JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY | **GENERAL PAPER**

A penalty-shift-insertion-based algorithm to minimize total flow time in no-wait flow shops

Dipak Laha, Jatinder ND Gupta & Sagar U Sapkal

Journal of the Operational Research Society (2013) doi:10.1057/jors.2013.118
Received 20 December 2012 Accepted 21 August 2013 Published online 02 October 2013

Abstract

This paper proposes a penalty-shift-insertion (PSI)-based algorithm for the no-wait flow shop scheduling problem to minimize total flow time. In the first phase, a penalty-based heuristic, derived from Vogel's approximation method used for the classic transportation problem is used to generate an initial schedule. In the second phase, a known solution is improved using a forward shift heuristic. Then the third phase improves this solution using a job-pair and a single-job insertion heuristic. Results of the computational experiments with a large number of randomly generated problem instances show that the proposed PSI algorithm is relatively more effective and efficient in minimizing total flow time in a no-wait flow shop than the state-of-the-art procedures. Statistical significance of better results obtained by the proposed algorithm is also reported.

Keywords: scheduling; no-wait flow shop; total flow time; Vogel's penalty-based heuristic; forward shift heuristic; insertion heuristic

References

Adiri I and Pohoryles D (1982). Flowshop/no-idle or no-wait scheduling to minimize the sum of completion times. *Naval Research Logistics* **29**(3): 495–504.

Aldowaisan T and Allahverdi A (2003). New heuristics for no-wait flowshops to minimize

makespan. *Computers and Operations Research* **30**(8): 1219–1231.

Aldowaisan T and Allahverdi A (2004a). New heuristics for m-machine no-wait flowshop to minimize total completion time. *Omega* **32**(5): 345–352.

Aldowaisan T and Allahverdi A (2004b). Three-machine no-wait flowshop with setup and removal times to minimize total completion time. *International Journal of Industrial Engineering* **11**(2): 113–123.

Bertolissi E (2000). Heuristic algorithm for scheduling in the no-wait flow-shop. *Journal of Materials Processing Technology* **107**(1): 459–465.

Bonney MC and Gundry SW (1976). Solutions to the constrained flowshop sequencing problem. *Operational Research Quarterly* **27**(4): 869–883.

Chen C, Neppalli V and Aljaber N (1996). Genetic algorithms applied to the continuous flow shop problem. *Computers and Industrial Engineering* **30**(4): 919–929.

Fink A and Voß S (2003). Solving the continuous flow-shop scheduling problem by metaheuristics. *European Journal of Operational Research* **151**(2): 400–414.

Framinan JM, Nagano JV and Moccellin JV (2010). An efficient heuristic for total flowtime minimization in no-wait flowshops. *International Journal of Advanced Manufacturing Technology* **46**(9–12): 1049–1057.

Gangadharan R and Rajendran C (1993). Heuristic algorithms for scheduling in the no-wait flowshop. *International Journal of Production Economics* **32**(3): 285–290.

Gilmore PC and Gomory RE (1964). Sequencing a one-state variable machine: A solvable case of the traveling salesman problem. *Operations Research* **12**(5): 655–679.

Grabowski J and Pempera J (2005). Some local search algorithms for no-wait flow-shop problem with makespan criterion. *Computers and Operations Research* **32**(8): 2197–2212.

Gupta JND (1976). Optimal flowshop schedules with no intermediate storage space. *Naval Research Logistics* **23**(3): 235–243.

Gupta JND (1979). A review of flowshop scheduling research. In: Ritzman LP, Krajewski LJ, Berry WL, Goodman SM, Hardy ST and Vitt LD (eds). *Disaggregation Problems in Manufacturing and Service Organizations*. Martin Nijhoff: The Hague, pp 363–388.

Gupta JND and Stafford EF (2006). Flowshop scheduling research after five decades. *European Journal of Operational Research* **169**(3): 699–711.

Hall NG and Sriskandarajah C (1996). A survey of machine scheduling problems with

blocking and no-wait in process. *Operations Research* **44**(3): 510–525.

Ignall E and Schrage L (1965). Application of the branch and bound technique to some flow-shop scheduling problems. *Operations Research* **13**(3): 400–412.

Jarboui B, Eddaly M and Siarry P (2011). A hybrid genetic algorithm for solving no-wait flowshop scheduling problems. *International Journal of Advanced Manufacturing Technology* **54**(9–12): 1129–1143.

King JR and Spachis AS (1980). Heuristics for flowshop scheduling. *International Journal of Production Research* **18**(3): 343–357.

Kreyszig E (1972). *Advanced Engineering Mathematics*. Wiley: New York.

Kumar A, Prakash A, Shankar R and Tiwari MK (2006). Psycho-clonal algorithm based approach to solve continuous flow shop scheduling problem. *Expert Systems with Applications* **31**(3): 504–514.

Laha D and Chakraborty UK (2009). A constructive heuristic for minimizing makespan in no-wait flow shop scheduling. *International Journal of Advanced manufacturing Technology* **41**(1–2): 97–109.

Liesegang G and Rüger M (1972). On the flow-shop sequencing problem with no wait in process. *Operations Research* **23**(4): 591.

Liu B, Wang L and Jin YH (2007). An effective hybrid particle swarm optimization for no-wait flow shop scheduling. *International Journal of Advanced Manufacturing Technology* **31**(9–10): 1001–1011.

Nawaz M, Enscore EE and Ham I (1983). A heuristic algorithm for the *m*-machine, *n*-job flow-shop sequencing problem. *Omega* **11**(1): 91–95.

Pan QK, Tasgetiren MF and Liang YC (2008a). A discrete particle swarm optimization algorithm for the no-wait flowshop scheduling problem. *Computers and Operations Research* **35**(9): 2807–2839.

Pan QK, Wang L, Tasgetiren MF and Zhao BH (2008b). A hybrid discrete particle swarm optimization algorithm for the no-wait flow shop scheduling problem with makespan criterion. *International Journal of Advanced Manufacturing Technology* **38**(3–4): 337–347.

Panwalkar SS and Woollam CR (1979). Flowshop sequencing problems with no in-process waiting: A special case. *Journal of the Operational Research Society* **30**(7): 661–664.

Panwalkar SS and Woollam CR (1980). Ordered flow shop problems with no in-process

waiting: Further results. *Journal of the Operational Research Society* **31**(11): 1039–1043.

Papadimitriou CH and Kanellakis PC (1980). Flowshop scheduling with limited temporary storage. *Journal of Associate Computer Machinery* **27**(3): 533–549.

Rajendran C (1994). A no-wait flowshop scheduling heuristic to minimize makespan. *Journal of the Operational Research Society* **45**(4): 472–478.

Rajendran C and Chaudhuri D (1990). Heuristic algorithms for continuous flow-shop problem. *Naval Research Logistics* **37**(5): 695–705.

Reddi SS and Ramamoorthy CV (1972). On the flow-shop sequencing problem with no wait in process. *Operational research Quarterly* **23**(3): 323–331.

Reinfeld NV and Vogel WR (1958). *Mathematical Programming*. Prentice Hall: Englewood Cliffs, NJ.

Rios-Mercado RZ and Bard JF (1999). An enhanced TST-based heuristic for makespan minimization in a flow shop with setup times. *Journal of Heuristics* **5**(1): 53–70.

Röck H (1984). The three-machine no-wait flow shop is NP-complete. *Journal of Associate Computer Machinery* **31**(2): 336–345.

Sahni S and Cho Y (1979). Complexity of scheduling shops with no wait in process. *Mathematics of Operations Research* **4**(4): 448–457.

Samarghandi H and ElMekkawy TY (2012). A meta-heuristic approach for solving the no-wait flowshop problem. *International Journal of Production Research*. doi: 10.1080/00207543.2011.648277, **50**(24): 7313–7326.

Shore HH (1970). The transportation problem and the Vogel approximation method. *Decision Sciences* **1**(3–4): 441–457.

Shyu SJ, Lin BMT and Yin PY (2004). Application of ant colony optimization for no-wait flowshop scheduling problem to minimize the total completion time. *Computers and Industrial Engineering* **47**(2–3): 181–193.

Simons JV (1992). Heuristics in flow shop scheduling with sequence dependent setup times. *Omega* **20**(2): 215–225.

Tseng FT, Gupta JND and Stafford EF (2006). A penalty-based heuristic algorithm for the permutation flowshop scheduling problem with sequence-dependent set-up times. *Journal of the Operational Research Society* **57**(5): 541–551.

Van Deman JM and Baker KR (1974). Minimizing mean flowtime in the flow shop with no

intermediate queues. *AIIE Transactions* **6**(1): 28–34.

Van der Veen JAA and Van Dal R (1991). Solvable cases of the no-wait flowshop scheduling problem. *Journal of the Operational Research Society* **42**(11): 971–980.

Wismer DA (1972). Solution of the flowshop-scheduling problem with no intermediate queues. *Operations Research* **20**(3): 689–697.

Download references

Author information

Affiliations

Jadavpur University, Kolkata, India

Dipak Laha & Sagar U Sapkal

University of Alabama in Huntsville, Huntsville, USA

Jatinder ND Gupta

Corresponding author

Correspondence to: Jatinder ND Gupta

Journal of the Operational Research Society ISSN 0160-5682 EISSN 1476-9360