MPI NAS Parallel Benchmarking

CSC 569

Ian Dunn
Computer Science Department
Cal Poly
San Luis Obispo, California
idunn01@calpoly.edu

Toshi Kuboi
Computer Science Department
Cal Poly
San Luis Obispo, California
tkuboi@calpoly.edu

Mitchell Rosen
Computer Science Department
Cal Poly
San Luis Obispo, California
mwrosen@calpoly.edu

Austin Wylie
Computer Science Department
Cal Poly
San Luis Obispo, California
awylie@calpoly.edu

1. INTRODUCTION

With the goal of exploring the performance benefits and drawbacks of distributed computing, we set up and ran various computationally-distributable benchmarks on two cluster types. A set of the Numerical Aerodynamic Simulation (NAS) Parallel Benchmarks (NPB) were run on both the machines in lab 14-302 (with 1 to 32 nodes) and Raspberry Pis (with 1 to 5 nodes). The Message Passing Interface (MPI) library was responsible for inter-machine communication. As an extra note, the lab machines have 3 GHz processors and 4 GB of memory; the Rasperry Pis have 700 MHz processors and 512 MB of memory.

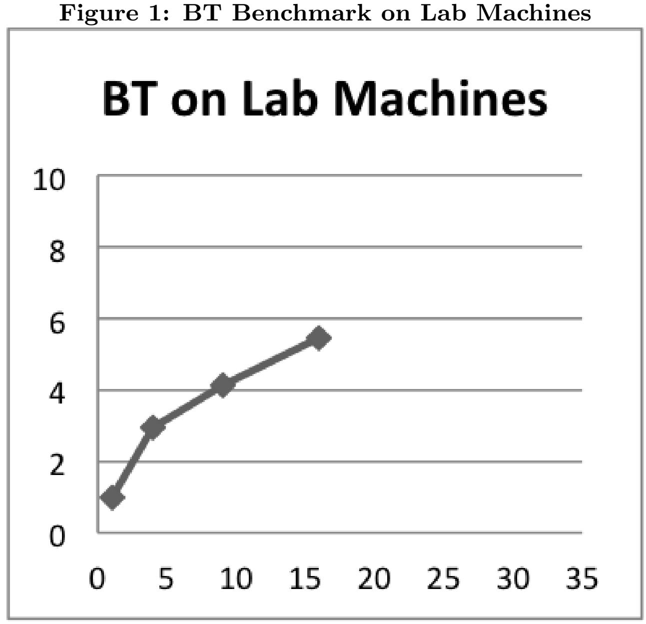
Because the Pis aren't very powerful, and to directly compare the cluster types, all of our results use the class A benchmarks, which are intended to test relatively slow machines.

2. RESULTS

The primary metric we explore in the benchmarks is speedup, which is calculated by dividing the time taken by the benchmark on the fewest number of nodes (usually one or two) by the time taken by the current run. We could comment on the raw runtimes of these different scenarios and the effect of different processors and RAM setups, but speedup best quantifies the improvement from actually distributing the work.

Tables 1 and 2 shows the NPB results for the lab machine cluster and the Pi cluster, including the specific benchmark, runtime in seconds, speedup, millions of operations per second (MOPS), and MOPS per process.

Figure 1: BT Benchmark on Lab Machines



Note that not all benchmarks can use any number of processes: many require a square number or a power of two, which is why some datapoints are absent in the following results.

In the graphs, vertical axes show the speedup and horizontal axes show the number of nodes the benchmark was run on.

2.1 Lab Machines

Table 1 shows the lab machines' NPB results.

Figures 1 through 7 graph those speedup results.

Table 1: Lab Machine Benchmark Results

Benchmark	Nodes	Time	Speedup	MOPS	Process MOPS
BT	1	82.94	1.00	2028.91	2028.91
BT	4	28.19	2.94	5970.02	1492.51
BT	9	20.18	4.11	8337.38	926.38
BT	16	15.25	5.44	11037.04	689.82
EP	1	20.14	1.00	26.65	26.65
EP	2	10.11	1.99	53.09	26.55
EP	4	5.07	3.97	105.85	26.46
EP	8	2.54	7.93	211.40	26.43
EP	16	1.34	15.03	401.95	25.12
EP	32	0.64	31.47	838.80	26.21
FT	1	7.61	1.00	938.07	938.07
FT	2	6.52	1.17	1094.71	547.36
FT	4	7.14	1.07	999.95	249.99
FT	8	6.7	1.14	1065.54	133.19
FT	16	3.69	2.06	1936.09	121.01
FT	32	3.26	2.33	2186.15	68.32
IS	1	0.75	1.00	102.74	102.74
IS	2	1.18	0.64	72.30	36.15
IS	4	1.85	0.41	39.36	9.84
IS	8	2.43	0.31	37.01	4.63
IS	16	2	0.38	60.67	3.79
IS	32	4.75	0.16	53.41	1.67
LU	1	81.75	1.00	1459.31	1459.31
LU	2	43.75	1.87	2726.65	1363.33
LU	4	23.65	3.46	5045.09	1261.27
LU	8	15.81	5.17	7543.72	942.97
LU	16	10.17	8.04	11726.37	732.90
LU	32	13.52	6.05	8825.54	275.80
MG	1	2.65	1.00	1466.37	1466.37
MG	2	1.5	1.77	2598.48	1299.24
MG	4	1.19	2.23	3279.58	819.89
MG	8	1.05	2.52	3698.19	462.27
MG	16	0.68	3.9	5734.90	358.43
MG	32	0.85	3.12	4587.27	143.35
SP	1	95.11	1.00	893.84	893.84
SP	4	32.87	2.89	2586.13	646.53
SP	9	28.16	3.38	3019.24	335.47
SP	16	21.08	4.51	4033.04	252.07

Figure 2: EP Benchmark on Lab Machines

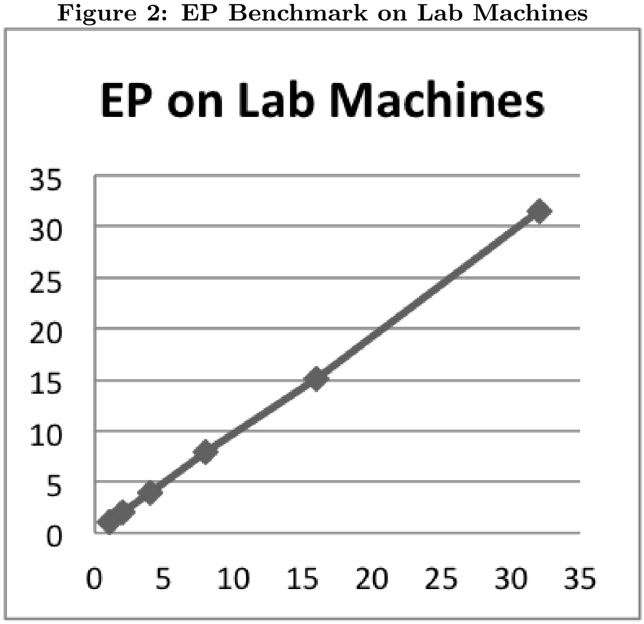


Figure 4: IS Benchmark on Lab Machines

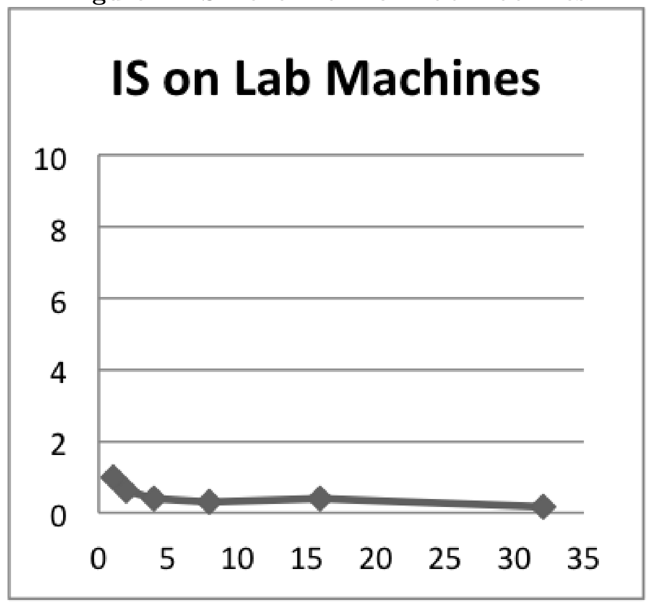


Figure 3: FT Benchmark on Lab Machines

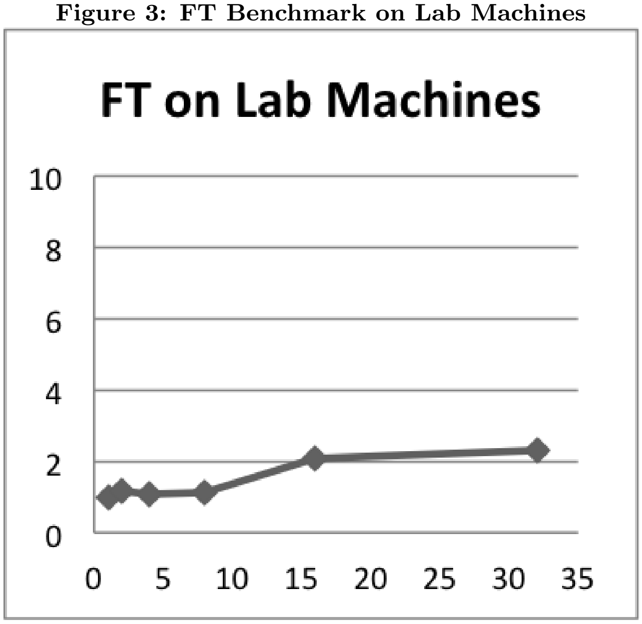


Figure 5: LU Benchmark on Lab Machines

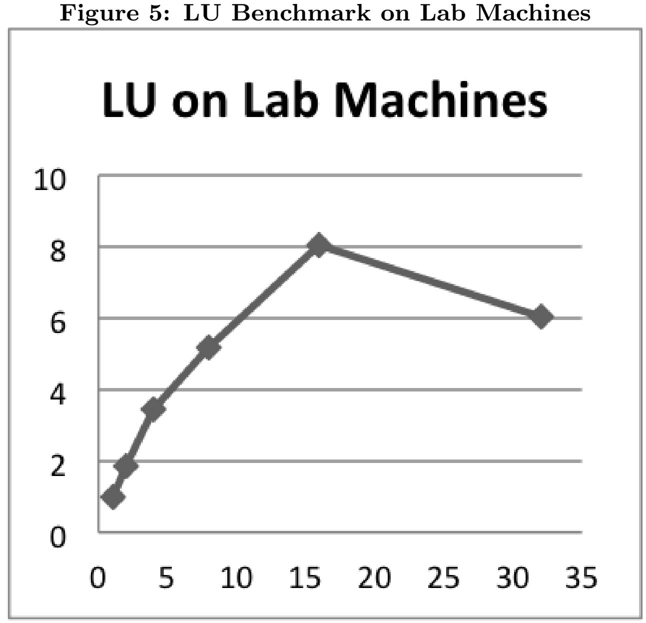


Figure 6: MG Benchmark on Lab Machines

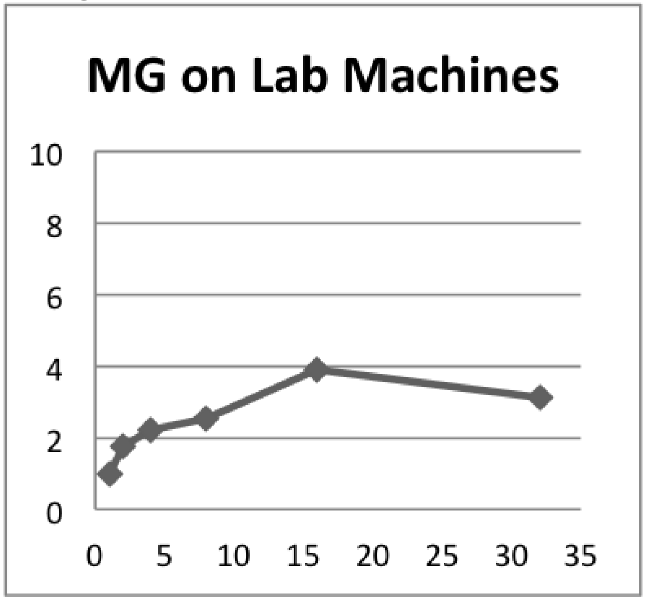


Figure 7: SP Benchmark on Lab Machines

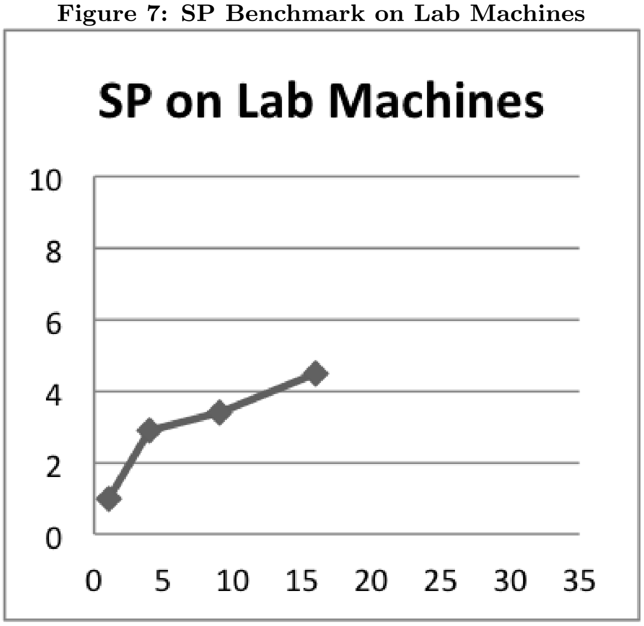
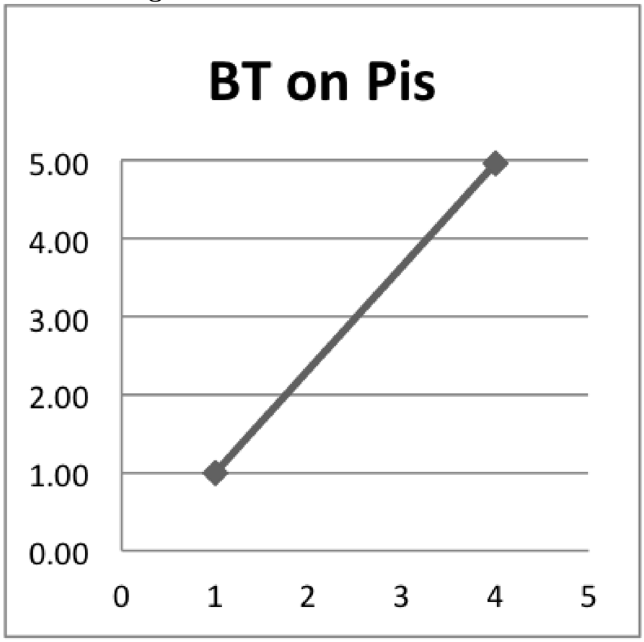


Figure 8: BT Benchmark on Pis



2.2 Raspberry Pis

Table 2 shows the Pis' NPB results. The class A benchmarks were used.

Figures 8 through 14 graph those speedup results.

3. ANALYSIS

Although it's not always the case, we typically notice a linear improvement of runtime when the number of nodes increases. This indicates that the NAS benchmarks, to some extent, can efficiently divide up their work for execution on separate systems, each with their own memory, and then simply combine the results as needed.

Of course, the higher the speedup, the less relient the nodes are on each other. In some cases, we notice that the number of nodes is almost completely tied to the speedup, with perhaps only a small performance hit due to added overhead.

In other situations, there's a very significant performance hit when the workload is distributed (see Figures 4 and 11) and the speedup can even descrease. This happens when the distributed system has to spend more time per node dealing with the extra overhead of initialization and message passing than it spends on the benchmark processing itself.

Figures 5 and 6 show this as well, but the correlation isn't as clear-cut: using up to 16 nodes improved performance, but past that, performance worsened. This indicates that we should take into account certain thresholds where workload distribution does more harm than good, and the extra nodes would be better used doing other tasks.

In a way, this benchmarking exercise serves to validate distrbuted computing in our eyes. Especially on the Raspberry Pis, despite being somewhat underwhelming individually, we

Figure 9: EP Benchmark on Pis

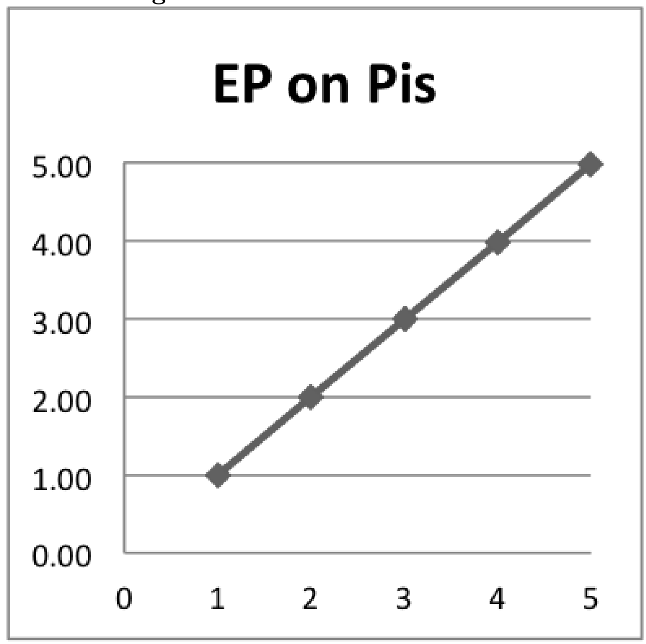


Figure 10: FT Benchmark on Pis

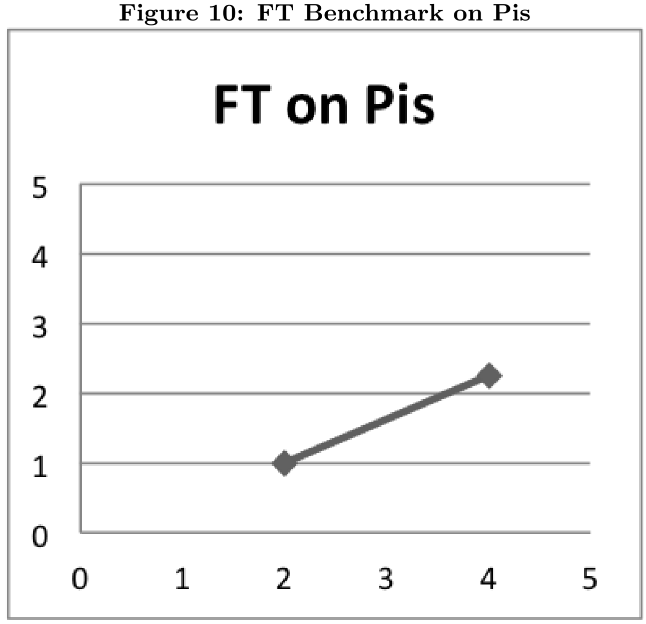


Table 2: Raspberry Pi Benchmark Results

Benchmark	Nodes	Time	Speedup	MOPS	Process MOPS
BT	1	4252.40	1.00	39.57	39.57
BT	4	858.28	4.95	196.07	49.02
EP	1	334.98	1.00	1.60	1.60
EP	2	167.65	2.00	3.20	1.60
EP	3	111.90	2.99	4.80	1.60
EP	4	84.16	3.98	6.38	1.59
EP	5	67.38	4.97	7.97	1.59
FT	2	211.66	1.00	33.72	16.86
FT	4	93.78	2.26	76.10	19.02
IS	1	24.78	1.00	3.39	3.39
IS	2	24.99	0.99	3.36	1.68
IS	4	16.07	1.54	5.22	1.31
LU	1	2507.90	1.00	47.57	47.57
LU	2	1297.50	1.93	91.95	45.97
LU	4	675.59	3.71	176.58	44.15
MG	2	98.53	1.00	39.50	19.75
MG	4	40.84	2.41	95.30	23.82
SP	1	3474.10	1.00	24.47	24.47
SP	4	938.64	3.70	90.57	22.64

Figure 11: IS Benchmark on Pis

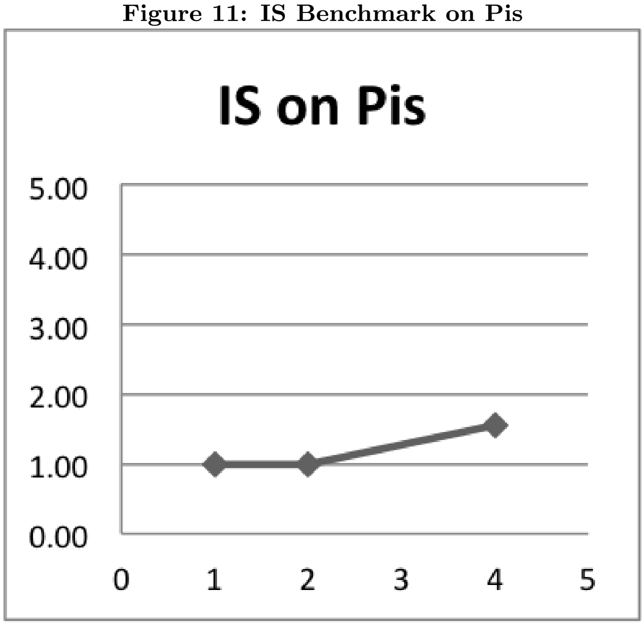
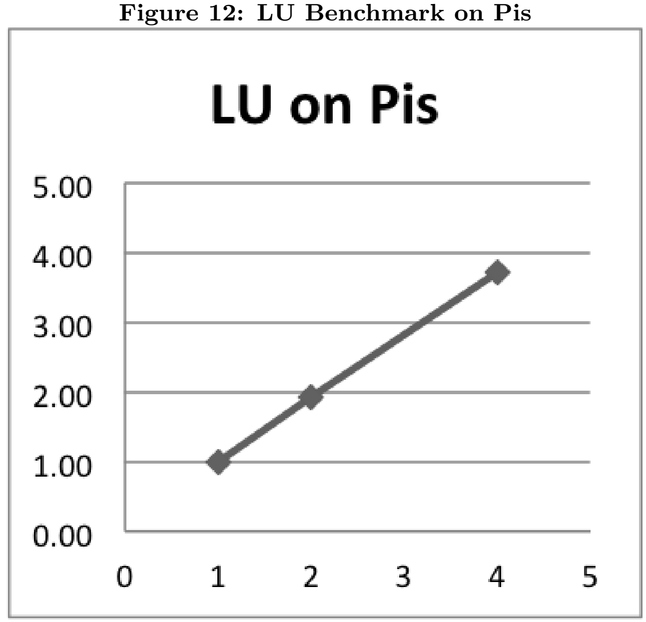


Figure 12: LU Benchmark on Pis



see that having them work together provides a huge increase in performance and that there's real value in using many (potentially unremarkable) systems to process large amounts of data.

Figure 13: MG Benchmark on Pis

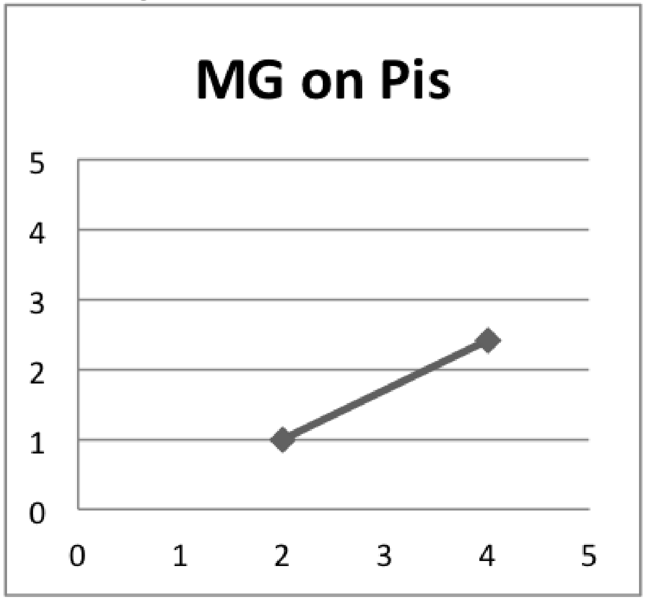


Figure 14: SP Benchmark on Pis