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Lab 4

Lab 4: Performance Measurement

Contents

List of Tables

1 Differences

1.1 Cycles Per Instruction

The Raspberry Pi cycles per instruction (CPI) typically is some multiple larger than the equivalent lab benchmark. Some notable anomalies occur in the blowfish and motion benchmarks. On the Raspberry Pi, the O1 optimization level is disproportionately larger than any of the other optimization levels, compared to the lab machine, as shown in Tables 5 and 6 and Tables 21 and 22.

There are some interesting relationships between the optimization level and the CPI. The relationship between the optimization levels changes depending on whether the lab machine or the Raspberry Pi compiles and runs it. Among the nonzero optimization levels, O2 is generally the lowest, followed closely by O3 and then finally O1. For most benchmarks on both the lab and the Raspberry Pi, no optimization typically shows a lower CPI than any of the other optimizations.

1.2 Instructions

Between the lab machine and the Raspberry Pi, the number of instructions of the latter is at least an order of magnitude large for nearly all of the benchmarks. The factor of increase is anywhere from $5\times$ to $10\times$, with some benchmarks differing by $20\times$.

Comparing optimization levels, we tend to see that O2 has the lowest instruction count, followed closely by O3 and O1. O0 usually has the largest instruction count, excepting anomalous benchmarks like blowfish and motion.

2 Conclusion

Differences between the two architectures make some amount of sense. Intel tends to have more complex instructions, where more can get done in fewer instructions. This means that the number of instructions in a compiled program will be smaller for the Intel architecture. This does not necessarily mean that the cycles per instruction will be higher compared to the Raspberry Pi, since the instructions may still be able to do more in a given cycle on an Intel chip.

Appendix A

Table 1: `adpcm-lab`

adpcm-lab	O0	O1	O2	O3
Average CPI	1.388889	1.470588	1.515152	1.470588
Instructions	551044	469071	475966	476500
Runtime(measured)	0.003100	0.003600	0.005000	0.003100
Runtime(calculated)	0.000334	0.000304	0.000318	0.000306
Function	filtep	filtez	upzero	decode

Table 2: `adpcm-rpi`

adpcm-pi	O0	O1	O2	O3
Average CPI	3.083000	3.277000	3.486000	3.581000
Instructions	2924522	2540038	2480426	2513706
Runtime(measured)	0.072200	0.066700	0.071900	0.071800
Runtime(calculated)	0.012879	0.011890	0.012352	0.012858
Function	filtep	filtez	upzero	decode

Table 3: `aes-lab`

aes-lab	O0	O1	O2	O3
Average CPI	1.449275	1.492537	1.470588	1.492537
Instructions	519030	460581	459693	457883
Runtime(measured)	0.003100	0.005200	0.005000	0.001600
Runtime(calculated)	0.000328	0.000300	0.000296	0.000294
Function	SubByte	ByteSub_ShiftRow	ByteSub_ShiftRow	AddRoundKey_InversMixColumn

Table 4: `aes-rpi`

aes-pi	O0	O1	O2	O3
Average CPI	3.595000	3.770000	3.769000	3.910000
Instructions	3006180	2998022	2863816	2991684
Runtime(measured)	0.086900	0.098100	0.079100	0.078600
Runtime(calculated)	0.015437	0.016147	0.015420	0.016710
Function	SubByte	ByteSub_ShiftRow	ByteSub_ShiftRow	AddRoundKey_InversMixColumn

Table 5: `blowfish-lab`

blowfish-lab	O0	O1	O2	O3
Average CPI	0.847458	1.052632	1.123596	1.123596
Instructions	1421892	916382	902083	900173
Runtime(measured)	0.003500	0.005200	0.005400	0.005700
Runtime(calculated)	0.000564	0.000421	0.000443	0.000441
Function	BF_encrypt	BF_encrypt	BF_encrypt	frame_dummy

Table 6: `blowfish-rpi`

blowfish-pi	O0	O1	O2	O3
Average CPI	2.194000	5.939000	2.579000	2.569000
Instructions	4366648	6315108	3468916	3431384
Runtime(measured)	0.404400	0.094800	0.075700	0.079000
Runtime(calculated)	0.013689	0.053575	0.012782	0.012594
Function	BF_encrypt	BF_encrypt	BF_encrypt	frame_dummy

Table 7: `dfadd-lab`

dfadd-lab	O0	O1	O2	O3
Average CPI	1.123596	1.219512	1.190476	1.190476
Instructions	891229	887069	882242	888228
Runtime(measured)	0.003500	0.005600	0.005200	0.004200
Runtime(calculated)	0.000440	0.000473	0.000459	0.000463
Function	extractFloat64Exp	float64_add		

Table 8: `dfadd-rpi`

dfadd-pi	O0	O1	O2	O3
Average CPI	3.438000	3.393000	3.440000	3.417000
Instructions	5318908	5141270	5203926	5139546
Runtime(measured)	0.205100	0.284200	0.200000	0.198000
Runtime(calculated)	0.026120	0.024924	0.025571	0.025090
Function	extractFloat64Exp	float64_add		

Table 9: `dfdiv-lab`

dfdiv-lab	O0	O1	O2	O3
Average CPI	1.470588	1.408451	1.449275	1.369863
Instructions	652036	640821	632685	641055
Runtime(measured)	0.003000	0.003700	0.005500	0.003900
Runtime(calculated)	0.000417	0.000393	0.000400	0.000384
Function	extractFloat64Exp	float64_add		

Table 10: `dfdiv-rpi`

dfdiv-pi	O0	O1	O2	O3
Average CPI	3.687000	3.745000	3.619000	3.582000
Instructions	4057570	4040362	3952460	3852100
Runtime(measured)	0.135400	0.147000	0.115500	0.135500
Runtime(calculated)	0.021374	0.021616	0.020434	0.019711
Function	extractFloat64Exp	float64_add		

Table 11: `dfmul-lab`

dfmul-lab	O0	O1	O2	O3
Average CPI	1.492537	1.470588	1.470588	1.408451
Instructions	625993	633416	621905	617514
Runtime(measured)	0.003400	0.005500	0.005600	0.005600
Runtime(calculated)	0.000409	0.000407	0.000402	0.000384
Function	extractFloat64Exp	float64_mul		

Table 12: `dfmul-rpi`

dfmul-pi	O0	O1	O2	O3
Average CPI	3.682000	3.665000	3.754000	3.626000
Instructions	3848648	3748184	3869184	3719028
Runtime(measured)	0.124000	0.137200	0.116800	0.134500
Runtime(calculated)	0.020243	0.019624	0.020749	0.019264
Function	extractFloat64Exp	float64_mul		

Table 13: `dfsin-lab`

dfsin-lab	O0	O1	O2	O3
Average CPI	1.111111	1.162791	1.176471	1.219512
Instructions	1053091	935737	872982	865661
Runtime(measured)	0.002900	0.003900	0.005700	0.005300
Runtime(calculated)	0.000515	0.000474	0.000452	0.000464
Function	extractFloat64Exp	roundAndPackFloat64	roundAndPackFloat64	roundAndPackFloat

Table 14: `dfsin-rpi`

dfsin-pi	O0	O1	O2	O3
Average CPI	3.135000	3.264000	3.474000	3.405000
Instructions	8037766	5783864	5878866	5659064
Runtime(measured)	0.318900	0.238600	0.217900	0.202400
Runtime(calculated)	0.035996	0.026967	0.029178	0.027523
Function	extractFloat64Exp	roundAndPackFloat64	roundAndPackFloat64	roundAndPackFloa

Table 15: `gsm-lab`

gsm-lab	O0	O1	O2	O3
Average CPI	1.724138	1.886792	1.785714	1.886792
Instructions	432128	406845	403525	401001
Runtime(measured)	0.003000	0.002800	0.005000	0.002200
Runtime(calculated)	0.000326	0.000364	0.000319	0.000335
Function	gsm_mult_r	gsm_mult_r	gsm_norm	Quantization_and_coding

Table 16: `gsm-rpi`

gsm-pi	O0	O1	O2	O3
Average CPI	3.351000	3.525000	3.578000	3.556000
Instructions	2403804	2338092	2294574	2310578
Runtime(measured)	0.072000	0.068900	0.066400	0.069600
Runtime(calculated)	0.011509	0.011774	0.011729	0.011737
Function	gsm_mult_r	gsm_mult_r	gsm_norm	Quantization_and_coding

Table 17: `jpeg-lab`

jpeg-lab	O0	O1	O2	O3
Average CPI	0.724638	0.735294	0.746269	0.840336
Instructions	4886159	2941714	2902746	2438334
Runtime(measured)	0.003000	0.006000	0.004300	0.005300
Runtime(calculated)	0.001546	0.000990	0.000948	0.000895
Function	buf_getv	buf_getb	buf_getb	decode_start

Table 18: `jpeg-rpi`

jpeg-pi	O0	O1	O2	O3
Average CPI	1.816000	2.055000	2.048000	2.444000
Instructions	18744012	22768700	12993626	10060694
Runtime(measured)	0.549800	0.406800	0.372400	0.301300
Runtime(calculated)	0.048615	0.066854	0.038008	0.035123
Function	buf_getv	buf_getb	buf_getb	decode_start

Table 19: `mips-lab`

mips-lab	O0	O1	O2	O3
Average CPI	1.818182	1.818182	1.754386	1.818182
Instructions	412839	413248	411227	412662
Runtime(measured)	0.003400	0.005600	0.002000	0.005000
Runtime(calculated)	0.000329	0.000362	0.000315	0.000380
Function				

Table 20: `mips-rpi`

mips-pi	O0	O1	O2	O3
Average CPI	3.533000	3.608000	3.552000	3.719000
Instructions	2306690	2258292	2235996	2365992
Runtime(measured)	0.072800	0.083100	0.062100	0.069800
Runtime(calculated)	0.011643	0.011641	0.011347	0.012570
Function				

Table 21: `motion-lab`

motion-lab	O0	O1	O2	O3
Average CPI	1.851852	1.851852	1.754386	1.785714
Instructions	415886	397004	403985	400830
Runtime(measured)	0.002400	0.004100	0.002800	0.005600
Runtime(calculated)	0.000341	0.000353	0.000312	0.000312
Function	Flush_Buffer	Flush_Buffer	Flush_Buffer	Flush_Buffer

Table 22: `motion-rpi`

motion-pi	O0	O1	O2	O3
Average CPI	3.392000	15.281000	3.615000	3.632000
Instructions	2215698	2452715	2228776	2245282
Runtime(measured)	0.416700	0.066400	0.078100	0.076500
Runtime(calculated)	0.010737	0.053541	0.011509	0.011649
Function	Flush_Buffer	Flush_Buffer	Flush_Buffer	Flush_Buffer

Table 23: `sha-lab`

sha-lab	O0	O1	O2	O3
Average CPI	0.869565	0.990099	0.909091	0.943396
Instructions	1658981	1015701	1030905	960325
Runtime(measured)	0.003800	0.003600	0.004900	0.004200
Runtime(calculated)	0.000630	0.000439	0.000410	0.000397
Function	local_memcpy	local_memcpy	sha_transform	sha_transform

Table 24: `sha-rpi`

sha-pi	O0	O1	O2	O3
Average CPI	2.021000	2.578000	2.589000	2.621000
Instructions	5739322	3423070	3491534	3342168
Runtime(measured)	0.109600	0.082200	0.086800	0.080300
Runtime(calculated)	0.016573	0.012605	0.012912	0.012514
Function	local_memcpy	local_memcpy	sha_transform	sha_transform