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A three-stage method with efficient calculation for lot streaming flow-shop scheduling

Key words: Lot streaming; Flow-shop scheduling; Transfer sublots; Variable size; Bounded size; Differential evolution

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Motivation

1. Considering the batch size of a job is greater than one in the real manufacturing environment, the lot streaming flow-shop scheduling problem is more complicated than traditional problems and has a more extensive practical relevance.

2. However, researchers have largely neglected the computation time issue associated with lot streaming, i.e., when the total number of transfer sublots in lot streaming is large, the computational effort to calculate job completion time can be significant.

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Main idea

1. In this study, we study an *n*-job, *m*-machine lot streaming flow shop scheduling problem with the makespan/total flow time criterion, where sublot sizes may be bounded because of the capacity-constrained transportation activities, and may vary from machine to machine.

2. A three-stage method with efficient makespan calculation is proposed: (1) initial lot splitting; (2) job sequencing optimization based on differential evolution; (3) transfer adjustment.

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Method

Framework of the three-stage method

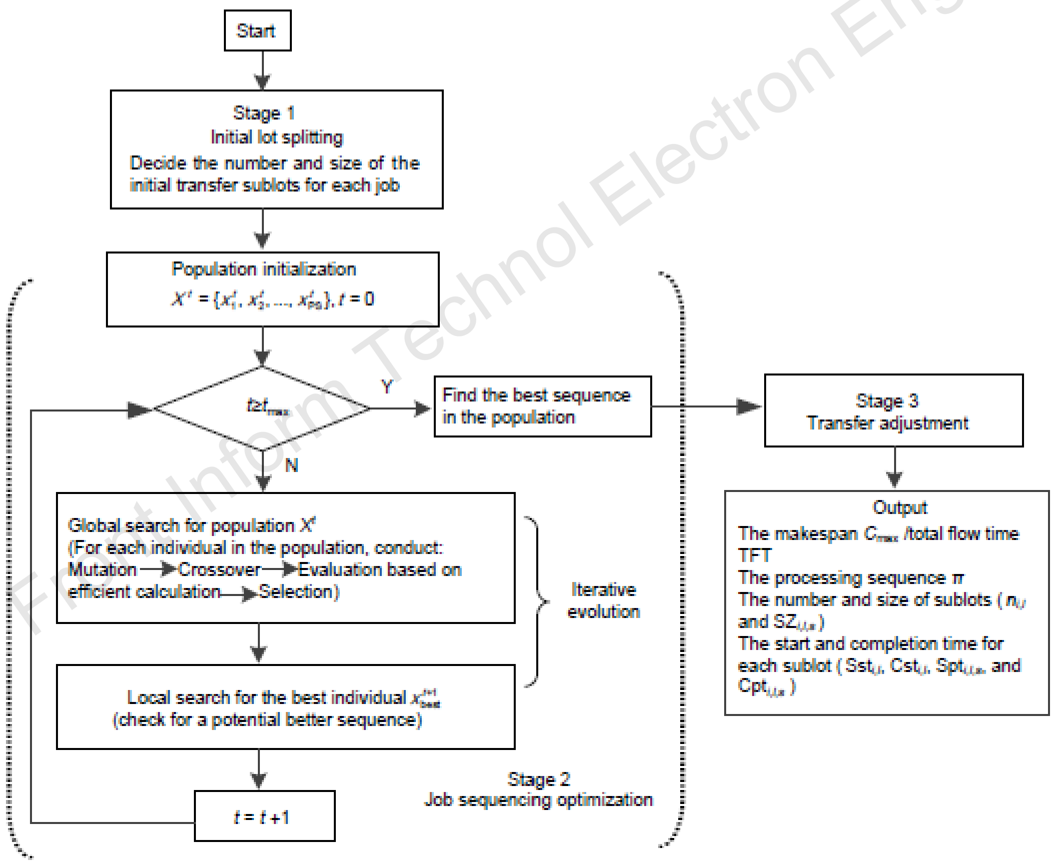

Fig. 4 Framework of the three-stage method

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Major results

Table 6 A comparison with DEA, and PSO for the makespan criterion in the 50-job problem

m	Dataset	DEA	PSO	TSM				m	Dataset	DEA	PSO	TSM			
				BM	SD	AG (s)	AT (s)					BM	SD	AG (s)	AT (s)
	1	**1345**	**1345**	**1345**	0	0.0078	16.22		1	1374	1384	**1354**	0	1.9212	19.33
	2	1155	1155	**1154**	0	0.1556	16.10		2	1357	1361	**1332**	0	1.4852	19.48
3	3	**1057**	**1057**	**1057**	0	0.0244	16.14	7	3	1169	1170	**1133**	0.24	7.5705	19.36
	4	**1148**	**1148**	**1148**	0	0.0135	16.12		4	1225	1228	**1189**	0	1.3111	19.26
	5	1254	1258	**1251**	0	0.5900	15.99		5	1340	1358	**1265**	0.84	11.261	19.43
	1	1349	1352	**1347**	0	0.1541	18.81		1	1458	1475	**1370**	4.68	14.914	22.80
	2	1334	1336	**1329**	0	0.3069	18.78		2	1422	1422	**1338**	1.85	13.196	22.83
5	3	1076	1075	**1059**	0	0.2677	18.76	10	3	1269	1280	**1195**	4.31	14.338	22.61
	4	1190	1197	**1186**	0	0.0749	18.73		4	1307	1306	**1230**	2.75	14.568	22.65
	5	1305	1316	**1258**	0	6.2930	18.81		5	1414	1427	**1316**	3.72	14.591	22.81

The results of DEA and PSO are from Chakaravarthy et al. (2013); the makespan/total flow time marked in bold refers to the minimum makespan/total flow time; the underlined numbers are improved makespans. BM: best makespan over 30 runs; SD: standard deviation of makespan obtained over 30 runs; AG: average CPU time consumed to reach convergence over 30 runs; AT: average CPU time consumed for one run over 30 runs

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Major results (Cont'd)

Table 7 A comparison between DEA and PSO for the total flow time criterion in the 50-job problem

m	Dataset	DEA	PSO	TSM BF	TSM SD	TSM AG (s)	TSM AT (s)	m	Dataset	DEA	PSO	TSM BF	TSM SD	TSM AG (s)	TSM AT (s)
3	1	30 751	30 178	**25 040**	36.108	12.725	17.67	7	1	34 514	34 346	**28 790**	66.106	14.023	20.49
	2	26 879	27 579	**21 553**	50.460	12.843	17.71		2	33 663	33 809	**26 550**	64.169	14.884	20.26
	3	24 848	24 429	**19 217**	28.189	12.657	17.70		3	29 351	29 924	**23 241**	64.769	15.437	20.27
	4	25 906	25 852	**20 934**	30.154	12.291	17.57		4	31 733	31 252	**25 028**	88.003	15.518	19.95
	5	29 185	28 471	**22 878**	27.495	12.902	17.51		5	32 606	33 376	**26 303**	71.508	15.205	20.12
5	1	32 775	33 390	**27 170**	73.194	14.167	19.26	10	1	37 760	37 452	**30 798**	73.554	17.691	23.67
	2	32 439	32 158	**24 771**	61.412	14.596	19.07		2	35 461	35 391	**28 361**	94.647	17.183	23.26
	3	26 377	26 650	**21 267**	68.665	14.234	19.29		3	32 269	32 263	**25 794**	73.184	17.086	23.18
	4	29300	29 505	**23320**	55.557	13.934	19.00		4	33 976	33 267	**27 406**	83.66	17.476	23.09
	5	31 732	31 350	**24 653**	58.744	14.046	19.09		5	35 589	35 553	**28 268**	66.106	14.023	20.49

The results of DEA and PSO are from Chakaravarthy et al. (2013). The makespan/total flow time marked in bold refers to the minimum makespan/total flow time. BF: the best total flow time over 30 runs; SD: standard deviation of makespan obtained over 30 runs; AG: average CPU time consumed to reach convergence over 30 runs; AT: average CPU time consumed for one run over 30 runs

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Major results (Cont'd)

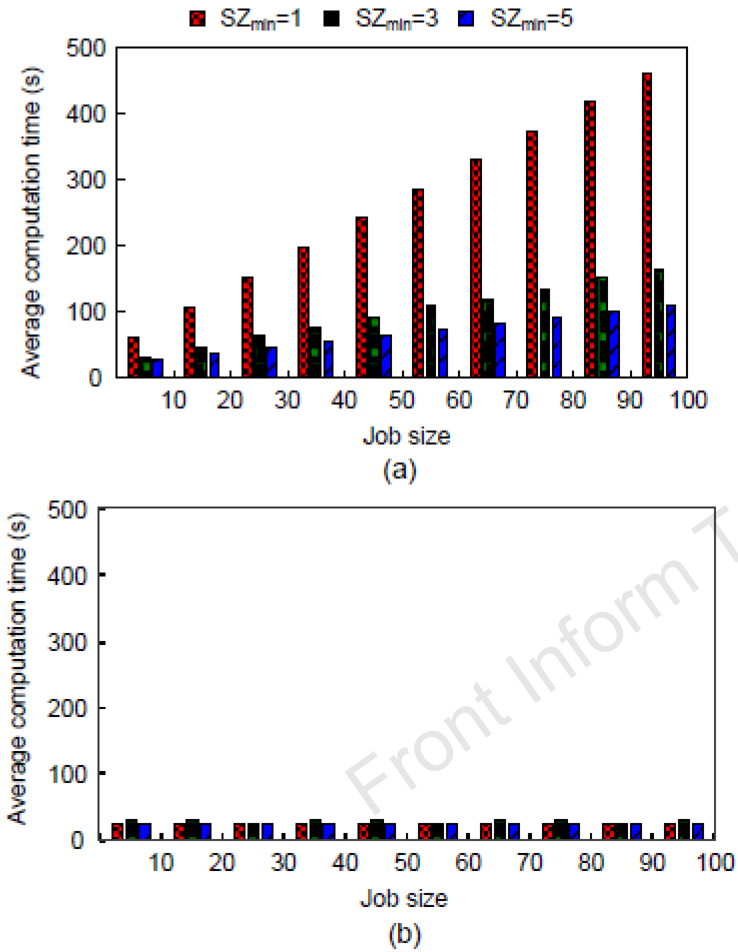

Fig. 9 Variation in the average computation time across different values of JS_i: (a) traditional calculation; (b) efficient calculation

References to color refer to the online version of this figure

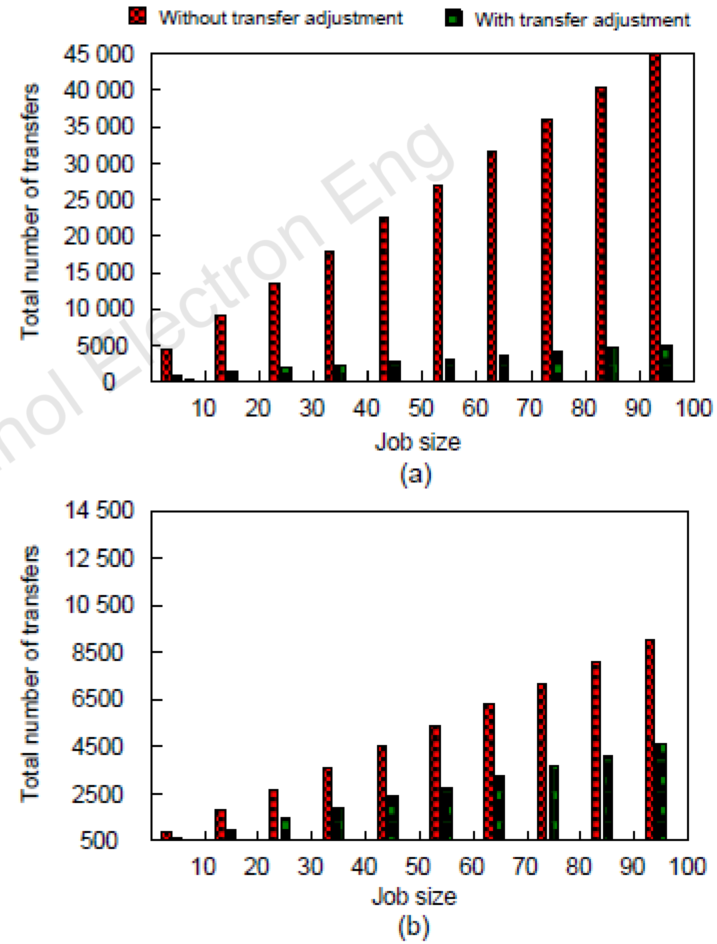

Fig. 10 Variation in the total number of transfers across different values of JS_i: (a) SZ_{min}=1; (b) SZ_{min}=5

References to color refer to the online version of this figure

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Conclusions

The experimental results confirm the effectiveness of the three-stage method from the following three aspects:

(1) The job sequencing optimization under the initial lot splitting can provide desirable optimization solution.

(2) The efficient calculation for the makespan/total flow time criterion can save much computation time in the context of lot streaming, especially when the number of jobs (production lots) is large.

(3) Transfer adjustment reduces the number of transfers between machines without affecting the optimized criterion, by adjusting the initial transfer sublots into variable size sublots.

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