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Harmonious Song-List Generation: An Application of the Sequence Dependent Machine Set Up Time Problem Model

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Abstract

Song-list generation, a crucial component of music information retrieval system, has been carried out based on users experiences and bias with no quantitative method to guarantee the generation and repeatability of harmonious arrangements. In this study, the problem of generating harmonious song-list has been modelled as a Single Machine Set-up Problem (MSP) and a solution software developed. Music factors that affect user perception and cognition of a smooth transition were identified through interview of experts and literature search. These factors were transformed into suitable quantitative scale for calibration. Thirty (30) Nigerian songs were selected for analysis. A cost matrix was developed for the songs. A MSP Solution algorithm, the Set-sequencing Solution Algorithm (SSA) was adopted as the solution procedure. An interactive version of the SSA was developed using the VB.NET. Using randomly generated song-lists as input sequences into the software, new song-list was generated and compared to the input sequence. An improvement on total song list harmony of about 57% was obtained using the MSP on thirty (30) songs. The software was seen to be user friendly. It is concluded that the new software is a useful tool for church worship and the entertainment industry in general.

Keywords: Worship, Songs, Set-Sequencing, Algorithm, Machine Setup, Travelling Salesman.

Introduction

In this study the Sequence Dependent Machine Setup Problem (MSP) otherwise known as the Travelling Salesman Problem (TSP) is extended to music or song production related applications. Conventionally song-list generation, a crucial component of music information retrieval system, has been carried out based on the users experience and bias with no quantitative method to guarantee the generation and repeatability of harmonious arrangement. However we observed that the problem of generating harmonious song-list can be modelled as a Single Machine Set-up Problem (MSP).

The scheduling problem of minimising the makespan on a single machine with sequence-dependent machine setup times S_{ij} (setup time if job j is processed immediately after job i) is the single Machine Setup Problem (MSP). Given N parts and a processor, the problem is concerned with finding the order (a sequence of the N parts) in which each part will pass through the processor or the processor will pass through each only once, so that the makespan is minimized. Note that MSP's rendition as a processor passing through the N parts (stations) is popularly interpreted as the Travelling Salesman Problem (TSP). It involves the determination of a sequence of the N operations that minimizes the total Set-Up cost or time. The setup time is defined as the time intervals (or other measure of cost incurred) between the end of a job's processing and beginning of the next job.

Many practical optimisation problems of interest have been formulated as the TSP or its variants. These problems cut across many applications such as printed circuit design and manufacturing (Bard et al, 1994; Foulds and Hamacher, 1993; Keuthen, 2003; Ohno et al, 1999; Rajkumar and Narendran, 1996,), weaving operation planning (Al-Haboub and Salime, 1993), glass manufacturing (Madsen, 1988), time reduction in crystal orientation experiments (Clarker and Ryan, 1989). Other applications include efficient manpower (labour) utilization (Ferreir, 1995) and maintenance work optimisation (Plante et al, 1987).

Music Arrangement and MSP: Problem Description

Take for instance two lead Choristers singing from a list of songs, while Chorister A, takes the songs down the list as it is and is having some difficulty transiting from one song to the other, Chorister B, shuffles the songs to make for smooth transition from one song to the other. The experience of transiting from one song to another is hereby considered with a view to minimising the difficulty therein. The problem of finding a smooth arrangement has been modelled as a single-machine setup problem.

The music information retrieval (MIR) is a field with growing interests, in which the application of TSP comes to hand readily. MIR is a blend of elements of music and information science (Byrd and Crawford, 2001), library science, musicology, music theory, audio engineering, law and business (Downie, 2003) psychoacoustics, sensation, neuro-science, computer science, philosophy and linguistics. Western music which is the basis for most MIR in literature is neither tonal nor art music but are primarily made from notes of definite-pitch. In music perception, the parameters of a definite-pitched musical note are the pitch, duration, loudness and timbre (Byrd and Crawford, 2001). While music cognition looks at the psychological and physiological mechanisms that allow musical experiences to take place. It is an approach to understanding the mental processes that support musical behaviours such as perception, comprehension, memory and attention.

The Development of Music Set-up Cost Matrix

A selection of thirty (30) songs was made cutting across some of the major Nigerian languages. Using a music keyboard the difficulty measure in transiting from one song to another is generated taken the beat change of the songs as a yardstick. The beat gradation of ½, 1, 1½ and 2 are obtained as shown in table 1.

Table 1: Difficulty gradation.

Beat	Gradation
½	1
1	2
1½	3
2	4

The set up cost matrix (appendix table2) was developed from a selection of thirty (30) songs cutting across some of the major Nigerian languages.

Solution Procedure

The resultant Asymmetric Travelling Salesman problem matrix was solved using the Set-Set Sequencing Algorithm (SSA) (Charles-Owaba, 2001, 2002; Oladokun, 2006; Charles-Owaba and Oladokun, 2007; Oladokun and Charles- Owaba 2008,). A Graphical User Interface (GUI) computer programme (called the song scheduler) of the SSA algorithm was developed for the implementing the song sequencing, with figure1 showing the output of the sequencing process for the thirty (30) songs. Surprisingly, the sequence turned out that the first song on the list should in reality be the last song to be rendered or listened. The output sequence is song 6, song 17, song 18, song 23, song 24, song 2, song 5, song 7, song 19, song 3, song 8, song 16, song 30, song 20, song 15, song 4, song 14, song 25, song 26, song 27, song 22, song 28, song 29, song 9, song 21, song 12, song 11, song 13, song 10, song 1. The cost of the input sequence is 69 units while the cost of the output sequence is 30 units. The average computation time was 84milliseconds.

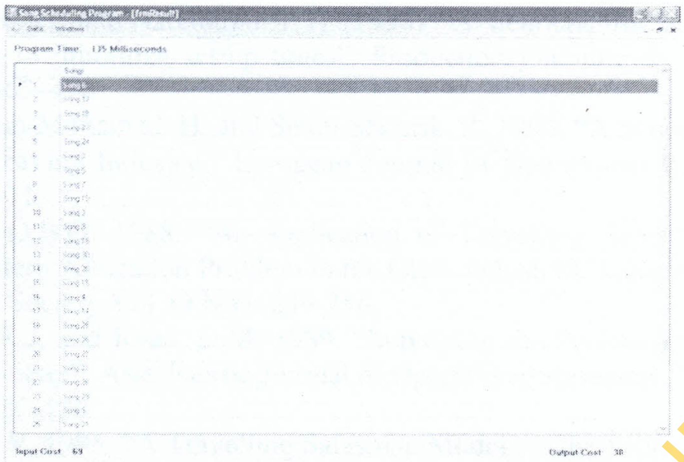

Figure 1: Output of the Song Scheduling Program.

Conclusion

Further sequencing of randomly generated song (problem) sizes of 25, 35, 40, 45 and 50 gave input sequence costs of 49, 87, 111, 106 and 126 units, while the output sequence costs are 25, 35, 40, 45 and 50 respectively. The resulting sequence having been sung and compared with the input sequence was adjudged as being smoother and more pleasant to the ears. The experience was that while the input sequence was used, there were breaks every now and then, while with the output sequence, the rendering of the songs was without breaks, smooth and melodious.

The successful application of the SSA songs sequencer has confirmed the extent of the applicability of TSP in our everyday life and in Church music. It is suggested that other TSP algorithm be used to this music problem

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Appendix

Table 2 30 x 30 Matrix of the Songs Sequencing.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	=	3	3	2	1	1	1	3	1	1	2	3	1	1	3	1	1	1	1	1	1	1	2	1	3	1	4	2	4	1
2	3	=	1	1	1	1	1	3	4	1	1	1	2	1	1	3	3	1	1	1	1	2	1	1	3	1	3	1	2	1
3	3	4	=	4	2	3	3	1	4	2	1	1	2	2	3	1	4	3	4	1	1	2	1	2	3	4	3	2	3	2
4	1	1	1	=	4	1	3	4	4	4	1	4	3	1	4	4	3	4	4	1	4	4	4	3	4	1	4	3	3	4
5	1	2	1	3	=	3	1	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	3	3	4	3	3	3
6	1	2	1	3	4	=	1	4	4	4	1	3	2	4	3	1	1	1	3	3	4	3	3	3	3	3	4	3	3	4
7	1	4	2	1	4	1	=	4	2	3	3	3	4	1	3	4	3	1	1	4	4	2	3	4	3	4	1	3	1	4
8	2	1	3	4	4	3	3	=	4	3	3	1	3	4	4	1	4	1	2	3	3	4	3	1	3	2	3	3	3	1
9	2	4	1	3	4	3	3	4	=	3	1	4	3	3	3	4	4	3	1	4	1	4	1	1	1	3	3	2	1	2
10	1	1	1	1	4	3	1	1	2	=	3	1	1	1	4	3	1	4	3	4	3	3	4	2	1	3	4	3	4	3
11	2	1	3	1	4	3	4	1	1	3	=	3	1	1	3	3	3	4	1	3	3	4	4	3	1	3	3	3	1	3
12	1	1	1	1	4	1	4	1	3	1	1	=	1	1	3	3	1	1	3	3	3	3	3	1	1	1	3	3	1	3
13	4	1	1	1	4	3	3	3	1	1	1	1	=	1	3	1	1	1	2	3	3	3	3	1	1	3	3	3	3	1
14	1	1	1	1	4	3	3	4	2	1	1	1	1	=	1	1	3	3	1	3	3	3	1	4	1	4	3	1	3	1
15	4	1	1	1	4	1	1	3	4	4	1	1	3	3	=	3	3	3	3	3	4	3	3	4	2	3	3	3	3	2
16	4	1	1	1	4	1	1	1	4	1	1	3	3	3	1	=	3	1	3	3	4	3	1	2	1	3	4	3	3	1
17	4	1	1	3	4	1	1	2	3	3	1	3	3	3	1	1	=	1	3	2	4	3	4	3	1	3	3	1	3	3
18	3	2	1	3	4	1	1	2	1	3	1	3	1	3	1	3	1	=	2	3	1	1	1	1	3	1	3	2	4	3
19	3	1	1	1	4	1	1	4	1	3	1	1	3	1	1	1	2	3	=	3	2	1	4	1	1	3	1	1	3	1
20	2	1	1	1	4	1	3	1	1	4	1	1	1	1	1	1	1	3	2	=	2	2	1	3	1	1	1	1	2	1
21	2	1	1	3	4	1	1	3	1	3	1	1	1	1	1	3	4	3	4	4	=	3	4	3	1	1	1	1	1	1
22	1	1	1	1	3	1	1	3	3	1	1	1	1	1	1	1	1	3	1	1	2	=	3	1	1	1	1	1	4	1
23	1	1	3	1	4	1	1	3	1	4	1	1	1	1	1	1	3	3	2	2	1	1	=	1	4	1	4	3	4	3
24	1	1	1	4	4	1	4	2	3	1	1	3	1	1	3	3	1	1	1	1	1	1	2	=	1	1	1	1	3	2
25	1	1	1	1	4	1	3	3	1	1	1	1	3	1	1	1	1	3	1	1	1	3	1	1	=	1	4	3	1	3
26	1	1	1	1	4	1	1	3	1	1	3	1	1	1	1	1	1	1	2	1	3	1	1	1	1	=	1	1	1	1
27	4	1	1	3	4	1	3	1	1	3	1	1	1	3	1	3	1	3	1	1	1	1	4	1	4	3	=	3	3	4
28	1	1	1	1	4	1	1	4	1	3	1	1	1	1	1	1	3	1	1	1	1	2	4	2	2	1	1	=	1	1
29	1	3	1	1	4	1	1	1	1	4	3	3	1	1	1	3	1	3	1	3	1	2	4	1	1	2	1	4	=	4
30	1	1	1	4	4	1	3	3	1	4	3	1	3	1	1	1	1	3	4	1	1	1	1	1	3	1	4	1	4	=