ECE 3056 Project 2 Report

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Contents

1 Cache Data structure

1.1 Cache Directory Structure

The data structure implemented for cache directory is a 2D dynamically allocated struct array. The struct is a three integer struct that contains the tag, valid and dirty information for one single cache line. The number of rows in the array is defined by the number of cache lines in every associative set. The number of columns is defined by the number of associative set. Valid and Dirty value are initialized to be 0 and tag value initialized to -1.

1.2 LRU Stack

The implementation of LRU stack is built on top of another 2D array. The number of row and column of the 2D array is also defined by the number of cache lines in every set and the set number respectively. Every row of LRU is a stack, with value in index 0 to be the least recently used memory index in cache and value stored in right most location to be the most recently used.

When updating the LRU (no write back) with index i in cache. The program would traverse the LRU stack at the corresponding line, find index i, shift the array and place index i in the rightmost spot. When a write back action is required, the LRU stack would return value stored at index 0 to its caller, stating that the memory located at this value location is the least recently used. The LRU stack would then shift leftwards by one position and place the returned value at most recently used spot.

2 Cache Configuration Plots

2.1 Miss rate vs Line Size

Line size from 32 byte to 512 byte, fixed associativity of 4. See Figure 1, 2, 3 and 4, at the end of docuemnt.

2.2 Miss Rates under Best Configuration

The assignment asks to compute the miss rates using the best overall configuration that minimizes the **sum of the overall miss rate across all traces**. Overall miss rate is calculated by $1 - \Sigma Hits_{Traces} \setminus \Sigma Access_{traces}$. The resulting configuration is Way count = 8, Block Size = 512. The computation of miss rates can be seen in Table 1. trace.stream1M and trace.random64k has N/A values for Write miss since it only contains read instructions and no write.

Trace Name	Overall Miss	Read Miss	Write Miss
trace.stream1M	0.7812%	0.7812%	N/A
trace.random64k	50.0915%	50.0915%	N/A
trace.merge	0.1976%	0.2102%	0.1247%
trace.bubble	0.1845%	0.1926%	0.1145%

Table 1: Overall, write & read miss rate for all traces with minimum overall sum miss rate.

2.3 Writeback Traffic

The configuration is the same as 2.2. trace.stream1M and trace.random64k have 0 writeback traffic since there's no write instruction that invoke these actions.

Trace Name	Writeback Traffic
trace.stream1M	0
trace.random64k	0
trace.merge	1744896
trace.bubble	1166336

Table 2: Write back traffic for all traces in bytes.

2.4 Total Memory Access Volume

Minimum sum memory access is Way count = 8, Block size = 32 byte.

Trace Name	Memory Access	Memory Referenced	Amount saved
trace.stream1M	1048576	8388608	7340032
trace.random64k	4203680	8388608	4184928
trace.merge	1296320	245709760	244413440
trace.bubble	718208	202314976	201596768

Table 3: Memory accessed and referenced for all traces in bytes

Compared to total referenced memory, using cache greatly saved the number of memory access count and reduces the time for instructions. The lower the miss rate, the higher the amount of memory saved from accessing the memory by having the cache.

3 Plot for Miss rates and Data Calculation of Best Configuration

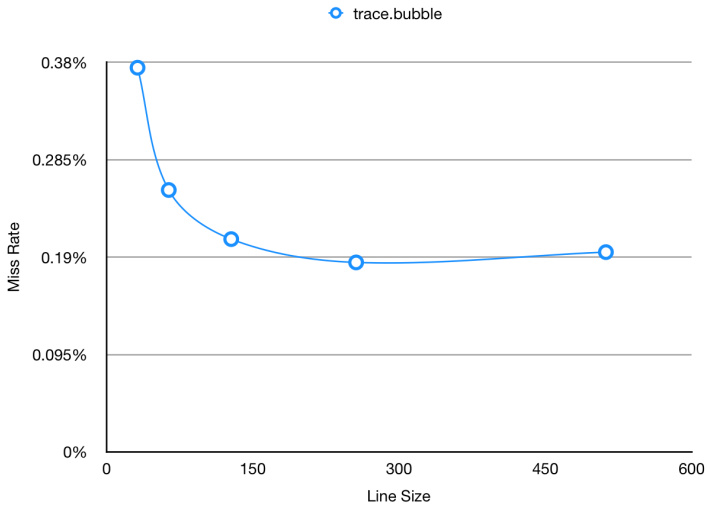


Figure 1: Miss rate vs Line size for trace.bubble test case

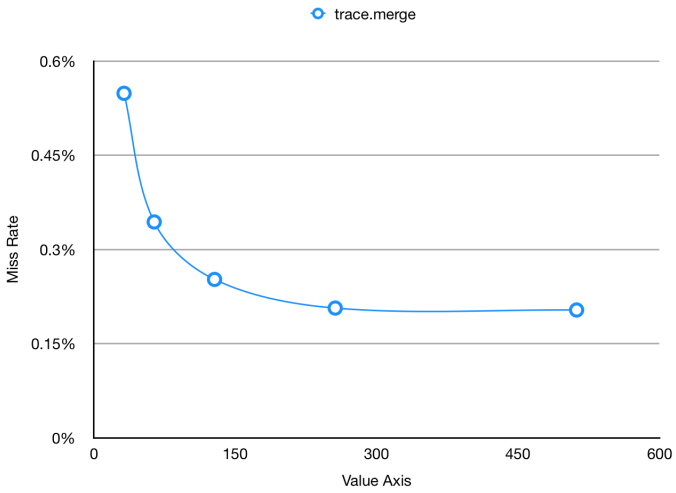


Figure 2: Miss rate vs Line size for trace.merge test case

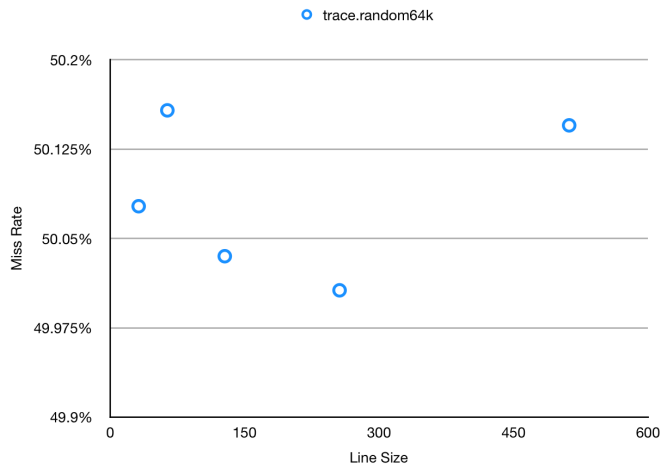


Figure 3: Miss rate vs Line size for trace.random64k test case

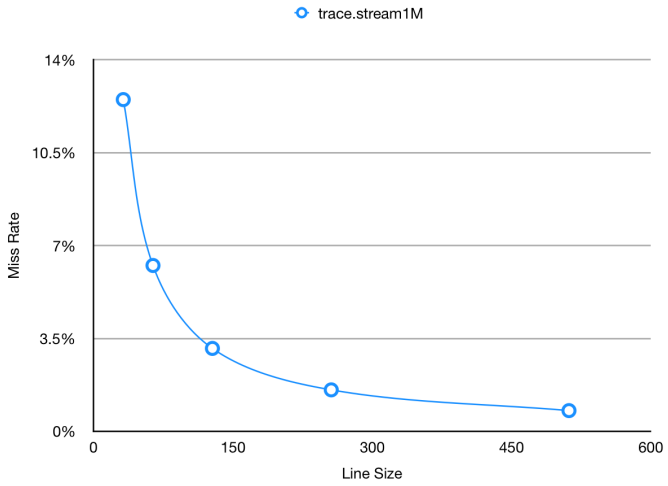
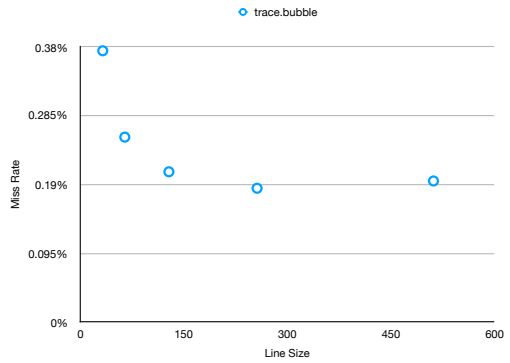
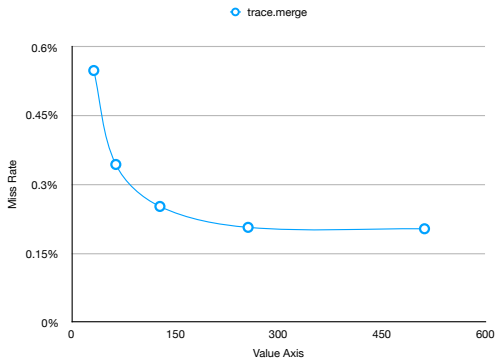


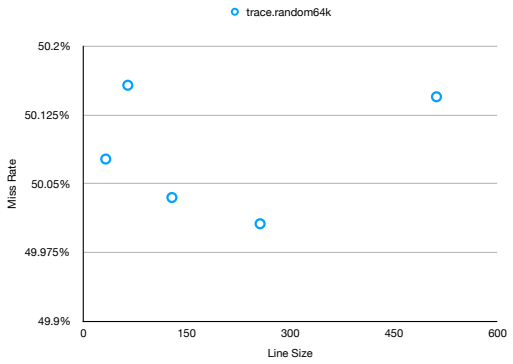
Figure 4: Miss rate vs Line size for trace.stream1M test case

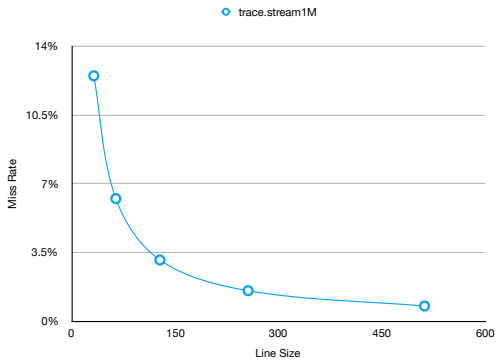
Table for Question 1

	Block Size	Cache Size	Ways Count	Access Count	Read Access	Write Access	Total Hits	Read Hits	Write Hits	Writeback traffic	Total Access Volume	Miss rate, in percentage
trace.bubble	32	64000	4	6322343	5666010	656333	6298650	5649037	649613	245152	758176	0.374750310130278%
trace.bubble	64	64000	4	6322343	5666010	656333	6306191	5653394	652797	303936	1033728	0.2554749085900059%
trace.bubble	128	64000	4	6322343	5666010	656333	6309218	5654842	654376	423424	1680000	0.207597088610978%
trace.bubble	256	64000	4	6322343	5666010	656333	6310655	5655486	655169	653312	2992128	0.184868173080766%
trace.bubble	512	64000	4	6322343	5666010	656333	6310020	5654467	655553	1213440	6309376	0.194911917939278%
trace.merge	32	64000	4	7678430	6544752	1133678	7636301	6516507	1119794	554368	1348128	0.548666849863844%
trace.merge	64	64000	4	7678430	6544752	1133678	7652035	6525615	1126420	630080	1689280	0.343755168699855%
trace.merge	128	64000	4	7678430	6544752	1133678	7659065	6529331	1129734	779264	2478720	0.252199994009195%
trace.merge	256	64000	4	7678430	6544752	1133678	7662567	6531124	1131443	1063424	4060928	0.206591712107818%
trace.merge	512	64000	4	7678430	6544752	1133678	7662804	6530502	1132302	1773568	8000512	0.203505143629623%
trace.random64k	32	64000	4	262144	262144	0	130870	130870	0	0	4200768	50.07705688847656%
trace.random64k	64	64000	4	262144	262144	0	130659	130659	0	0	8415040	50.1575469970703%
trace.random64k	128	64000	4	262144	262144	0	130980	130980	0	0	16788992	50.0350952148438%
trace.random64k	256	64000	4	262144	262144	0	131055	131055	0	0	33558784	50.0064849853516%
trace.random64k	512	64000	4	262144	262144	0	130692	130692	0	0	67303424	50.1449584960938%
trace.stream1M	32	64000	4	262144	262144	0	229376	229376	0	0	1048576	12.5%
trace.stream1M	64	64000	4	262144	262144	0	245760	245760	0	0	1048576	6.25%
trace.stream1M	128	64000	4	262144	262144	0	253952	253952	0	0	1048576	3.125%
trace.stream1M	256	64000	4	262144	262144	0	258048	258048	0	0	1048576	1.5625%
trace.stream1M	512	64000	4	262144	262144	0	260096	260096	0	0	1048576	0.78125%









Best Configuration Marked in Green

Table for Question 2 to 4

	Block Size	Cache Size	Ways Count	Access Count	Memory Referenced	Read Access	Write Access	Total Hits	Read Hits	Write Hits	Writeback traffic	Total Access Volume	Overall Miss	Read Miss	Write Miss	Overall miss rate =	Total Memory Access	Total Memory referenced	
trace.stream1M	32	64000	2	262144	8388608	262144	0	229376	229376	0	0	1048576	12.5%	12.5%		1.619290962013 86%	7526496	464801952	
trace.random64k	32	64000	2	262144	8388608	262144	0	130951	130951	0	0	4198176	50.0461578369141%	50.0461578369141%					
trace.merge	32	64000	2	7678430	245709760	6544752	1133678	7633371	6513841	1119530	576448	1441888	0.586825692231352%	0.472302082645759%	1.24797341043939 3%				
trace.bubble	32	64000	2	6322343	202314976	5666010	656333	6296160	5646620	649540	256512	837856	0.414134443512482%	0.342216127398287%	1.03499290756369 %				
trace.stream1M	32	64000	4	262144	8388608	262144	0	229376	229376	0	0	1048576	12.5%	12.5%		1.582533801407 1%	7355648	464801952	
trace.random64k	32	64000	4	262144	8388608	262144	0	130870	130870	0	0	4200768	50.07705688476 56%	50.07705688476 56%					
trace.merge	32	64000	4	7678430	245709760	6544752	1133678	7636301	6516507	1119794	554368	1348128	0.548666849863844%	0.431567154874624%	1.22468637479073 %				
trace.bubble	32	64000	4	6322343	202314976	5666010	656333	6298650	5649037	649613	245152	758176	0.374750310130278%	0.299558242925801%	1.02387050475902 %				
trace.stream1M	32	64000	8	262144	8388608	262144	0	229376	229376	0	0	1048576	12.5%	12.5%		1.563415120941 66%	7266784	464801952	
trace.random64k	32	64000	8	262144	8388608	262144	0	130779	130779	0	0	4203680	50.11177062988 28%	50.11177062988 28%					
trace.merge	32	64000	8	7678430	245709760	6544752	1133678	7637920	6518162	1119758	543456	1296320	0.527581810344047%	0.406279718467562%	1.22786187965189 %				
trace.bubble	32	64000	8	6322343	202314976	5666010	656333	6299899	5650202	649697	241504	718208	0.354994975755 03%	0.278997036715434%	1.01107212344953 %				
trace.stream1M	64	64000	2	262144	16777216	262144	0	245760	245760	0	0	1048576	6.25%	6.25%		1.347216373136 06%	12523776	929603904	
trace.random64k	64	64000	2	262144	16777216	262144	0	130649	130649	0	0	8415680	50.1613616943359%	50.1613616943359%					
trace.merge	64	64000	2	7678430	491419520	6544752	1133678	7649009	6522862	1126147	674560	1882944	0.383164266653468%	0.334466454955051%	0.66429797526281 8%				
trace.bubble	64	64000	2	6322343	404629952	5666010	656333	6303959	5651251	652708	323712	1176576	0.290778276344705%	0.260483126574085%	0.55231109817729 4%				
trace.stream1M	64	64000	4	262144	16777216	262144	0	245760	245760	0	0	1048576	6.25%	6.25%		1.310948022868 89%	12186624	929603904	
trace.random64k	64	64000	4	262144	16777216	262144	0	130659	130659	0	0	8415040	50.1575469970703%	50.1575469970703%					
trace.merge	64	64000	4	7678430	491419520	6544752	1133678	7652035	6525615	1126420	630080	1689280	0.343755168699855%	0.292402217838 05%	0.64021706339895 1%				
trace.bubble	64	64000	4	6322343	404629952	5666010	656333	6306191	5653394	652797	303936	1033728	0.255474908590059%	0.222661096609433%	0.53875090845653 1%				
trace.stream1M	64	64000	8	262144	16777216	262144	0	245760	245760	0	0	1048576	6.25%	6.25%		1.292125382468 28%	12011648	929603904	
trace.random64k	64	64000	8	262144	16777216	262144	0	130613	130613	0	0	8417984	50.1750946044922%	50.1750946044922%					
trace.merge	64	64000	8	7678430	491419520	6544752	1133678	7653622	6527182	1126440	611776	1587712	0.323086881042089%	0.268459370194618%	0.63845289403163 8%				
trace.bubble	64	64000	8	6322343	404629952	5666010	656333	6307384	5654526	652858	291584	957376	0.236605321792882%	0.202682310832492%	0.52945684583892 7%				
trace.stream1M	128	64000	2	262144	33554432	262144	0	253952	253952	0	0	1048576	3.125%	3.125%		1.219574912628 6%	22674432	1859207808	
trace.random64k	128	64000	2	262144	33554432	262144	0	130955	130955	0	0	16792192	50.0446319580078%	50.0446319580078%					
trace.merge	128	64000	2	7678430	982839040	6544752	1133678	7655875	6526601	1129274	900864	2887040	0.293744945255736%	0.277336711918186%	0.38847009468296 9%				
trace.bubble	128	64000	2	6322343	809259904	5666010	656333	6307135	5652894	654241	471680	1946624	0.240543735131105%	0.231485648631047%	0.31874063929147 %				
trace.stream1M	128	64000	4	262144	33554432	262144	0	253952	253952	0	0	1048576	3.125%	3.125%		1.183100022781 31%	21996288	1859207808	
trace.random64k	128	64000	4	262144	33554432	262144	0	130980	130980	0	0	16788992	50.0350952148438%	50.0350952148438%					
trace.merge	128	64000	4	7678430	982839040	6544752	1133678	7659065	6529331	1129734	779264	2478720	0.252199994009195%	0.235623901409865%	0.34789419923479 %				
trace.bubble	128	64000	4	6322343	809259904	5666010	656333	6309218	5654842	654376	423424	1680000	0.207597088610978%	0.197105193954827%	0.29817181217460 8%				
trace.stream1M	128	64000	8	262144	33554432	262144	0	253952	253952	0	0	1048576	3.125%	3.125%		1.159547625996 2%	21558400	1859207808	
trace.random64k	128	64000	8	262144	33554432	262144	0	130825	130825	0	0	16808832	50.0942230224609%	50.0942230224609%					
trace.merge	128	64000	8	7678430	982839040	6544752	1133678	7660994	6531214	1129780	745856	2231808	0.227077670825937%	0.206852757751552%	0.34383660968987 4%				
trace.bubble	128	64000	8	6322343	809259904	5666010	656333	6310865	5656438	654427	394112	1469184	0.181546619662998%	0.168937223901833%	0.29040136637956 7%				
trace.stream1M	256	64000	2	262144	67108864	262144	0	258048	258048	0	0	1048576	1.5625%	1.5625%		1.167141397891 55%	43399168	3718415616	
trace.random64k	256	64000	2	262144	67108864	262144	0	130866	130866	0	0	33607168	50.0785827636719%	50.0785827636719%					
trace.merge	256	64000	2	7678430	1965678080	6544752	1133678	7658019	6527411	1130608	1402880	5225216	0.265822570499441%	0.264960383525614%	0.27079999788299 8%				
trace.bubble	256	64000	2	6322343	1618519808	5666010	656333	6308600	5653559	655041	737536	3518208	0.217371945811862%	0.219748994422393%	0.19685129347449 8%				
trace.stream1M	256	64000	4	262144	67108864	262144	0	258048	258048	0	0	1048576	1.5625%	1.5625%		1.120380836954 84%	41660416	3718415616	
trace.random64k	256	64000	4	262144	67108864	262144	0	131055	131055	0	0	33558784	50.0064849853516%	50.0064849853516%					
trace.merge	256	64000	4	7678430	1965678080	6544752	1133678	7662567	6531124	1131443	1063424	4060928	0.206591712107818%	0.208227905350733%	0.19714592679755 9%				
trace.bubble	256	64000	4	6322343	1618519808	5666010	656333	6310655	5655486	655169	653312	2992128	0.184868173080766%	0.185739170950983%	0.17734899814574 5%				
trace.stream1M	256	64000	8	262144	67108864	262144	0	258048	258048	0	0	1048576	1.5625%	1.5625%		1.103781939366 72%	41043200	3718415616	
trace.random64k	256	64000	8	262144	67108864	262144	0	131107	131107	0	0	33545472	49.9866485595703%	49.9866485595703%					
trace.merge	256	64000	8	7678430	1965678080	6544752	1133678	7663884	6532440	1131444	1021440	3723776	0.189439768285959%	0.188120191567231%	0.19705771832918 6%				
trace.bubble	256	64000	8	6322343	1618519808	5666010	656333	6311697	5656494	655203	610816	2725376	0.168386941360188%	0.167948874075408%	0.17216870094906 %				
trace.stream1M	512	64000	2	262144	134217728	262144	0	260096	260096	0	0	1048576	0.78125%	0.78125%		1.168704214047 71%	86914560	7436831232	
trace.random64k	512	64000	2	262144	134217728	262144	0	130834	130834	0	0	67230720	50.0907897949219%	50.0907897949219%					
trace.merge	512	64000	2	7678430	3931356160	6544752	1133678	7656393	6525859	1130534	2829312	11282944	0.286998774489056%	0.288674039902503%	0.27732742454206 2%				
trace.bubble	512	64000	2	6322343	3237039616	5666010	656333	6307983	5652605	655378	1452032	7352320	0.227130986091706%	0.236586239699543%	0.14550540655429 2%				
trace.stream1M	512	64000	4	262144	134217728	262144	0	260096	260096	0	0	1048576	0.78125%	0.78125%		1.111520289868 15%	82661888	7436831232	
trace.random64k	512	64000	4	262144	134217728	262144	0	130692	130692	0	0	67303424	50.1449584960938%	50.1449584960938%					
trace.merge	512	64000	4	7678430	3931356160	6544752	1133678	7662804	6530502	1132302	1773568	8000512	0.203505143629623%	0.217731703202806%	0.12137485247133 4%				
trace.bubble	512	64000	4	6322343	3237039616	5666010	656333	6310020	5654467	655553	1213440	6309376	0.194911917939278%	0.203723607971 04%	0.11884211215953 4%				
trace.stream1M	512	64000	8	262144	134217728	262144	0	260096	260096	0	0	1048576	0.78125%	0.78125%		1.102962665698 96%	82025472	7436831232	
trace.random64k	512	64000	8	262144	134217728	262144	0	130832	130832	0	0	67231744	50.0915527343 75%	50.0915527343 75%					
trace.merge	512	64000	8	7678430	3931356160	6544752	1133678	7663253	6530989	1132264	1744896	7770624	0.197657594065459%	0.210290626749499%	0.12472677426923 5%				
trace.bubble	512	64000	8	6322343	3237039616	5666010	656333	6310674	5655093	655581	1166336	5974528	0.184567651581069%	0.192675268839981%	0.11457598505636 4%				