70068
SCHEDULING AND RESOURCE ALLOCATION

Coursework: Image Processing Workflow

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GROUP MEMBERS

ALICIA LAW JIAYUN
01105518

LOO WEI SIN
01572543

1.0 Job Processing Times

Table 1: Job Processing Times obtained from Azure VM.

Filter Name	*mean*	std dev	Filter Name	*mean*	std dev
	s	s		s	s
vii	21.1218	± 0.8585	muse	13.2213	± 1.0760
emboss	1.9645	± 0.0729	night	25.7214	± 1.0185
blur	6.0954	± 0.1257	onnx	5.8572	± 0.4845
wave	17.5761	± 1.2900			

2.0 Search Algorithms Intermediate Results

2.1 Least Cost Last (LCL)

Table 2: Intermediate Results following the Least Cost Last (LCL) algorithm.

K	Jobs with n=0	T_j (s)	Selected S[k]	K	Jobs with n=0	T_j (s)	Selected S[k]
34	**wave_6**	**261**	wave_6	17	emboss_1, emboss_3, **onnx_3**, wave_2	139, 86, **84**, 123	onnx_3
33	**onnx_1**, emboss_1, emboss_3	**123**, 276, 223	onnx_1	16	emboss_1, **emboss_3**, wave_2	134, **81**, 118	emboss_3
32	**muse_1**, emboss_1, emboss_3	**206**, 270, 217	muse_1	15	emboss_1, **vii_1**, wave_2	132, **0**, 116	vii_1
31	emboss_1, **blur_1,** emboss_3	257, **182**, 204	blur_1	14	emboss_1, **blur_2**, wave_2	111, **0**, 95	blur_2
30	emboss_1, emboss_3, blur_4, **emboss_4,** blur_6	251, 198, 16, **0,** 128	emboss_4	13	emboss_1, **wave_1**, wave_2	104, **0**, 88	wave_1
29	emboss_1, emboss_3, blur_4, **onnx_2**, blur_6	249, 196, 14, **0**, 126	onnx_2	12	emboss_1, **blur_3**, wave_2	87, **0**, 71	blur_3
28	emboss_1, emboss_3, **blur_4**, onnx_3, blur_6	243, 190, **8**, 188, 120	blur_4	11	emboss_1, **wave_2**	81, **65**	wave_2
27	emboss_1, emboss_3, onnx_3, **blur_5**, blur_6	237, 184, 182, **0**, 114	blur_5	10	emboss_1, **wave_3**	63, **0**	wave_3
26	emboss_1, emboss_3, onnx_3, wave_2, **blur_6**	231, 178, 176, 215, **108**	blur_6	9	emboss_1, **wave_4**	46, **0**	wave_4
25	emboss_1, emboss_3, onnx_3, wave_2, **night_1**	225, 172, 170, 209, **34**	night_1	8	emboss_1, **emboss_5**, emboss_6	28, **0**, 0	emboss_5
24	emboss_1, emboss_3, onnx_3, wave_2, **muse_2**	199, 146, 144, 183, **0.6**	muse_2	7	emboss_1, **onnx_4**, emboss_6	26, **0**, 0	onnx_4
23	emboss_1, emboss_3, onnx_3, wave_2, **emboss_7**	186, 133, 131, 170, **0**	emboss_7	6	emboss_1, **emboss_6**	20, **0**	emboss_6
22	emboss_1, emboss_3, onnx_3, wave_2, **onnx_6**	184, 131, 129, 168, **58**	onnx_6	5	emboss_1, **onnx_5**	18, **0**	onnx_5
21	emboss_1, emboss_3, onnx_3, wave_2, **wave_5**	178, 125, 123, 162, **0**	wave_5	4	emboss_1, **vii_2**	12, **0**	vii_2
20	emboss_1, emboss_3, onnx_3, wave_2, **emboss_8**, muse_3	161, 108, 106, 145, **0,** 0	emboss_8	3	**emboss_1**	**0**	emboss_1
19	emboss_1, emboss_3, onnx_3, wave_2, **muse_3**	159, 106, 104, 143, **0**	muse_3	2	**emboss_2**	**0**	emboss_2
18	emboss_1, emboss_3, onnx_3, wave_2, **onnx_7**	145, 92, 90, 129, **61**	onnx_7	1	**onnx_8**	**0**	onnx_8

**Jobs with least cost (T_j) at each k and their T_j values have been bolded. Only whole numbers shown for simplicity.*

Max Tardiness, $T_{j,max}$: 261.2315s **Total Tardiness, $\sum T_j$:** 2242.916 **Schedule:** see data/lcl/lcl.csv or lcl.json

2.2 Tabu Search

For this section, only the first 3 iterations are shown, as well as those where new optimums were found.

Table 3: Intermediate Results for Tabu Search (i) K=10.

K	Candidate Swap Pair	$\sum T_j$ (s)	Tabu List, τ	g_{best}
1	(onnx_7, vii_2)	2566.5249	[]	inf
2	(muse_3, emboss_8)	2577.7817	[(31, 22)]	2566.5249
3	(onnx_7, emboss_8)	2581.6744	[(31, 22), (30, 29)]	2566.5249

Total Tardiness, $\sum T_j$: 2566.5249s **Best Schedule:** see data/tabu/tabu_10.csv

Table 4: Intermediate Results for Tabu Search (ii) K=100 (same as K=1000).

K	Candidate Swap Pair	(s)	Tabu List,	g_{best}
1	(onnx_7, vii_2)	2566.5249	[]	inf
2	(muse_3, emboss_8)	2577.7817	[(31, 22)]	2566.5249
3	(onnx_7, emboss_8)	2581.6744	[(31, 22), (30, 29)]	2566.5249
32	(onnx_7, wave_3)	2565.6938	[(29, 17), (26, 16), (27, 16), (28, 16), (30, 16)]	2566.5249
33	(emboss_8, wave_3)	2550.0822	[(26, 16), (27, 16), (28, 16), (30, 16), (31, 16)]	2565.6938

34	(muse_2, onnx_3)	2544.2250	[(27, 16), (28, 16), (30, 16), (31, 16), (29, 16)]	2550.0822
35	(emboss_7, onnx_3)	2538.3678	[(28, 16), (30, 16), (31, 16), (29, 16), (25, 13)]	2544.2250
36	(onnx_6, onnx_3)	2532.5106	[(30, 16), (31, 16), (29, 16), (25, 13), (26, 13)]	2538.3678
37	(wave_5, onnx_3)	2526.6534	[(31, 16), (29, 16), (25, 13), (26, 13), (27, 13)]	2532.5106
38	(muse_3, onnx_3)	2520.7962	[(29, 16), (25, 13), (26, 13), (27, 13), (28, 13)]	2526.6534
39	(onnx_7, onnx_3)	2514.9390	[(25, 13), (26, 13), (27, 13), (28, 13), (30, 13)]	2520.7962
40	(emboss_8, onnx_3)	2509.0818	[(26, 13), (27, 13), (28, 13), (30, 13), (31, 13)]	2514.9390
49	(emboss_7, wave_2)	2494.2148	[(21, 13), (22, 13), (18, 13), (19, 13), (25, 15)]	2509.0818
50	(onnx_6, wave_2)	2478.3229	[(22, 13), (18, 13), (19, 13), (25, 15), (26, 15)]	2494.2148
51	(wave_5, wave_2)	2460.7468	[(18, 13), (19, 13), (25, 15), (26, 15), (27, 15)]	2478.3229
52	(muse_3, wave_2)	2443.1707	[(19, 13), (25, 15), (26, 15), (27, 15), (28, 15)]	2460.7468
53	(onnx_7, wave_2)	2432.6242	[(25, 15), (26, 15), (27, 15), (28, 15), (30, 15)]	2443.1707
54	(emboss_8, wave_2)	**2415.0481**	[(26, 15), (27, 15), (28, 15), (30, 15), (31, 15)]	2432.6242

Total Tardiness, $\sum T_j$: 2415.0481s **Best Schedule:** see data/tabu/tabu_100.csv

Table 5: Intermediate Results for Tabu Search (iii) K=1000 (same as K=100).

K	Candidate Swap Pair	$\sum T_j$ (s)	Tabu List, τ	g_{best}
1	(onnx_7, vii_2)	2566.5249	[]	inf
2	(muse_3, emboss_8)	2577.7817	[(31, 22)]	2566.5249
3	(onnx_7, emboss_8)	2581.6744	[(31, 22), (30, 29)]	2566.5249
32	(onnx_7, wave_3)	2565.6938	[(29, 17), (26, 16), (27, 16), (28, 16), (30, 16)]	2566.5249
33	(emboss_8, wave_3)	2550.0822	[(26, 16), (27, 16), (28, 16), (30, 16), (31, 16)]	2565.6938
34	(muse_2, onnx_3)	2544.2250	[(27, 16), (28, 16), (30, 16), (31, 16), (29, 16)]	2550.0822
35	(emboss_7, onnx_3)	2538.3678	[(28, 16), (30, 16), (31, 16), (29, 16), (25, 13)]	2544.2250
36	(onnx_6, onnx_3)	2532.5106	[(30, 16), (31, 16), (29, 16), (25, 13), (26, 13)]	2538.3678
37	(wave_5, onnx_3)	2526.6534	[(31, 16), (29, 16), (25, 13), (26, 13), (27, 13)]	2532.5106
38	(muse_3, onnx_3)	2520.7962	[(29, 16), (25, 13), (26, 13), (27, 13), (28, 13)]	2526.6534
39	(onnx_7, onnx_3)	2514.9390	[(25, 13), (26, 13), (27, 13), (28, 13), (30, 13)]	2520.7962
40	(emboss_8, onnx_3)	2509.0818	[(26, 13), (27, 13), (28, 13), (30, 13), (31, 13)]	2514.9390
49	(emboss_7, wave_2)	2494.2148	[(21, 13), (22, 13), (18, 13), (19, 13), (25, 15)]	2509.0818
50	(onnx_6, wave_2)	2478.3229	[(22, 13), (18, 13), (19, 13), (25, 15), (26, 15)]	2494.2148
51	(wave_5, wave_2)	2460.7468	[(18, 13), (19, 13), (25, 15), (26, 15), (27, 15)]	2478.3229
52	(muse_3, wave_2)	2443.1707	[(19, 13), (25, 15), (26, 15), (27, 15), (28, 15)]	2460.7468
53	(onnx_7, wave_2)	2432.6242	[(25, 15), (26, 15), (27, 15), (28, 15), (30, 15)]	2443.1707
54	(emboss_8, wave_2)	**2415.0481**	[(26, 15), (27, 15), (28, 15), (30, 15), (31, 15)]	2432.6242

Total Tardiness, $\sum T_j$: 2415.0481s **Best Schedule:** see data/tabu/tabu_1000.csv

3.0 Azure VM Experiments

3.1 Results

Table 6: Measured total completion time and tardiness for different schedules.

Schedule	total completion time, $\sum C_j$	total tardiness, $\sum T_j$
	s	s
LCL	305.8080 ± 3.1993	1223.8325 ± 45.5073
S_{init} (topological sort)	309.0527 ± 0.7341	1794.3777 ± 18.7643
Tabu with K=10	307.6739 ± 4.5760	1778.9092 ± 45.4836
Tabu with K=100	305.0251 ± 3.4359	1592.0226 ± 33.1001
Tabu with K=1000	307.6157 ± 3.5305	1624.4023 ± 38.4423

3.2 Comment on Tabu Search

Tabu Search performance can definitely improve. Currently it performs poorer against LCL due to suboptimal parameters. As $\Delta_{max} \approx 17.5$, the current threshold (γ=30) is too large, preventing tabu search from filtering through the search space efficiently. Instead, it just accepts the first candidate at each iteration. Through tuning threshold (γ) and tabu list length (L) parameters, it was found that $\boldsymbol{\gamma}$ **= 13**, **L = 9** at K=1000 could yield a significantly better schedule. This optimised schedule can be found in **data/tabu/tabu_optimal.csv**, and has a **total tardiness $\sum T_j$ = 2182.1186s**, better than those found in Section 2.0. Running this on the Azure VM, a 30% decrease in $\sum T_j$ was observed:

Table 7: Optimised tabu search result.

Schedule	*total completion time, $\sum C_j$*	*total tardiness, $\sum T_j$*
	s	s
Tabu Optimised (K = 1000, γ = 13 and L = 9)	301.1290 ± 1.1092	1122.1753 ± 13.7929

Potentially better schedules could also be obtained by increasing K, as the algorithm is given more time to escape local optimums and reach a globally optimal solution. However, this can be computationally expensive and hence, this trade-off must be taken into account when devising the optimal schedule.