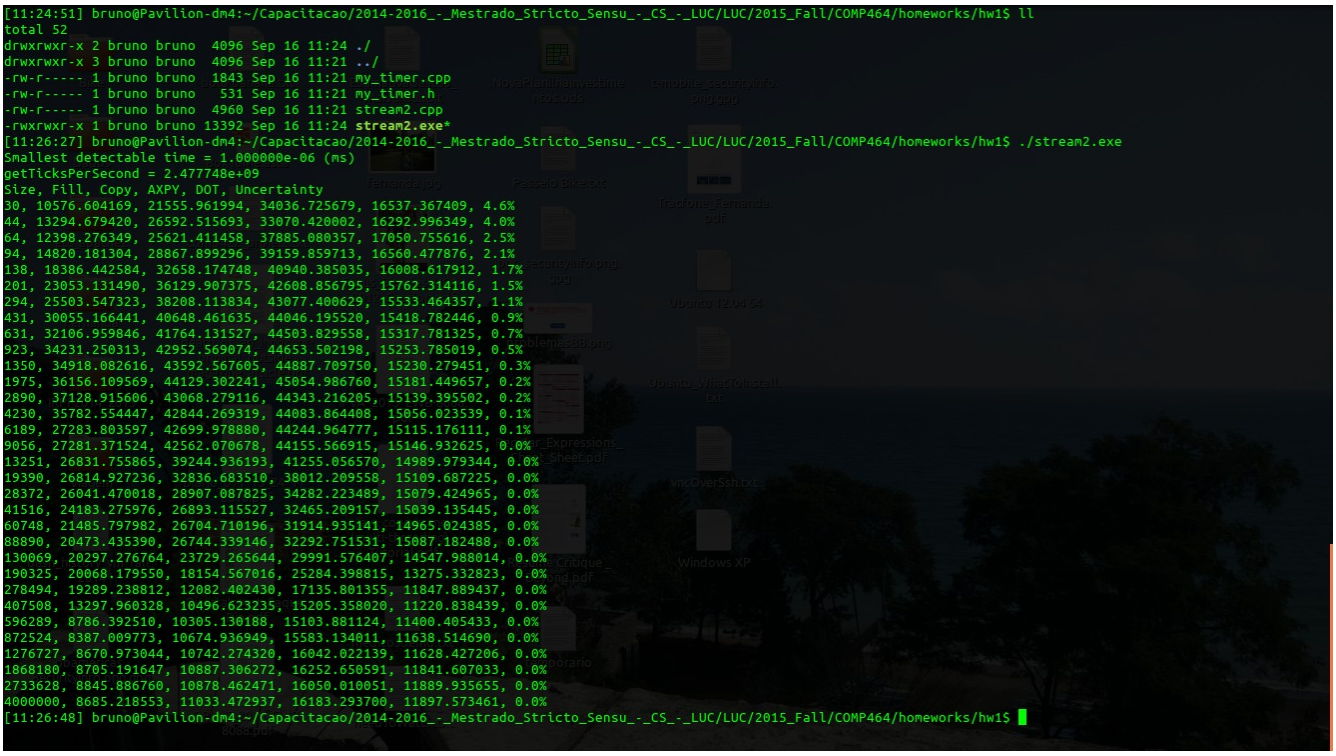
COMP 464 – Homework 1

Bruno Correa – bcorrea@luc.edu

Part 1

(1) Screen output:



(2) Machine properties:

CPU:
- Intel(R) Core(TM) i5-2430M CPU @ 2.40GHz
- Cache L1:
  - 2 x 32 KB 8-way set associative instruction caches
  - 2 x 32 KB 8-way set associative data caches
- Cache L2:
  - 2 x 256 KB 8-way set associative caches
- Cache L3:
  - 3072 KB 12-way set associative shared cache

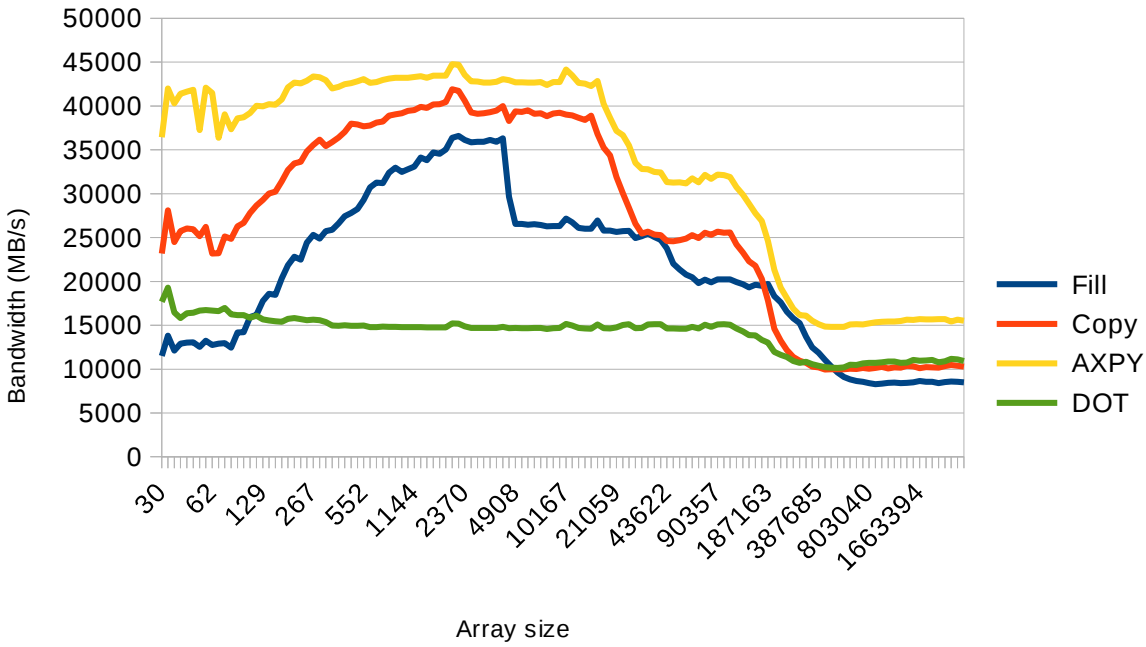
Main Memory:
- DDR3 – 1333 MHz – 2 x 4096 MB (8 GB Total)

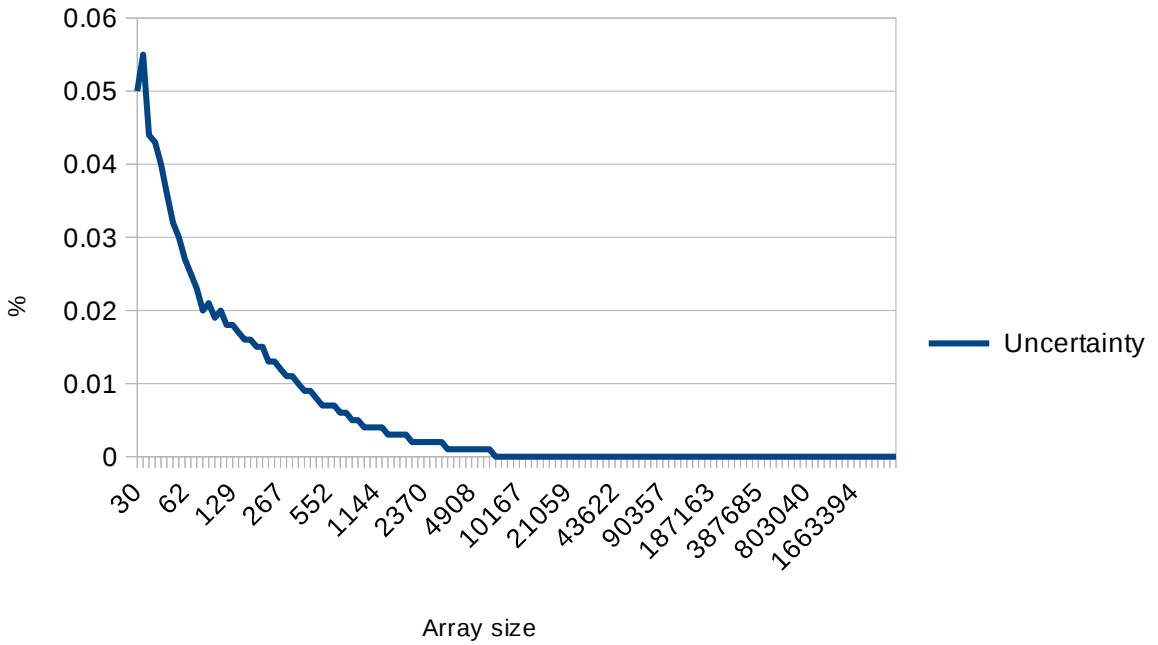
OS:
- Ubuntu 15.04 (vivid) x86_64 – kernel 3.19.0-28-generic

Compiler:
- g++ (Ubuntu 4.9.2-10ubuntu13) 4.9.2

Part 2

Plot the bandwidth for the four tests as a function of array size. Also plot the uncertainty. Write a brief summary of your results discussing the bandwidth as a function of size. Explain how you would predict where the bandwidth should change.





Considering the information gathered in the part 1 of the homework we can predict at which moment a drastic bandwidth change would happen. As learned in the previous classes, this change should happen when the data used cannot fit in the current memory cache level. Considering the fact that the size of each element of the array used in the benchmark is 8B, we can create the following table:

Cache Level	Size (KB)	# of array elements
L1	64	8192
L2	512	65536
L3	3072	393216

From the information shown in the table we could say, for instance, that a drastic change in the bandwidth would happen when the array size reach around 65536 elements. At this moment the array elements would not fit into the L2 cache level, forcing the use of L3 cache level that is slower than the previous one.

The chart shows that a drastic bandwidth drop happens for all four kernels when the array size reach around 150000 elements. At this moment the array probably cannot be fully contained in the L3 cache and therefore the use of ram memory starts, decreasing the bandwidth.

For some reason the values shown in the table and those seen in the graph does not accurately match. It could be a result of cpu optimizations or a misunderstanding of the problem by myself.

Data gathered

Size	Fill	Copy	AXPY	DOT	Uncertainty
30	11493.42759	23191.611696	36452.396069	17666.434376	0.05
33	13825.802142	28106.838119	41988.818458	19302.867518	0.055
36	12099.241324	24473.669372	40314.838895	16460.872136	0.044
39	12892.678018	25733.250478	41385.068281	15832.812879	0.043
43	13032.902925	26030.525684	41628.234592	16377.183882	0.04
47	13067.338444	25962.87207	41851.907036	16425.849561	0.036
52	12545.429643	25171.951472	37255.602005	16678.253619	0.032
57	13224.129623	26216.060296	42092.126841	16742.553123	0.03
62	12745.314901	23186.501535	41482.270777	16673.312976	0.027
68	12913.436663	23196.883035	36361.700121	16609.642499	0.025
75	12971.470354	25135.861937	39046.953277	16992.761513	0.023
82	12459.735183	24854.991164	37344.027657	16248.332911	0.02
89	14181.416437	26270.569971	38602.480052	16142.99546	0.021
98	14205.406691	26673.037911	38725.284187	16157.310406	0.019
107	15941.27785	27785.964822	39195.212361	15865.276556	0.02
118	16202.404827	28648.494041	40037.302523	16102.254577	0.018
129	17768.524447	29289.942053	39978.447212	15658.656369	0.018
141	18594.714877	30011.720671	40216.31969	15542.972766	0.017
154	18457.367726	30236.591765	40144.025416	15465.893814	0.016
169	20359.014228	31412.406145	40764.96909	15386.324331	0.016
185	21839.535412	32698.050367	42132.376419	15738.89977	0.015
203	22801.176301	33462.2674	42676.014346	15807.888624	0.015
222	22481.137116	33640.388009	42570.46505	15702.164842	0.013
243	24418.140446	34836.507208	42878.641839	15570.691198	0.013
267	25302.372916	35559.588802	43361.300635	15635.995021	0.012
292	24868.005508	36153.014251	43263.492676	15564.841512	0.011
320	25745.228856	35449.543148	42954.586505	15379.360688	0.011
350	25871.274408	35903.887165	42006.870705	14963.288133	0.01
384	26610.692848	36404.096759	42179.528728	14940.622558	0.009
420	27433.496899	37044.001806	42498.378101	14990.124192	0.009
460	27817.303189	37974.853301	42610.107861	14934.981692	0.008
504	28269.506589	37898.081642	42836.807405	14928.010603	0.007
552	29298.826973	37673.285259	43063.030027	14973.5482	0.007
605	30731.942706	37778.673245	42650.742413	14786.916483	0.007
663	31263.587866	38119.9904	42721.896998	14792.601437	0.006
726	31196.544516	38247.78007	42984.76153	14842.096787	0.006
795	32383.176614	38886.61549	43130.947548	14819.673388	0.005
871	32976.269312	39043.779946	43233.709105	14832.395484	0.005
954	32481.697321	39179.080068	43233.252843	14804.640492	0.004
1044	32788.35091	39452.847702	43221.148506	14780.191662	0.004
1144	33104.025543	39531.627213	43304.185609	14780.249638	0.004
1253	34139.335655	39921.936096	43383.919552	14782.333204	0.004
1372	33824.972601	39791.080125	43217.490459	14748.982593	0.003
1503	34714.802076	40180.005668	43450.93704	14753.297073	0.003
1646	34554.860338	40202.151815	43444.812115	14761.829308	0.003
1803	35038.814916	40462.725284	43453.670263	14752.178629	0.003
1975	36387.634244	41922.739554	44756.944851	15205.832847	0.002

2163	36599.95912	41727.73731	44718.009872	15169.156	0.002
2370	36122.312335	40610.100594	43539.004827	14889.961831	0.002
2595	35862.542582	39268.066632	42808.576982	14682.708413	0.002
2843	35925.51476	39111.286342	42785.471473	14699.931294	0.002
3114	35929.88445	39180.71862	42655.534265	14680.002718	0.002
3410	36141.706945	39293.267713	42668.963248	14682.351019	0.001
3735	35916.622111	39463.676821	42764.746277	14699.678969	0.001
4091	36328.98663	39983.942381	43071.515836	14811.65883	0.001
4481	29645.07524	38287.249158	42947.056508	14672.859628	0.001
4908	26563.918647	39389.616156	42689.851206	14698.004138	0.001
5376	26541.012759	39315.979738	42692.864666	14666.409224	0.001
5888	26459.09067	39506.107071	42655.733002	14671.524994	0.001
6449	26516.264424	39110.339651	42669.230247	14680.011784	0.001
7064	26440.051616	39184.975359	42720.877475	14692.369808	0
7737	26291.147566	38848.13314	42401.128948	14566.869597	0
8475	26310.492093	39139.123882	42715.849666	14664.079237	0
9282	26301.042168	39235.63144	42713.666048	14699.236904	0
10167	27166.27506	39004.685695	44149.917322	15165.629484	0
11136	26722.867792	38925.088124	43507.495319	14981.390617	0
12197	26104.118537	38667.704793	42651.903461	14684.128305	0
13359	26020.897437	38426.203447	42536.117328	14643.645943	0
14632	26001.433239	38905.819264	42271.739715	14597.949747	0
16027	26942.515041	36792.822793	42849.340682	15086.680163	0
17554	25808.352865	35255.8744	40243.240578	14672.476587	0
19227	25789.066561	34366.92097	38663.288177	14640.420995	0
21059	25637.407398	31908.840723	37161.566933	14741.782218	0
23066	25725.81963	30053.409107	36689.181907	15027.049775	0
25264	25760.977045	28389.322995	35490.394885	15113.005831	0
27672	24961.348301	26596.379296	33520.702003	14654.609647	0
30309	25156.084074	25454.613917	32813.516974	14690.279323	0
33198	25455.270178	25664.125864	32802.481481	15073.827257	0
36361	25076.266747	25341.994195	32490.255897	15124.248446	0
39826	24733.217882	25294.607738	32429.007437	15137.611682	0
43622	23751.010993	24621.151015	31330.202544	14640.474906	0
47779	22022.123702	24590.009892	31272.670615	14629.754083	0
52332	21341.334267	24692.465853	31302.43006	14614.58176	0
57319	20774.141988	24877.349835	31189.626846	14603.921949	0
62782	20484.837712	25279.423279	31749.145036	14819.413814	0
68765	19815.011219	24949.070021	31293.732608	14625.730103	0
75318	20205.795212	25568.503729	32159.798148	15053.904867	0
82495	19891.274762	25312.796932	31704.51318	14831.627075	0
90357	20217.142808	25659.068643	32180.298862	15103.720593	0
98968	20216.705595	25556.277729	32117.369584	15108.651416	0
108399	20232.16838	25581.020301	31915.792278	15056.972424	0
118730	19935.485989	24209.390921	30754.762542	14648.036391	0
130044	19683.092812	23303.207923	29888.528805	14294.386248	0
142437	19319.265173	22314.821848	28872.031638	13886.891999	0
156011	19613.961049	21772.158798	27775.939493	13849.56254	0
170879	19506.475555	20305.07175	26892.743116	13342.79236	0
187163	19716.676832	17835.43368	24597.83678	13020.476071	0
204999	18325.408944	14607.596843	21326.761447	11962.064068	0
224535	17608.606253	13232.457814	19281.929495	11624.150366	0
245933	16551.879965	12155.268353	18117.218652	11397.958303	0

269370	15793.273251	11385.528699	16889.241615	10935.849548	0
295041	15235.661135	10959.706363	16163.817285	10697.408379	0
323157	13684.100284	10701.216332	16097.978082	10842.857151	0
353954	12464.251763	10297.726399	15528.17864	10563.405247	0
387685	11881.630658	10194.331171	15120.40171	10388.9858	0
424630	11064.089596	9955.889771	14835.917134	10229.645339	0
465097	10314.770051	9988.283415	14830.817154	10175.838638	0
509419	9612.561919	9996.449938	14824.72878	10137.34099	0
557966	9106.301867	9976.673088	14809.315133	10211.865815	0
611139	8819.863776	10031.90078	15074.455521	10491.062556	0
669379	8631.651125	10020.59814	15108.489187	10489.216507	0
733170	8556.986838	10142.757978	15096.672437	10659.226358	0
803040	8403.64035	10027.084727	15211.250873	10696.245126	0
879568	8279.297231	10152.413134	15331.945969	10711.047454	0
963389	8359.379411	10251.855781	15385.032086	10760.027312	0
1055198	8425.994795	10077.171548	15433.335908	10850.261439	0
1155756	8471.427475	10187.557536	15427.848482	10865.861693	0
1265897	8410.740817	10162.946966	15479.233731	10704.225818	0
1386534	8429.623206	10364.243043	15630.400722	10754.791918	0
1518668	8496.504686	10313.818393	15609.565499	11033.472234	0
1663394	8627.462682	10106.943565	15693.608435	10956.013972	0
1821912	8559.522265	10215.621299	15682.031028	10974.816098	0
1995537	8547.067814	10209.947085	15661.910558	11034.086566	0
2185707	8388.262856	10170.399371	15693.237003	10787.771835	0
2394001	8515.037642	10335.954599	15698.6676	10904.053742	0
2622144	8567.217389	10466.922829	15434.876975	11172.037771	0
2872029	8546.841638	10363.777668	15654.888034	11090.360295	0
3145728	8489.019805	10278.092177	15512.609963	10940.689336	0