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The analysis from the algorithms makes sense and the results are expected.

FCFS - This algorithm has relatively even wait/response/turnaround time

RR - This algorithm has the lowest response time, but high wait/turnaround time

Priority - This algorithm has average wait/response/turnaround due to the randomization and even distribution of data; priority is as good as FCFS if the priorities don't relate to any other properties of the data. The preemptive version has lower response but higher wait/turnaround.

SJF (non-pre) - This algorithm has the lowest average wait of non-preemptive algorithms, as expected. This results in low response times as well, but is an unfair algorithm.

SJF (pre) - This algorithm has the lowest average wait of all algorithms, and results in lower response times and wait times compared to its non-preeemptive counterpart.

Extra Credit

ML - This multi-level algorithm (RR10, RR20, FCFS) provides low response time, but at the cost of high wait/turnaround times. The response time is higher than RR but the wait/turnaround time is lower.

ML2 - This multi-level algorithm (SJF, RR10, RR20) provides lower wait/turnaround times compared to ML, and ML2-pre has lower values for all three performance metrics than ML-pre. The advantage of using an algorithm that implements SJF in its first layer ensures that small processes are finished quickly, while negating the low response time that SJF can achieve if a process is starved via the RR 2nd and 3rd queues. If a time-based aging system is implemented with this algorithm, the large quantum used for the 3rd queue would help ensure that processes that have been around for a longer time are allowed to finish more quickly than processes that are younger, minimizing extreme values of turnaround time that can result from neglected processes.

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First Come First Serve

	Wait	Response	Turnaround
Min	0	0	7
Mean	159.17	159.17	195.01
Max	345	345	381
StdDev	101.99	101.99	104.03

Round Robin (equal time)

	Wait	Response	Turnaround
Min	0	0	7
Mean	269.32	9.75	305.17
Max	968	40	1049
StdDev	220.25	8.41	229.93

Priority (non-preemptive)

	Wait	Response	Turnaround
Min	0	0	7
Mean	154.31	154.31	190.15
Max	2067	2067	2118
StdDev	347.38	347.38	348.49

Priority (preemptive)

	Wait	Response	Turnaround
Min	0	0	7
Mean	200.28	82.61	236.12
Max	3274	1799	3325
StdDev	500.66	253.88	503.02

Shortest Job First (non-preemptive)

	Wait	Response	Turnaround
Min	0	0	7
Mean	98.3	98.3	134.14
Max	1564	1564	1629
StdDev	273.79	273.79	282.47

Shortest Job First (preemptive)

	Wait	Response	Turnaround
Min	0	0	3
Mean	94.2	88.88	130.04
Max	1564	1564	1629
StdDev	277.19	276.02	286.47

Multi-Level Priority (non-preemptive)

	Wait	Response	Turnaround
Min	0	0	7
Mean	231.54	47.63	267.38
Max	2053	2053	2104
StdDev	309.72	217.13	314.88

Multi-Level Priority (preemptive)

	Wait	Response	Turnaround
Min	0	0	8
Mean	264.68	66.32	300.52
Max	3156	3156	3207
StdDev	426.96	378.55	431.76

Multi-Level Priority 2 (non-preemptive)

	Wait	Response	Turnaround
Min	0	0	7
Mean	224.99	53.98	260.83
Max	2067	2054	2118
StdDev	313.5	215.09	318.52

Multi-Level Priority 2 (preemptive)

	Wait	Response	Turnaround
Min	0	0	8
Mean	246.68	28.25	282.52
Max	3218	1215	3269
StdDev	436	135.92	440.42

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	FCFS	Priority (non-pre)	Priority (pre)	RR (q=10)	SJF (non-pre)	SJF (pre)	MLP (non-pre)	MLP (pre)	MLP2 (non-pre)	MLP2 (pre)
Mean	159.17	154.31	200.28	269.32	98.3	94.2	231.54	264.68	224.99	246.68
Max	345	2067	3274	968	1564	1564	2053	3156	2067	3218
StdDev	101.99	347.38	500.66	220.25	273.79	277.19	309.72	426.96	313.5	436

Response

	FCFS	Priority (non-pre)	Priority (pre)	RR (q=10)	SJF (non-pre)	SJF (pre)	MLP (non-pre)	MLP (pre)	MLP2 (non-pre)	MLP2 (pre)
Mean	159.17	154.31	82.61	9.75	98.3	88.88	47.63	66.32	53.98	28.25
Max	345	2067	1799	40	1564	1564	2053	3156	2054	1215
StdDev	101.99	347.38	253.88	8.41	273.79	276.02	217.13	378.55	215.09	135.92

Turn Around

	FCFS	Priority (non-pre)	Priority (pre)	RR (q=10)	SJF (non-pre)	SJF (pre)	MLP (non-pre)	MLP (pre)	MLP2 (non-pre)	MLP2 (pre)
Mean	195.01	190.15	236.12	305.17	134.14	130.04	267.38	300.52	260.83	282.52
Max	381	2118	3325	1049	1629	1629	2104	3207	2118	3269
StdDev	104.03	348.49	503.02	229.93	282.47	286.47	314.88	431.76	318.52	440.42

Data Source Information	
Processes	100
Average Burst	40
Average Arrival	34
Average Priority	4

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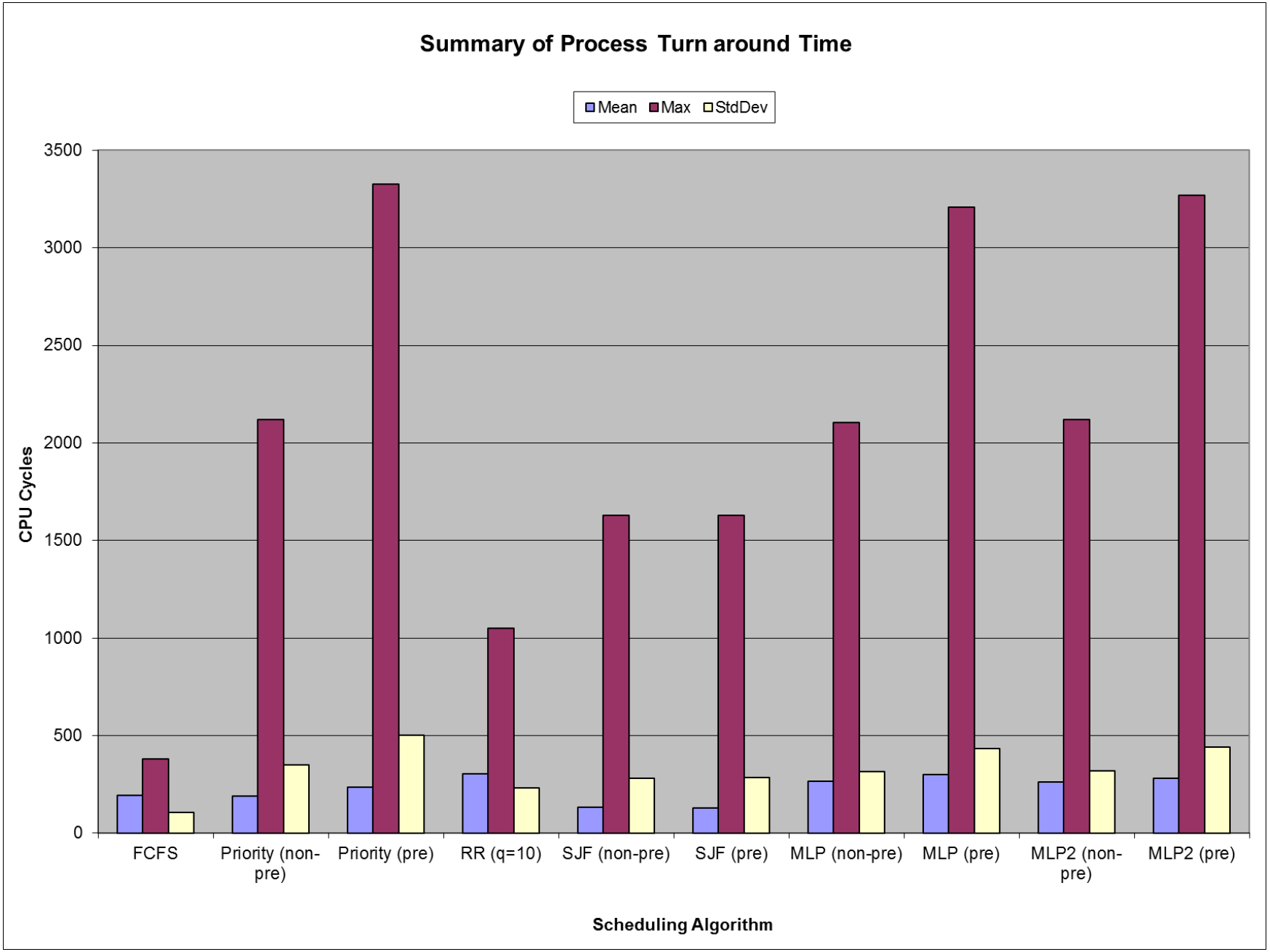

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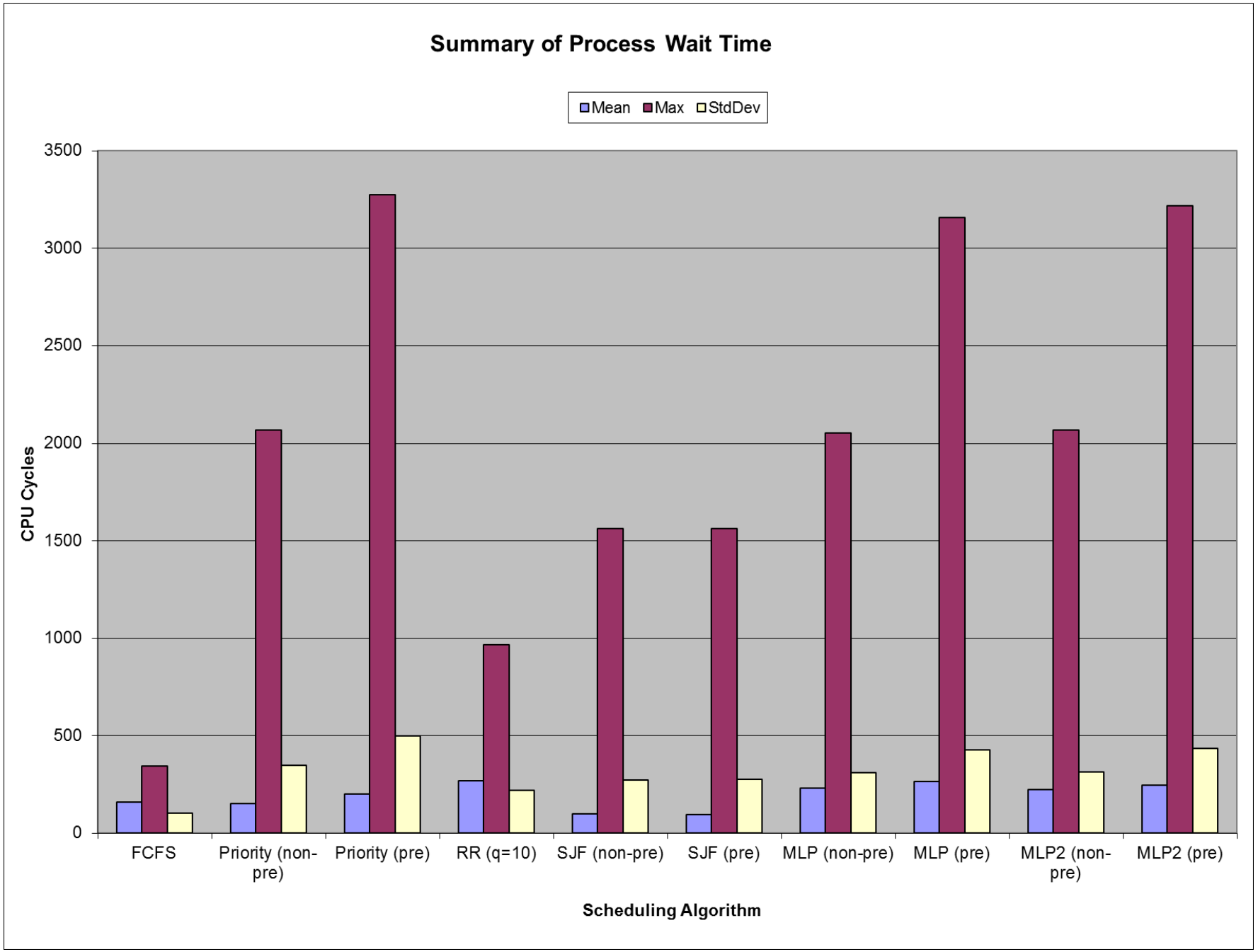

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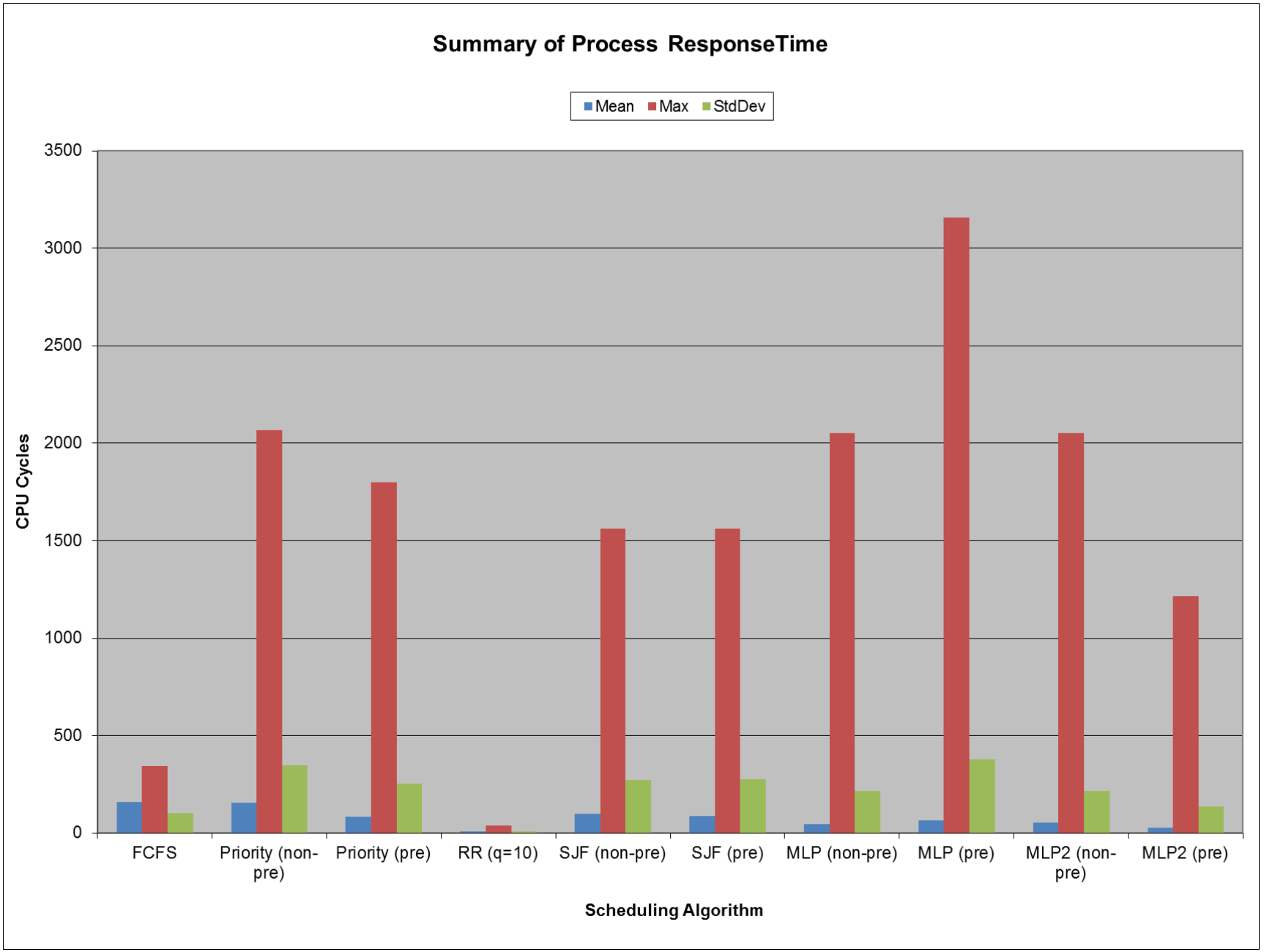

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All tests had samples of 250 processes.

For a CPU burst of 20
    Waiting time: 787.8
    Turnaround time: 807.06

For a CPU burst of 40:
    Waiting time: 3000.46
    Turnaround time: 3037.85

For a CPU burst of 60:
    Waiting time: 5475.14
    Turnaround time: 5532.36

For a CPU burst of 80:
    Waiting time: 7870.08
    Turnaround time: 7946.46

The larger the burst size, the higher the turnaround and waiting time get. This result is intuitive because each process takes longer to process with higher burst sizes. Also, things like the convoy effect can happen, where a process with a small burst time gets held up behind a process with a large burst time.

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Based on our results, turnaround and waiting time wasn't shown to be better or worse depending on the relationship between average priority and average burst, as worded by the question. This is simply because the distribution is normalized. For example, burst 30 and average priority 2 will have the exact same statistical appearance as burst 30 and average priority 7, since the source data with average priority 7 will have the same shape, just with all process priorities on average being shifted up 5 more values than the priority 2 average source data. By increasing the burst from 30 to 70, we see the same shapes repeated but everything just takes longer.

I think what this question really means to ask, is how does the placement of the average burst distribution along a range of priorities affect the turnaround and waiting time. In this scenario, having processes with priorities inversely proportional to their CPU burst would greatly increase the performance of your algorithm, due to the fact that higher priorities will have lower burst times, and lower priorities will have higher burst time. Preemption will exaggerate this effect, and make the wait and turnaround times even less. This will mimic behavior similar to a SJF.

Data Source	Information
Processes	250
Average Burst	Varies
Average Arrival	20
Average Priority	Varies

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Processes - 250, Avg Burst - 30, Avg arrival - 20, Avg Priority - 2

Priority (non-preemptive) B30 P2

	Wait	Response	Turnaround
Min	0	0	1
Mean	784.44	784.44	812.22
Max	6754	6754	6795
StdDev	1665.53	1665.53	1687.69

Processes - 250, Avg Burst - 70, Avg arrival - 20, Avg Priority - 2

Priority (non-preemptive) B70 P2

	Wait	Response	Turnaround
Min	0	0	48
Mean	5585.54	5585.54	5652.56
Max	16488	16488	16569
StdDev	1827.88	1827.88	2031.47

Processes - 250, Avg Burst - 30, Avg arrival - 20, Avg Priority - 2

Priority (preemptive) B30 P2

	Wait	Response	Turnaround
Min	0	0	1
Mean	792.26	658.16	820.04
Max	6754	6754	6795
StdDev	1703.43	1543.63	1725.81

Processes - 250, Avg Burst - 70, Avg arrival - 20, Avg Priority - 2

Priority (preemptive) B70 P2

	Wait	Response	Turnaround
Min	0	0	22
Mean	5640.5	5517.91	5707.52
Max	16488	16488	16569
StdDev	2010.87	1751.6	2197.33

Processes - 250, Avg Burst - 30, Avg arrival - 20, Avg Priority - 7

Priority (non-preemptive) B30 P7

	Wait	Response	Turnaround
Min	0	0	1
Mean	789.02	789.02	816.8
Max	6383	6383	6424
StdDev	1678.39	1678.39	1700.3

Processes - 250, Avg Burst - 70, Avg arrival - 20, Avg Priority - 7

Priority (non-preemptive) B70 P7

	Wait	Response	Turnaround
Min	0	0	29
Mean	5562.49	5562.49	5629.52
Max	16046	16046	16121
StdDev	1649.16	1649.16	1873.11

Processes - 250, Avg Burst - 30, Avg arrival - 20, Avg Priority - 7

Priority (preemptive) B30 P7

	Wait	Response	Turnaround
Min	0	0	1
Mean	806.95	660.7	834.73
Max	6577	6148	6612
StdDev	1707.33	1512.14	1729.61

Processes - 250, Avg Burst - 70, Avg arrival - 20, Avg Priority - 7

Priority (preemptive) B70 P7

	Wait	Response	Turnaround
Min	0	0	22
Mean	5657.4	5469.43	5724.43
Max	16075	16075	16156
StdDev	1935.22	1549.72	2128.45

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Wait

	Pri (np) B30 P2	Pri (np) B30 P7	Pri (np) B70 P2	Pri (np) B70 P7	Pri (p) B30 P2	Pri (p) B30 P7	Pri (p) B70 P2	Pri (p) B70 P7
Mean	784.44	789.02	5585.54	5562.49	792.26	806.95	5640.5	5657.4
Max	6754	6383	16488	16046	6754	6577	16488	16075
StdDev	1665.53	1678.39	1827.88	1649.16	1703.43	1707.33	2010.87	1935.22

Response

	Pri (np) B30 P2	Pri (np) B30 P7	Pri (np) B70 P2	Pri (np) B70 P7	Pri (p) B30 P2	Pri (p) B30 P7	Pri (p) B70 P2	Pri (p) B70 P7
Mean	784.44	789.02	5585.54	5562.49	658.16	660.7	5517.91	5469.43
Max	6754	6383	16488	16046	6754	6148	16488	16075
StdDev	1665.53	1678.39	1827.88	1649.16	1543.63	1512.14	1751.6	1549.72

Turn Around

	Pri (np) B30 P2	Pri (np) B30 P7	Pri (np) B70 P2	Pri (np) B70 P7	Pri (p) B30 P2	Pri (p) B30 P7	Pri (p) B70 P2	Pri (p) B70 P7
Mean	812.22	816.8	5652.56	5629.52	820.04	834.73	5707.52	5724.43
Max	6795	6424	16569	16121	6795	6612	16569	16156
StdDev	1687.69	1700.3	2031.47	1873.11	1725.81	1729.61	2197.33	2128.45

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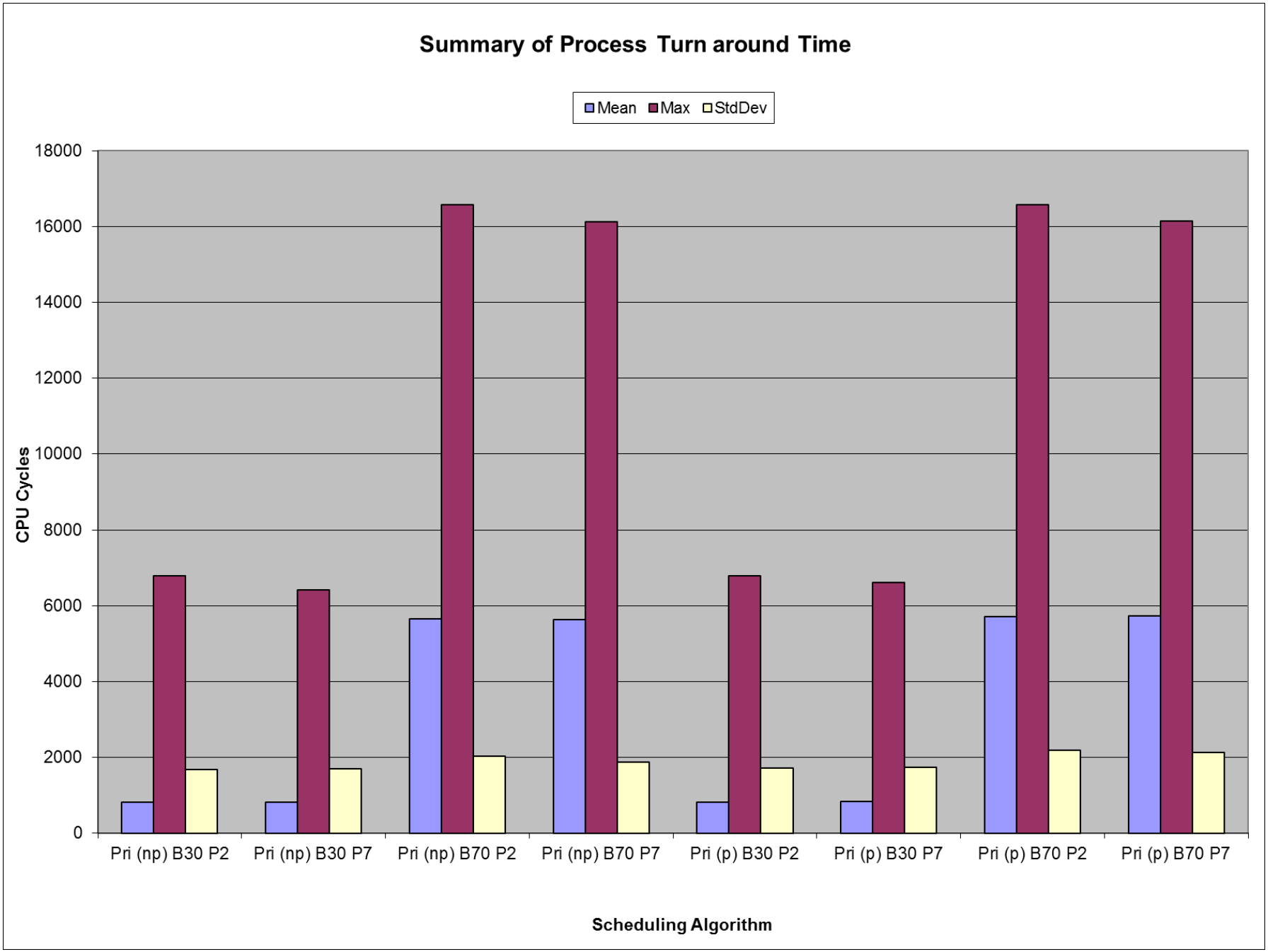

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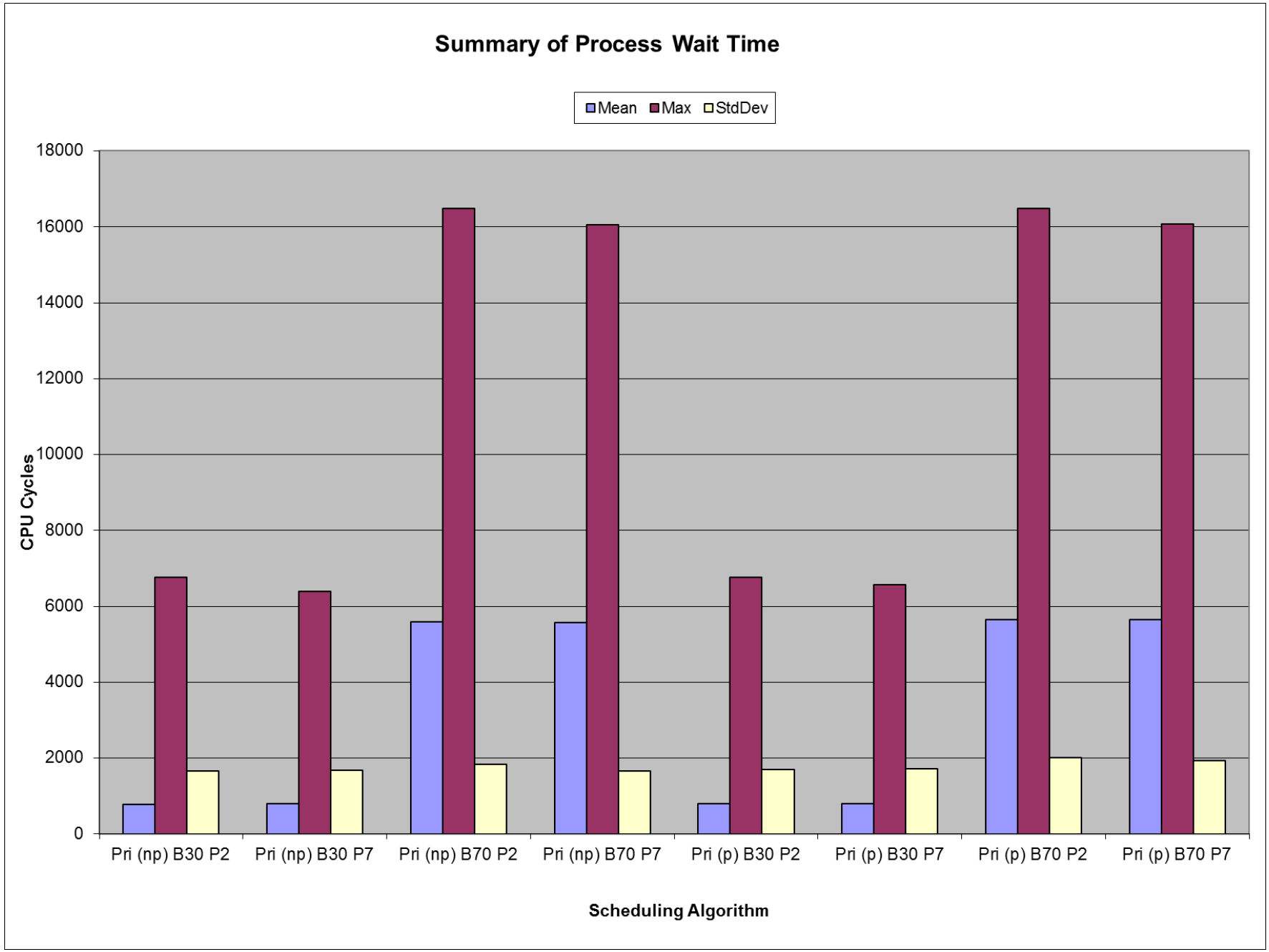

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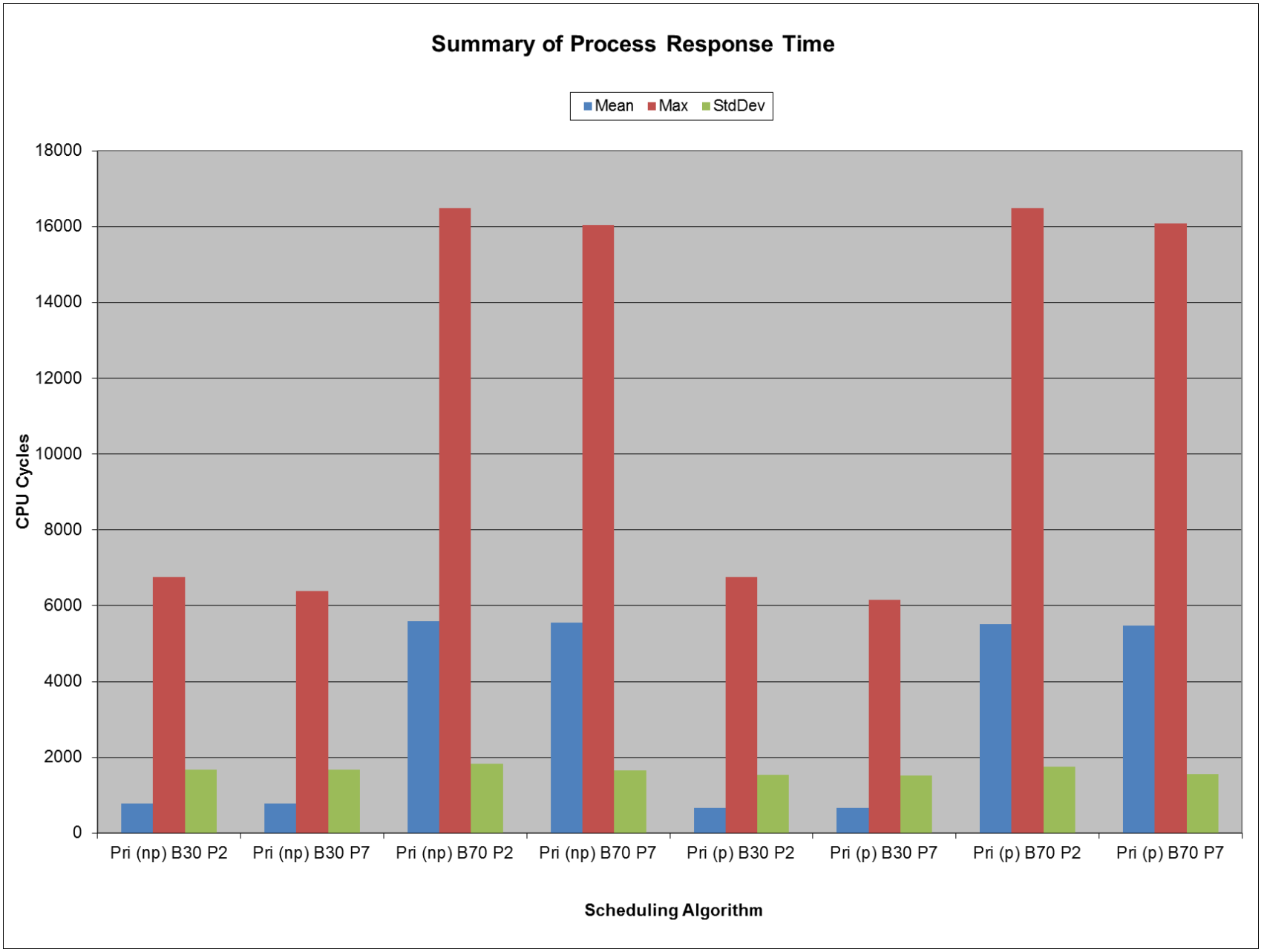

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The average burst size greatly increases turnaround time and waiting time, but not in a directly linear way. From an average burst of 20 to an average burst of 40, non-preemptive waiting time increased by a factor of 40, while turnaround time increased by a factor of 26. The preemptive waiting time increased by a factor of 47, while the preemptive turnaround time increased by a factor of 29. From the average 40 burst to the average 60 burst results, the wait and turn time increased by roughly 2.5 times for non-preemptive, and about 3 times for the wait and turn time of the preemptive version. From an average burst of 60 to an average burst of 80, both preemptive and non-preemptive increased by just under a factor of two. We can see then that wait and turnaround time increase, but at a decreasing rate as burst size increases.

This is intuitive, since increasing burst time gives a higher probability of processes being starved out due to the CPU not being able to keep up quickly enough with the arrival of processes. This isn't a problem initially with a burst size of 20 since the arrival of new processes was slower than the rate that processes were being completed. As the CPU gets backed up, processes will queue up, and the rate of degradation increases by factors, which our results show. At a certain point, the queue is so hopelessly behind that additional processes to the queue decrease performance more linearly, since one more process is small compared to the relative size of the queue. We can say then, that when a process is being overwhelmed initially, wait time and turnaround time increase exponentially, but at a decreasing rate. At a certain point in time, the rate at which the wait and turnaround time increase will be linear, and then subsequently, sub-linear.

The preemptive version of the process provides a slightly better turnaround time, but for the most part, SJF non-preemptive and SJF preemptive for our data give almost the same results once the processor gets overwhelmed. For lower bursts, SJF preemptive will give lower turnaround time because the more processes on average will be completed sooner.

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Processes - 250, Avg Burst - 20, Avg arrival - 20, Avg Priority - 4

SJF (non-preemptive) Burst 20

	Wait	Response	Turnaround
Min	0	0	1
Mean	32.97	32.97	52.22
Max	734	734	794
StdDev	80.2	80.2	87.5

Processes - 250, Avg Burst - 40, Avg arrival - 20, Avg Priority - 4

SJF (non-preemptive) Burst 40

	Wait	Response	Turnaround
Min	0	0	5
Mean	1308.94	1308.94	1346.33
Max	8598	8598	8680
StdDev	2536.19	2536.19	2560.87

Processes - 250, Avg Burst - 60, Avg arrival - 20, Avg Priority - 4

SJF (non-preemptive) Burst 60

	Wait	Response	Turnaround
Min	0	0	12
Mean	3545.43	3545.43	3602.65
Max	13341	13341	13440
StdDev	3906.347	3906.347	3921.206

Processes - 250, Avg Burst - 80, Avg arrival - 20, Avg Priority - 4

SJF (non-preemptive) Burst 80

	Wait	Response	Turnaround
Min	0	0	32
Mean	5964.77	5964.77	6041.15
Max	18278	18278	18377
StdDev	5436.119	5436.119	5450.071

Processes - 250, Avg Burst - 20, Avg arrival - 20, Avg Priority - 4

SJF (preemptive) Burst 20

	Wait	Response	Turnaround
Min	0	0	1
Mean	27.64	22.94	46.9
Max	734	734	794
StdDev	85.01	80.96	93.66

Processes - 250, Avg Burst - 40, Avg arrival - 20, Avg Priority - 4

SJF (preemptive) Burst 40

	Wait	Response	Turnaround
Min	0	0	1
Mean	1307.62	1304.94	1345
Max	8598	8598	8680
StdDev	2537.72	2538.97	2562.41

Processes - 250, Avg Burst - 60, Avg arrival - 20, Avg Priority - 4

SJF (preemptive) Burst 60

	Wait	Response	Turnaround
Min	0	0	9
Mean	3544.82	3541.5	3602.04
Max	13341	13341	13440
StdDev	3907.119	3909.713	3921.987

Processes - 250, Avg Burst - 80, Avg arrival - 20, Avg Priority - 4

SJF (preemptive) Burst 80

	Wait	Response	Turnaround
Min	0	0	32
Mean	5964.53	5963.42	6040.91
Max	17921	17921	18020
StdDev	5435.424	5436.606	5449.382

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Performance Metric Ratio by Avg Burst (Avg burst = 20 as baseline case)

Avg Burst	NP Avg Wait Ratio	NP Avg Resp Ratio	NP Avg Turn Ratio	P Avg Wait Ratio	P Avg Resp Ratio	P Avg Turn Ratio
20	1	1	1	1	1	1
40	40	40	26	47	57	29
60	108	108	69	128	154	77
80	181	181	116	216	260	129

Wait

	SFJ (non-pre) B20	SFJ (non-pre) B40	SFJ (non-pre) B60	SFJ (non-pre) B80	SFJ (pre) B20	SFJ (pre) B40	SFJ (pre) B60	SFJ (pre) B80
Mean	32.97	1308.94	3545.43	5964.77	27.64	1307.62	3544.82	5964.53
Max	734	8598	13341	18278	734	8598	13341	17921
StdDev	80.2	2536.19	3906.347	5436.119	85.01	2537.72	3907.119	5435.424

Response

	SFJ (non-pre) B20	SFJ (non-pre) B40	SFJ (non-pre) B60	SFJ (non-pre) B80	SFJ (pre) B20	SFJ (pre) B40	SFJ (pre) B60	SFJ (pre) B80
Mean	32.97	1308.94	3545.43	5964.77	22.94	1304.94	3541.5	5963.42
Max	734	8598	13341	18278	734	8598	13341	17921
StdDev	80.2	2536.19	3906.347	5436.119	80.96	2538.97	3909.713	5436.606

Turn Around

	SFJ (non-pre) B20	SFJ (non-pre) B40	SFJ (non-pre) B60	SFJ (non-pre) B80	SFJ (pre) B20	SFJ (pre) B40	SFJ (pre) B60	SFJ (pre) B80
Mean	52.22	1346.33	3602.65	6041.15	46.9	1345	3602.04	6040.91
Max	794	8680	13440	18377	794	8680	13440	18020
StdDev	87.5	2560.87	3921.206	5450.071	93.66	2562.41	3921.987	5449.382

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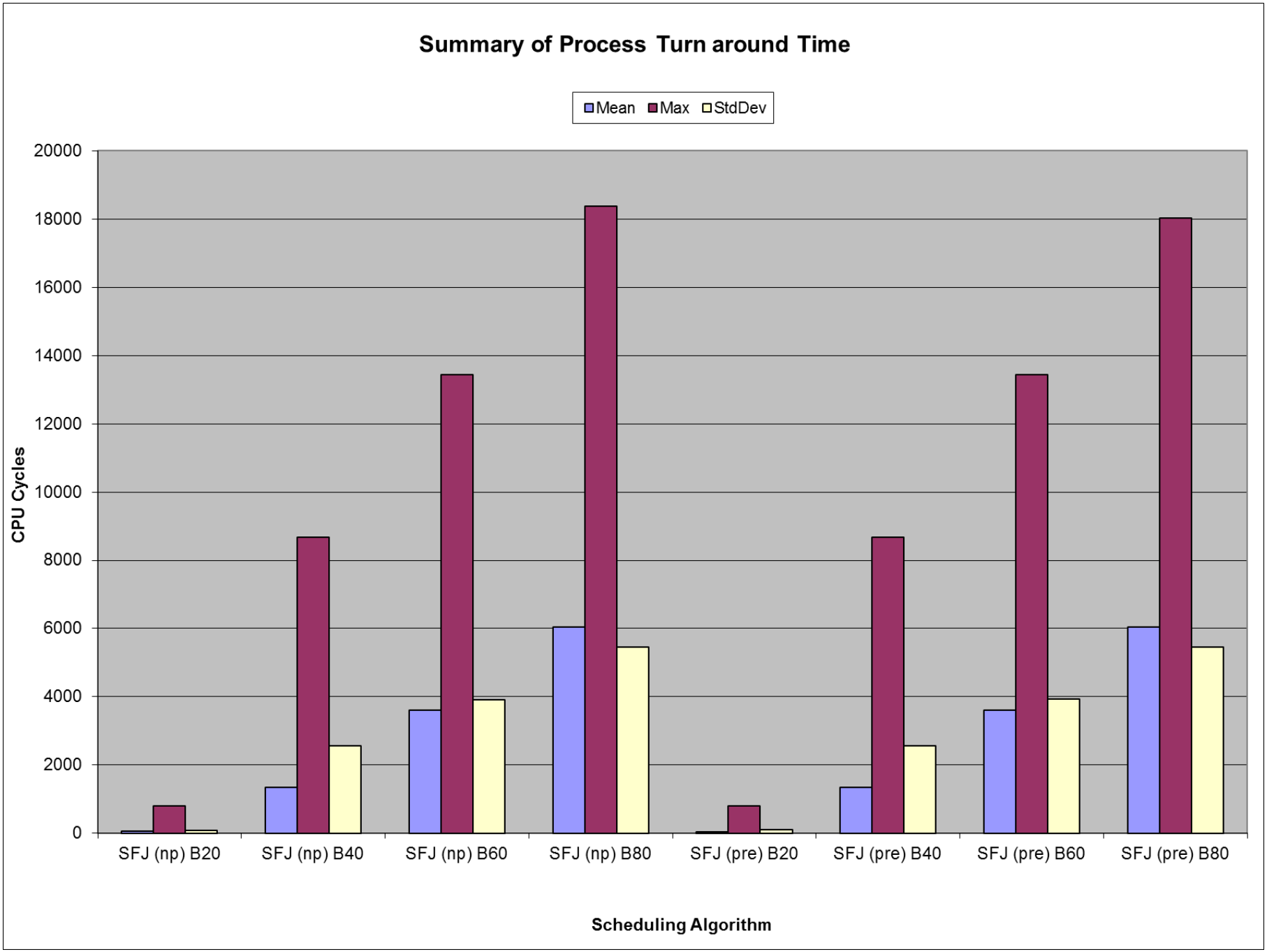

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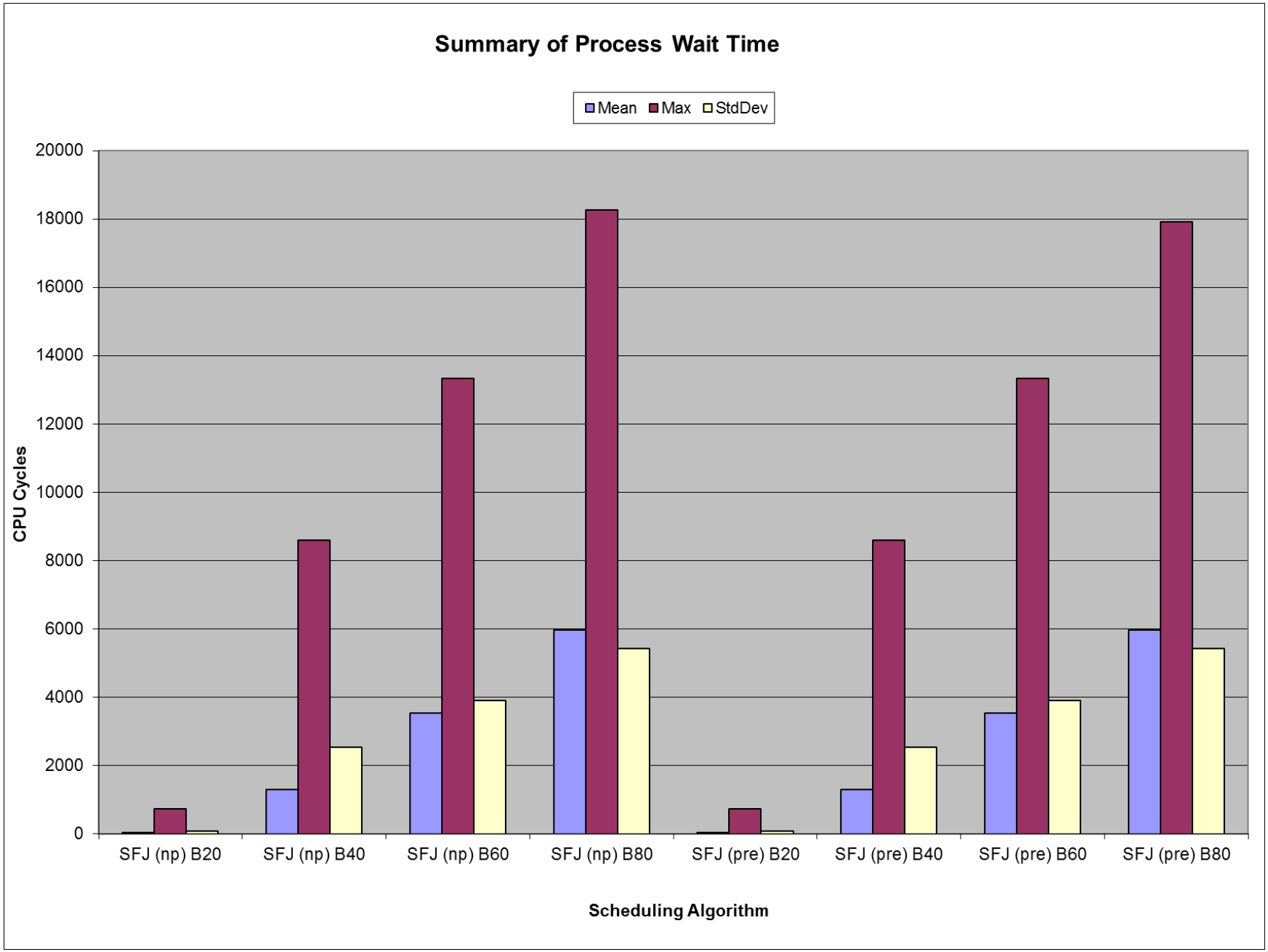

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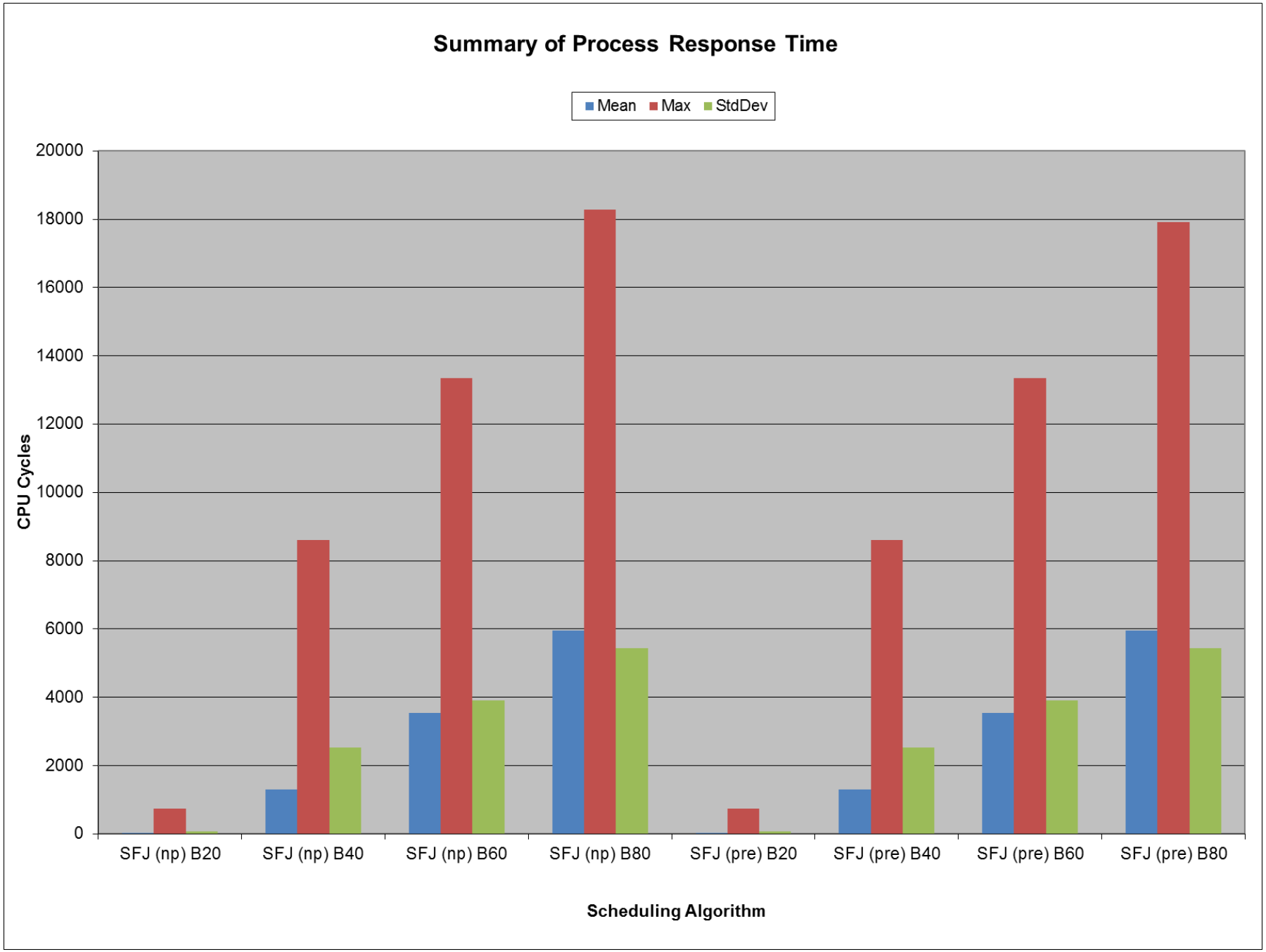

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All tests were run with 250 processes.

It is better to use larger quantums with longer running jobs because each job has a longer burst time. If the time quantums are too small with longer running jobs, more time is spent switching between jobs, rather than executing the current job, which makes it inefficient.