23.1%
6	20	46.65	27.42	41.2%
7	22	50.28	28.91	42.5%
8	24	56.86	36.02	36.7%
9	24	55.77	32.36	42.0%
10	28	53.72	35.40	34.1%
11	28	64.99	42.09	35.2%
12	30	70.04	39.19	44.1%
13	60	148.42	66.81	55.1%

3.0 Discussion of Results

The software salient capabilities include: self-teaching subsystem for learning how to use it; provision of part's optimal processing sequence, the associated machine set-up tasks and code number. Hence, a student can learn how to set-up the machine for processing any of the parts without instructor's assistance. An operator too can call for an optimal solution to the machine set-up problem and then sequentially process a batch of parts in conformance with the optimal sequence. Processing a batch in this manner may save as much as 55% of-its makespan as evident in Table-2. This is due to the power of optimizing algorithms.

4.0 Conclusion

This study introduced a PC-based, easy-to-apply and home-developed software for solving the machine setup problem. It also aids in the management of a University Production Engineering workshop with a promising performance. It may therefore serve, not only a useful training tool for Engineering students, but also enhance the productivity of academic Engineering workshops in Third World countries.

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