OLAP DMBSs Analysis

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1 Introduction

However due to the increasing use of databases in industry, there is also an increasing need for standards to compare databases. In this report we aim to monitor and study some of the most known databases of OLAP useing TPC-H benchmark

2 Configuration

2.1 Sofware

- Docker: 18.06.1-ce, build e68fc7a
- Postgres: 11.1 (Debian 11.1-1.pgdg90+1)
- HDFS: v1.2.1
- Spark: v2.3.0
- OS: Ubuntu 16.04.1 LTS GNU/Linux 4.4.0-141-generic
- Java: openjdk 1.8.0_191
- Python: v3.5.2
- Dstat: 0.7.3

2.2 Hardware

- CPU: Intel(R) Xeon(R) E5530 @ 2.40GHz
- RAM: 40 GB, DIMM DDR3 Synchronous 1333 MHz (0.8 ns) (+ 39GiB Linux swap / Solaris partition)
- Storage: 3725GiB SCSI Disk 15000 RPM

3 Performance Test

TPC-H decision support benchmark was used, In order for the results to be comparable and to be used in standard analysis.
In each performance test we measure and compare these parameters:

- CPU usage: measured in percent of all core usage (which is equal to the sum user usage and waited tasks)
- CPU load: number of tasks in queue of CPU.
- CPU context switches and interrupt: A consistent parameter to measure dbms DBMS batch it's tasks.
- Memory: RAM usage plus Swap reserved by all process in system.
- Disk: bytes read or write from hard disk when DBMS is under the test.
- Execution Time: Total amount of running and returning result from DMBS to terminals which is measured in seconds.

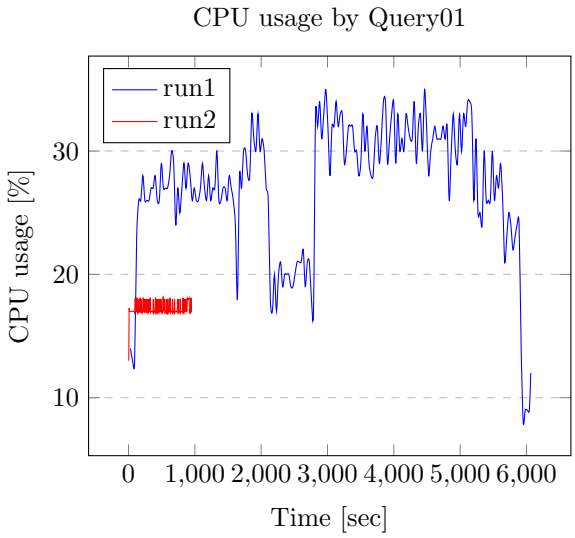
Note that every test was ran on a single node so that the network won't effect the results.
TPC-H was applied benchmark to Postgres and spark. Spark was tested with HDFS and avro, parquet and orc file systems.
All tests has ran twice and compared for each run.
Scale factor for generating data was 100. Out benchmark test skipped power test and refresh function test.

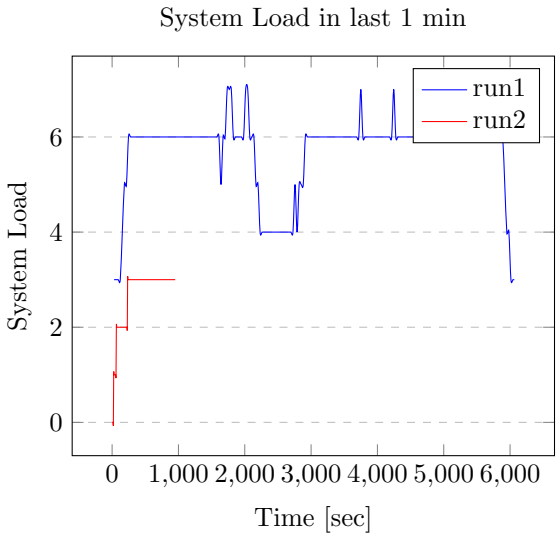
4 Postgres results

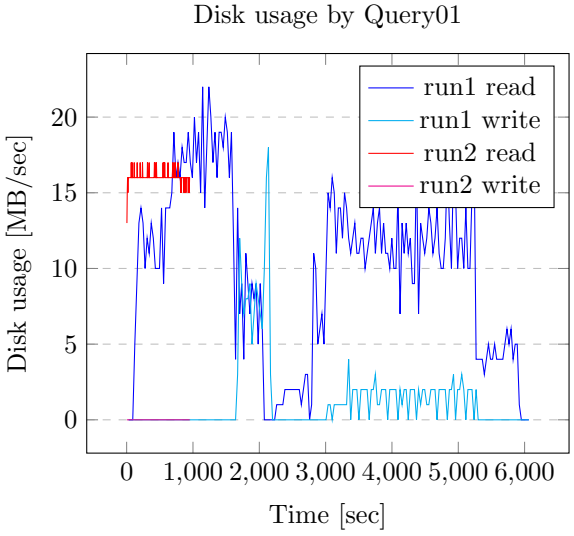
Postgres were ran on single node without cluster and shm size set to 512MB.
Results of the first and the second run in postgres test has much diffrence with each other. Sometimes second run ends in $\frac{1}{6}$ first run and somtime viceversa. Also in some tests it seemed DBMS slow down itself and every measured parametes gets down for a while. It seemed envirment parameters are very effective on this DBMS.
Creating tables and loading all data (scale factor was 100) takes 13227 seconds.

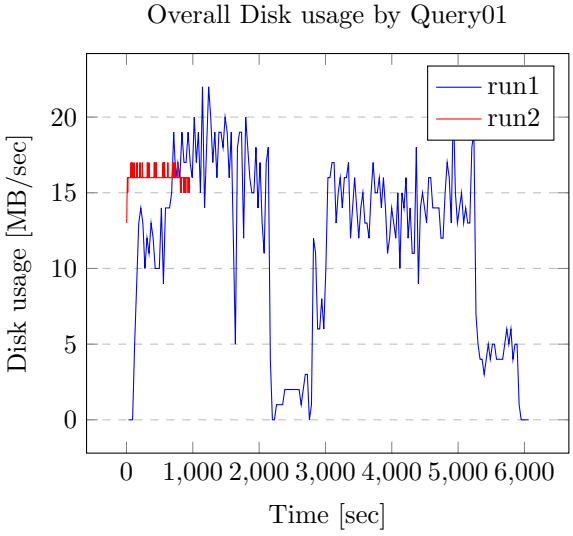
Load	Memory	Disk IO	Execution Time
6.20	37415.77 MB	11.96 MB/sec	3508.50 sec

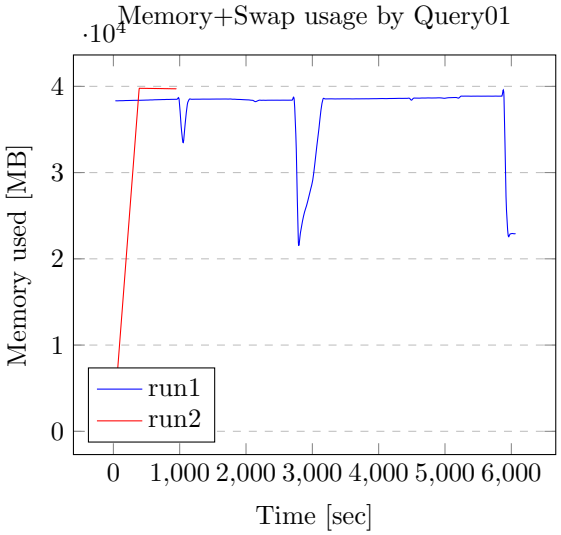
Table 1: Average Parametes over Runtime for Query01

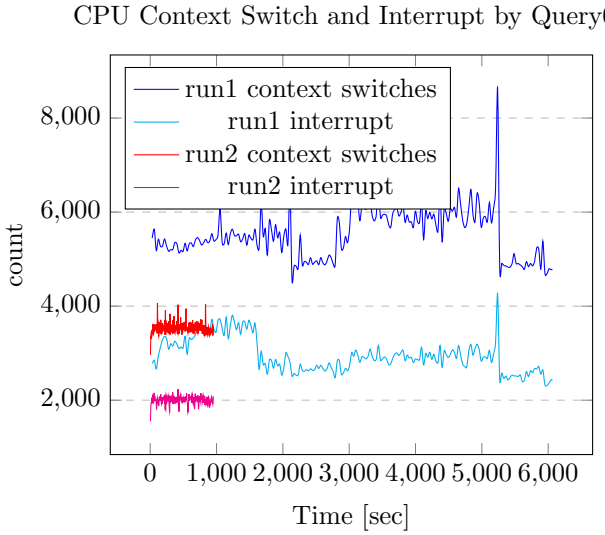






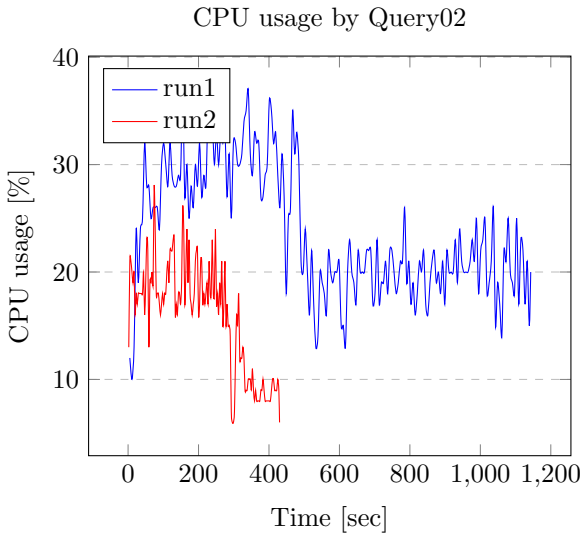


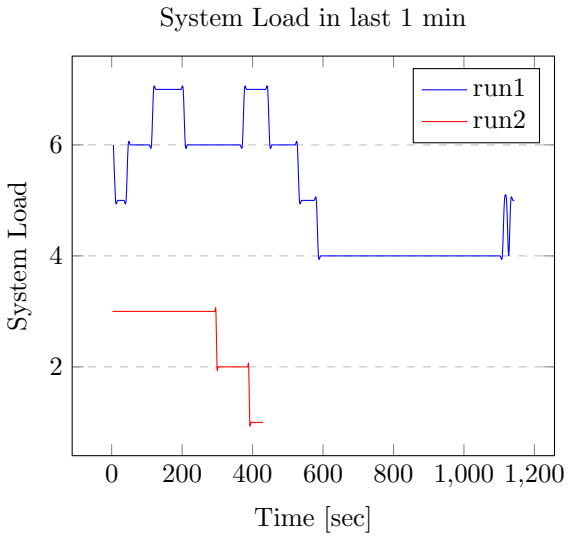


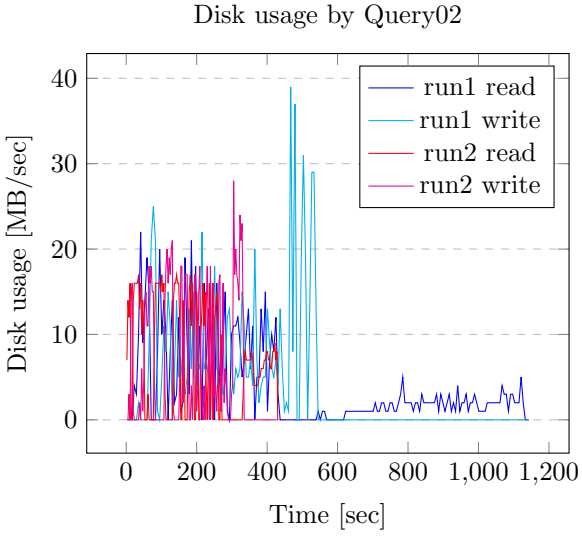


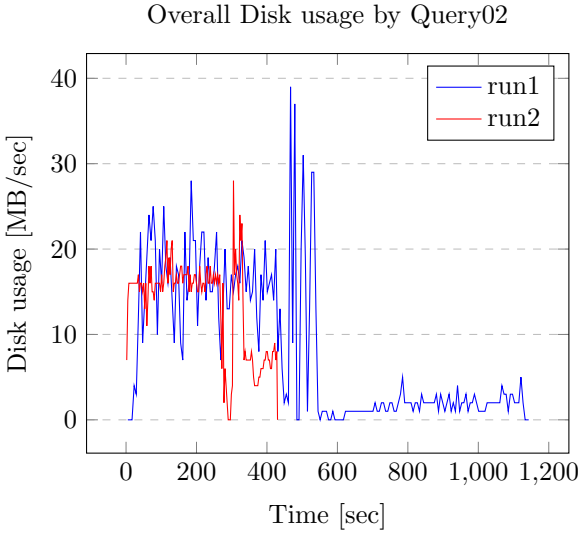
Load	Memory	Disk IO	Execution Time
5.68	38404.04 MB	8.56 MB/sec	787.50 sec

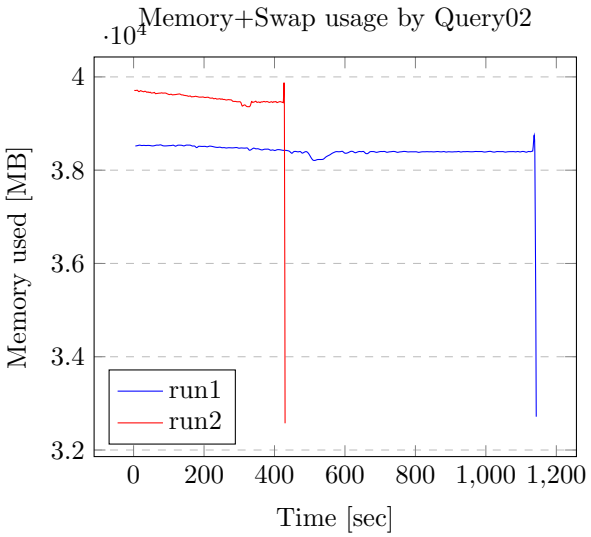
Table 2: Average Parametes over Runtime for Query02

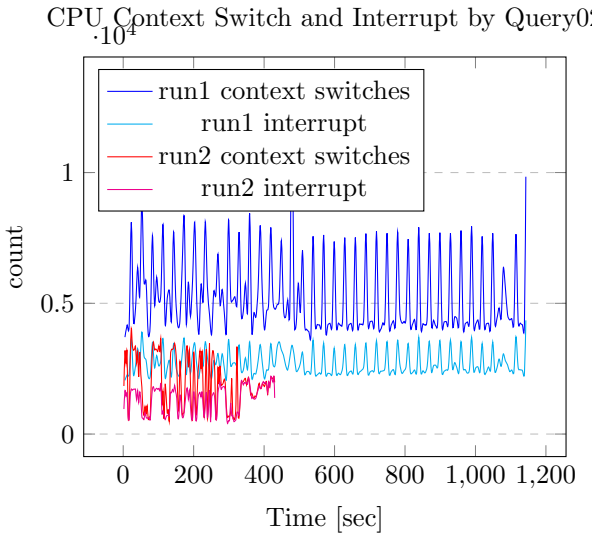






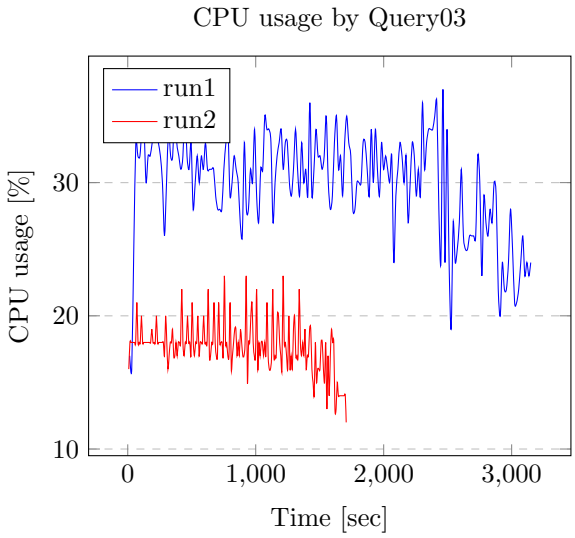


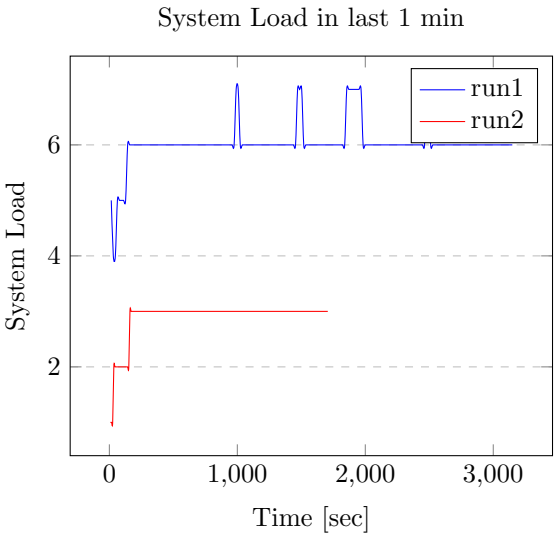


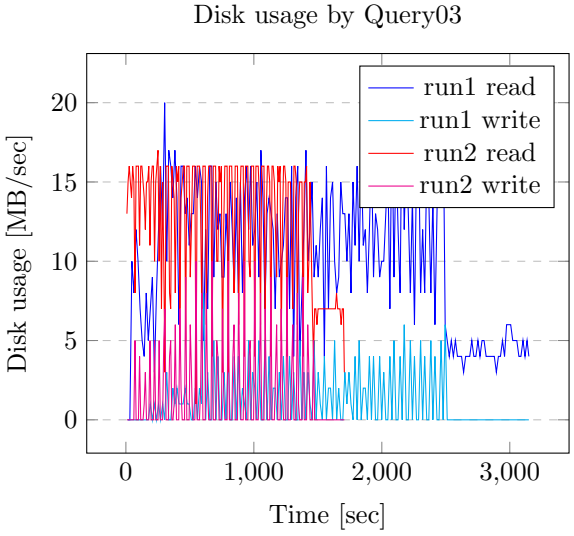


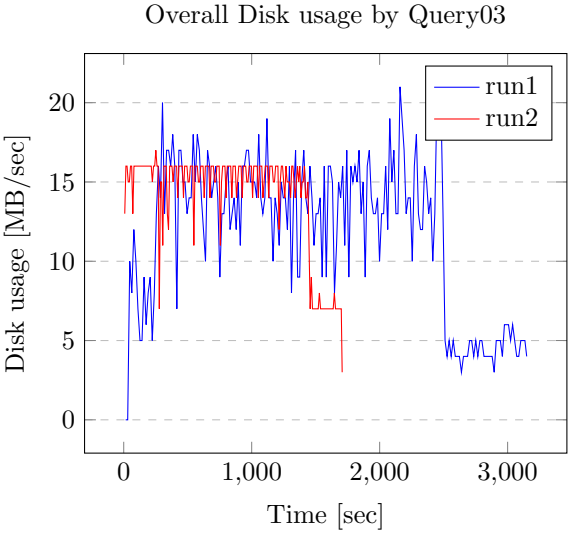
Load	Memory	Disk IO	Execution Time
6.57	37404.01 MB	12.19 MB/sec	2429.00 sec

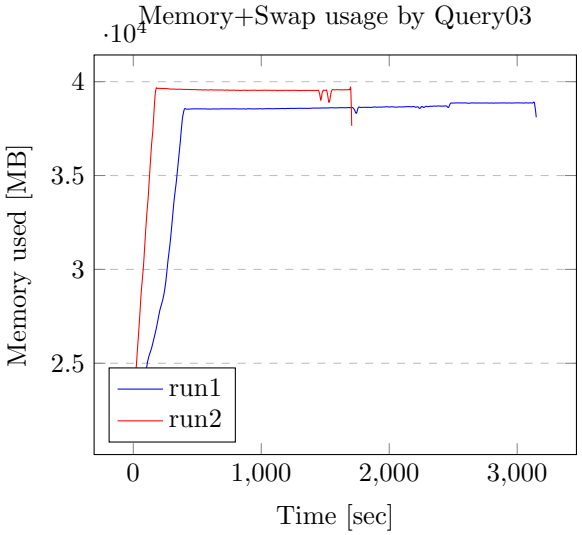
Table 3: Average Parametes over Runtime for Query03

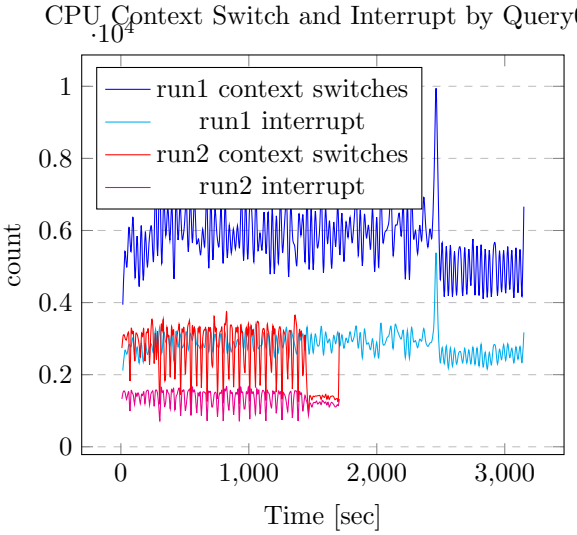








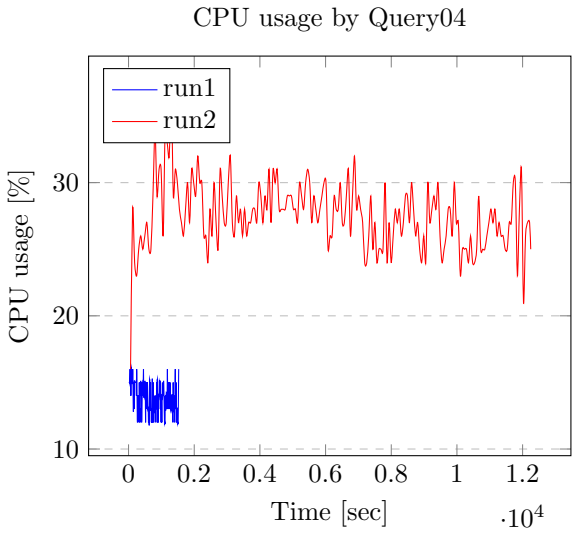


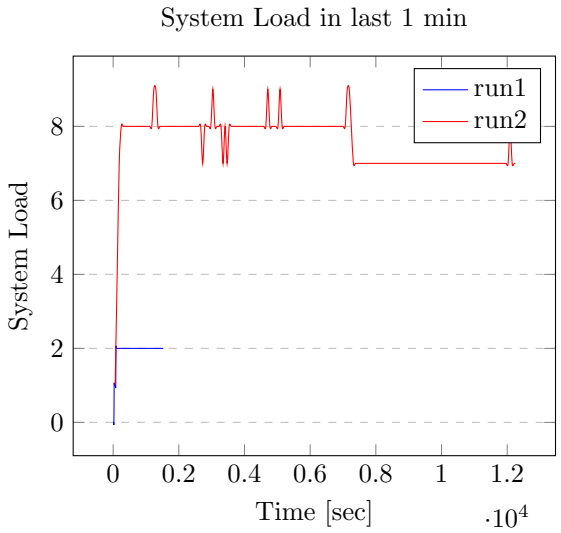


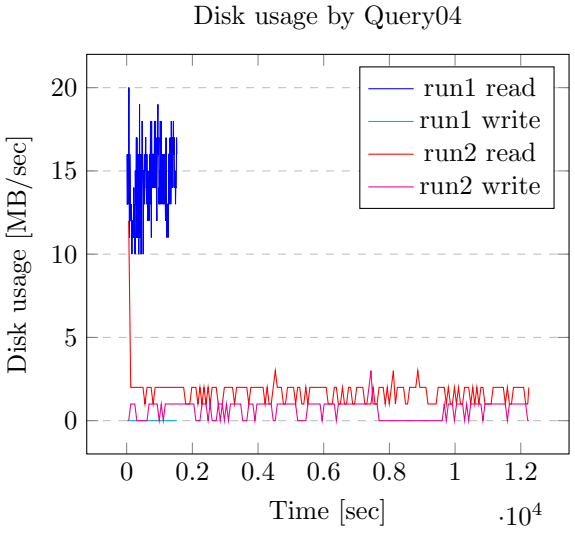
Several consecutive read and write to disk are shown in plots. It seems DBMS needs to compare small buckets of data together.

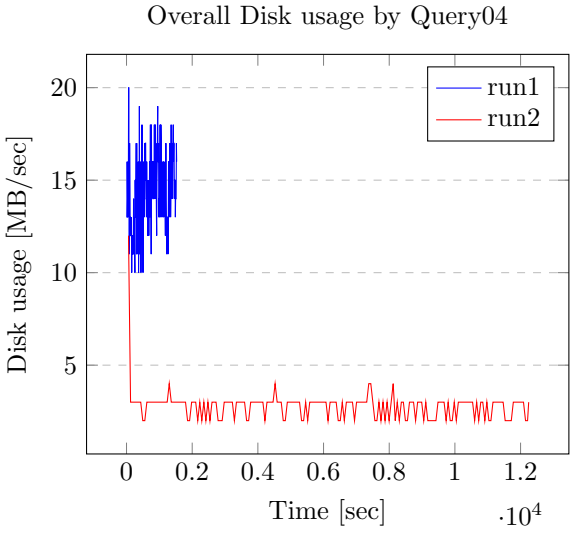
Load	Memory	Disk IO	Execution Time
2.50	39552.73 MB	14.88 MB/sec	6888.00 sec

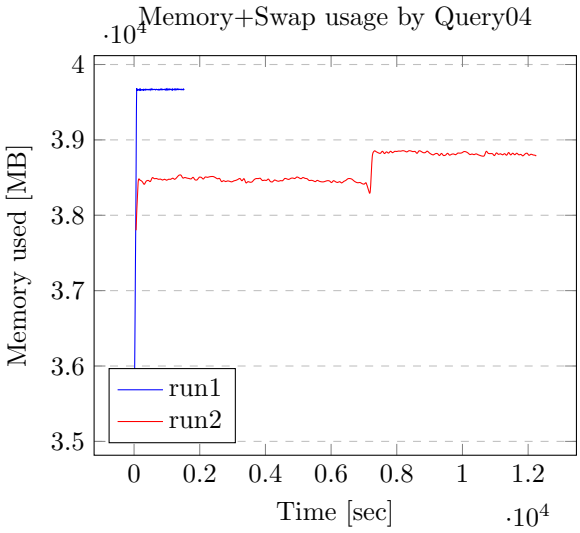
Table 4: Average Parametes over Runtime for Query04

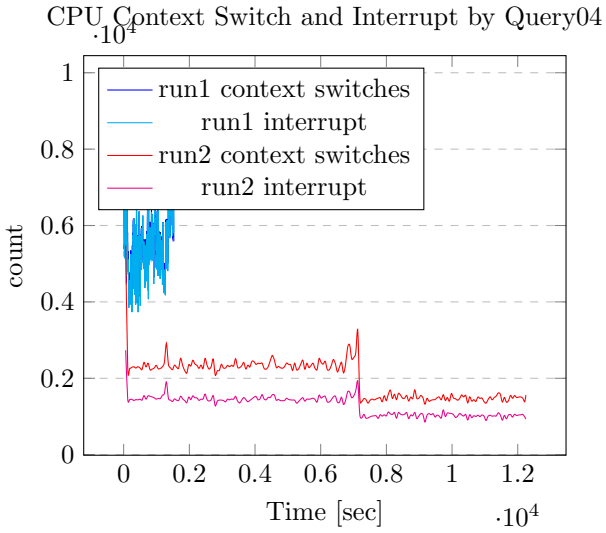






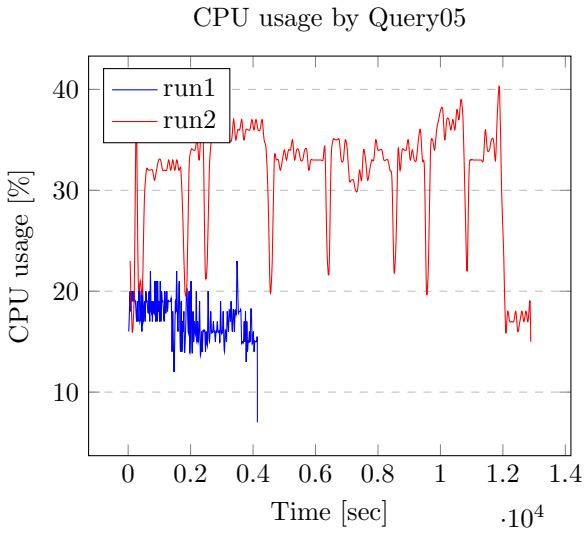


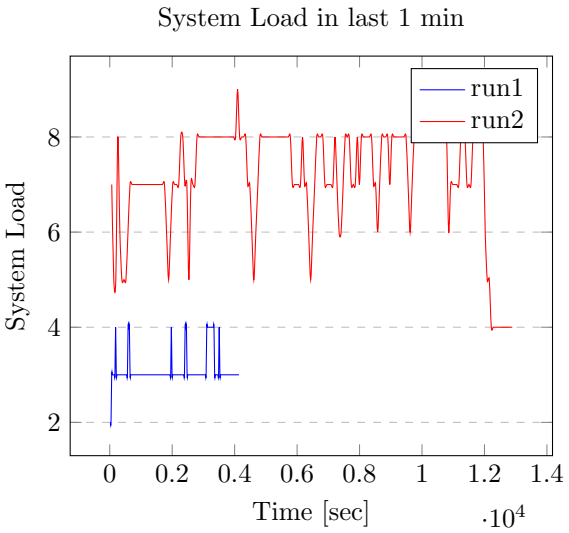


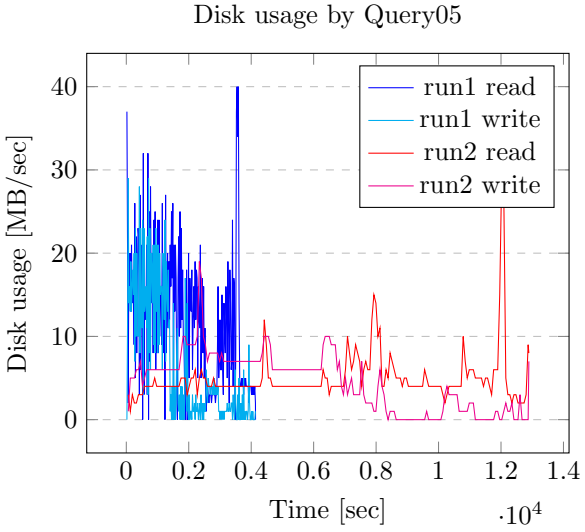


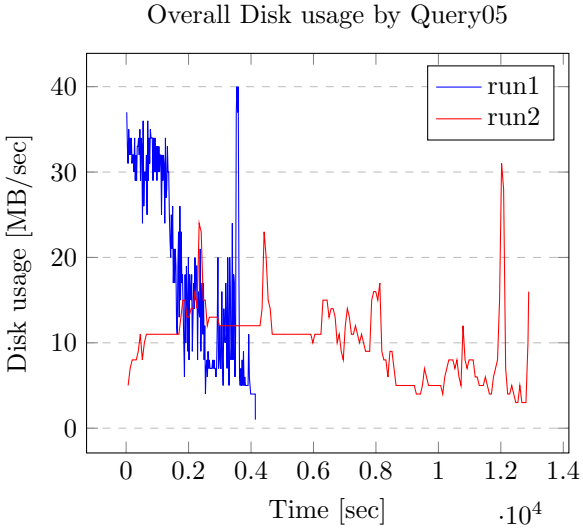
Load	Memory	Disk IO	Execution Time
3.64	39370.85 MB	19.41 MB/sec	8516.50 sec

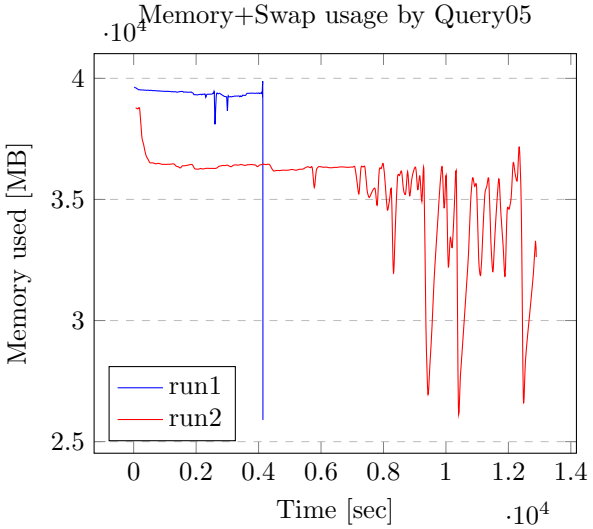
Table 5: Average Parametes over Runtime for Query05

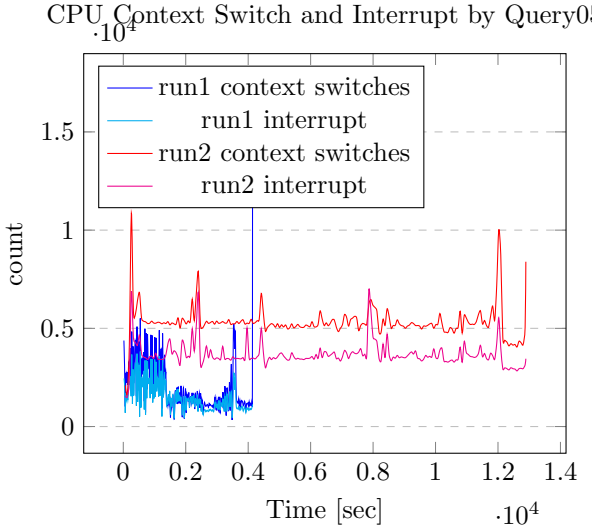








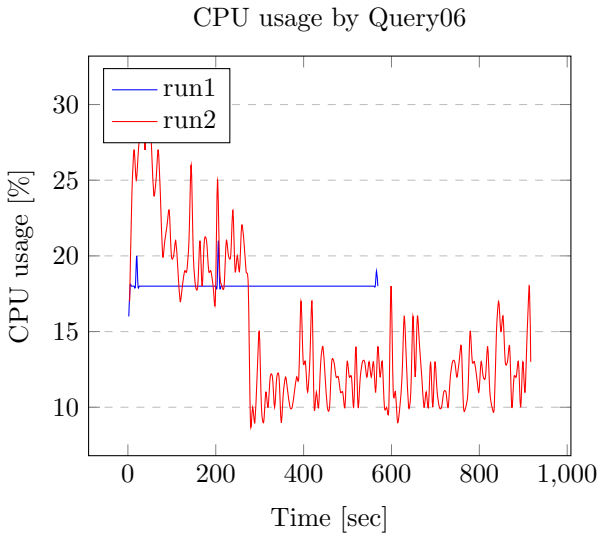


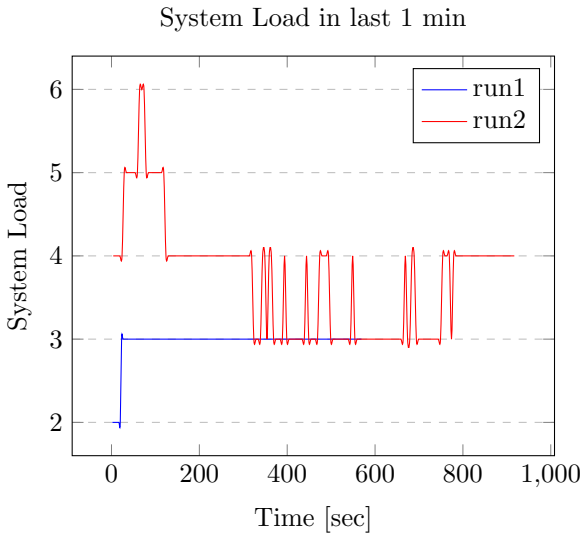


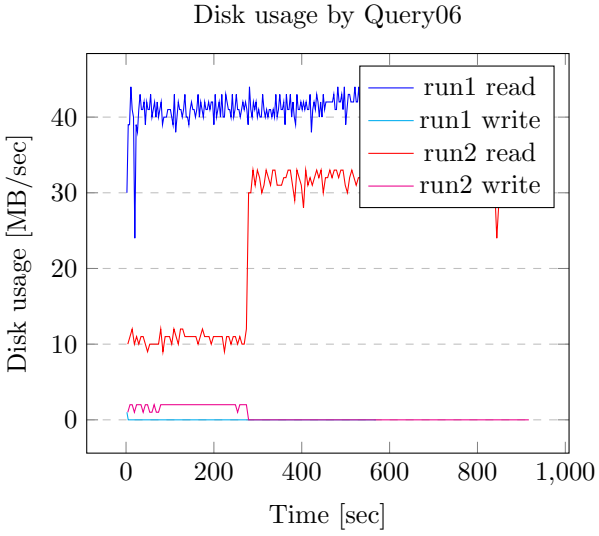
At last half of runs, postgres free some memory but uses more disk.

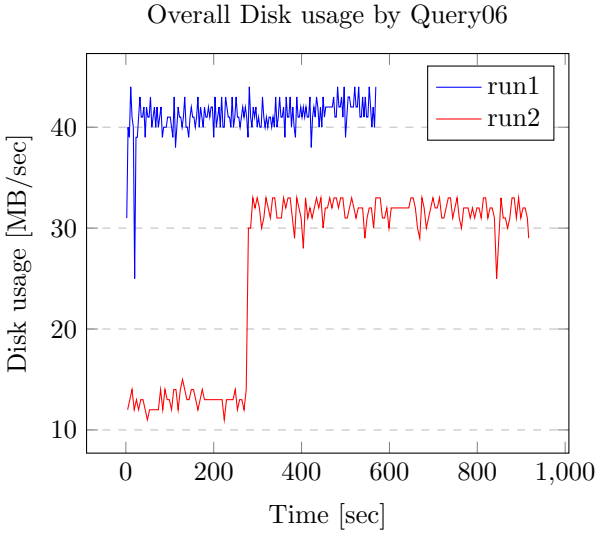
Load	Memory	Disk IO	Execution Time
3.06	37423.94 MB	41.61 MB/sec	744.00 sec

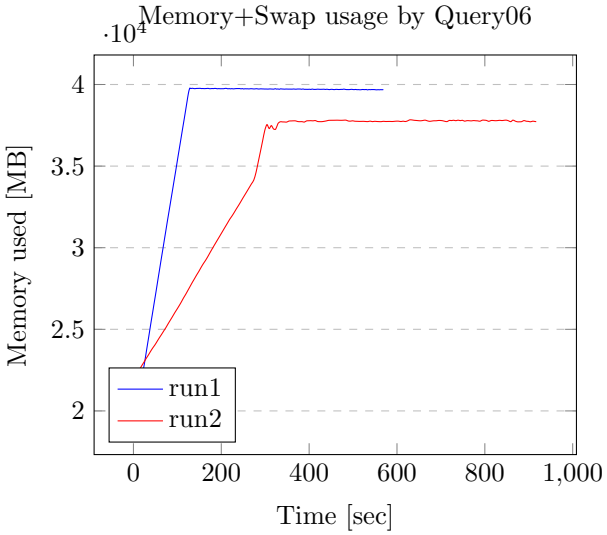
Table 6: Average Parametes over Runtime for Query06

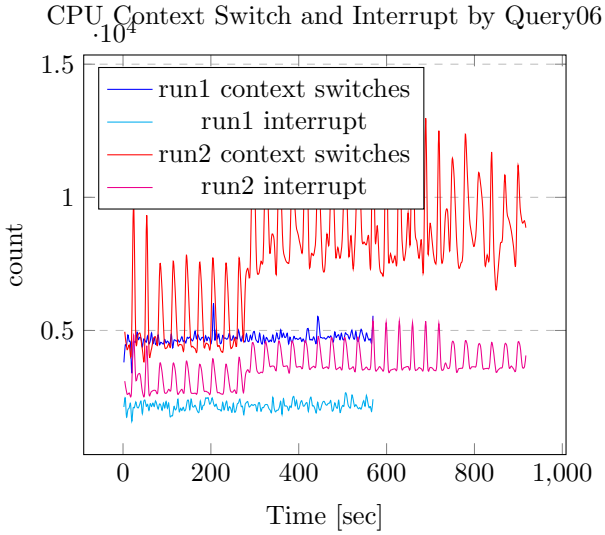






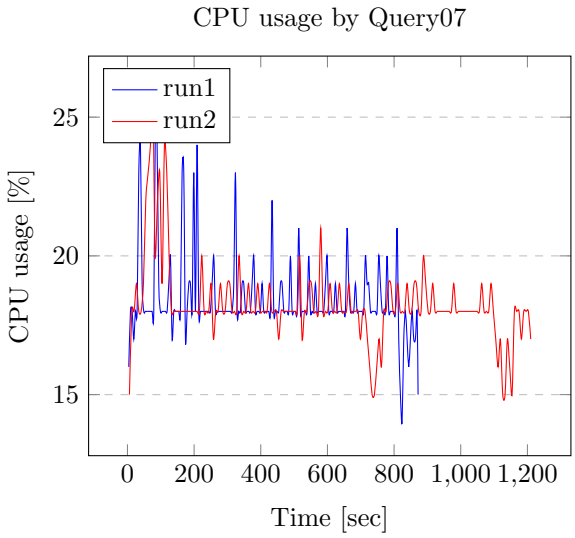


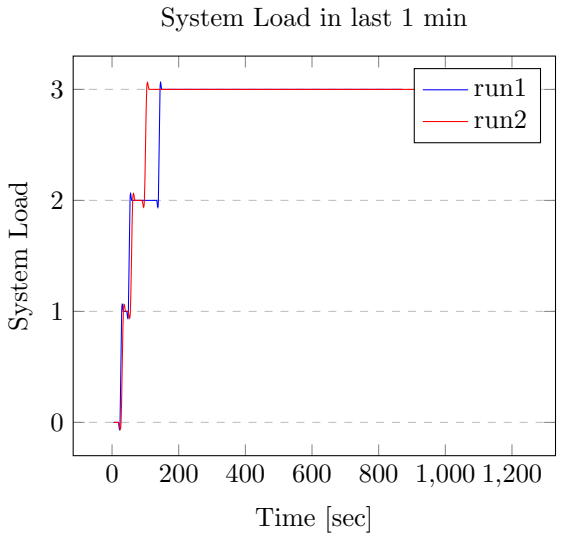


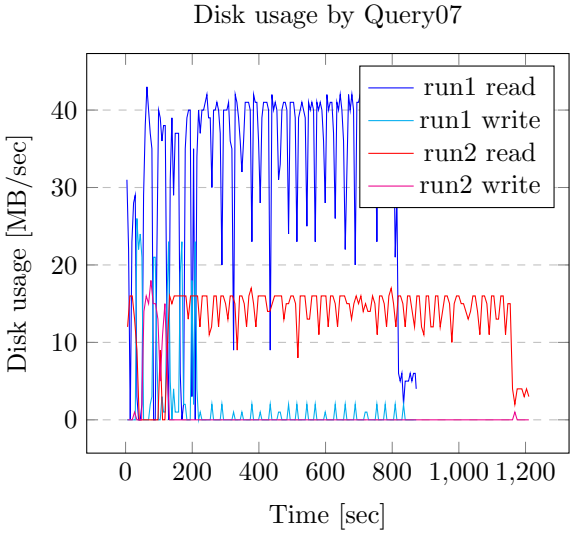


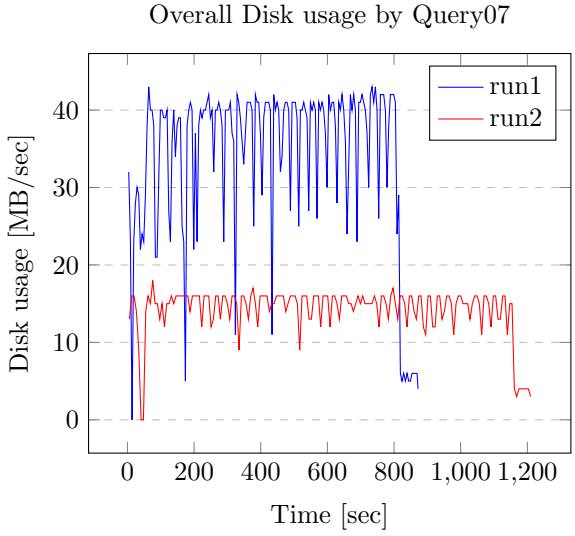
Load	Memory	Disk IO	Execution Time
2.95	39577.62 MB	34.43 MB/sec	1042.00 sec

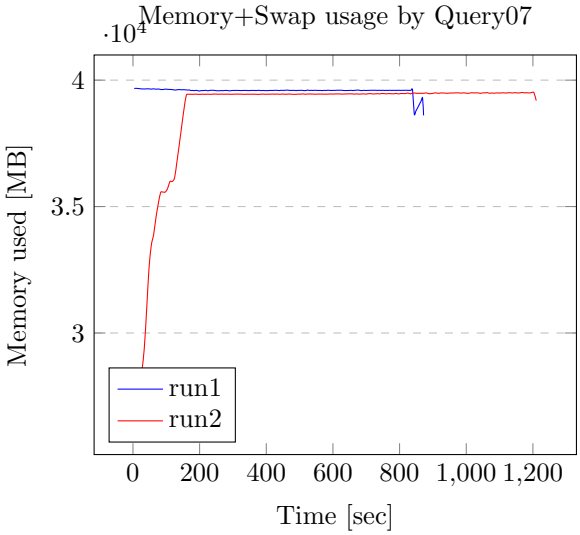
Table 7: Average Parametes over Runtime for Query07

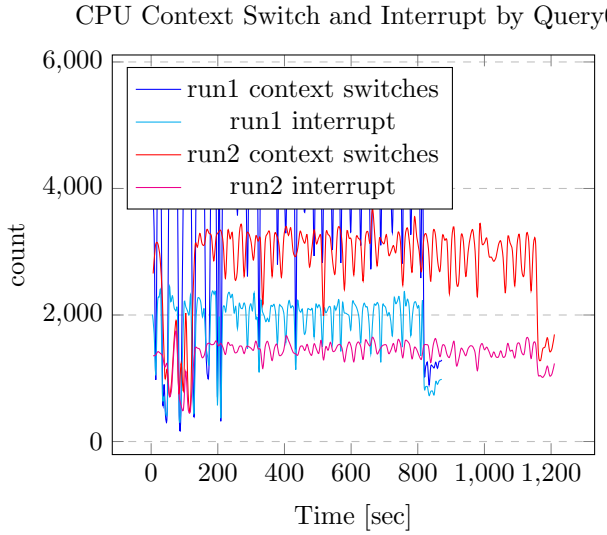








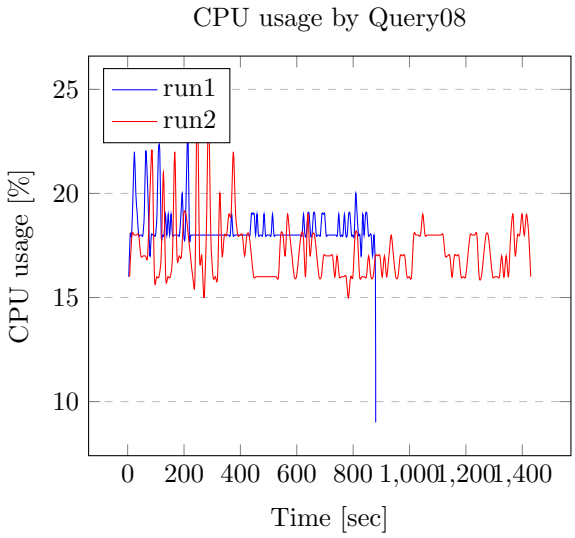


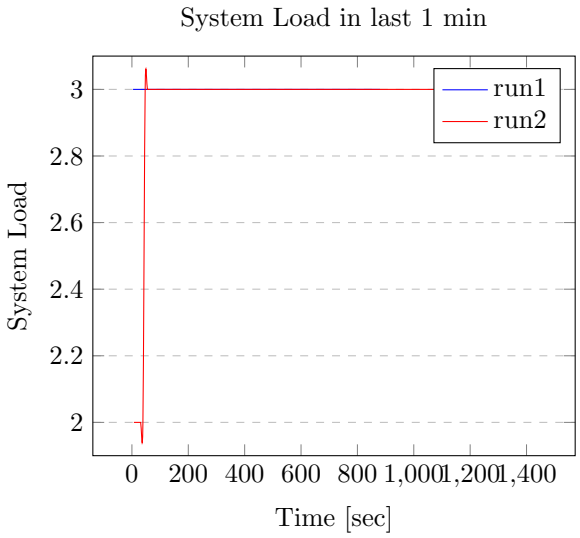


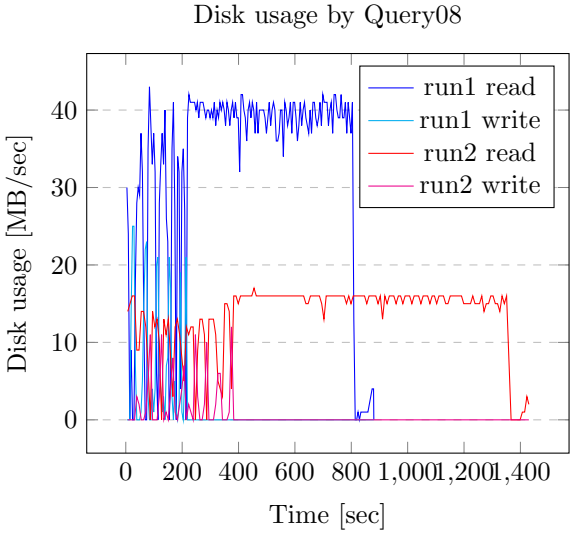
At first, DBMS writes a lot and loads needed data to memeory. Then in a stable usage of memory reads several time from disk and uses lot more in steady form from processor.

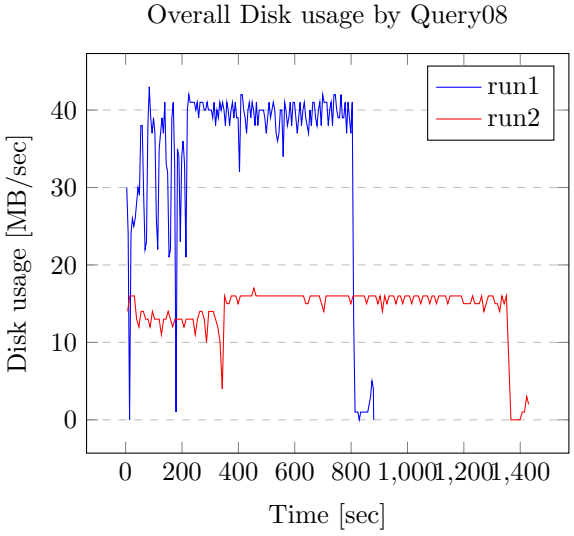
Load	Memory	Disk IO	Execution Time
3.16	39370.30 MB	34.62 MB/sec	1156.00 sec

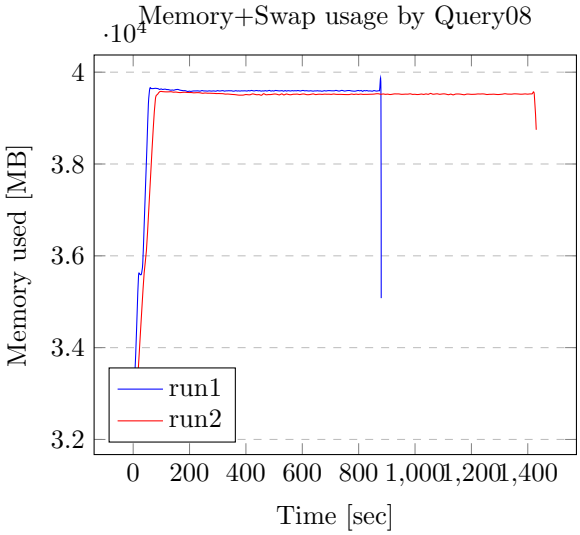
Table 8: Average Parametes over Runtime for Query08

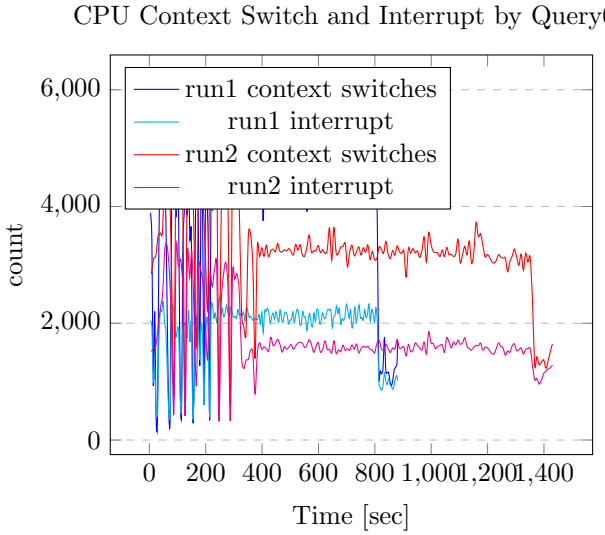






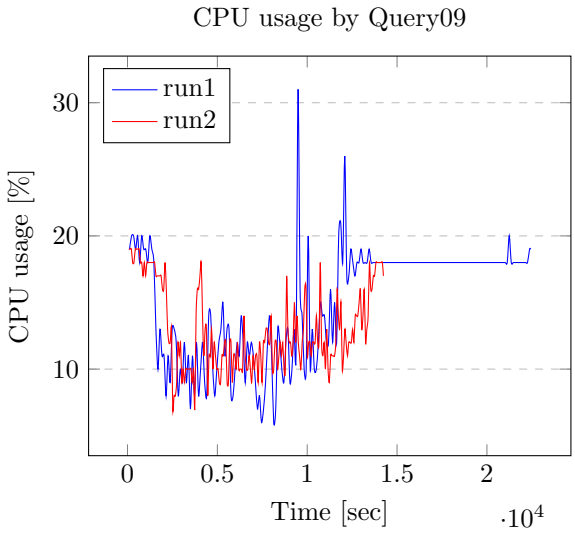


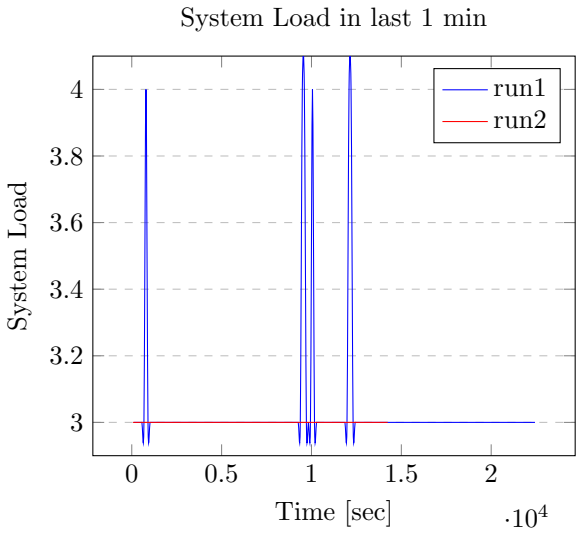


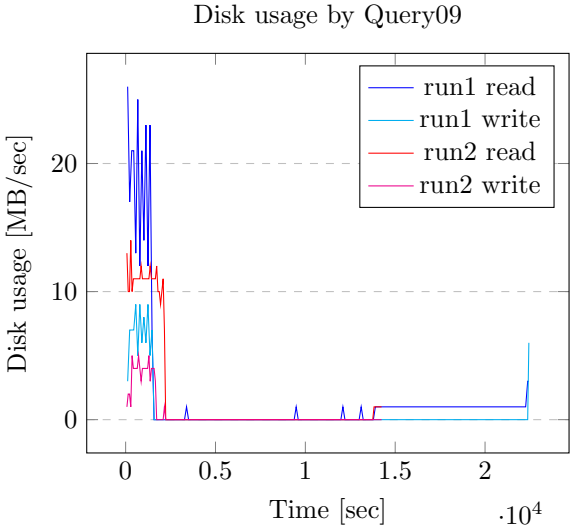


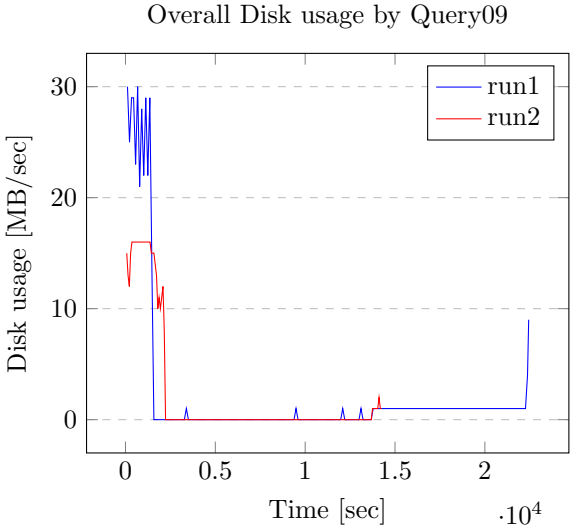
Load	Memory	Disk IO	Execution Time
3.21	39136.33 MB	2.64 MB/sec	18340.00 sec

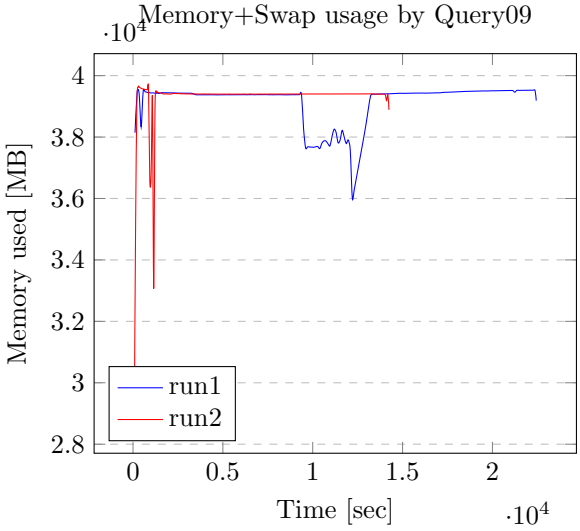
Table 9: Average Parametes over Runtime for Query09

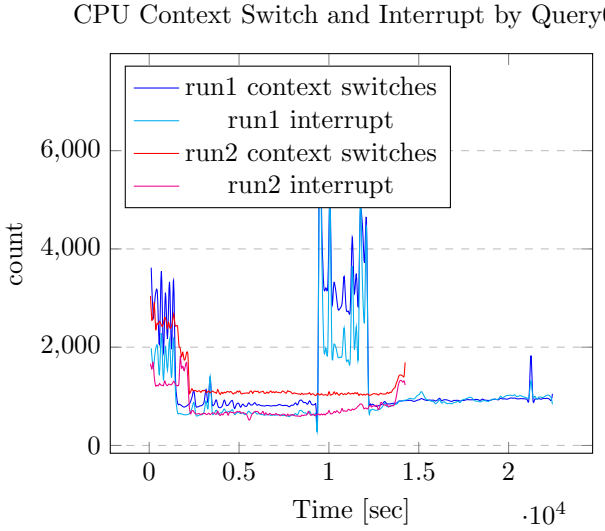






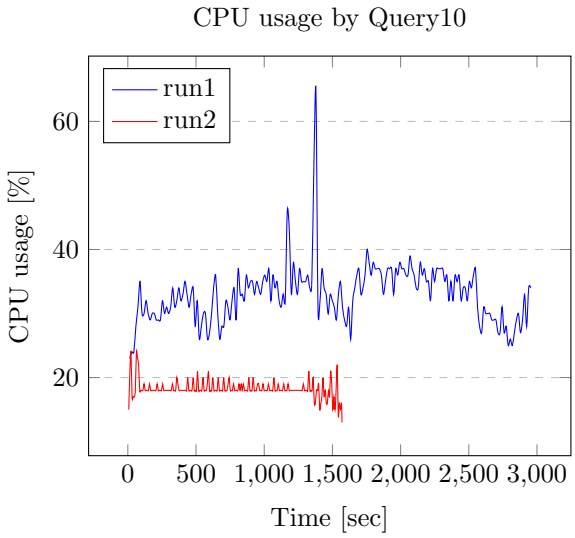


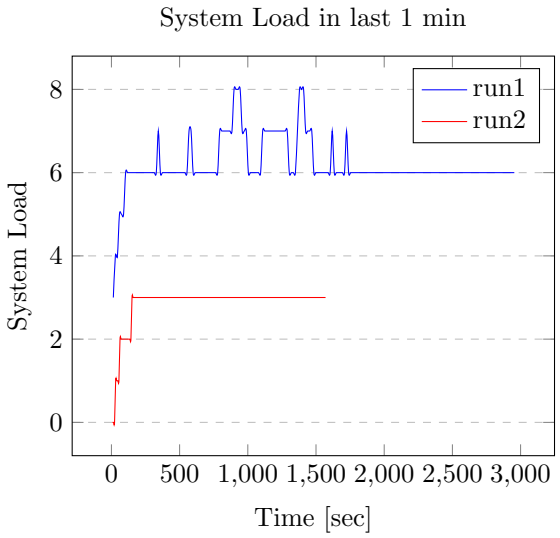


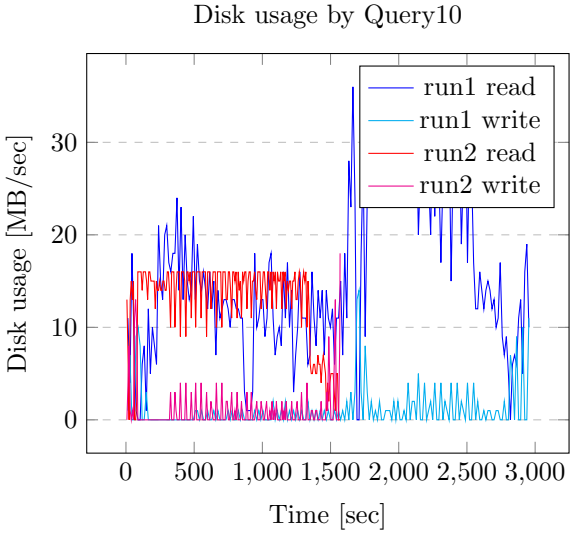


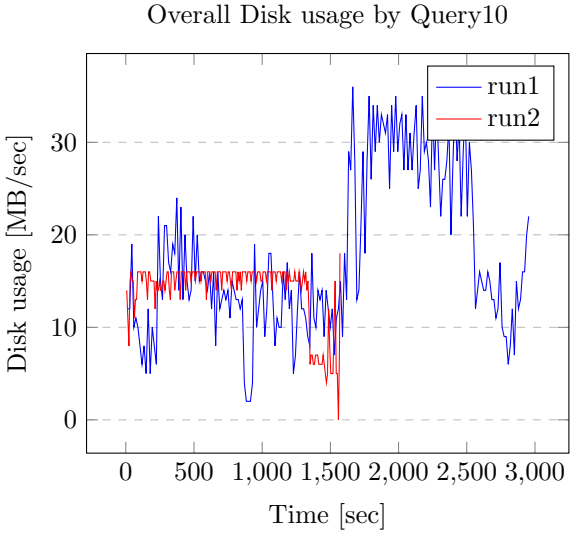
Load	Memory	Disk IO	Execution Time
6.71	38100.66 MB	18.28 MB/sec	2263.00 sec

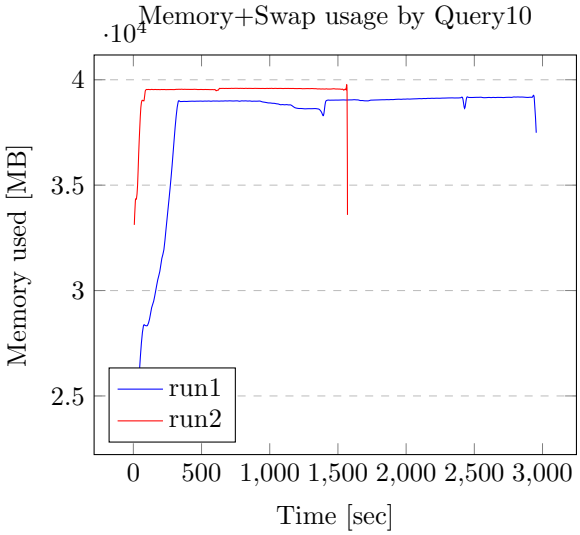
Table 10: Average Parametes over Runtime for Query10

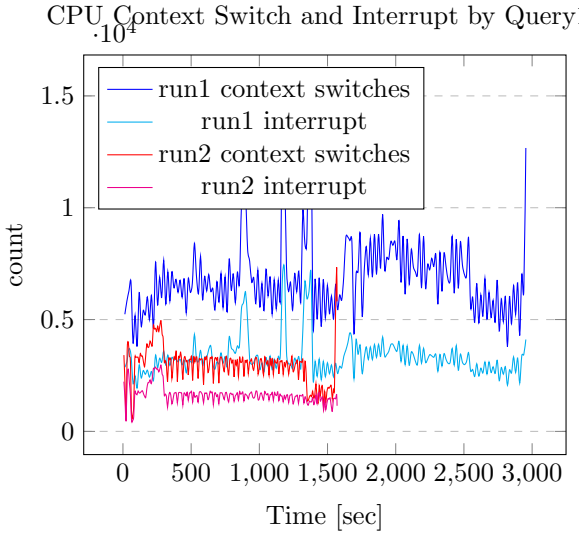






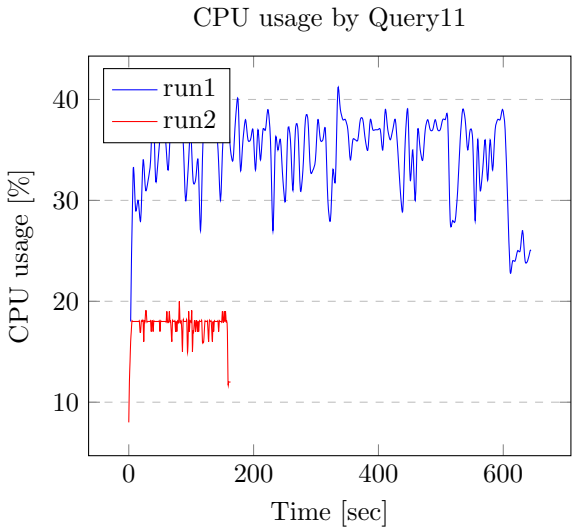


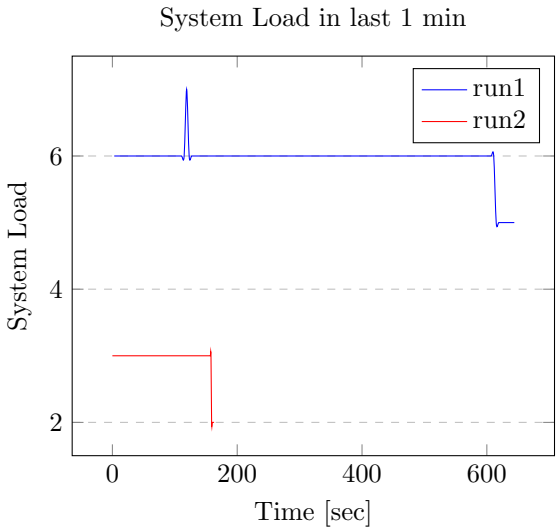


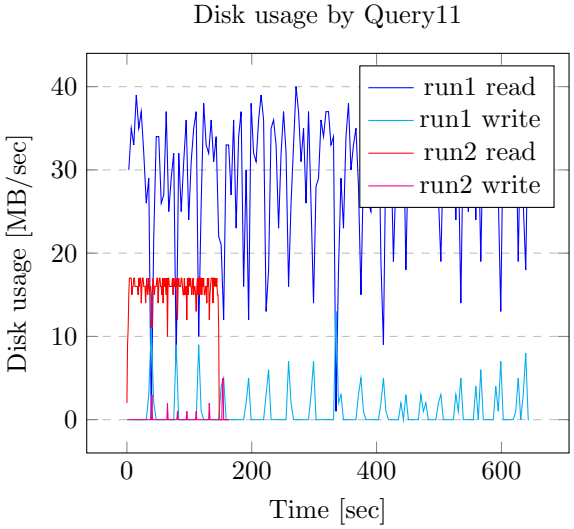


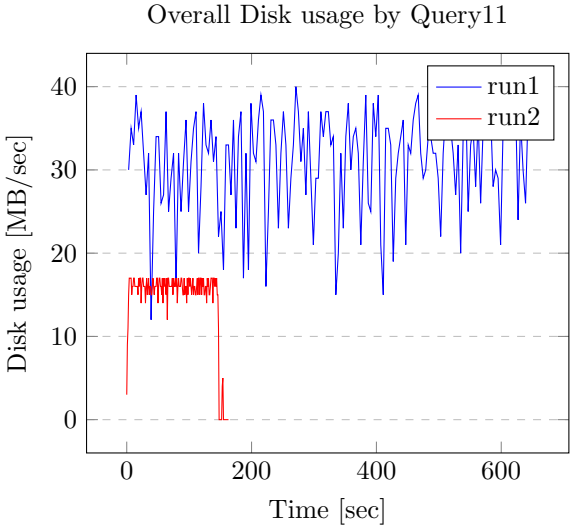
Load	Memory	Disk IO	Execution Time
6.33	38399.85 MB	31.56 MB/sec	404.50 sec

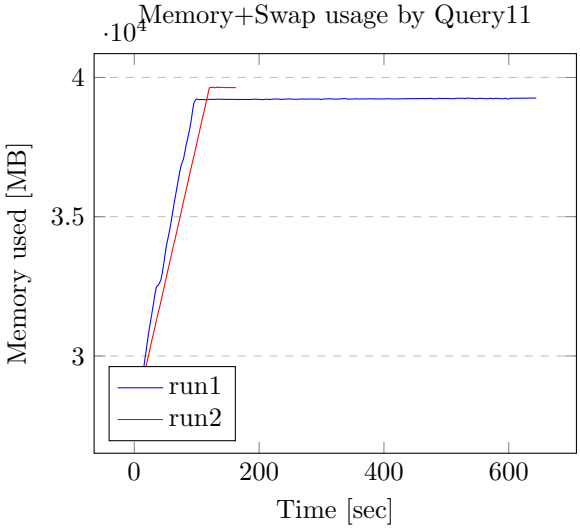
Table 11: Average Parametes over Runtime for Query11

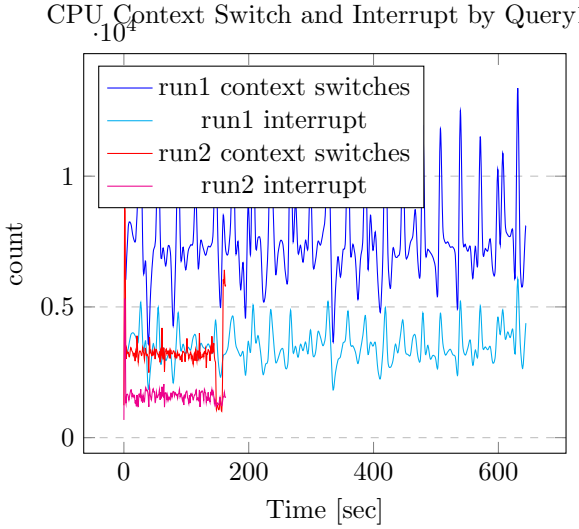






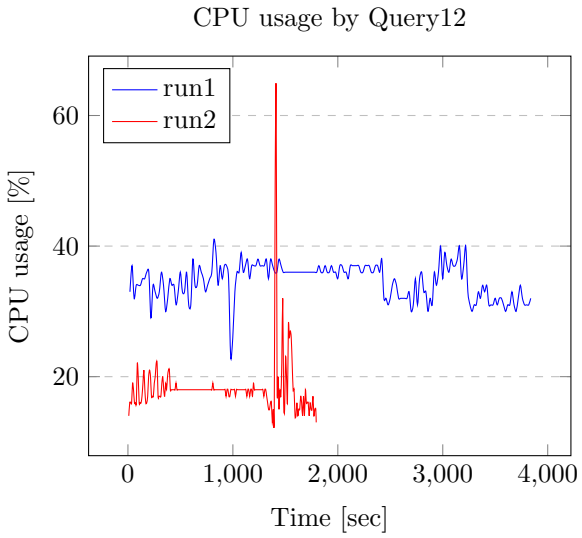


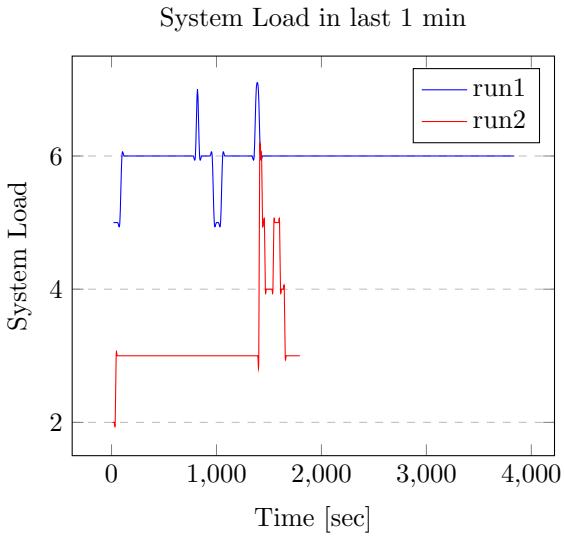


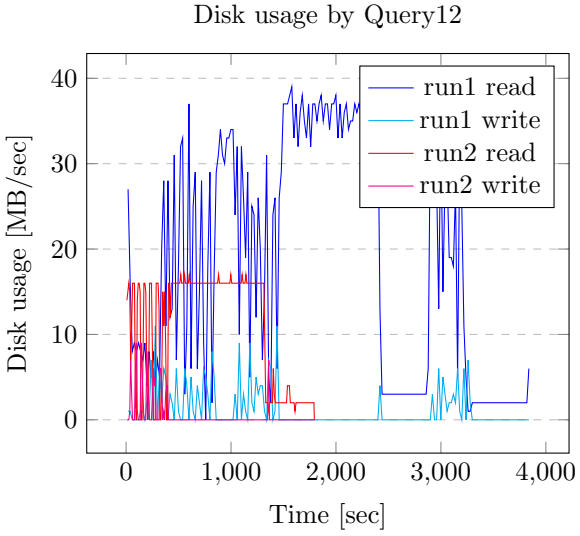


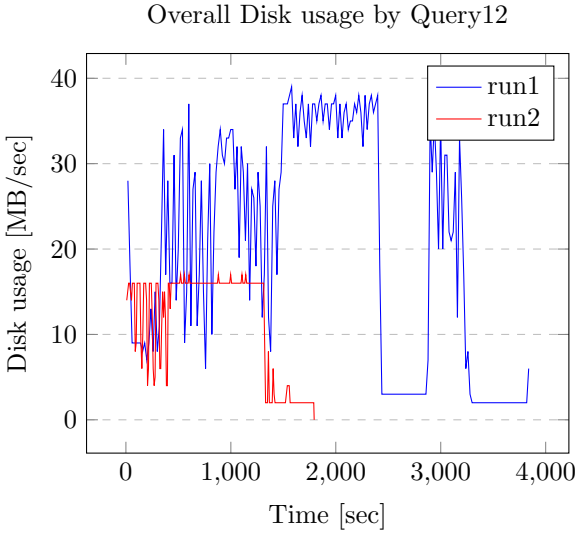
Load	Memory	Disk IO	Execution Time
6.38	38726.13 MB	20.44 MB/sec	2817.00 sec

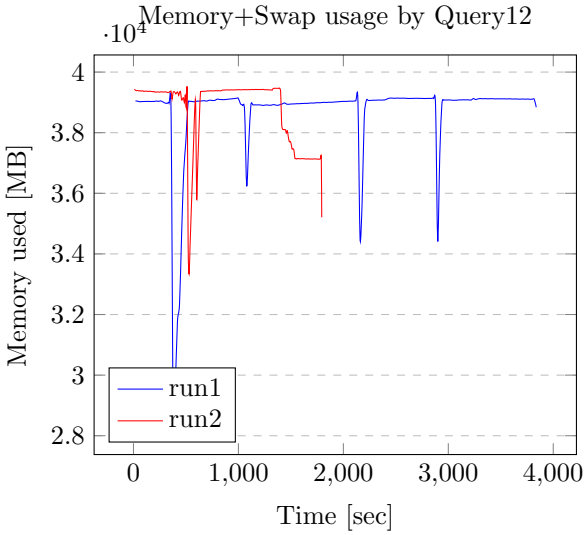
Table 12: Average Parametes over Runtime for Query12

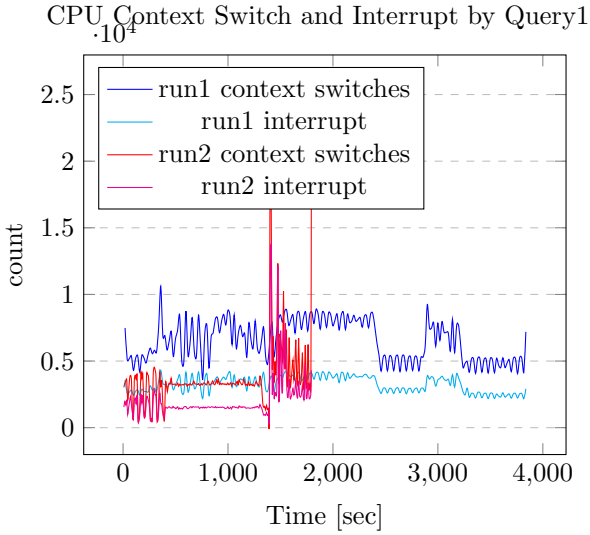






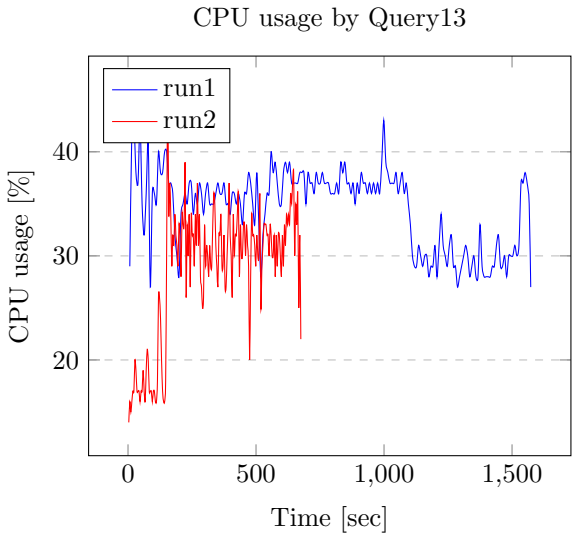


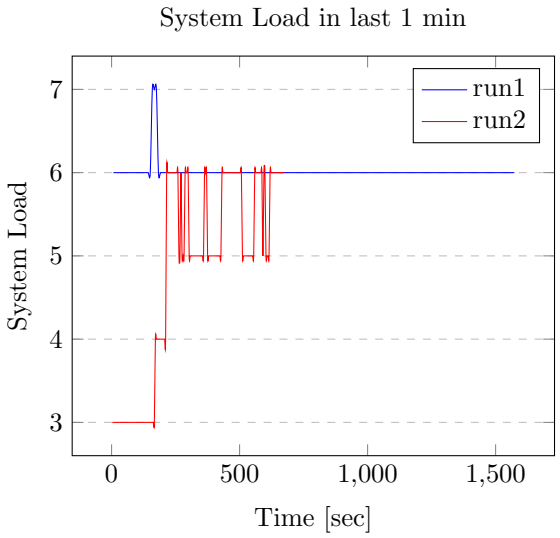


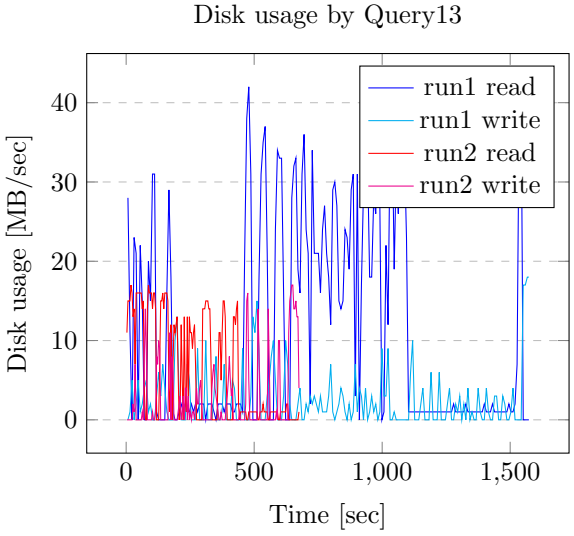


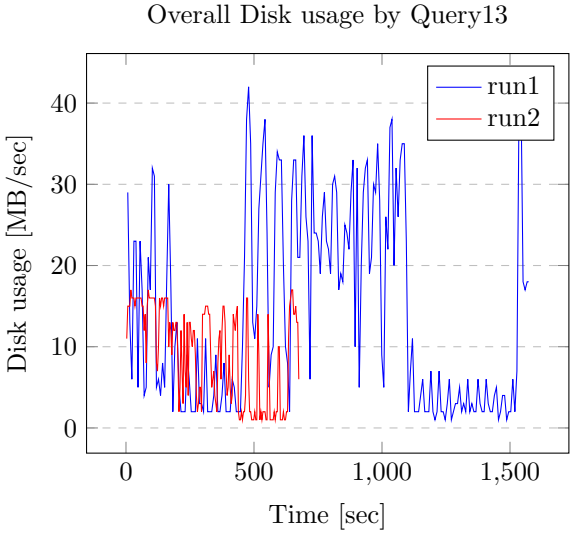
Load	Memory	Disk IO	Execution Time
6.51	38832.73 MB	14.61 MB/sec	1125.00 sec

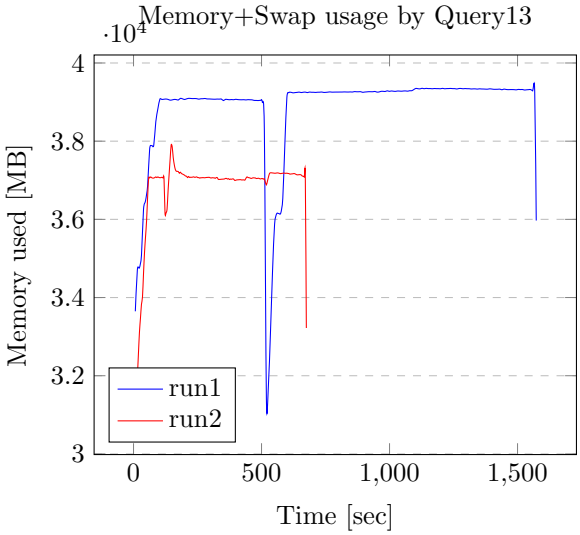
Table 13: Average Parametes over Runtime for Query13

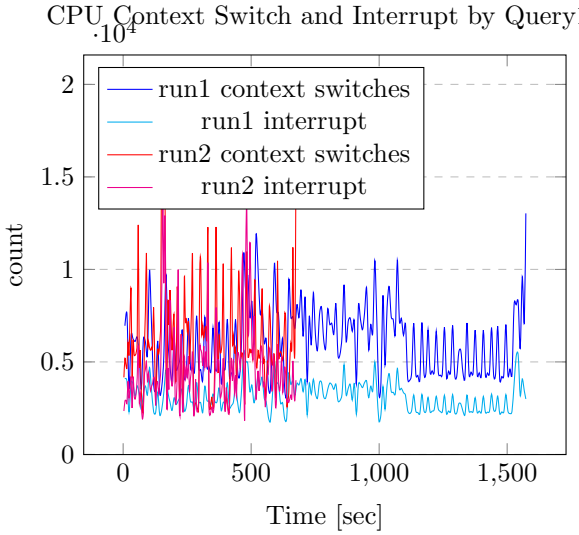






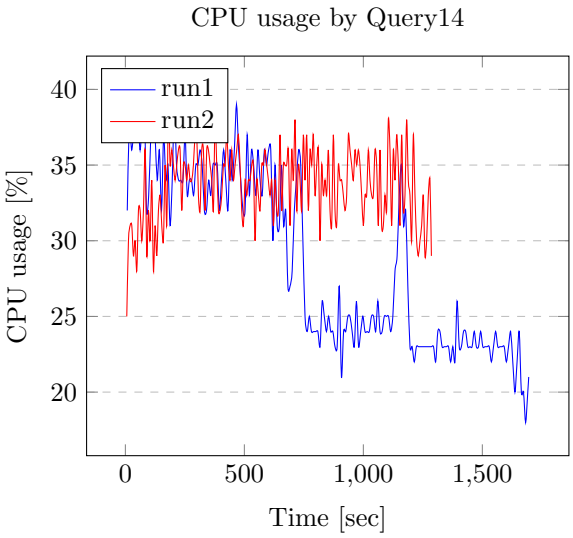


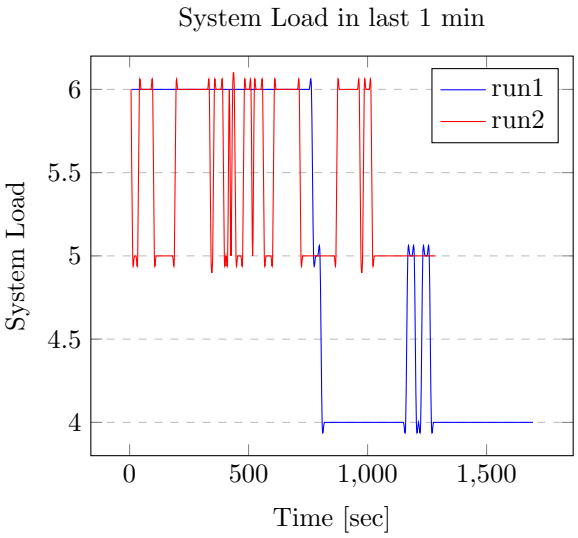


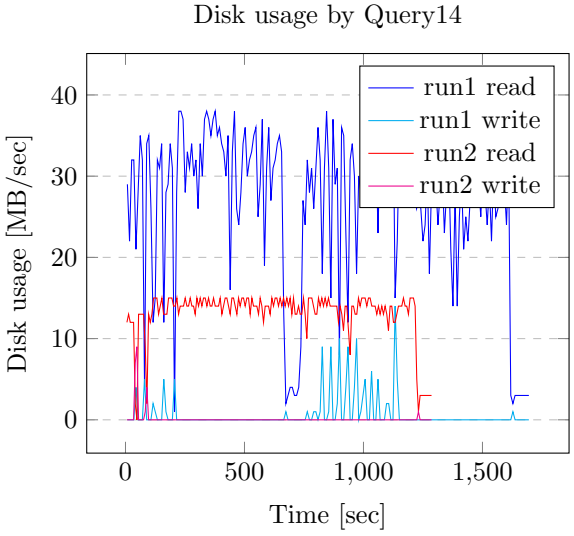


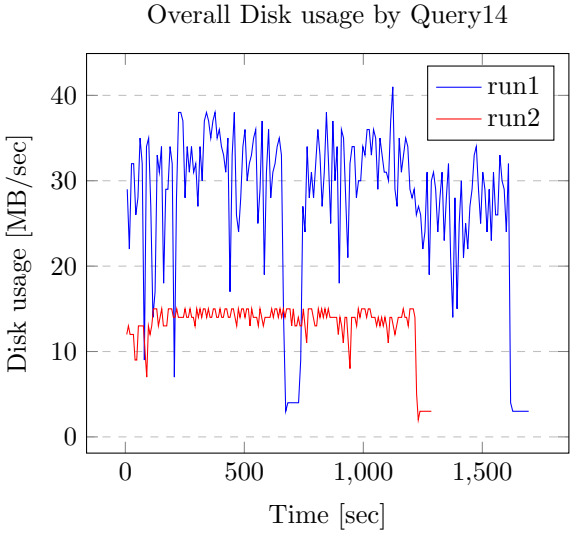
Load	Memory	Disk IO	Execution Time
5.32	39395.19 MB	27.92 MB/sec	1491.50 sec

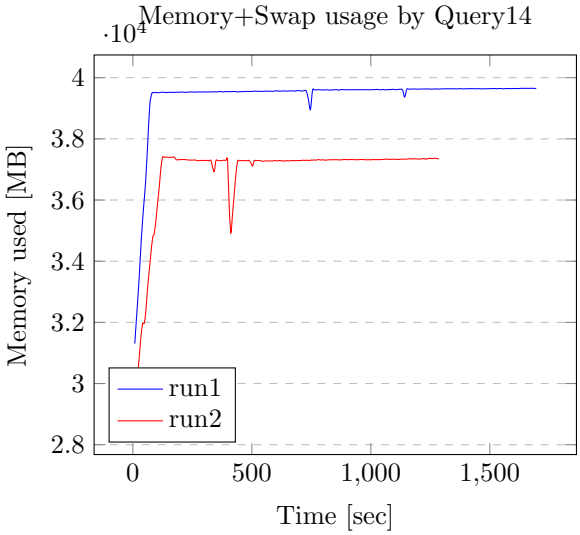
Table 14: Average Parametes over Runtime for Query14

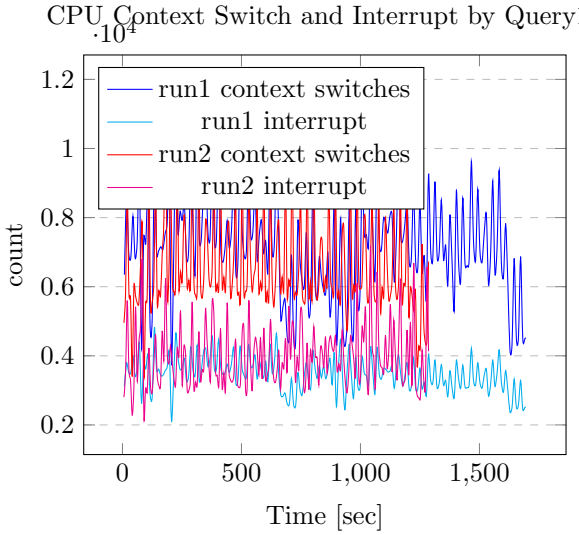






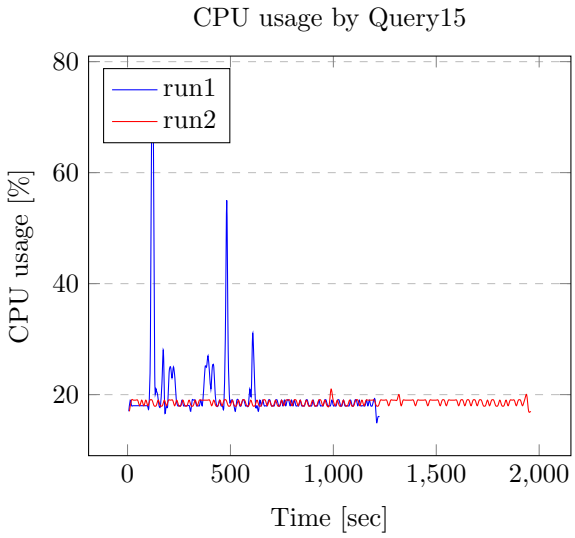


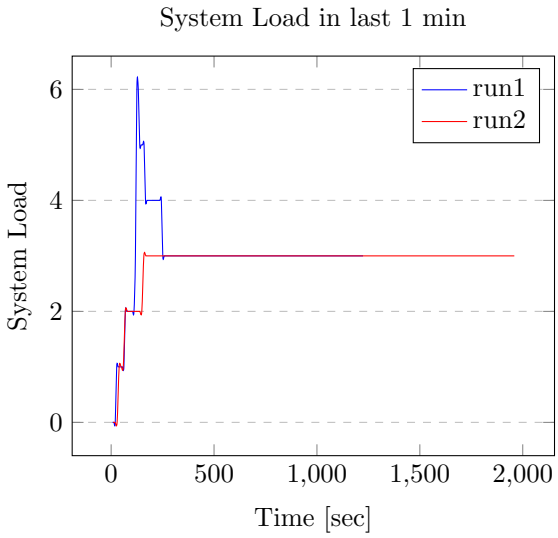


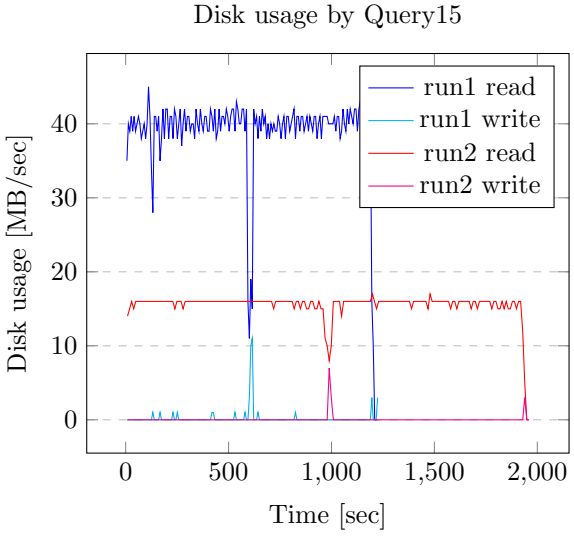


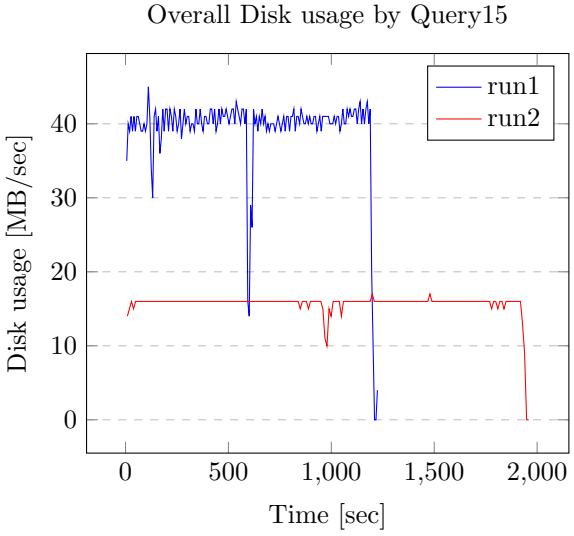
Load	Memory	Disk IO	Execution Time
3.33	37460.35 MB	39.52 MB/sec	1592.50 sec

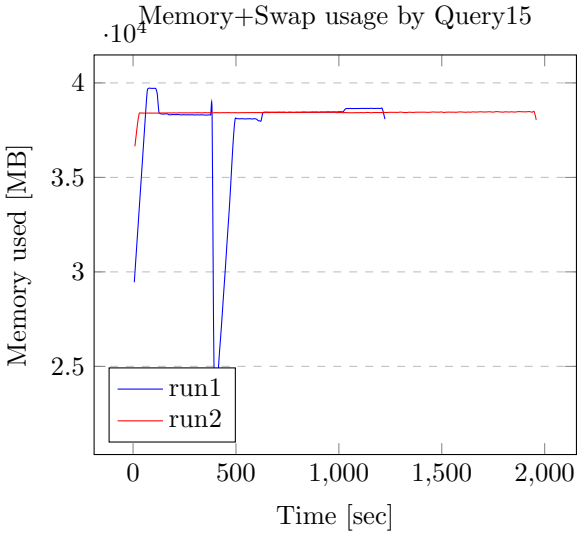
Table 15: Average Parametes over Runtime for Query15

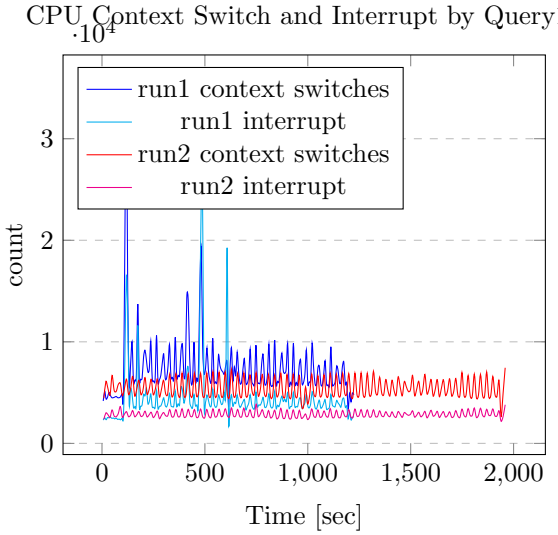






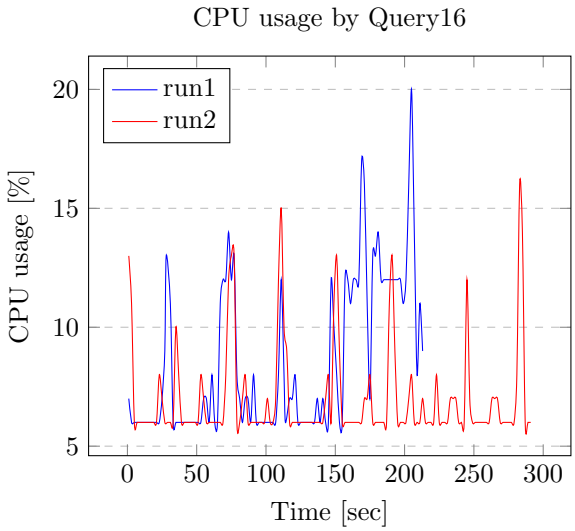


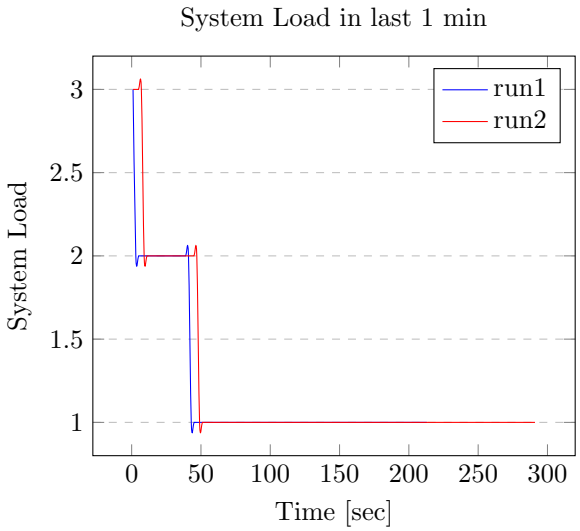


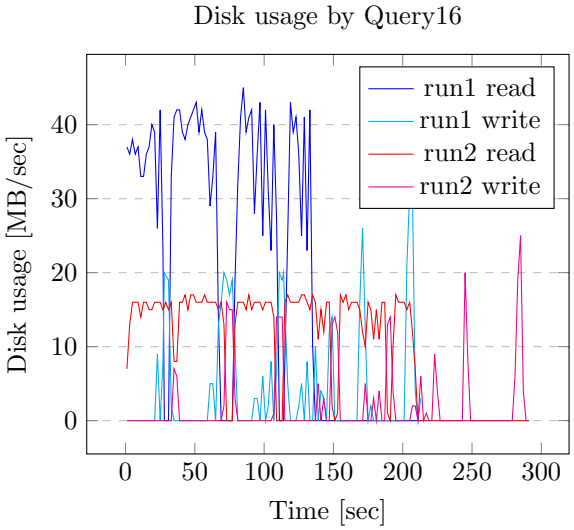


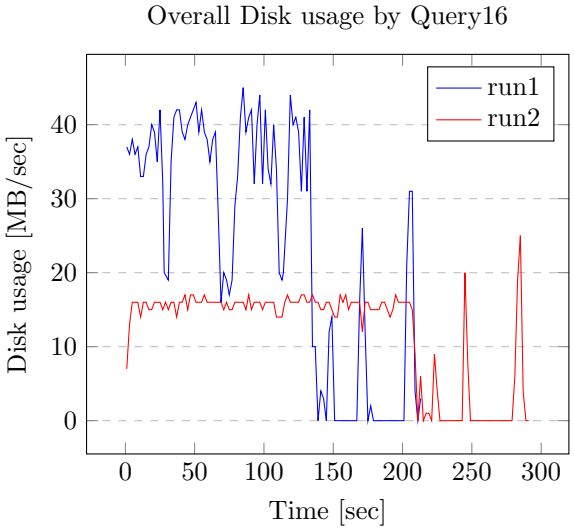
Load	Memory	Disk IO	Execution Time
1.96	38097.41 MB	24.12 MB/sec	253.00 sec

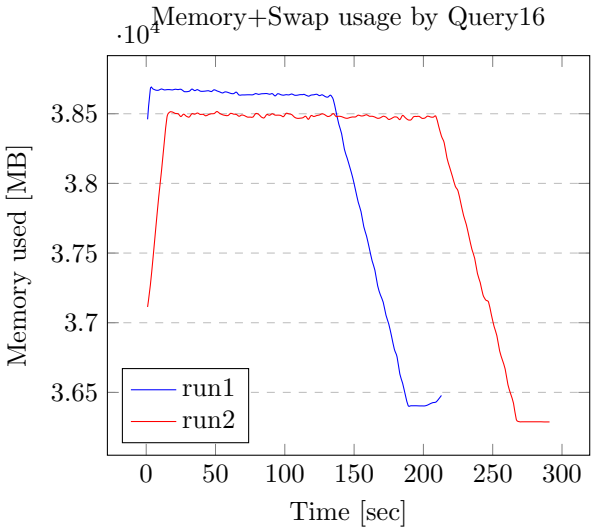
Table 16: Average Parametes over Runtime for Query16

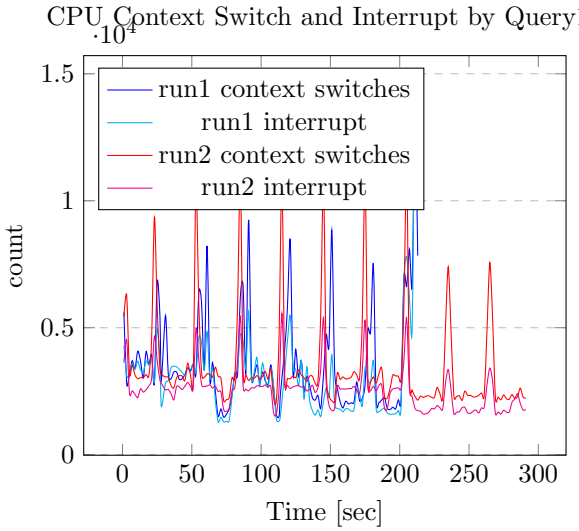






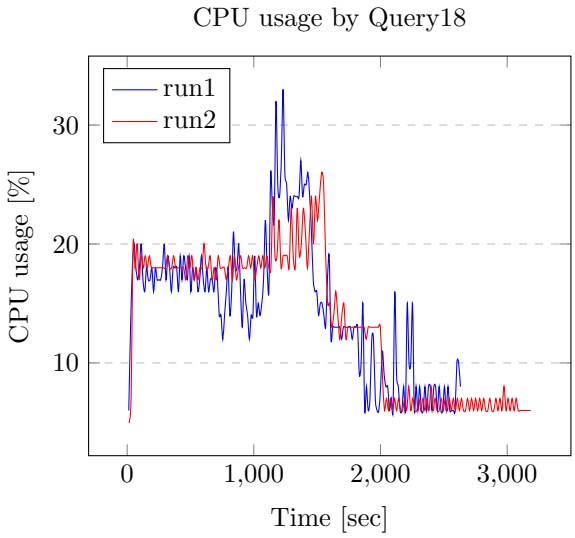


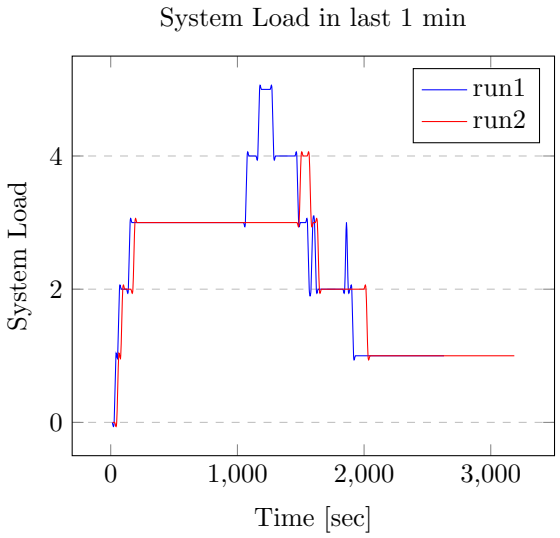


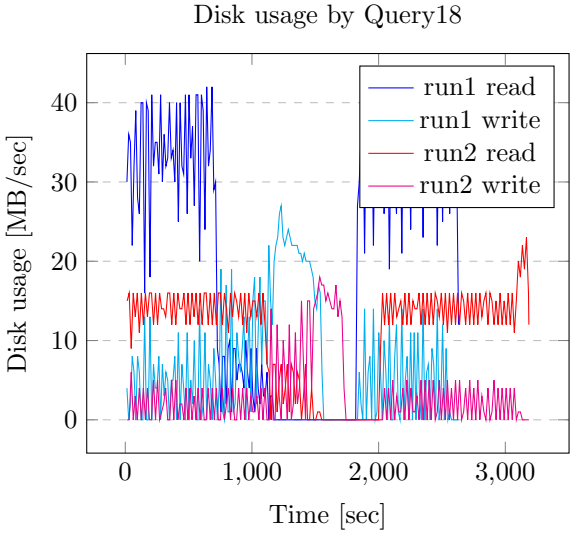


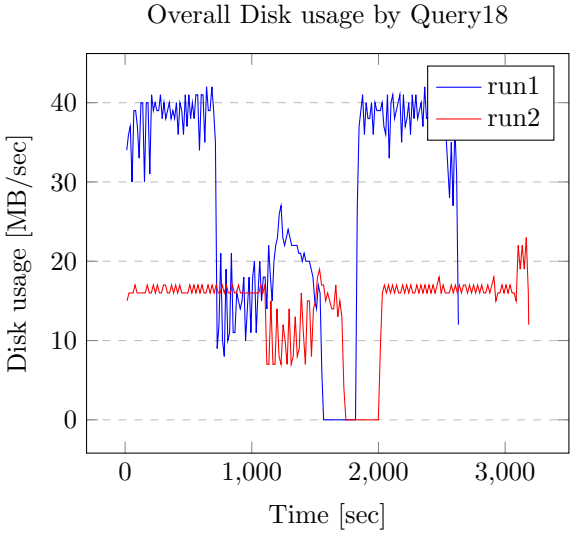
Load	Memory	Disk IO	Execution Time
2.87	34627.95 MB	27.98 MB/sec	2909.50 sec

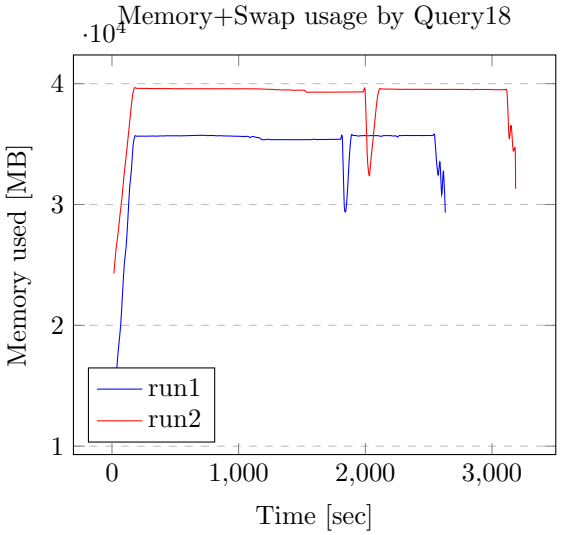
Table 17: Average Parametes over Runtime for Query18

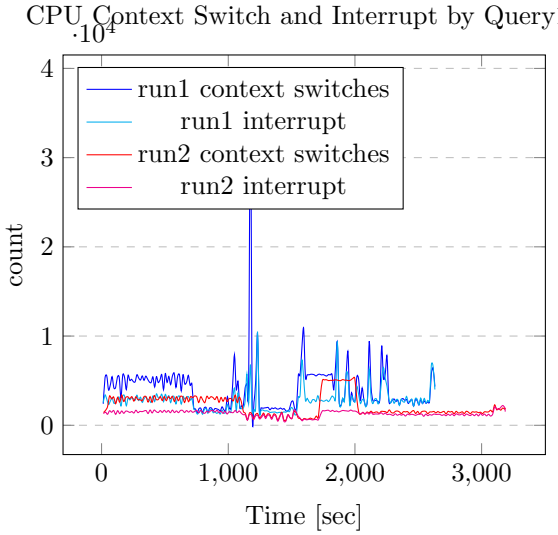








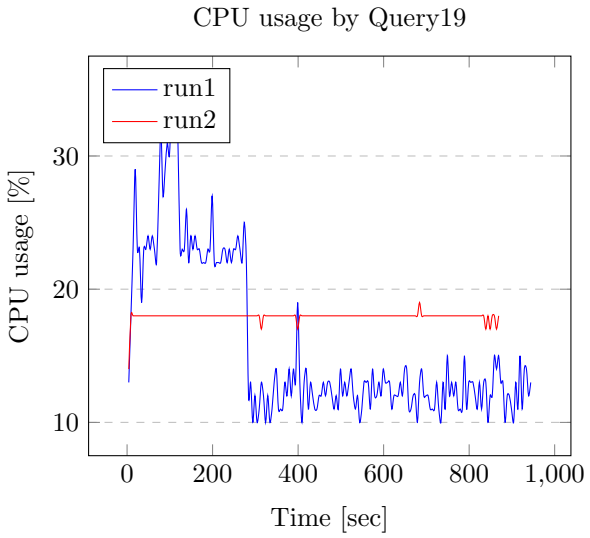


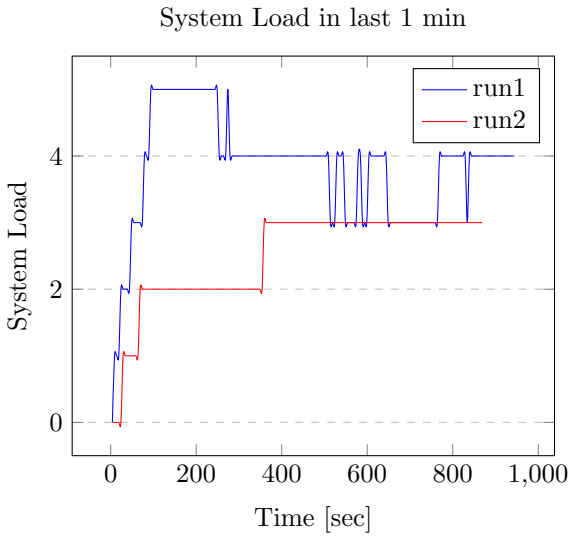


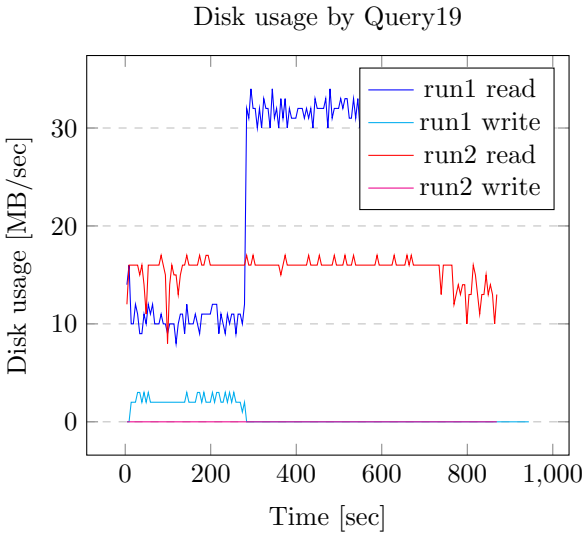
In the middle of each run, postgres writes huge amount of data to disk using heavy processor jobs, then frees some memory and loads new data from disks again. This pattern repeats several times in other query processing.

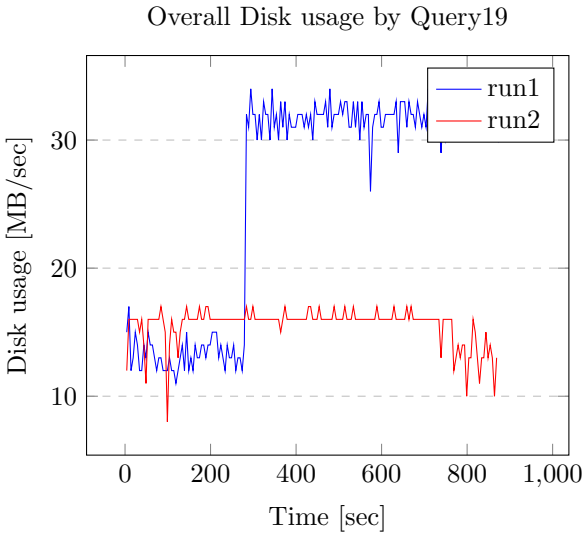
Load	Memory	Disk IO	Execution Time
4.27	37715.97 MB	26.78 MB/sec	907.50 sec

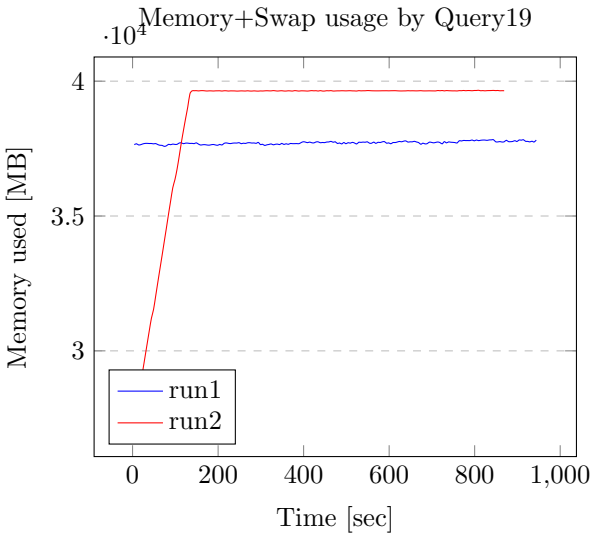
Table 18: Average Parametes over Runtime for Query19

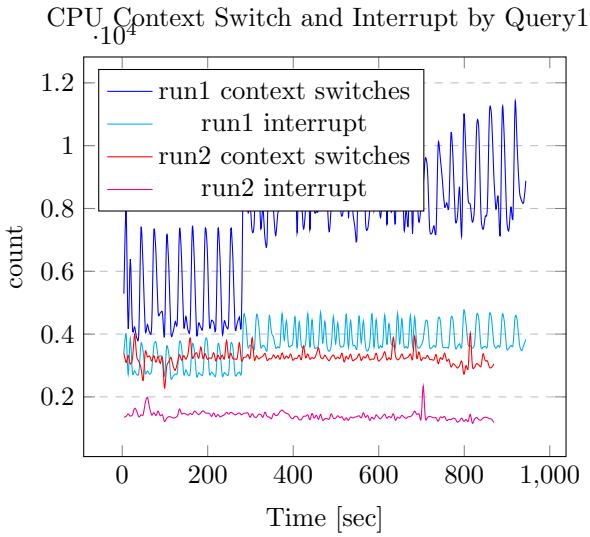






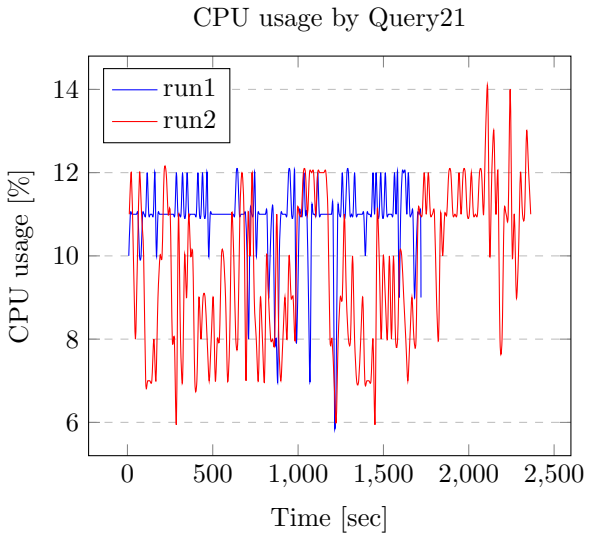


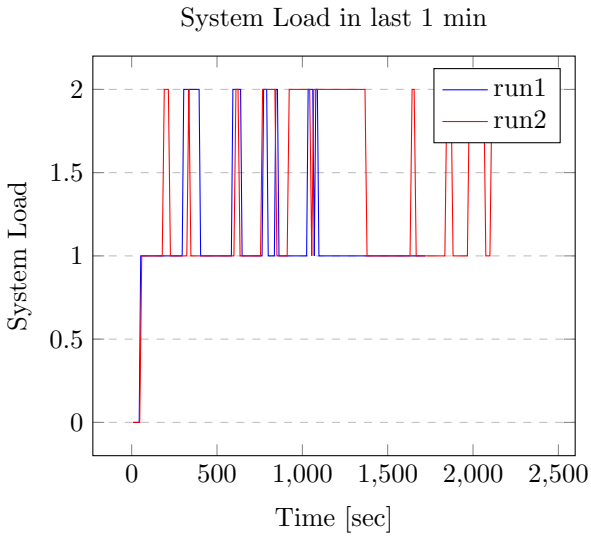


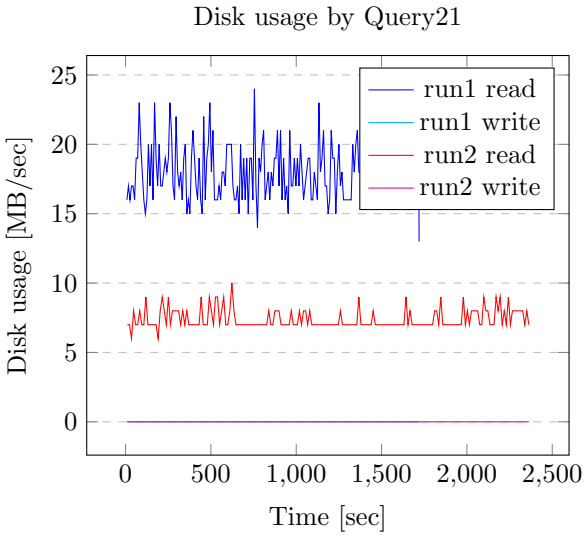


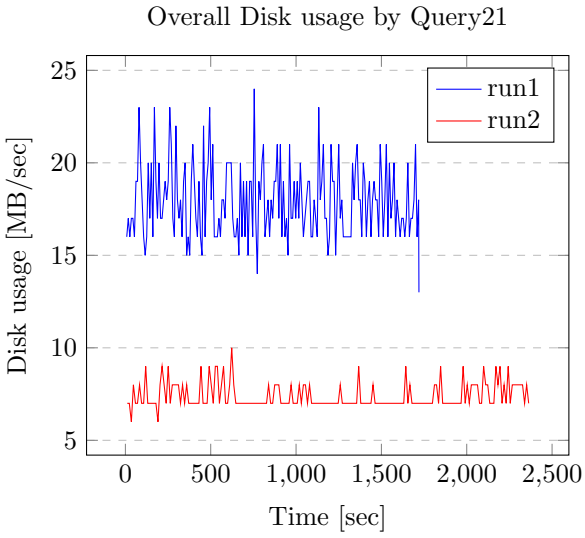
Load	Memory	Disk IO	Execution Time
1.86	33771.81 MB	18.45 MB/sec	2042.50 sec

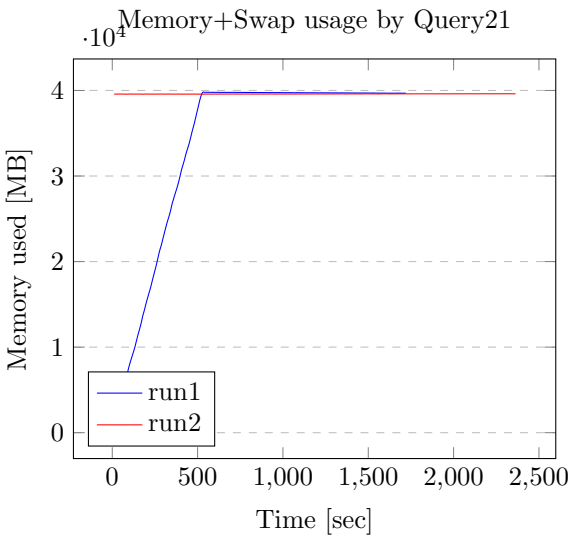
Table 19: Average Parametes over Runtime for Query21

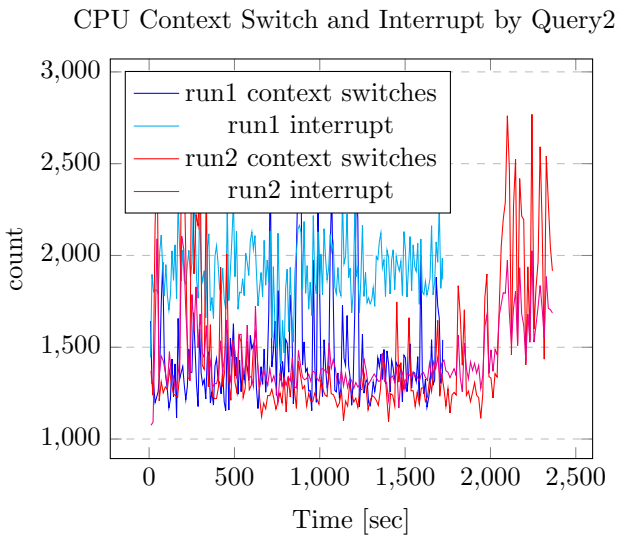






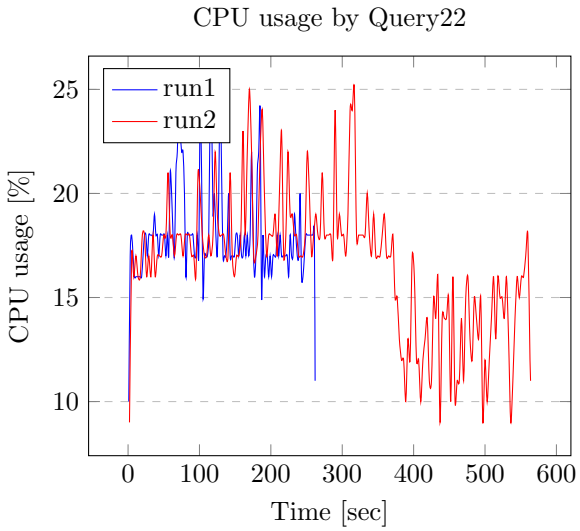


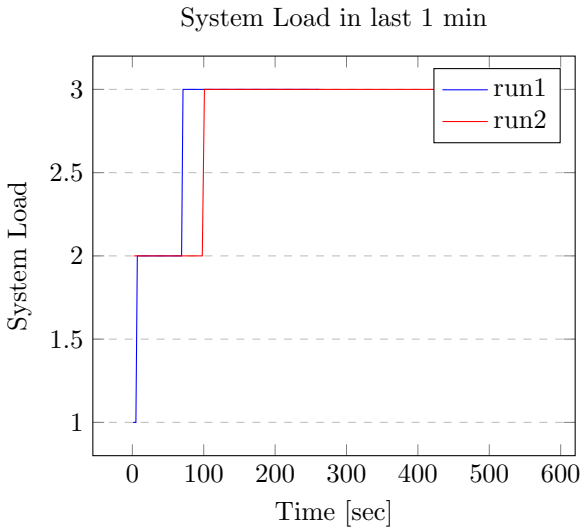


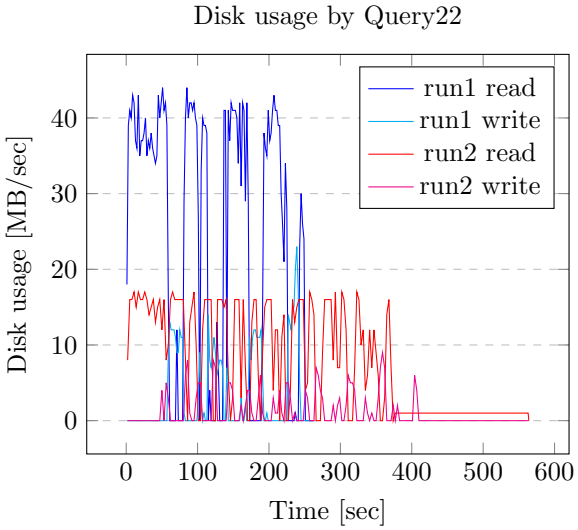


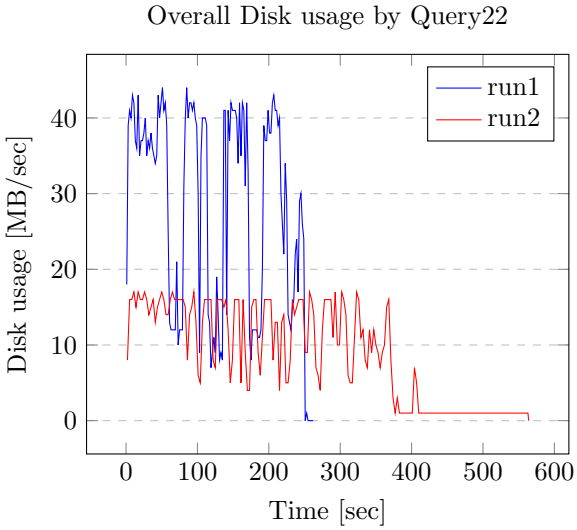
Load	Memory	Disk IO	Execution Time
3.10	39518.21 MB	28.41 MB/sec	414.00 sec

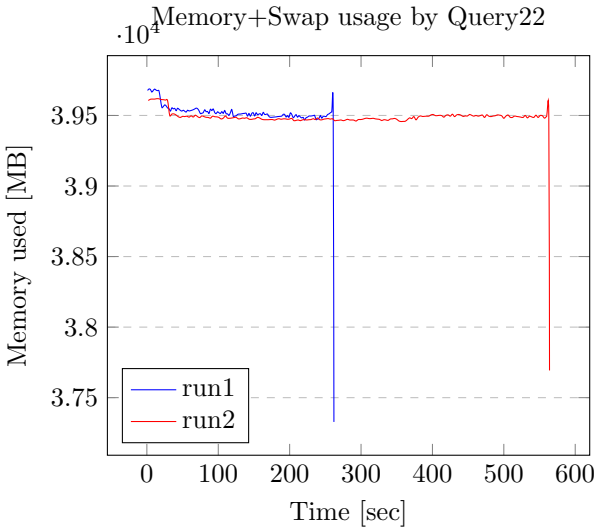
Table 20: Average Parametes over Runtime for Query22

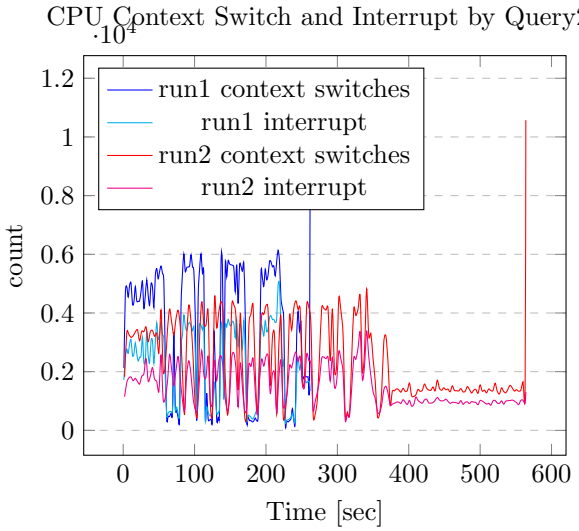








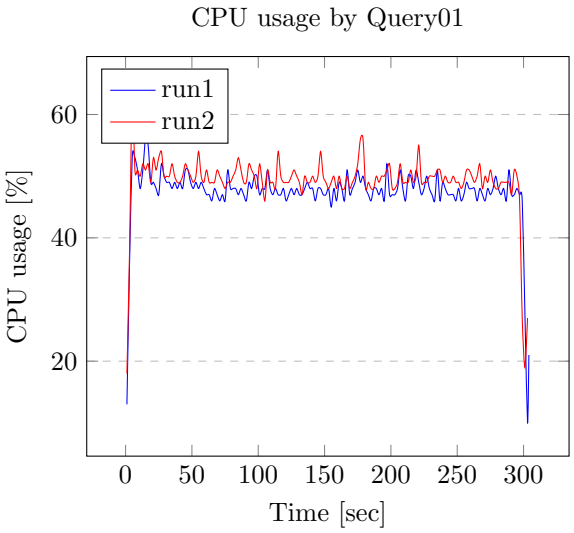


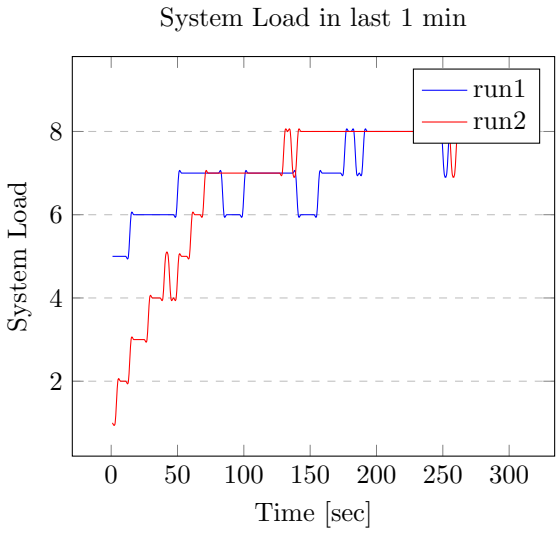


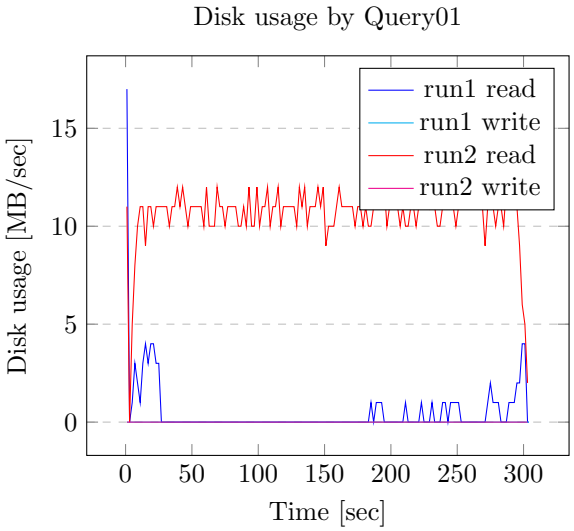
5 Spark results

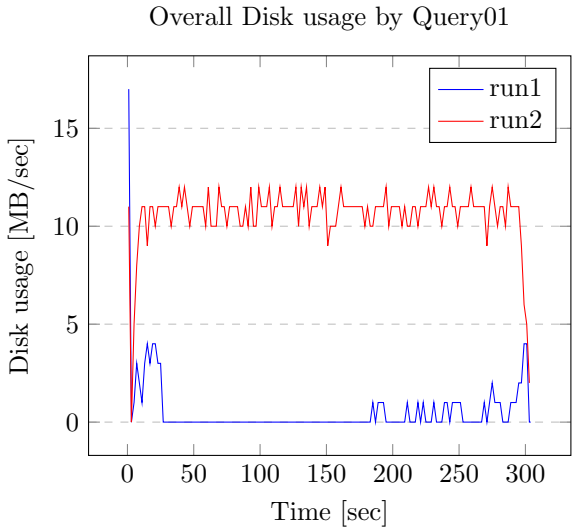
Spark has one worker and one master which ran on single node but dockerized on one network. Also hdfs used one namnode and one datanode as same condition. So networks will never be bottleneck. Unlike postgres spark uses all the resources all the time and plot of CPU and memory shows steady growth or stable usage of processors. Also parameters of first and second run are very close in most of queries.

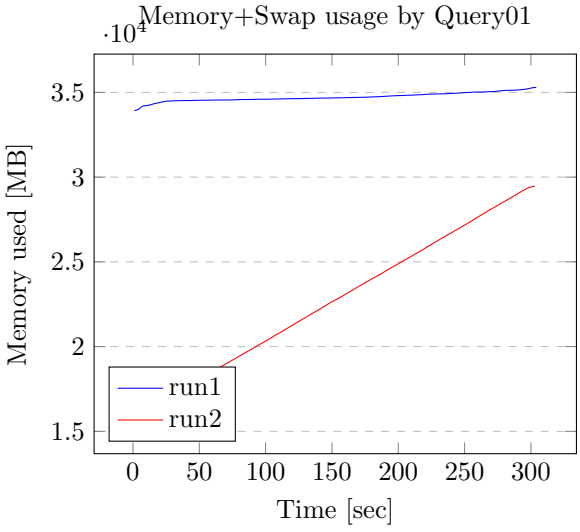
5.1 Spark and Parquet

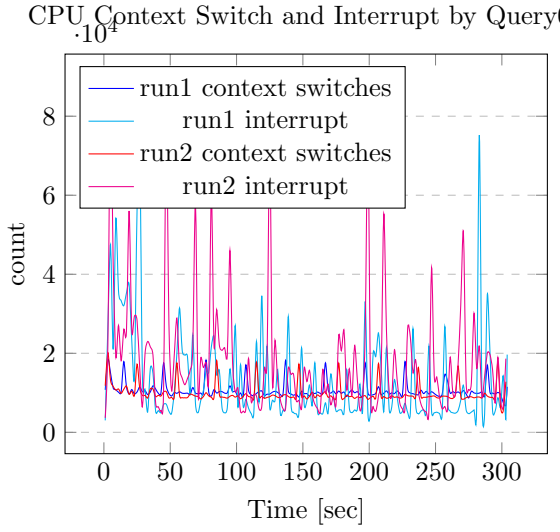










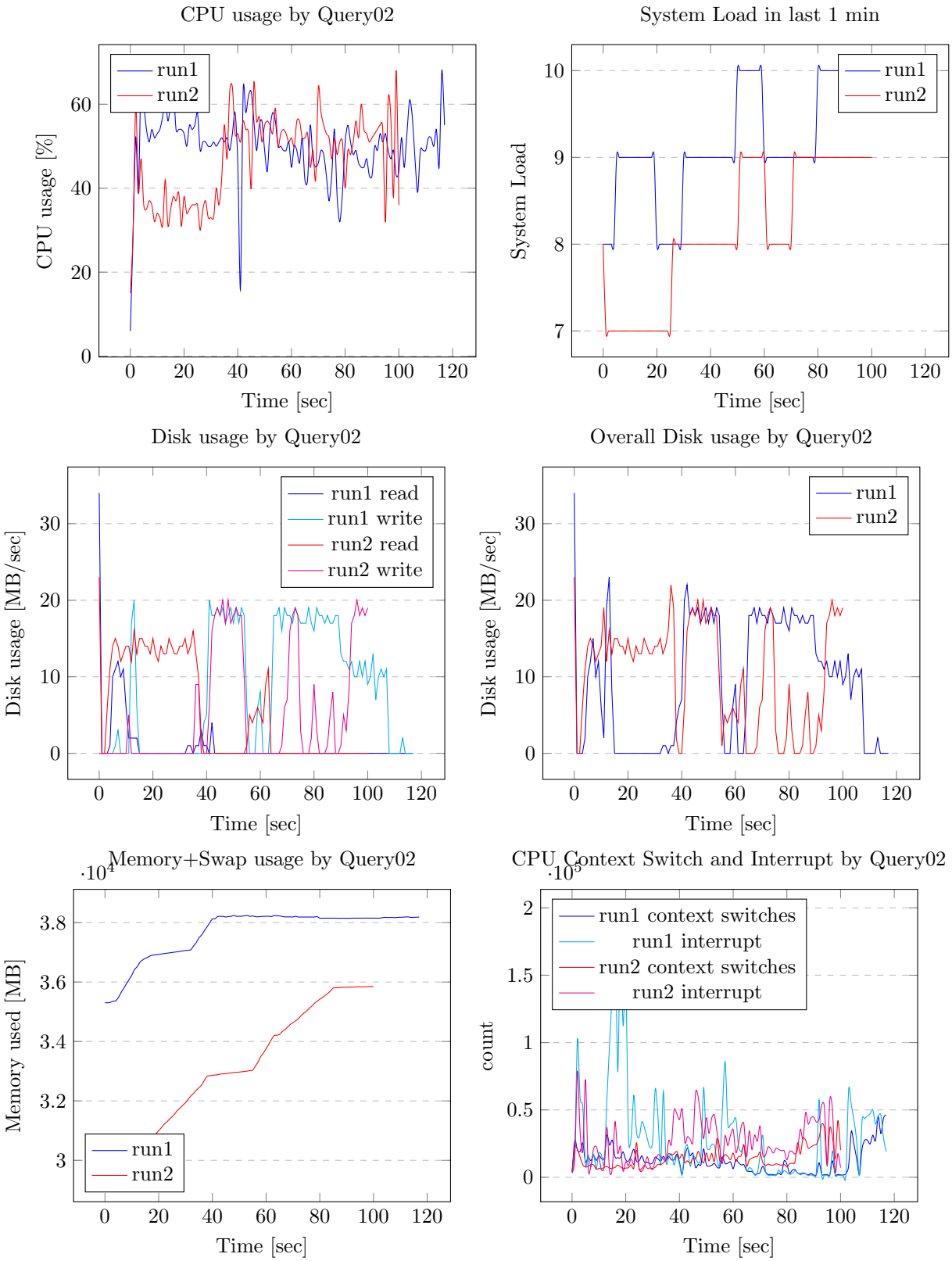


Load	Memory	Disk IO	Execution Time
7.51	34721.47 MB	0.91 MB/sec	304.50 sec

Table 21: Average Parametes over Runtime for Query01

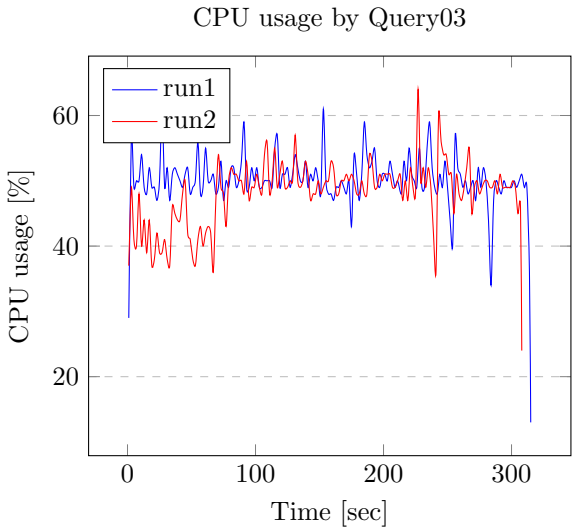
Load	Memory	Disk IO	Execution Time
9.71	37669.72 MB	9.80 MB/sec	109.50 sec

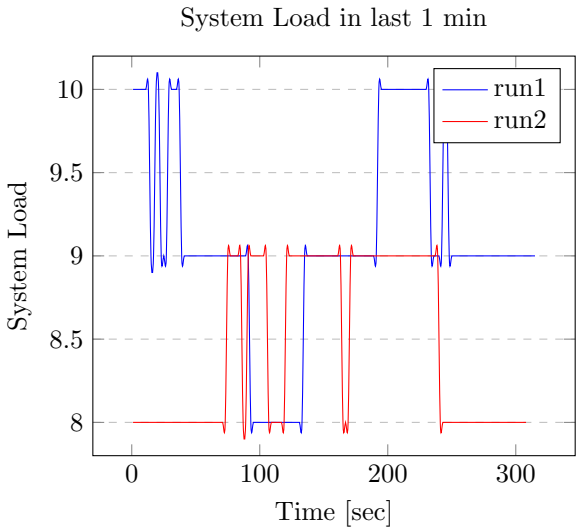
Table 22: Average Parametes over Runtime for Query02

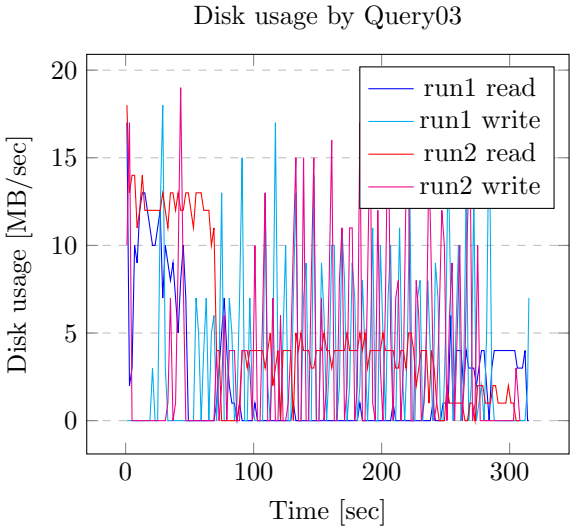


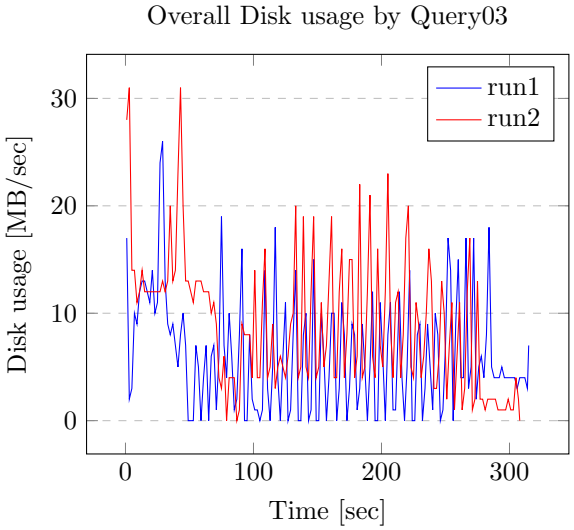
Load	Memory	Disk IO	Execution Time
9.57	37478.01 MB	6.70 MB/sec	312.00 sec

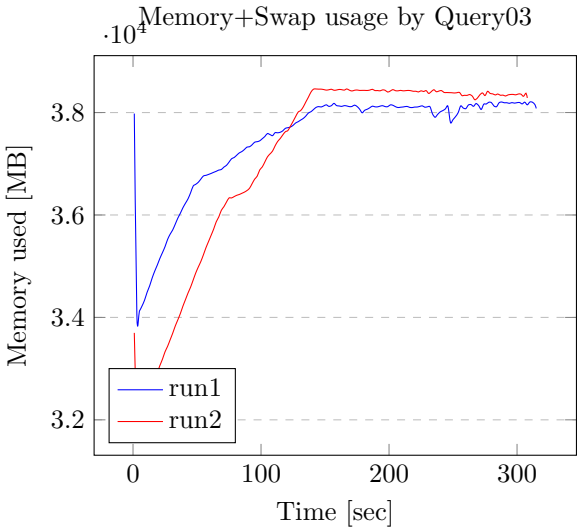
Table 23: Average Parametes over Runtime for Query03

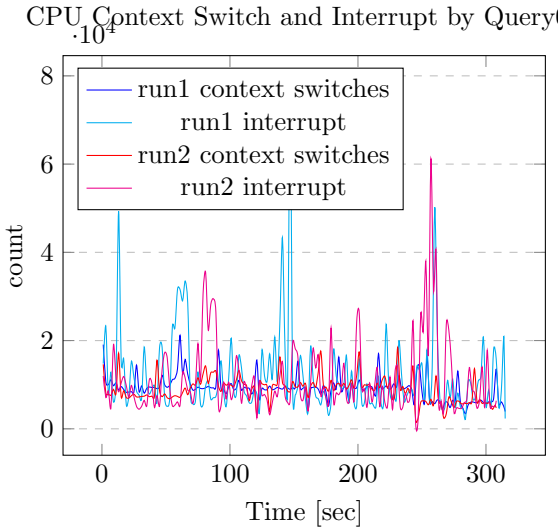






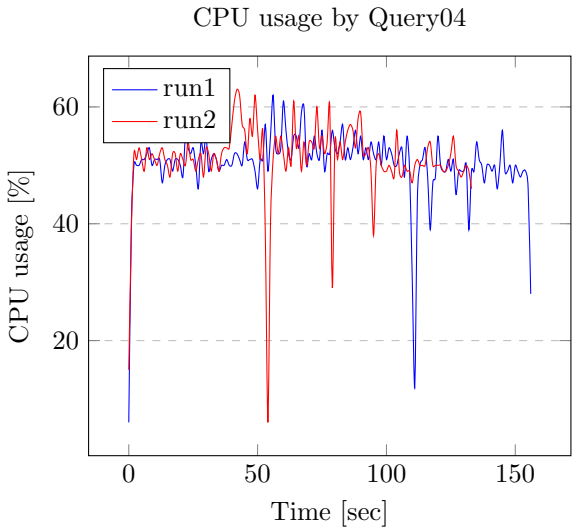


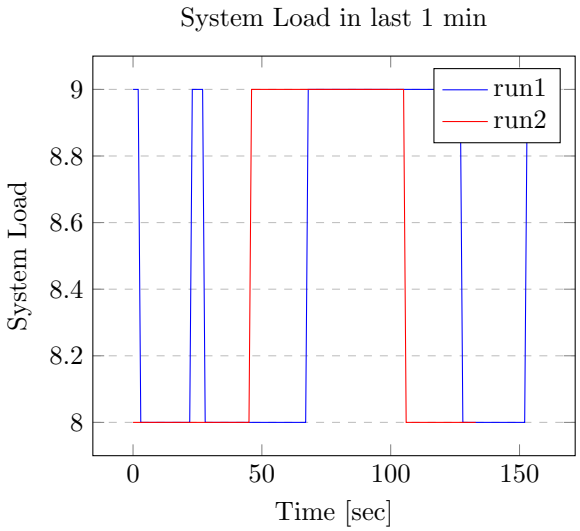


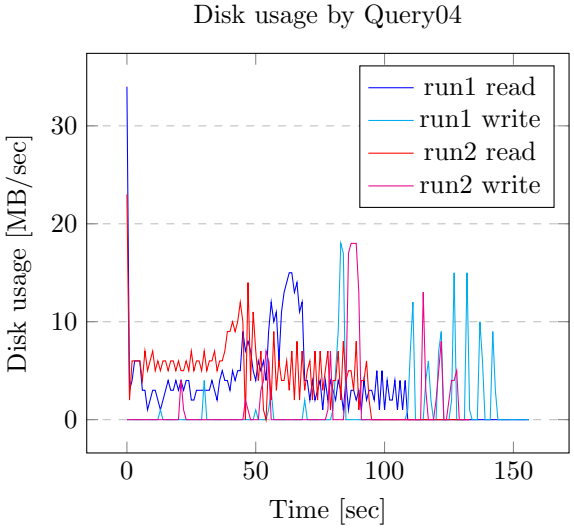


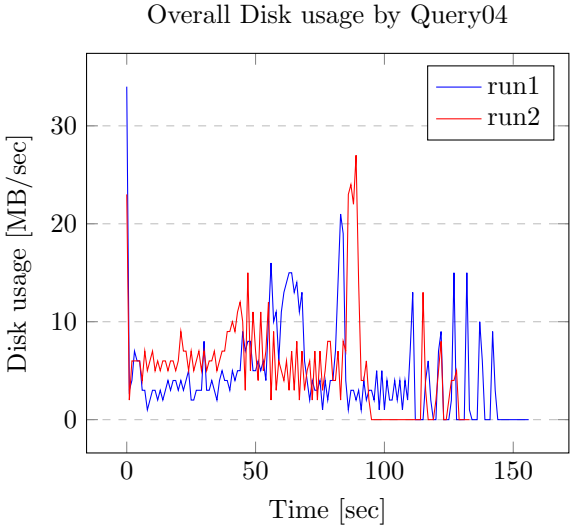
Load	Memory	Disk IO	Execution Time
9.07	37134.43 MB	4.93 MB/sec	145.50 sec

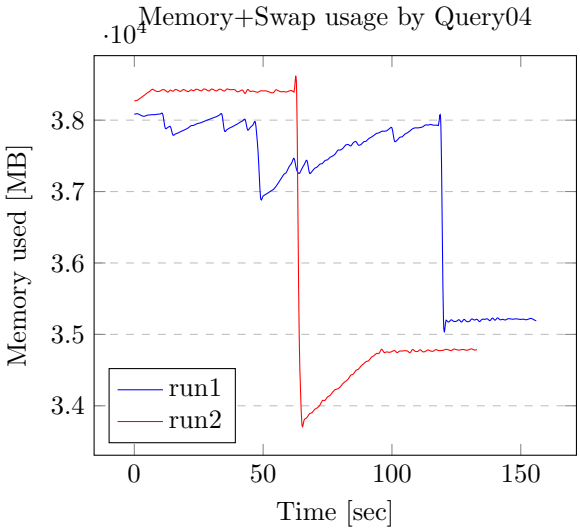
Table 24: Average Parametes over Runtime for Query04

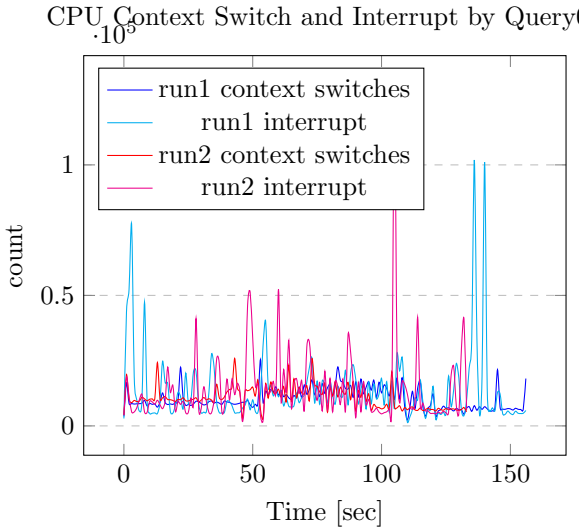






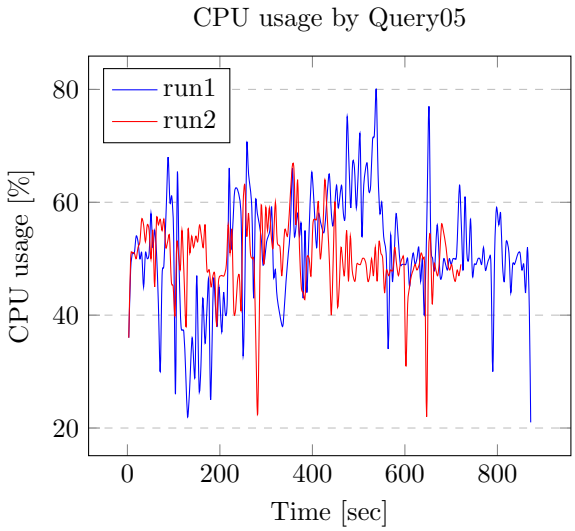


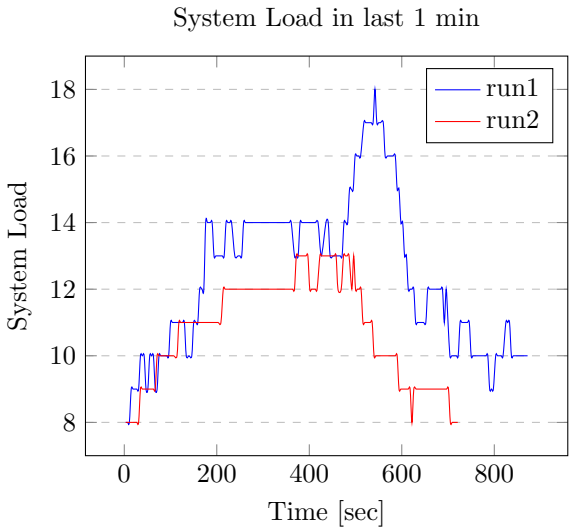


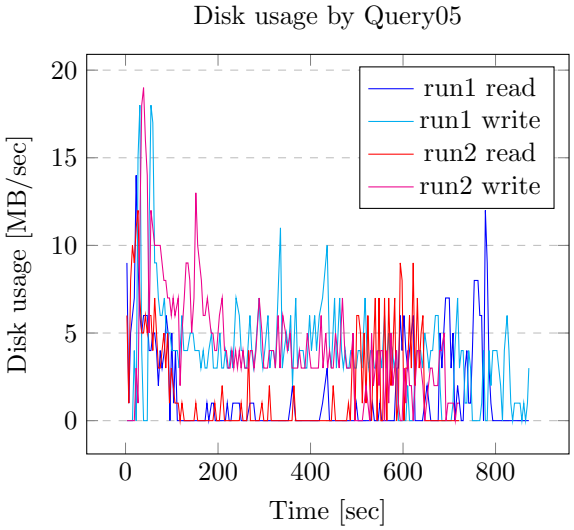


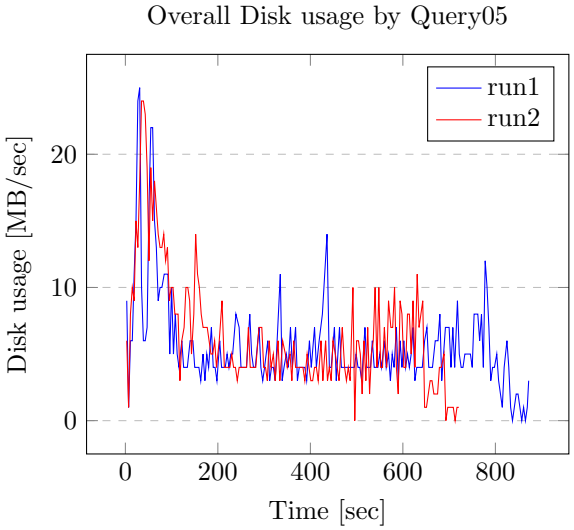
Load	Memory	Disk IO	Execution Time
12.78	37925.04 MB	6.06 MB/sec	735.50 sec

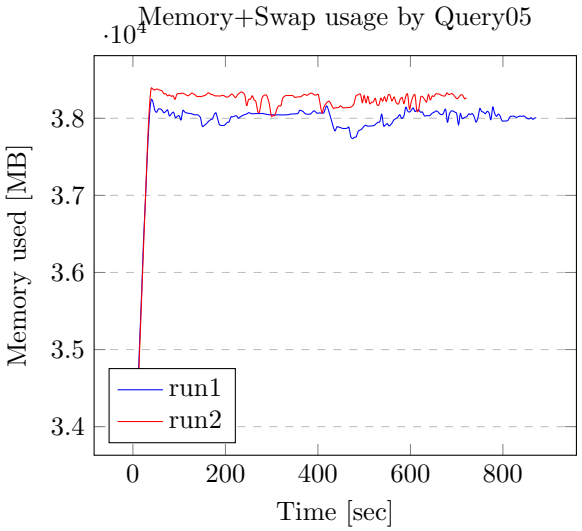
Table 25: Average Parametes over Runtime for Query05

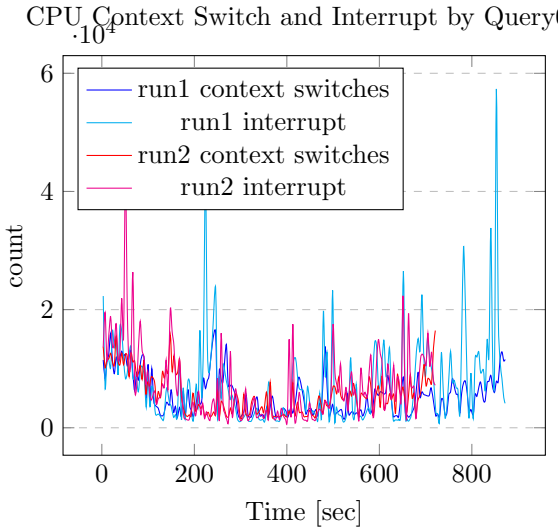






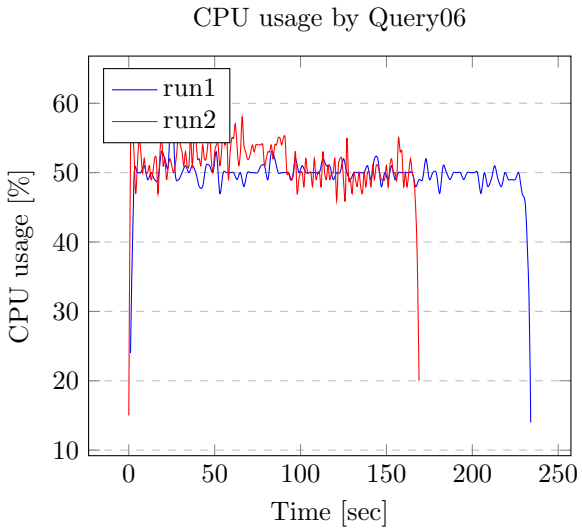


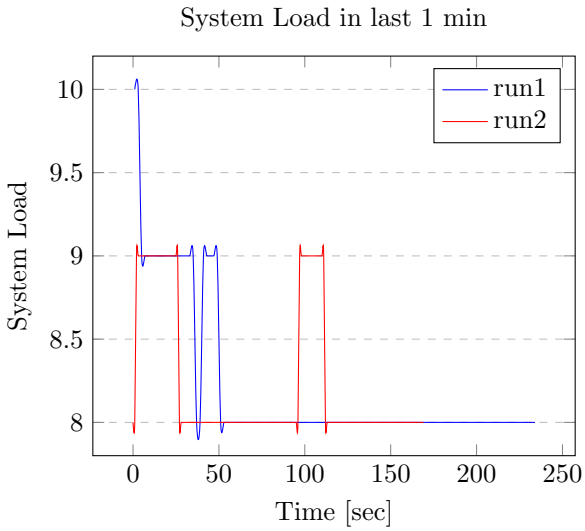


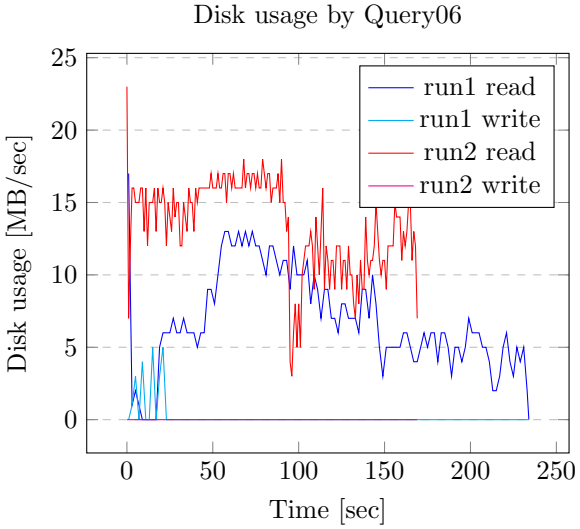


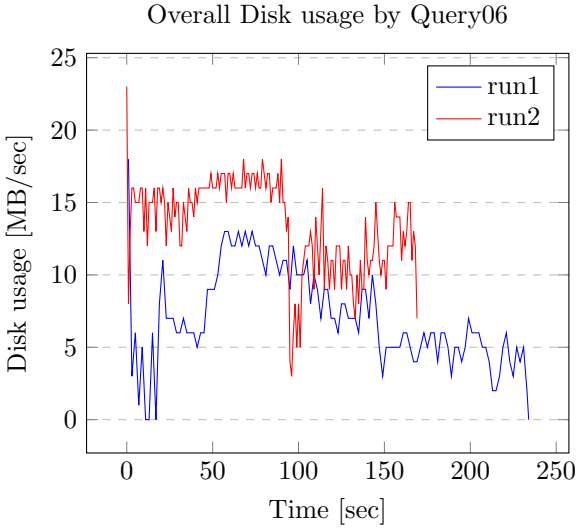
Load	Memory	Disk IO	Execution Time
8.68	29986.37 MB	7.61 MB/sec	202.50 sec

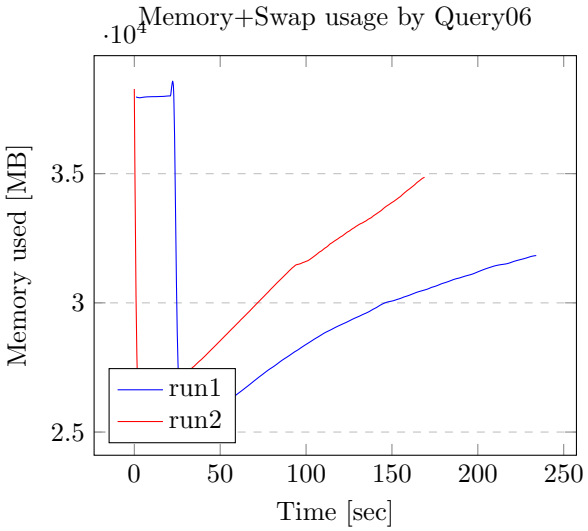
Table 26: Average Parametes over Runtime for Query06

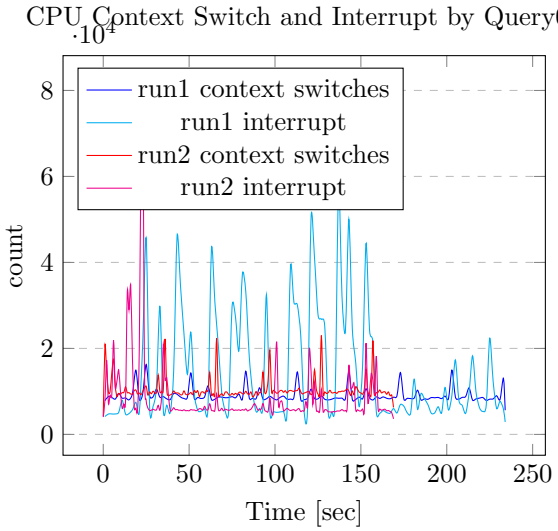






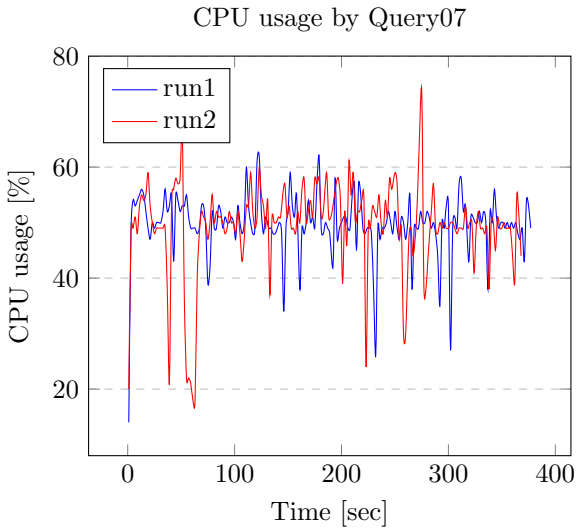


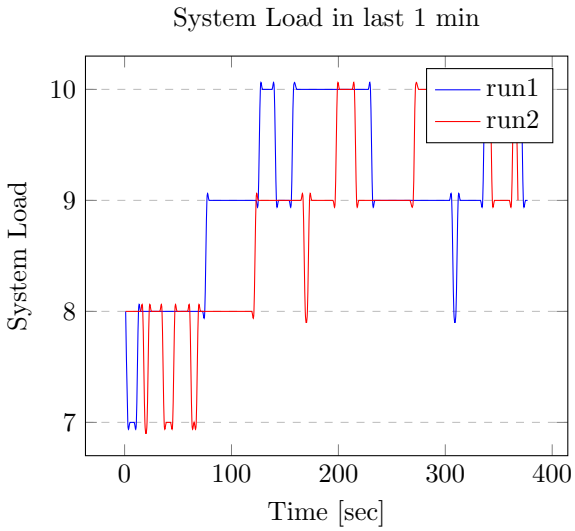


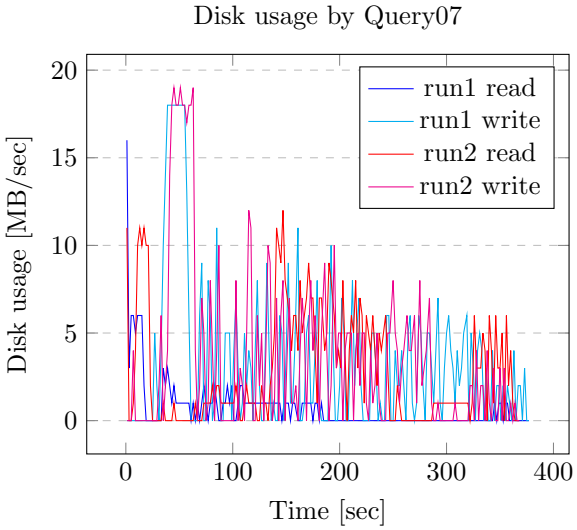


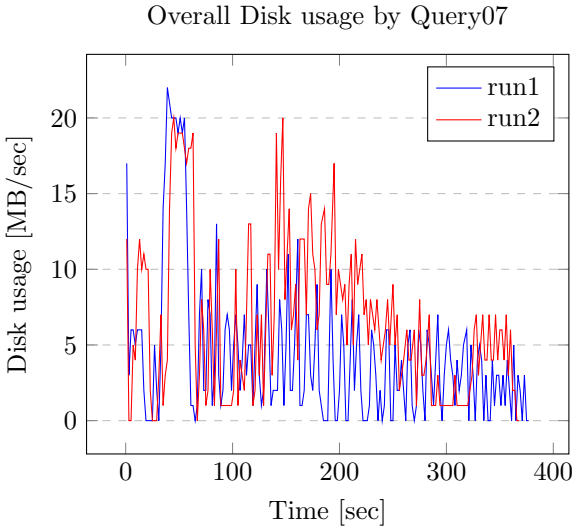
Load	Memory	Disk IO	Execution Time
9.55	36546.44 MB	4.80 MB/sec	368.00 sec

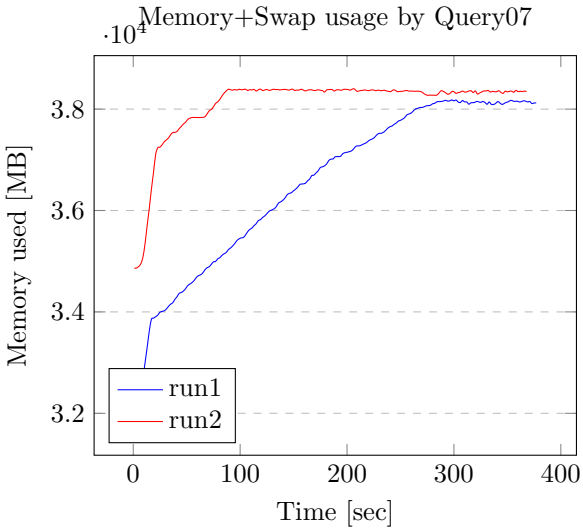
Table 27: Average Parametes over Runtime for Query07

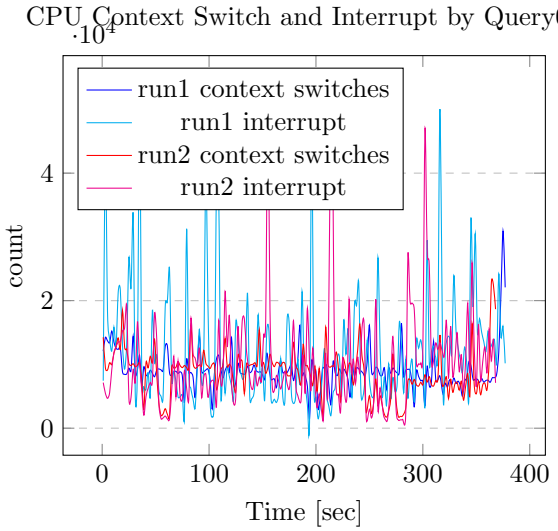






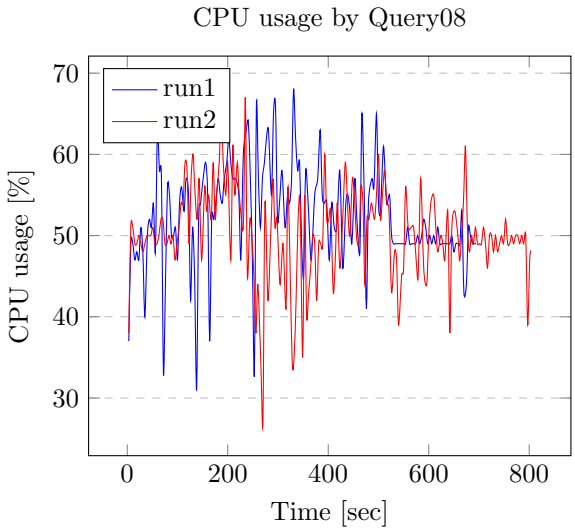


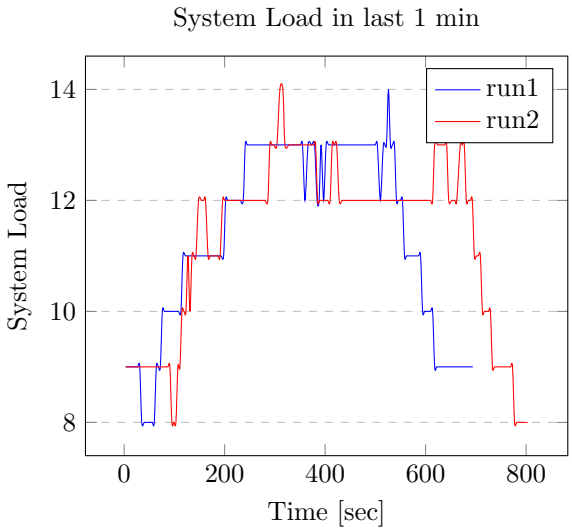


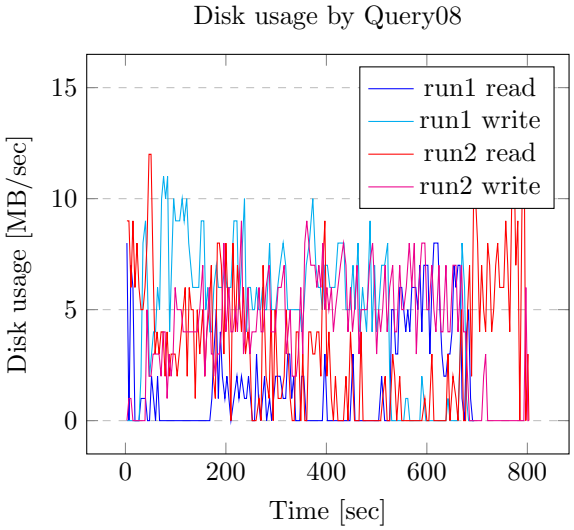


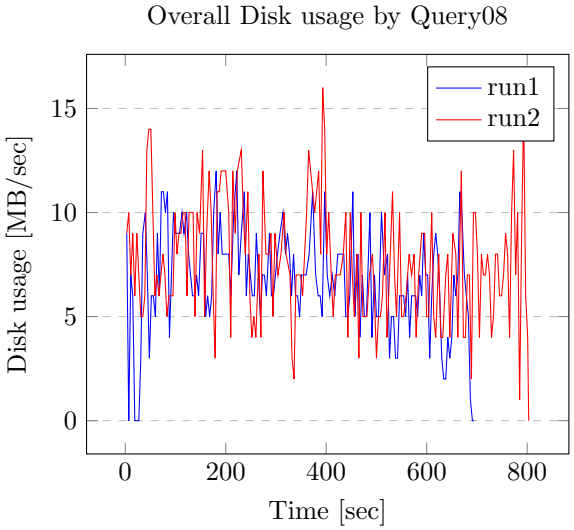
Load	Memory	Disk IO	Execution Time
11.68	37520.41 MB	7.19 MB/sec	686.50 sec

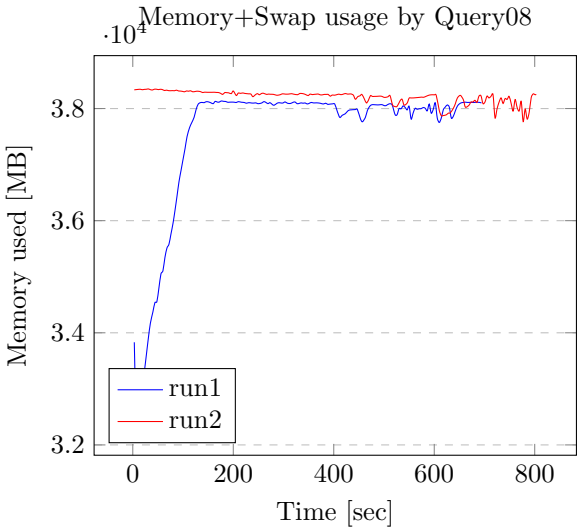
Table 28: Average Parametes over Runtime for Query08

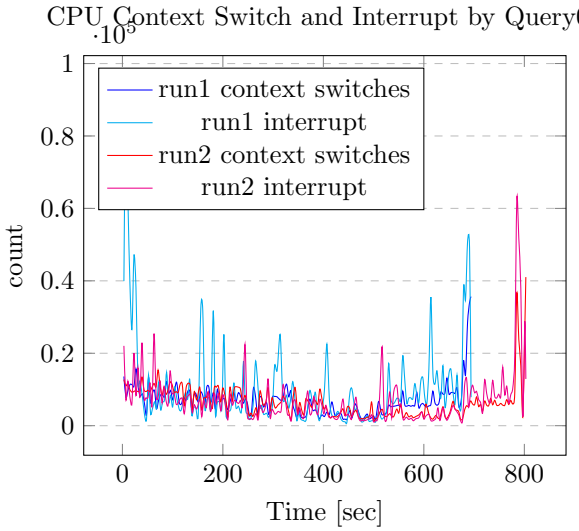






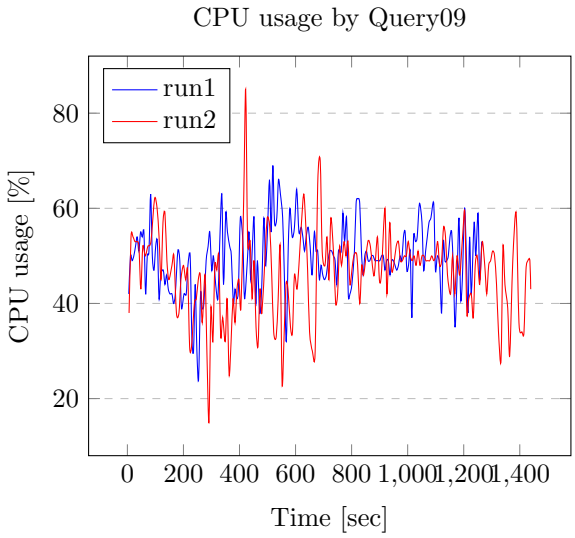


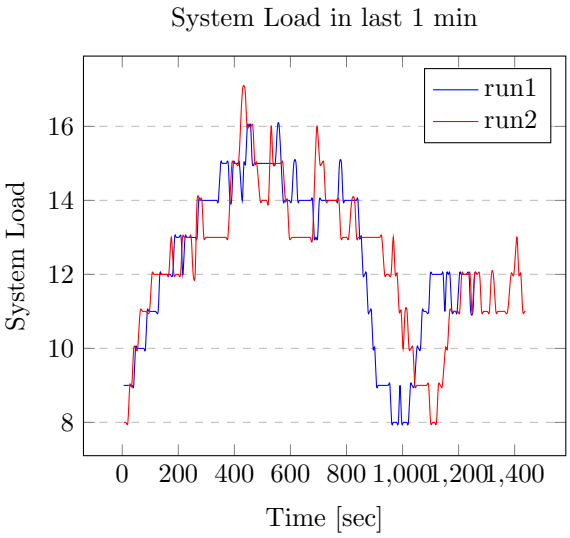


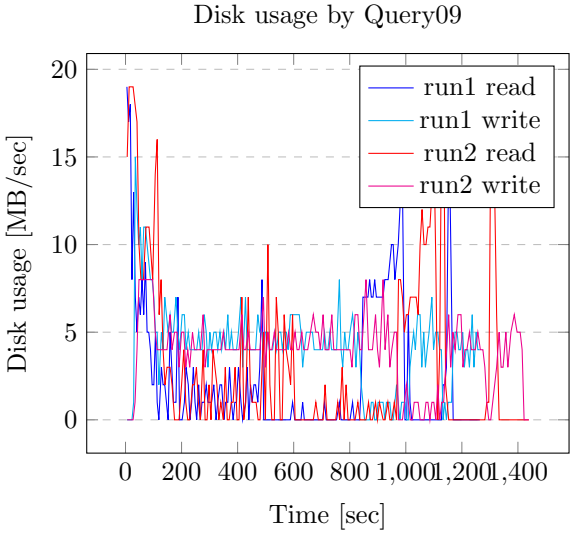


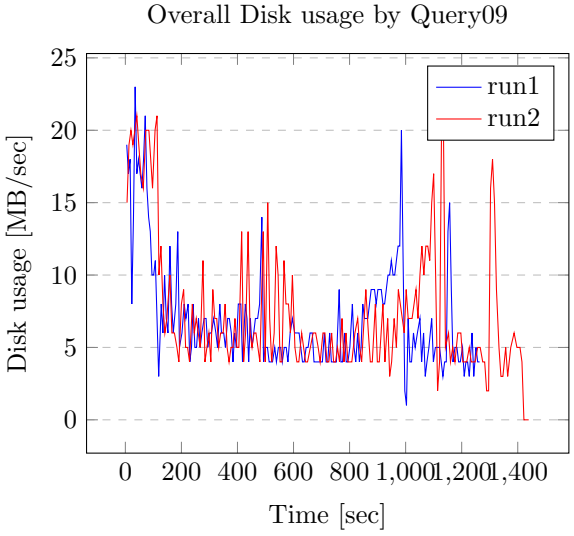
Load	Memory	Disk IO	Execution Time
12.86	37540.41 MB	7.57 MB/sec	1224.50 sec

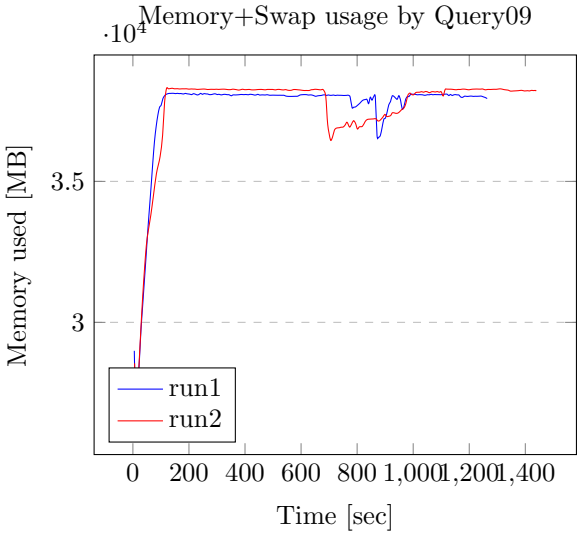
Table 29: Average Parametes over Runtime for Query09

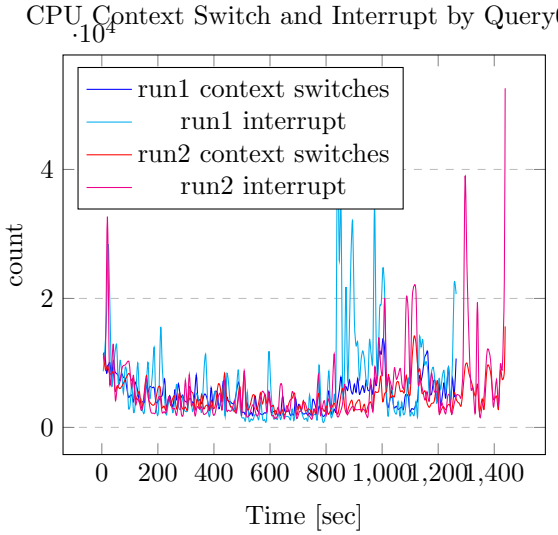






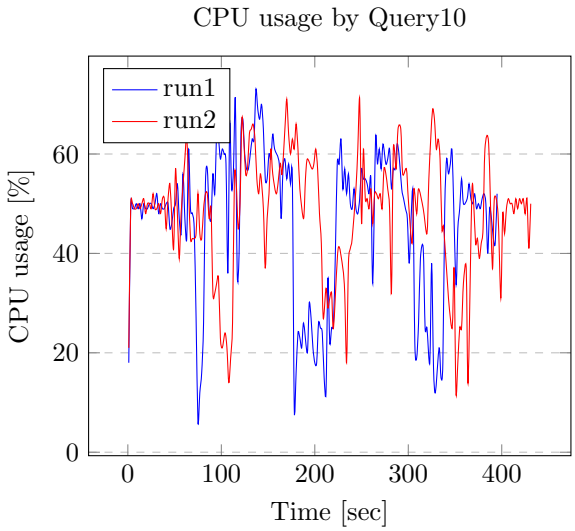


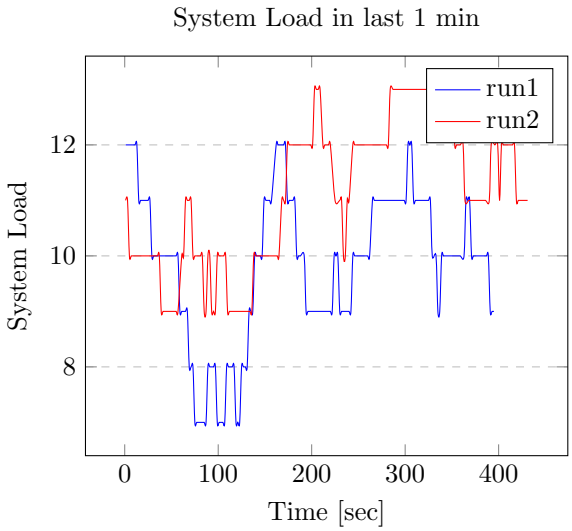


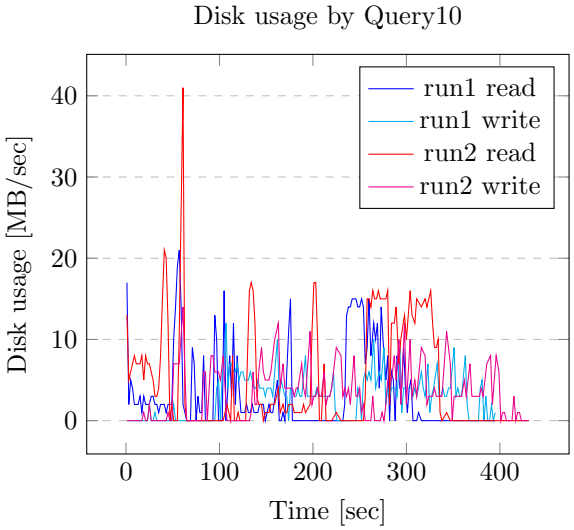


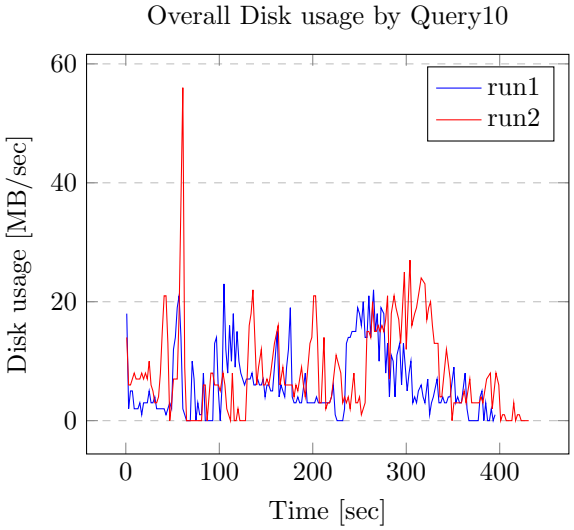
Load	Memory	Disk IO	Execution Time
10.31	26451.74 MB	6.70 MB/sec	381.00 sec

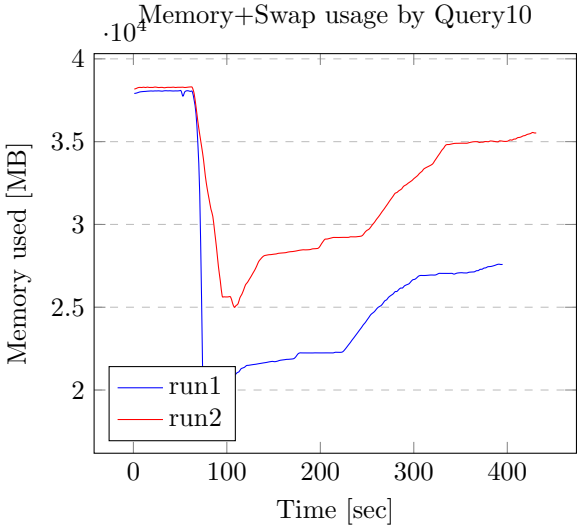
Table 30: Average Parametes over Runtime for Query10

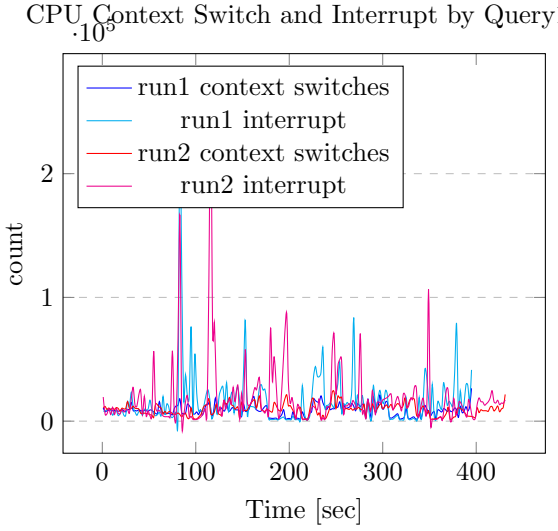






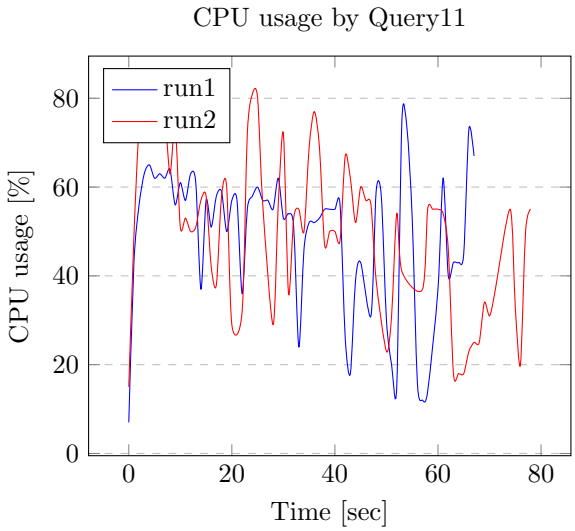


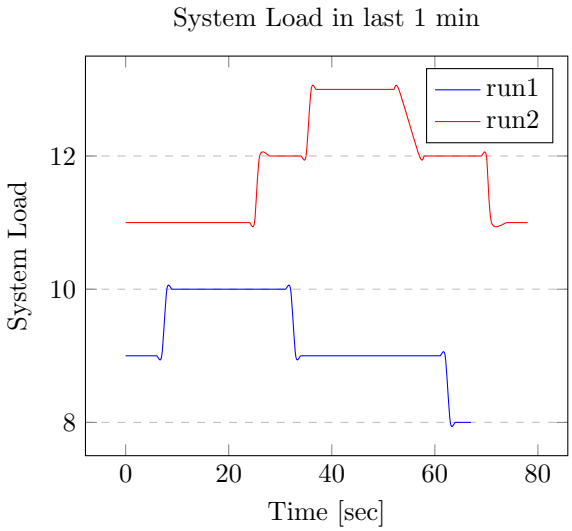


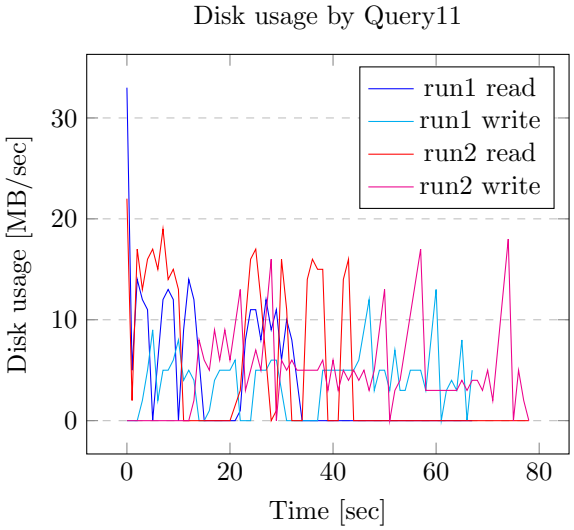


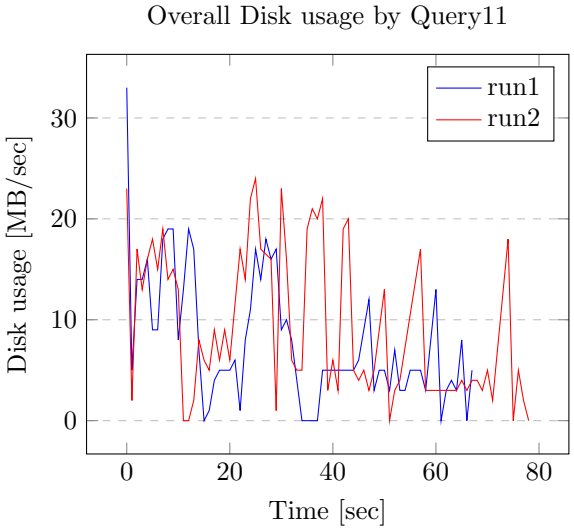
Load	Memory	Disk IO	Execution Time
9.76	30161.78 MB	8.21 MB/sec	68.50 sec

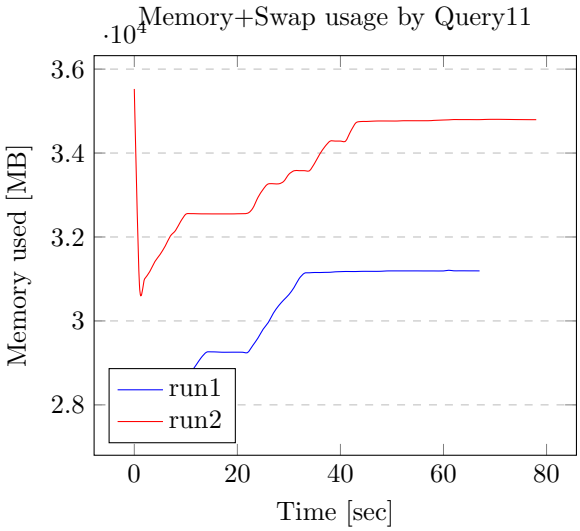
Table 31: Average Parametes over Runtime for Query11

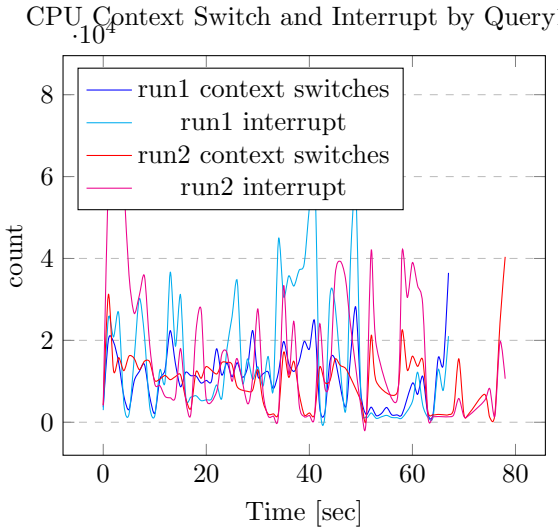






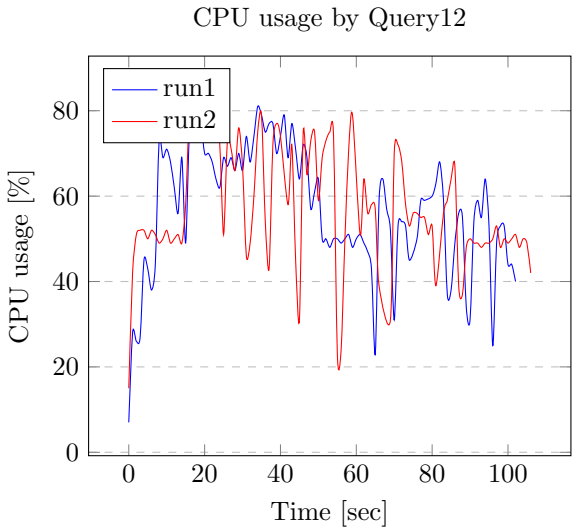


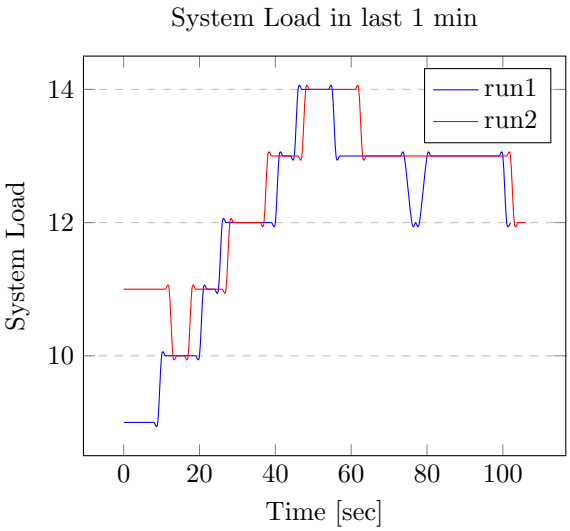


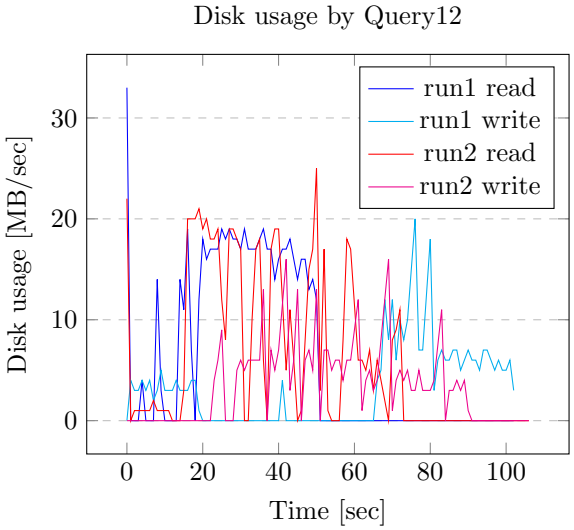


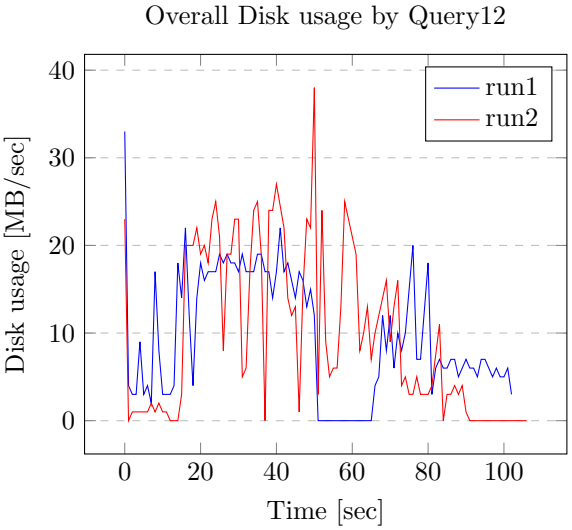
Load	Memory	Disk IO	Execution Time
12.50	30997.83 MB	10.01 MB/sec	101.50 sec

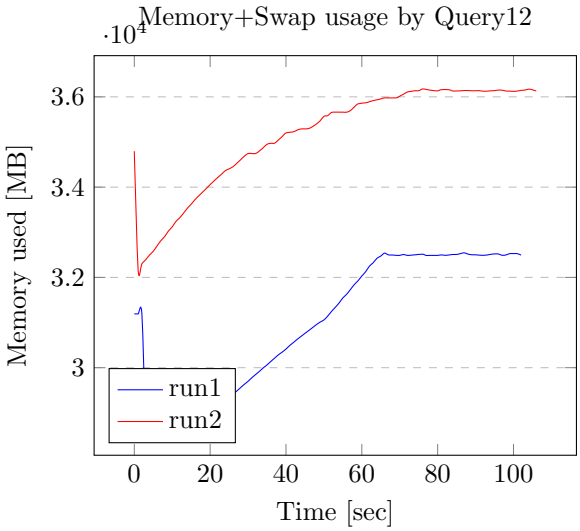
Table 32: Average Parametes over Runtime for Query12

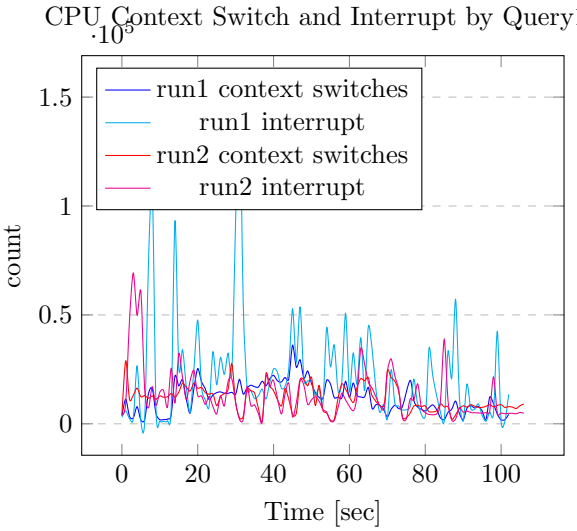






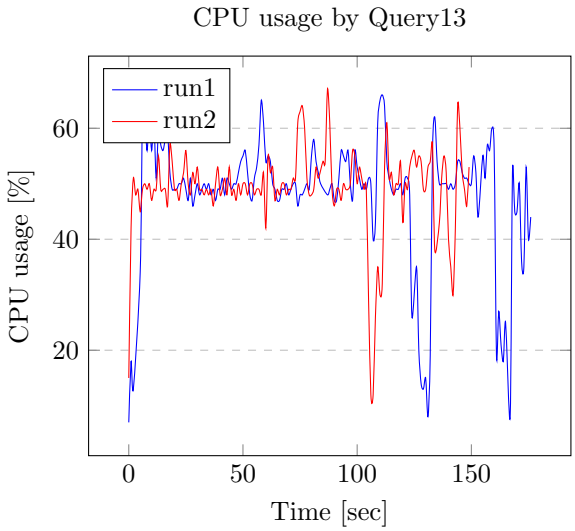


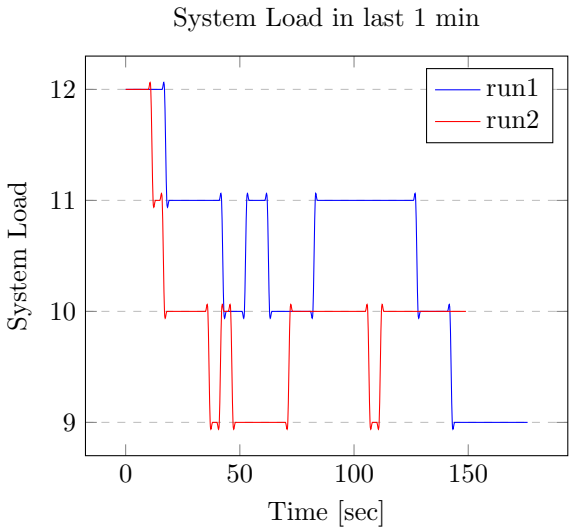


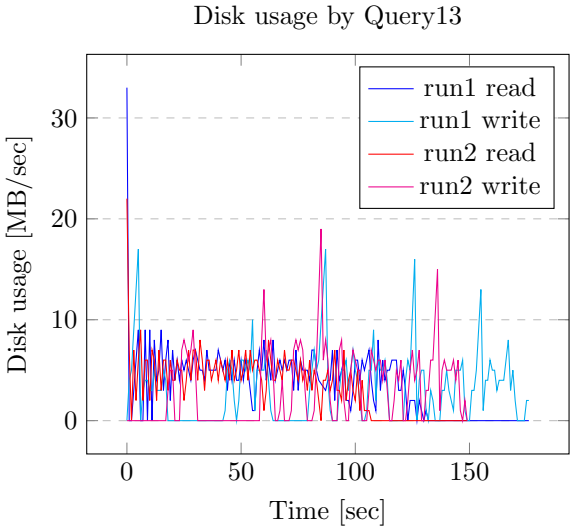


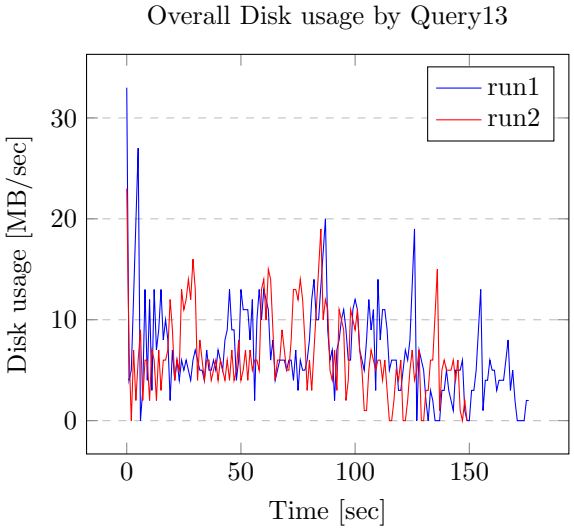
Load	Memory	Disk IO	Execution Time
10.92	33825.26 MB	7.01 MB/sec	159.00 sec

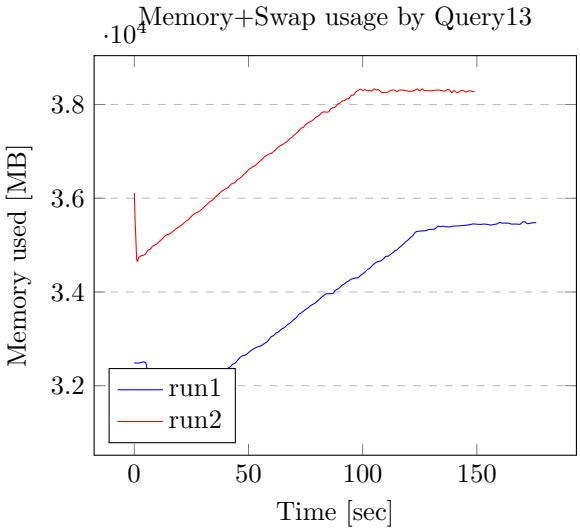
Table 33: Average Parametes over Runtime for Query13

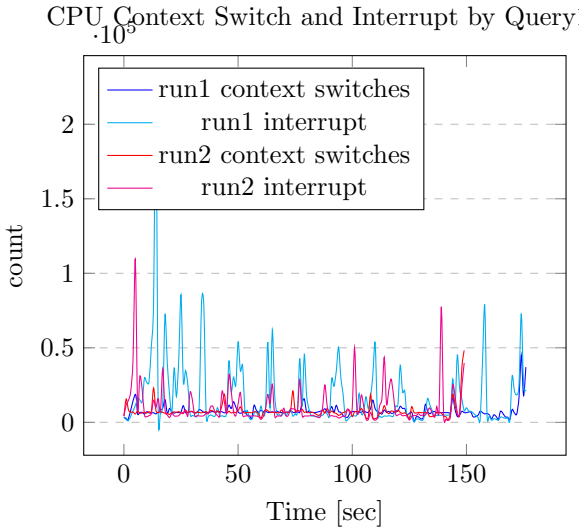






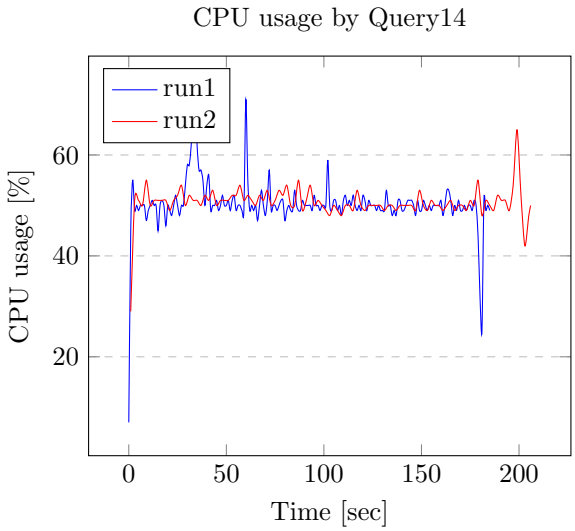


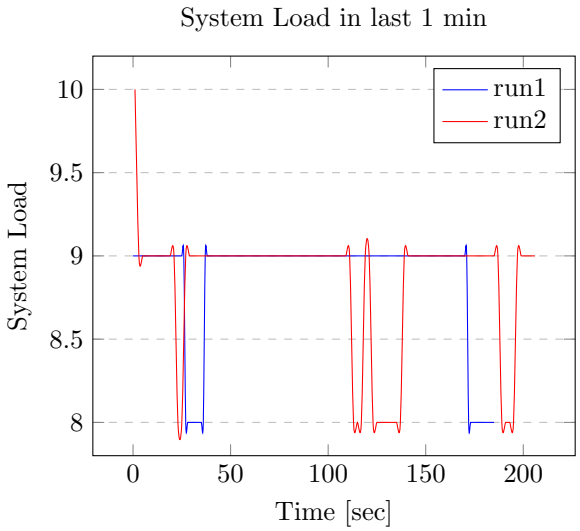


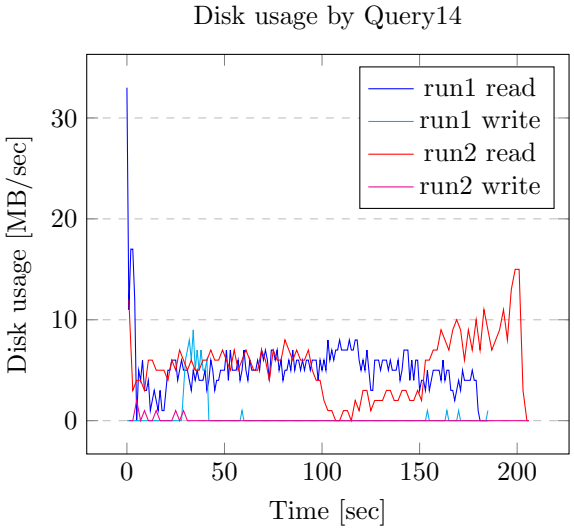


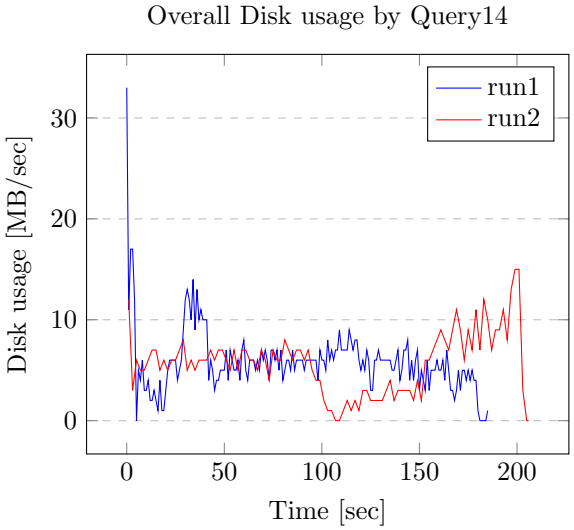
Load	Memory	Disk IO	Execution Time
9.29	36162.94 MB	6.35 MB/sec	196.50 sec

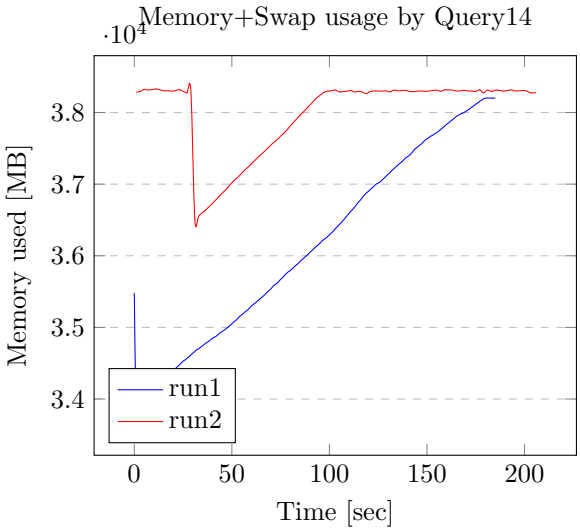
Table 34: Average Parametes over Runtime for Query14

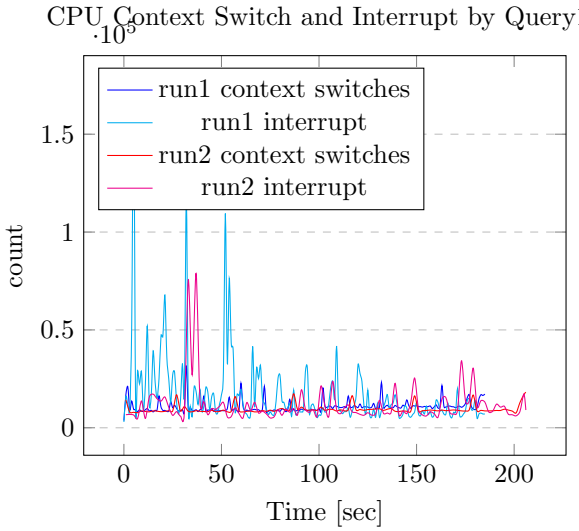






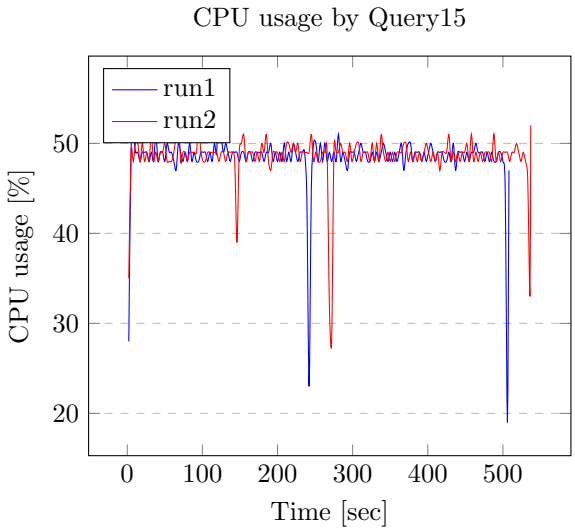


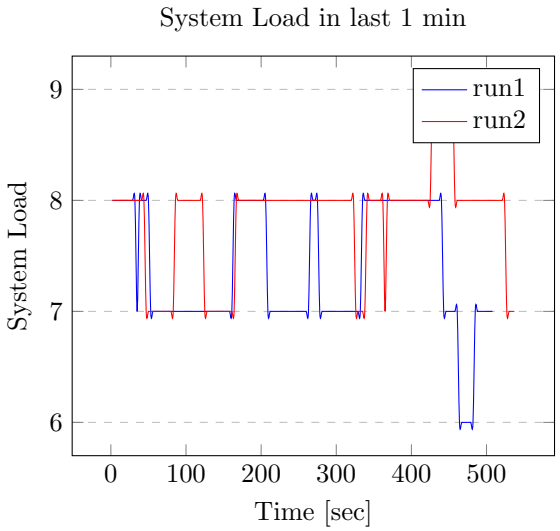


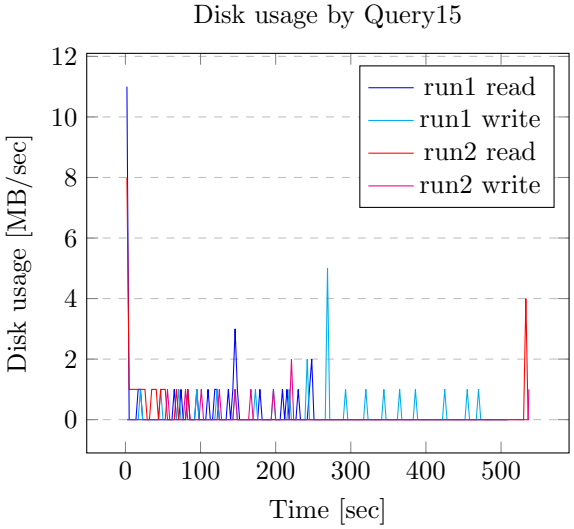


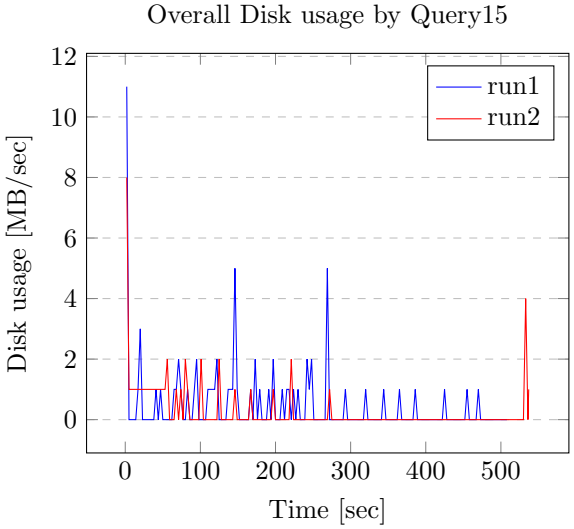
Load	Memory	Disk IO	Execution Time
7.79	35000.78 MB	0.79 MB/sec	523.50 sec

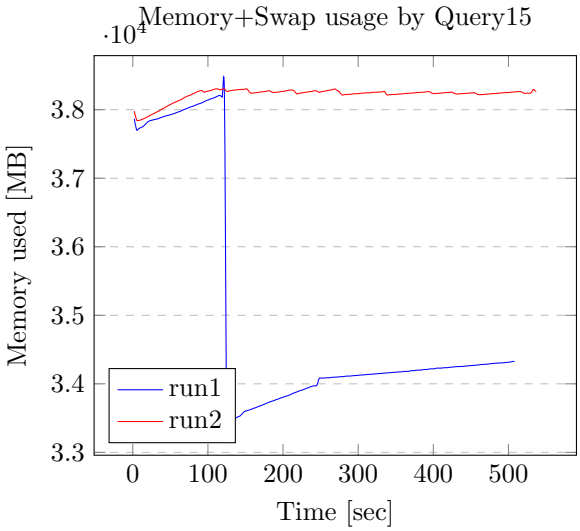
Table 35: Average Parametes over Runtime for Query15

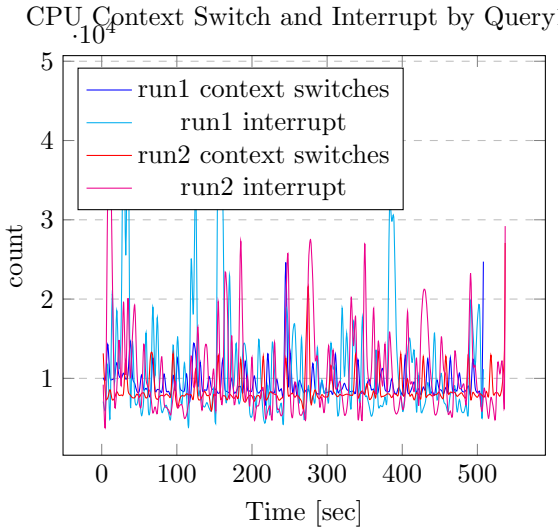






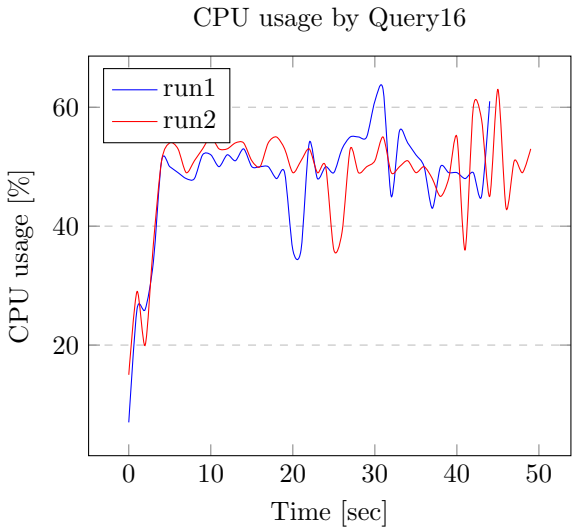


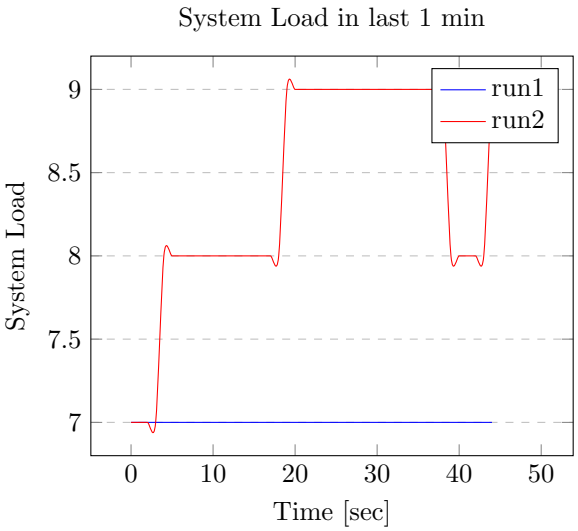


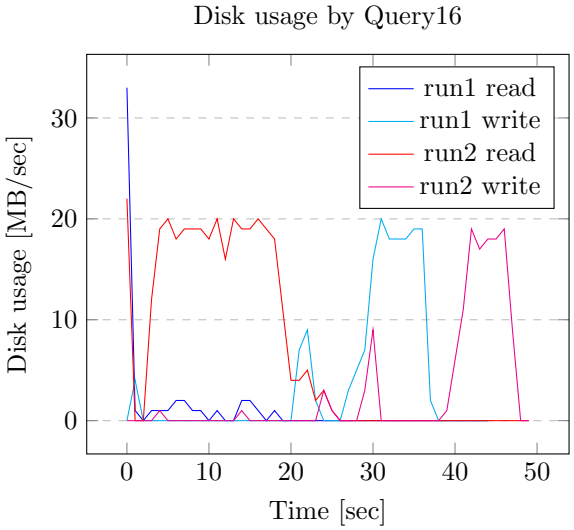


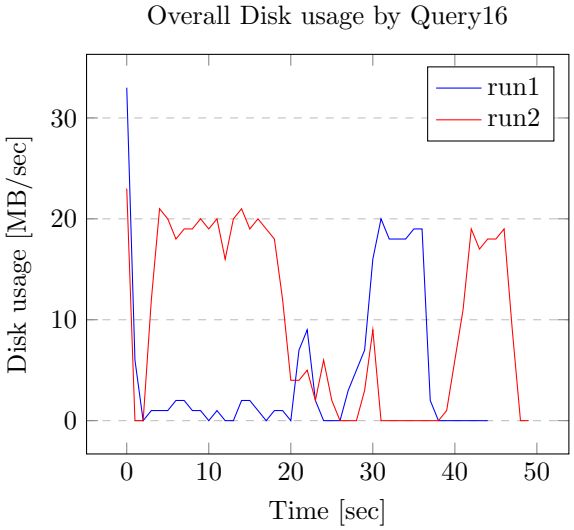
Load	Memory	Disk IO	Execution Time
7.36	35028.55 MB	5.20 MB/sec	47.50 sec

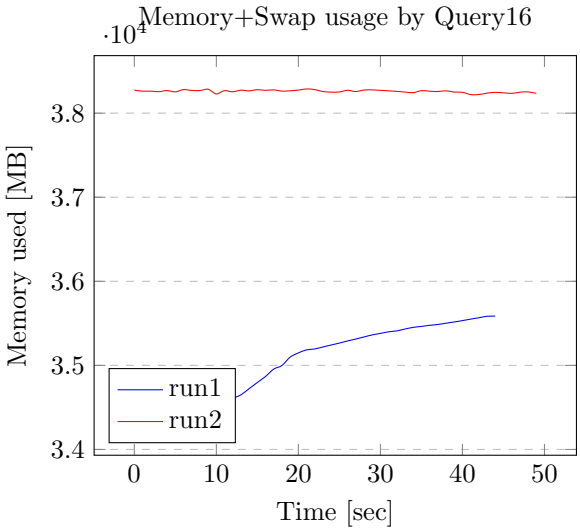
Table 36: Average Parametes over Runtime for Query16

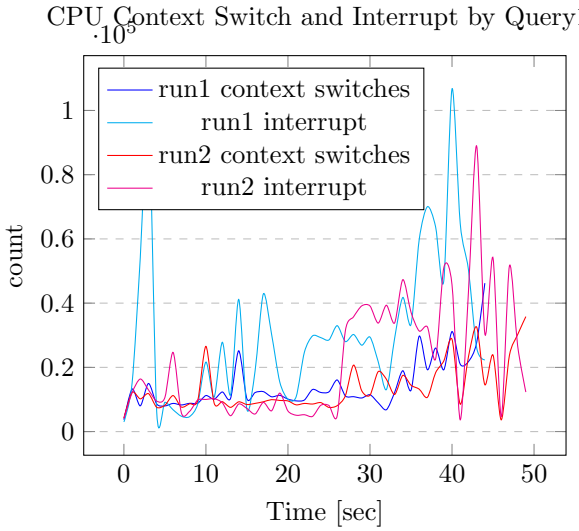






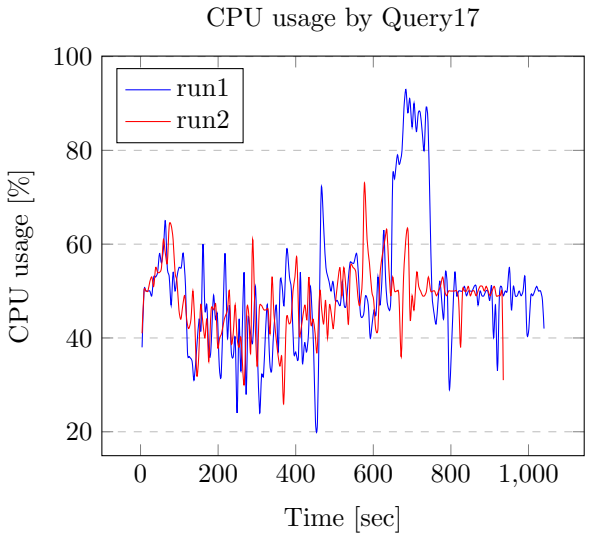


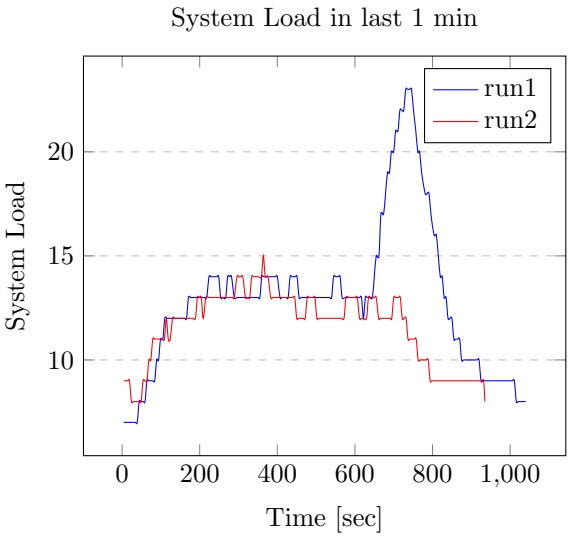


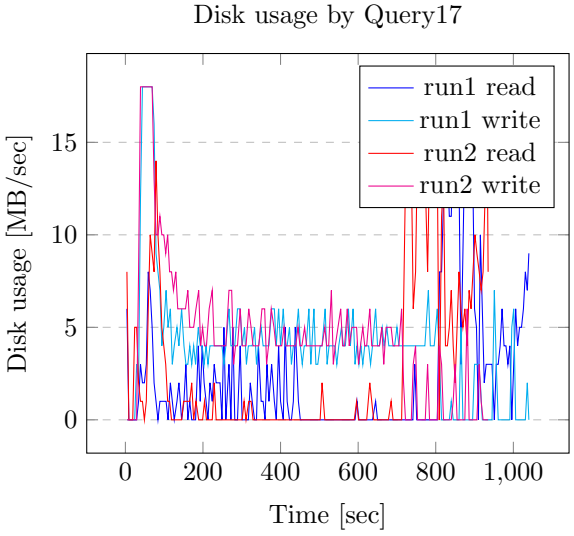


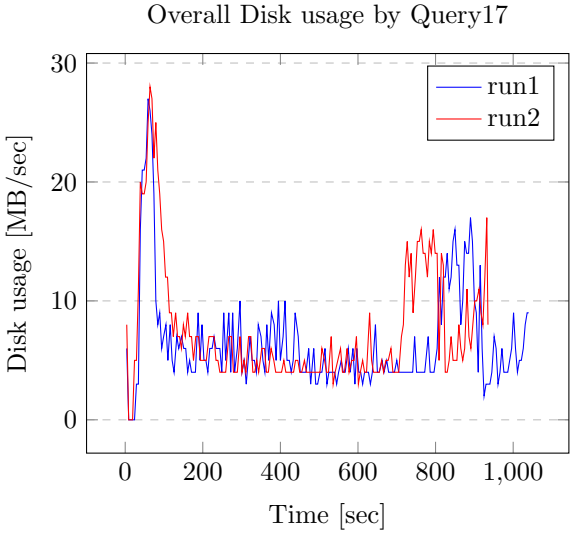
Load	Memory	Disk IO	Execution Time
13.31	37951.60 MB	7.09 MB/sec	923.50 sec

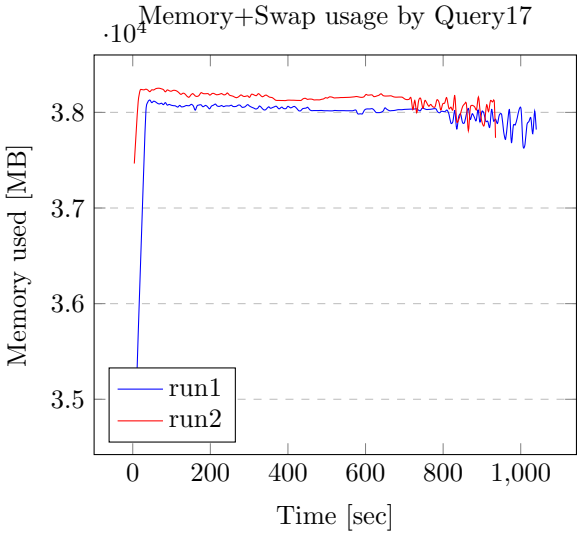
Table 37: Average Parametes over Runtime for Query17

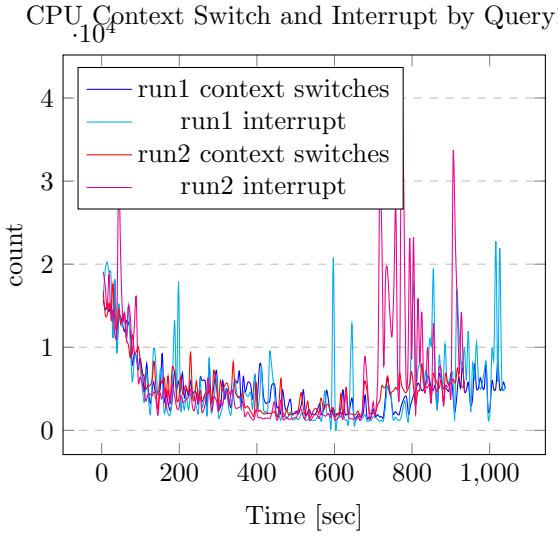






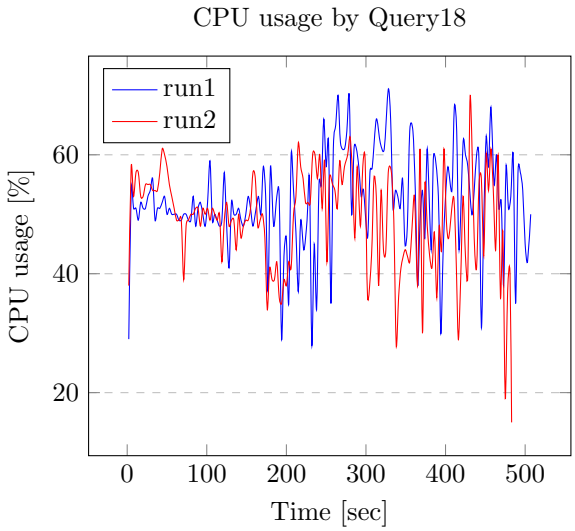


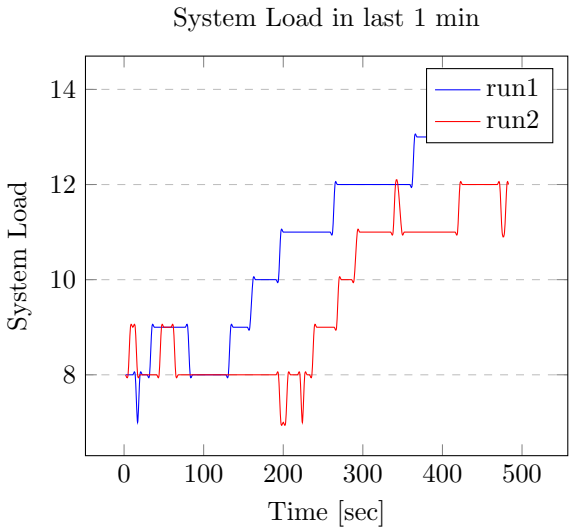


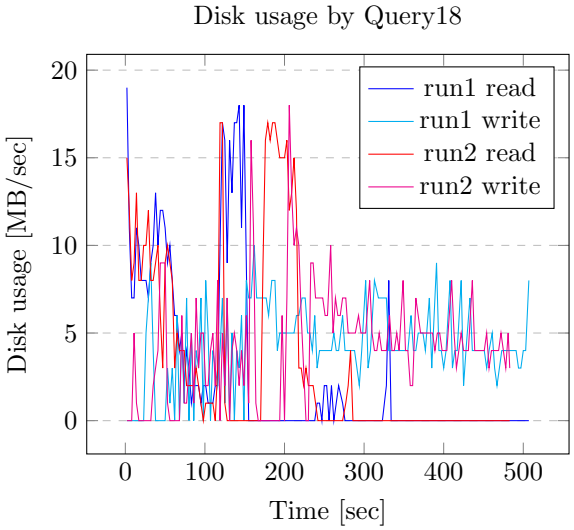


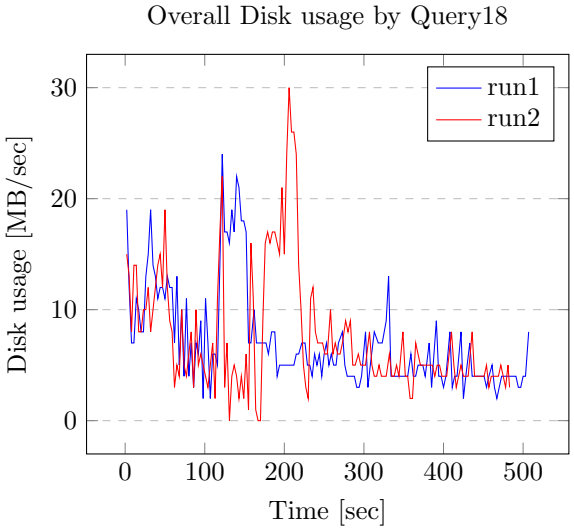
Load	Memory	Disk IO	Execution Time
11.38	32025.87 MB	7.64 MB/sec	473.00 sec

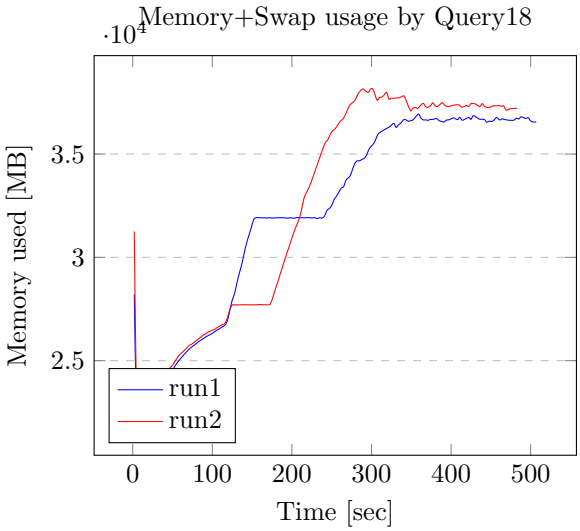
Table 38: Average Parametes over Runtime for Query18

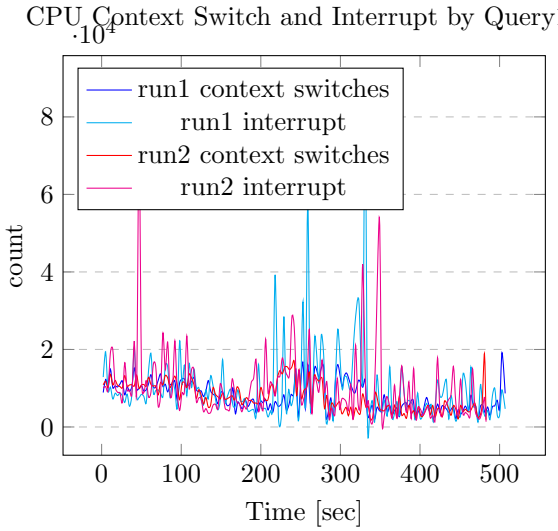






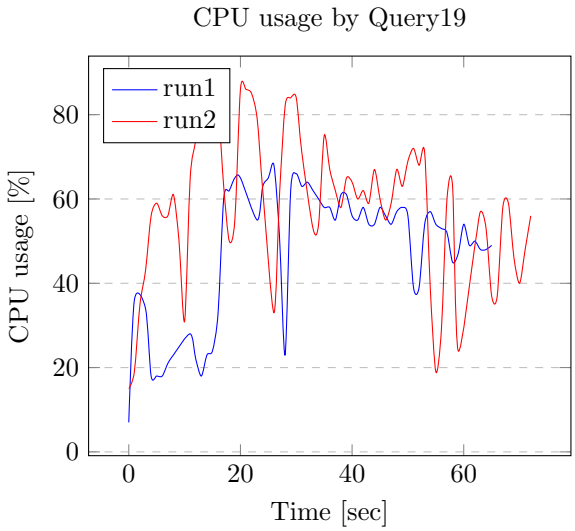


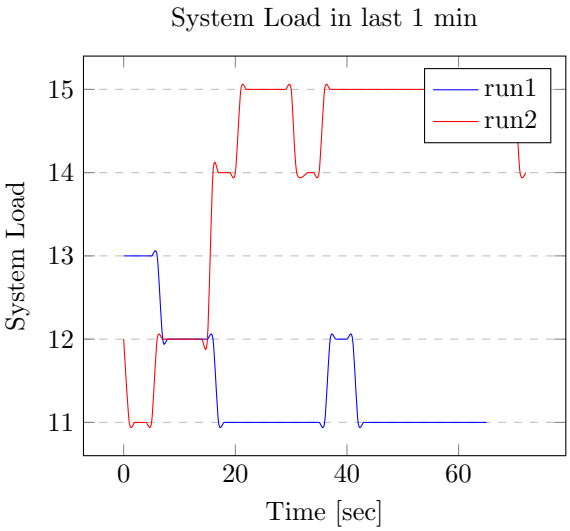


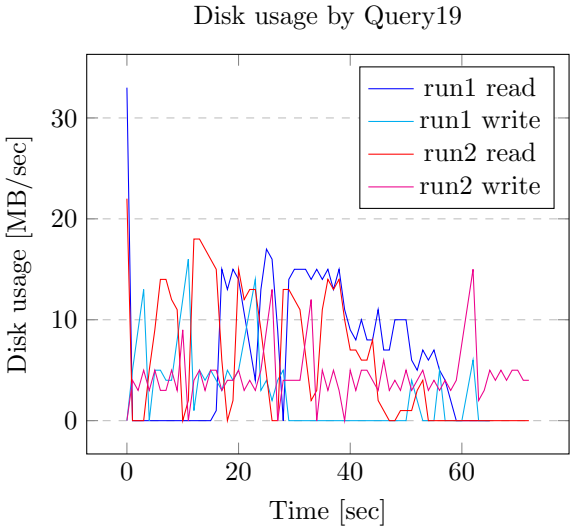


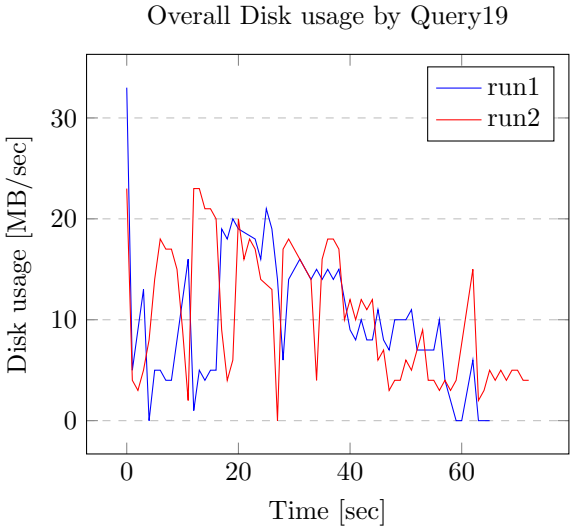
Load	Memory	Disk IO	Execution Time
11.90	37318.39 MB	10.22 MB/sec	65.00 sec

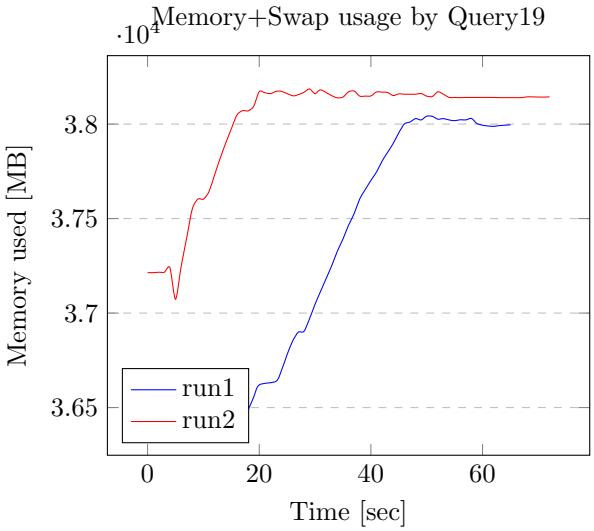
Table 39: Average Parametes over Runtime for Query19

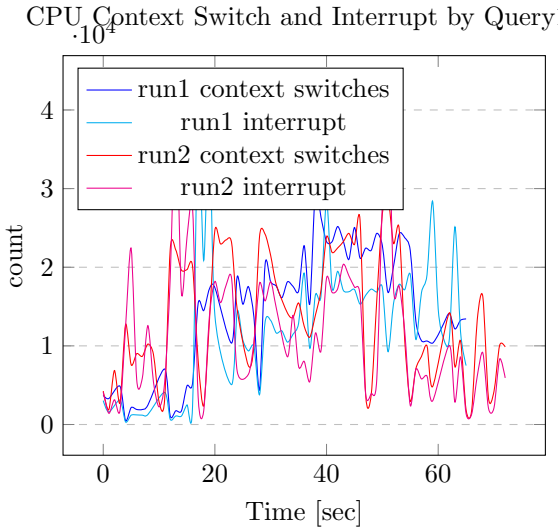






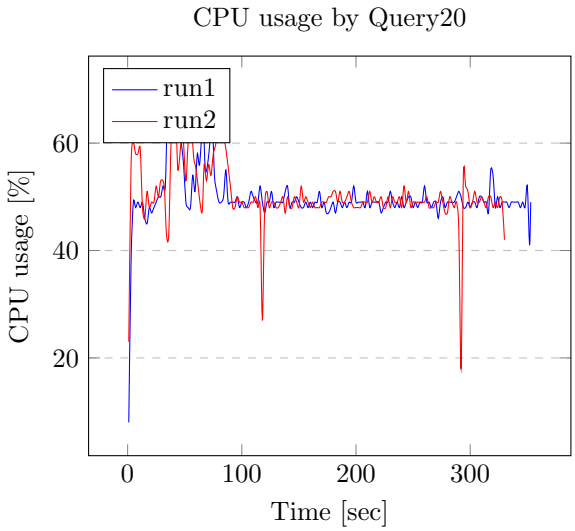


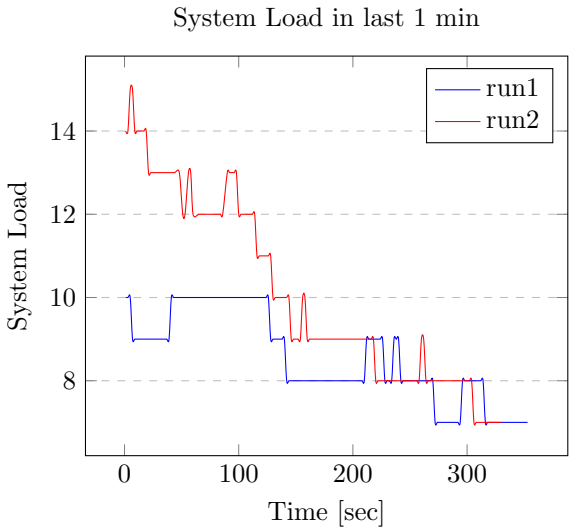


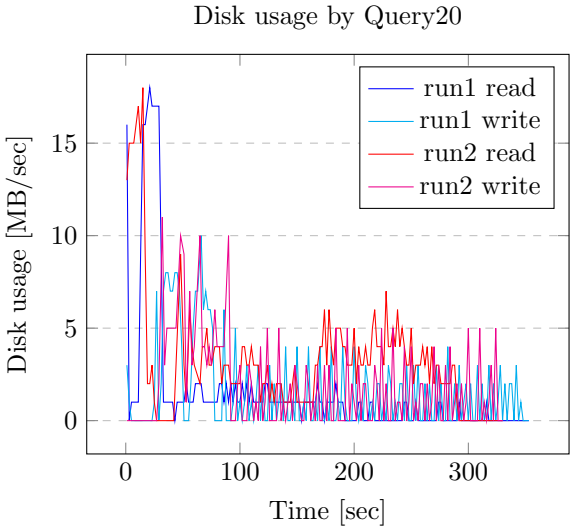


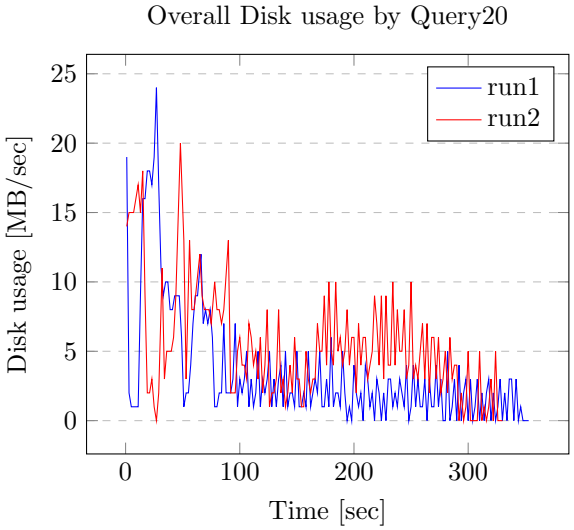
Load	Memory	Disk IO	Execution Time
9.11	37999.16 MB	4.00 MB/sec	336.50 sec

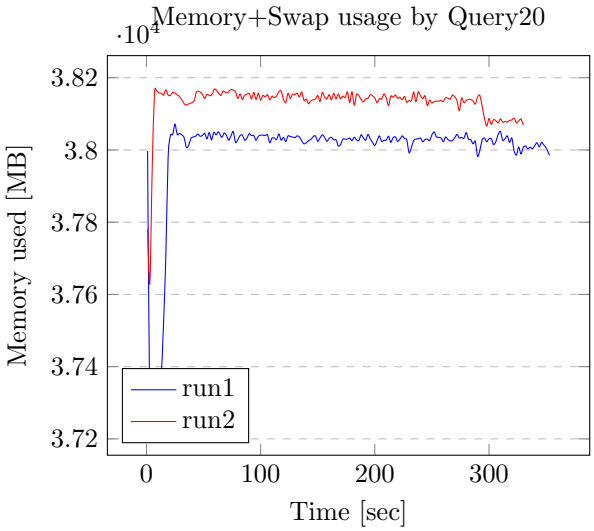
Table 40: Average Parametes over Runtime for Query20

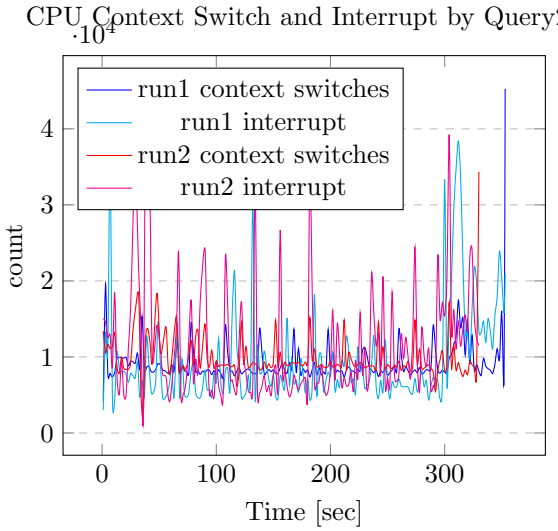






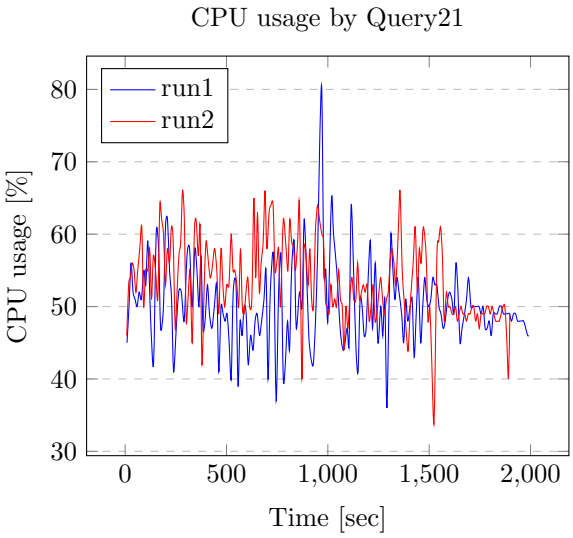


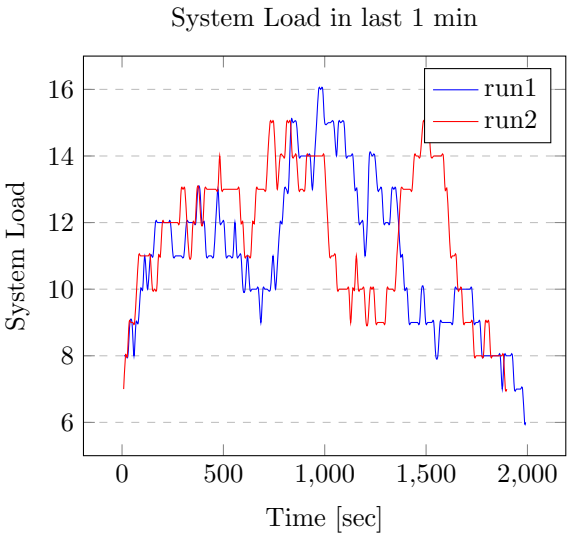


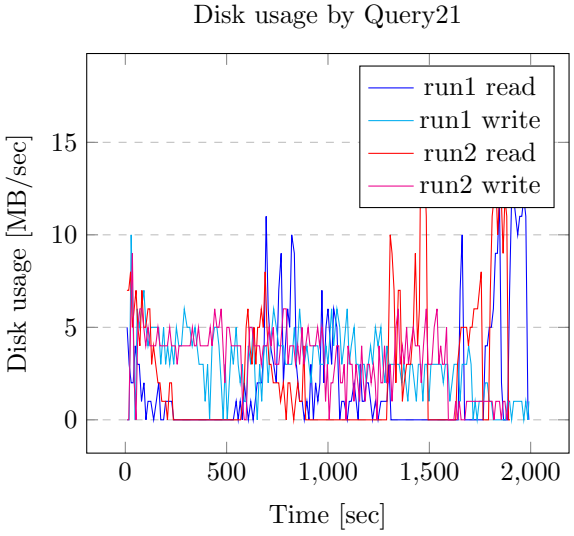


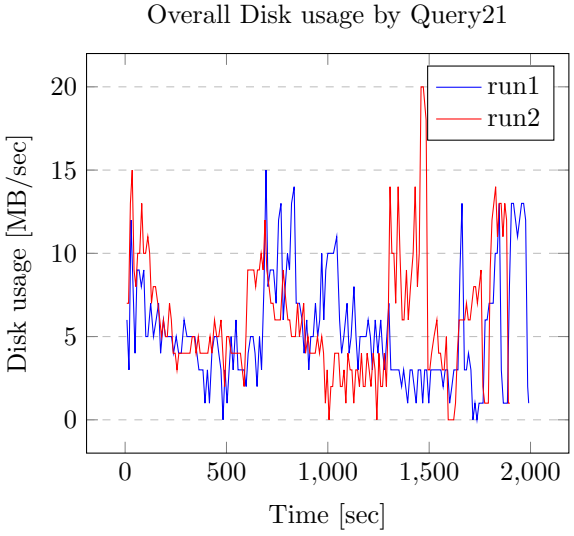
Load	Memory	Disk IO	Execution Time
11.44	37699.89 MB	5.78 MB/sec	1807.50 sec

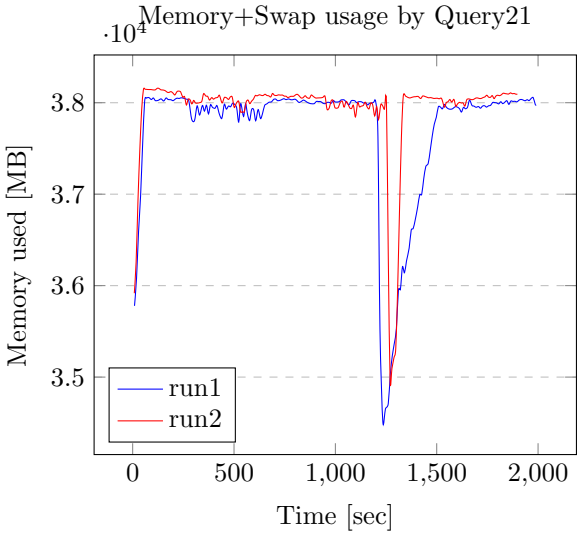
Table 41: Average Parametes over Runtime for Query21

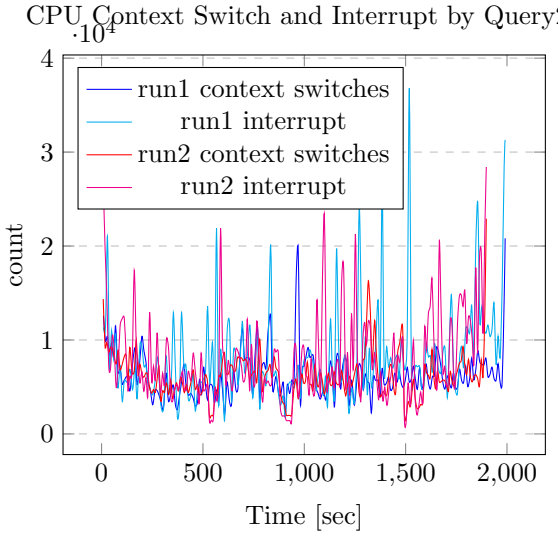






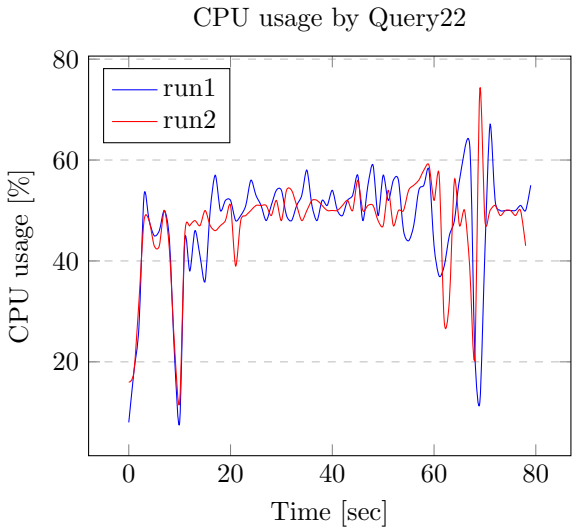


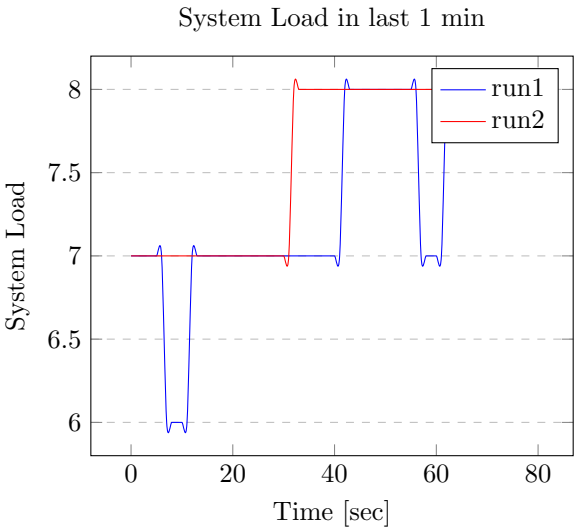


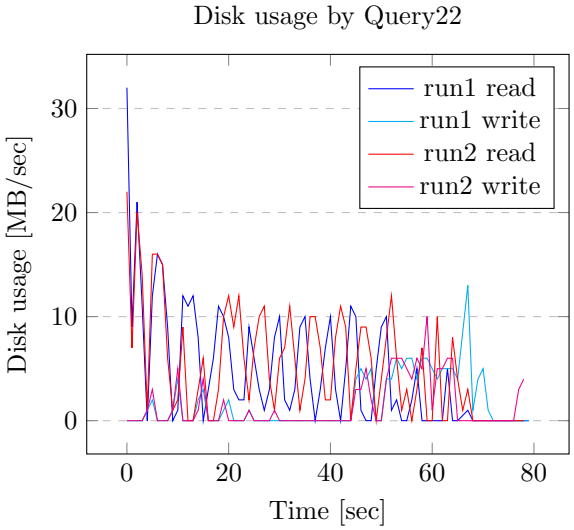


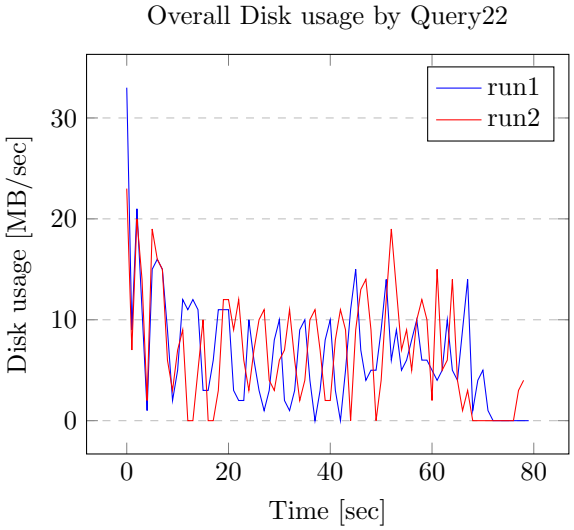
Load	Memory	Disk IO	Execution Time
7.84	38057.87 MB	7.04 MB/sec	79.00 sec

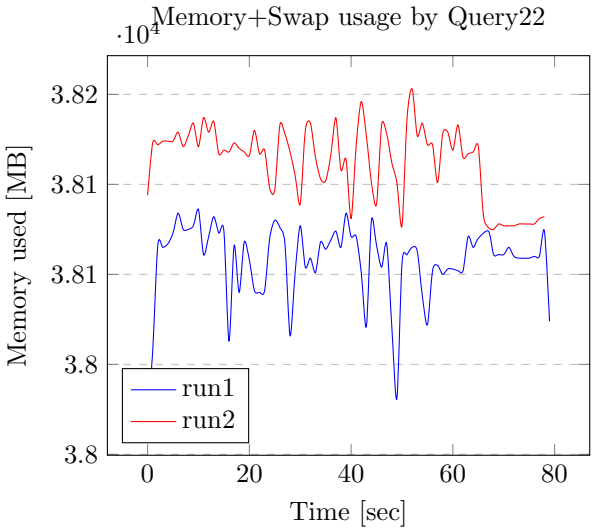
Table 42: Average Parametes over Runtime for Query22

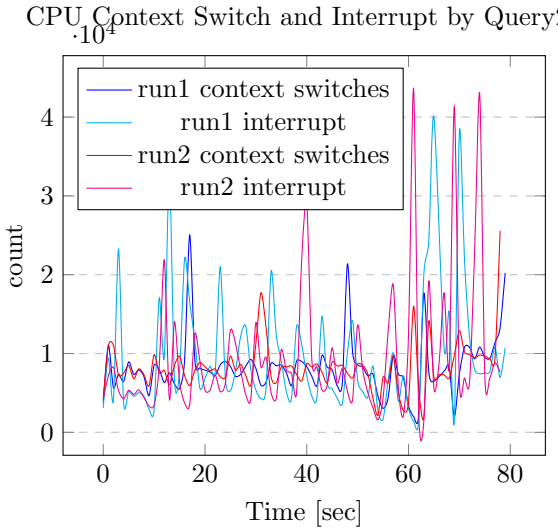








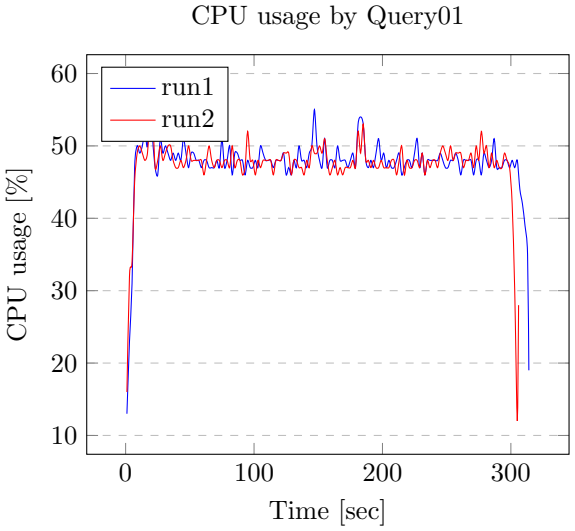


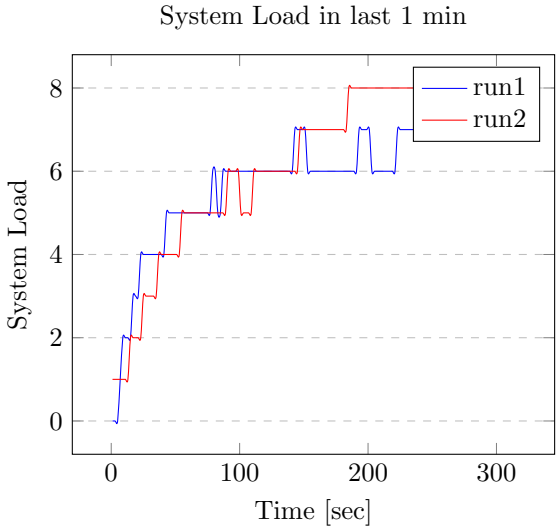


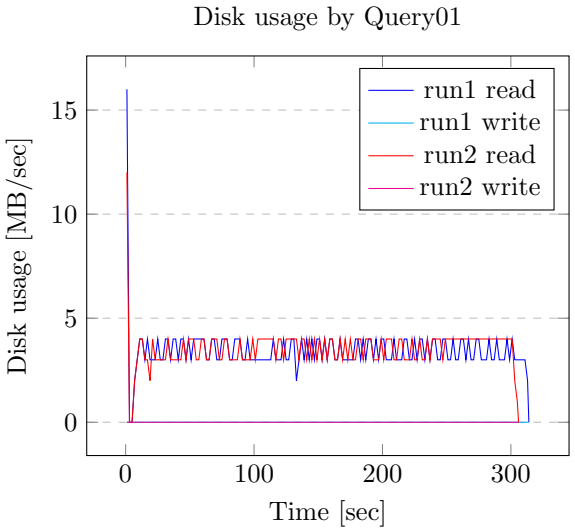
Load	Memory	Disk IO	Execution Time
6.32	18584.58 MB	3.92 MB/sec	311.00 sec

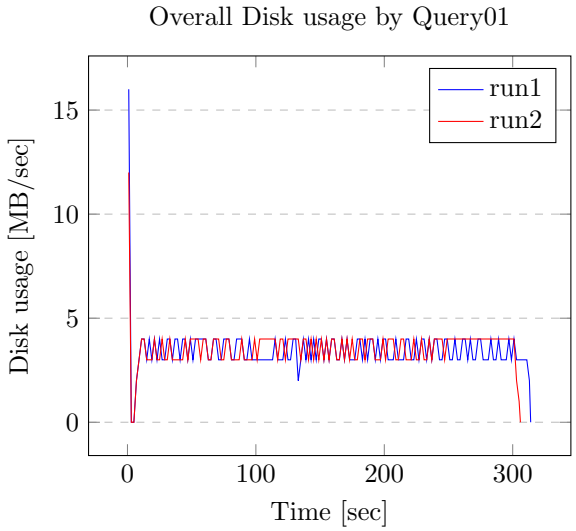
Table 43: Average Parametes over Runtime for Query01

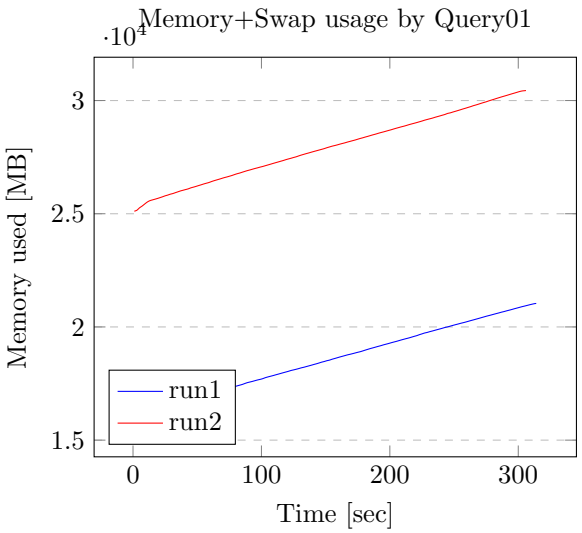
5.2 Spark and ORC

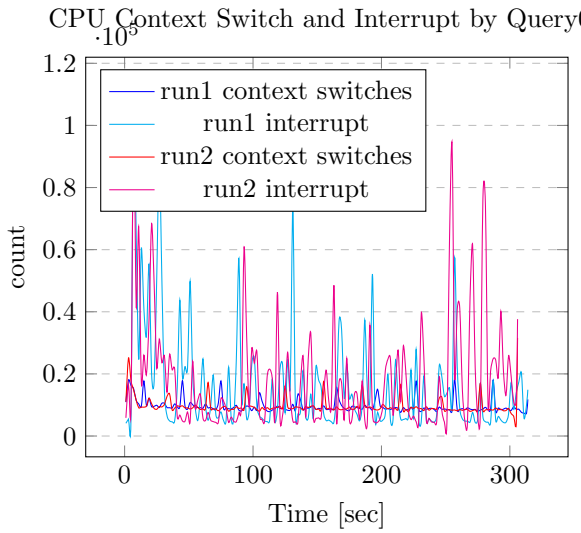






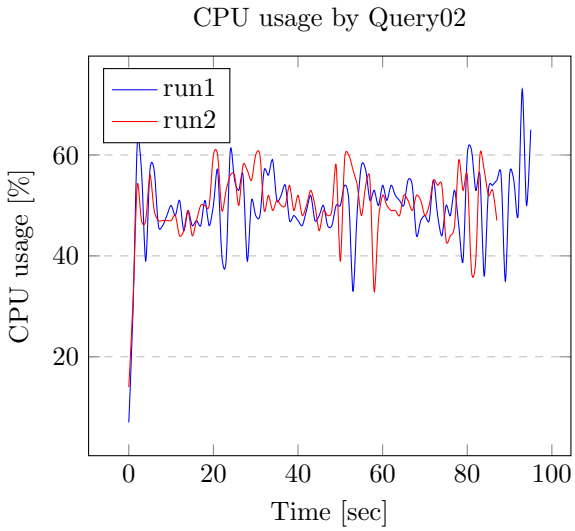


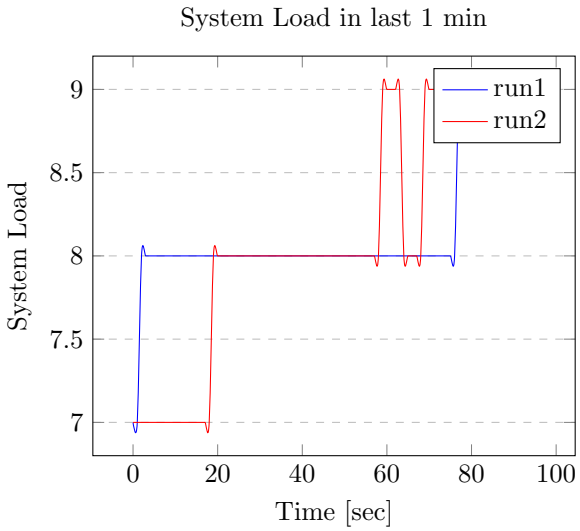


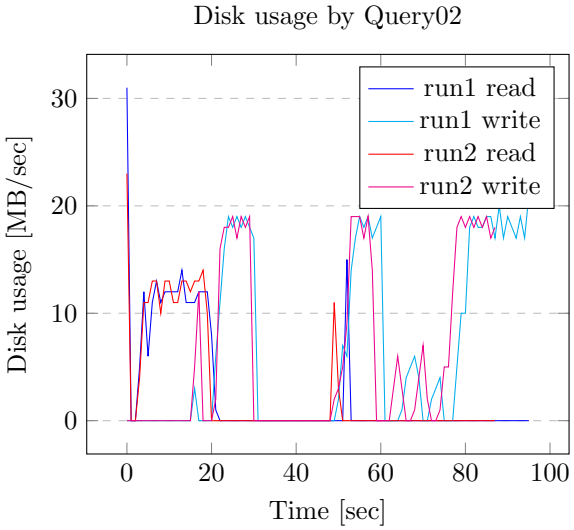


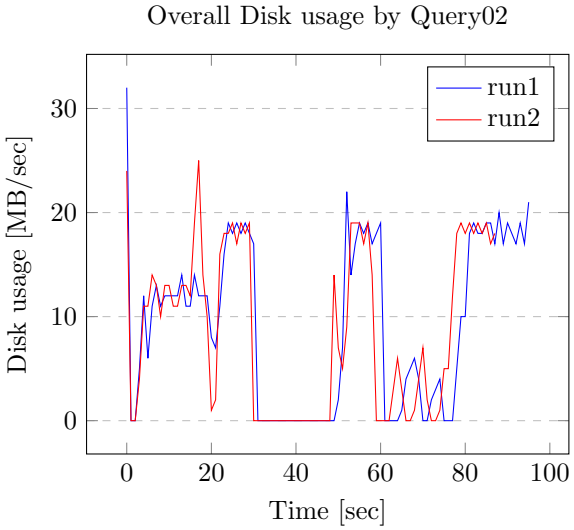
Load	Memory	Disk IO	Execution Time
8.46	24040.47 MB	9.70 MB/sec	92.00 sec

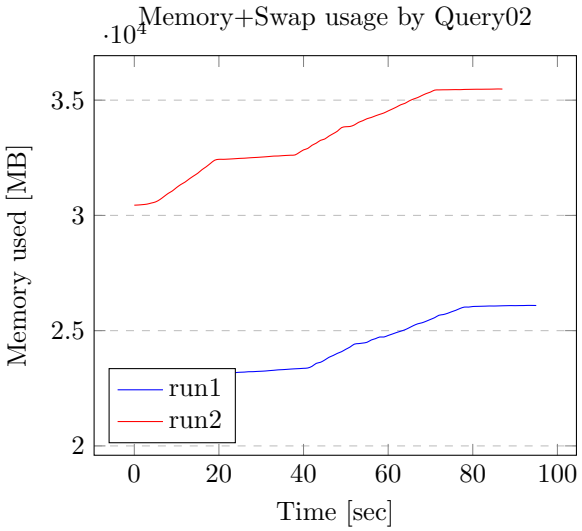
Table 44: Average Parametes over Runtime for Query02

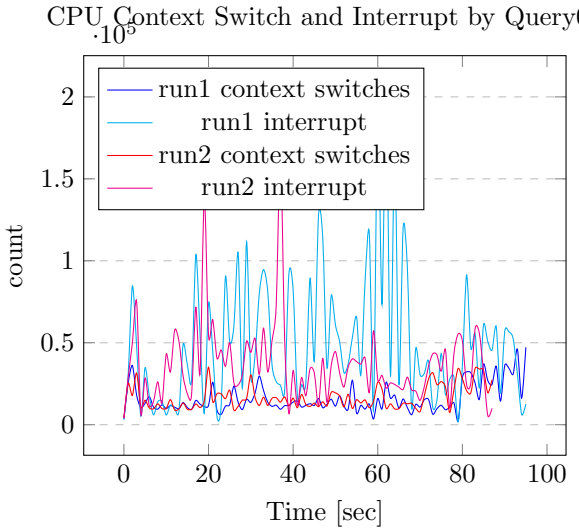






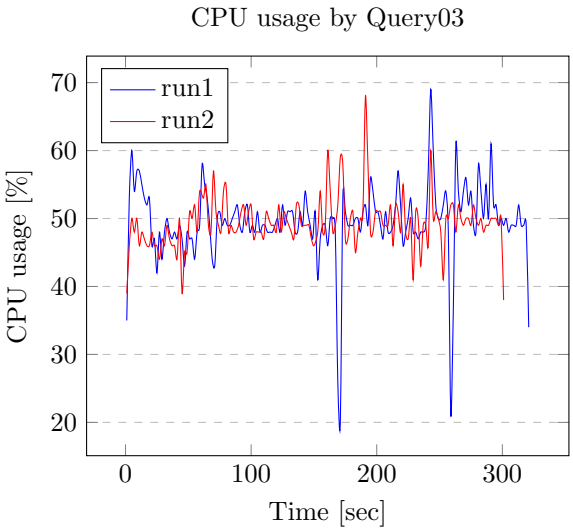


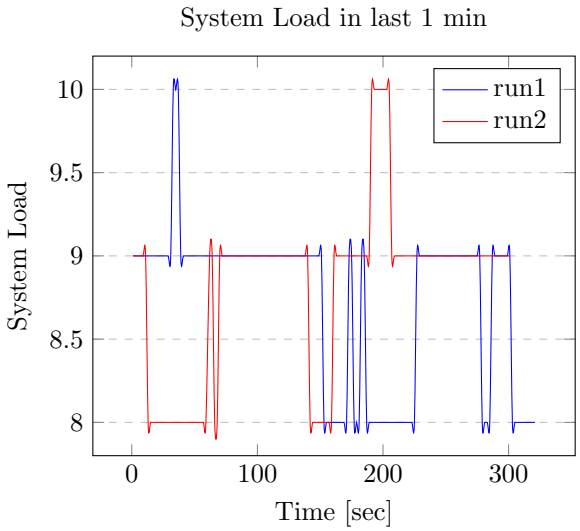


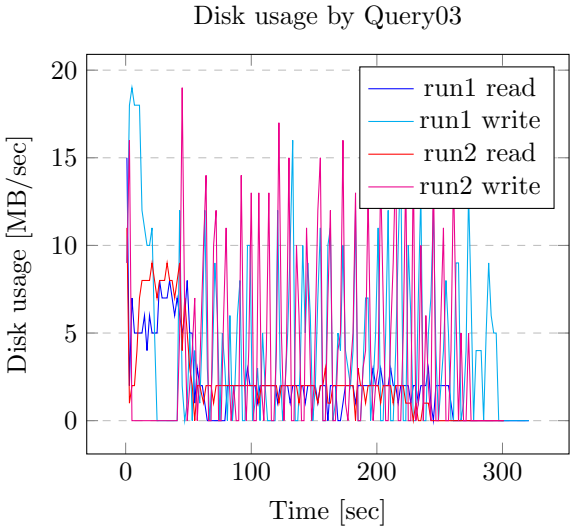


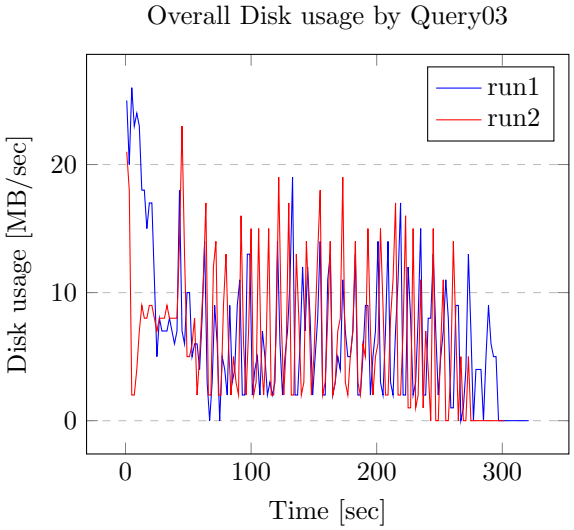
Load	Memory	Disk IO	Execution Time
9.26	26894.77 MB	7.23 MB/sec	311.00 sec

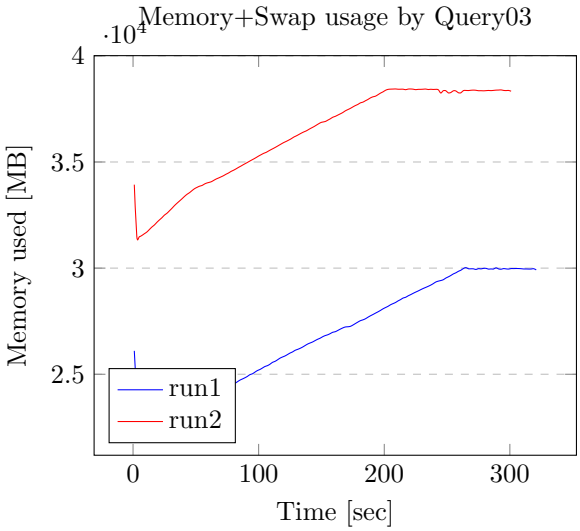
Table 45: Average Parametes over Runtime for Query03

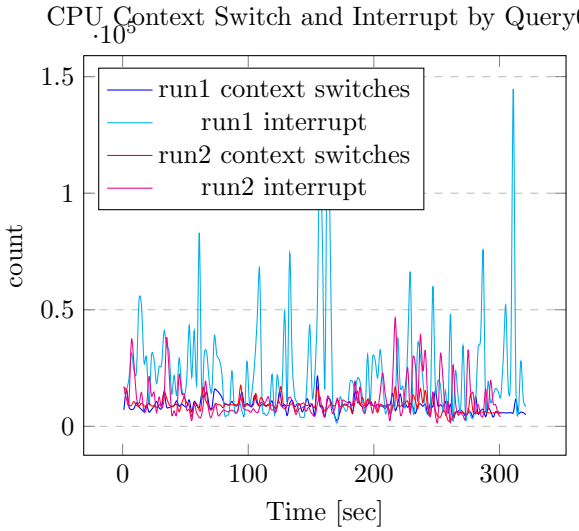






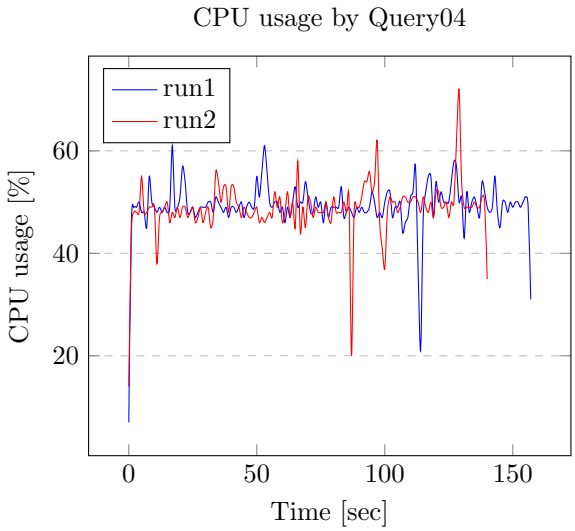


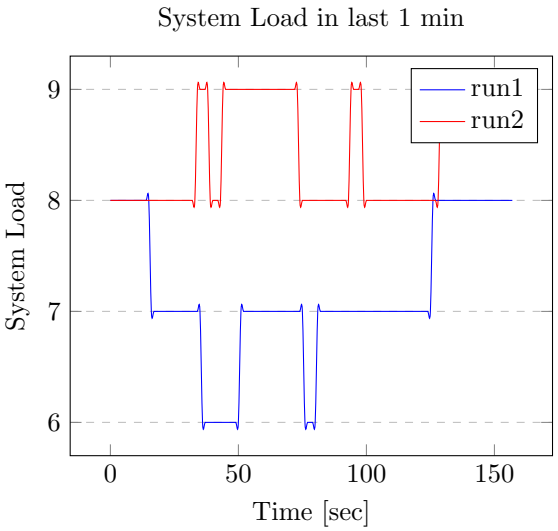


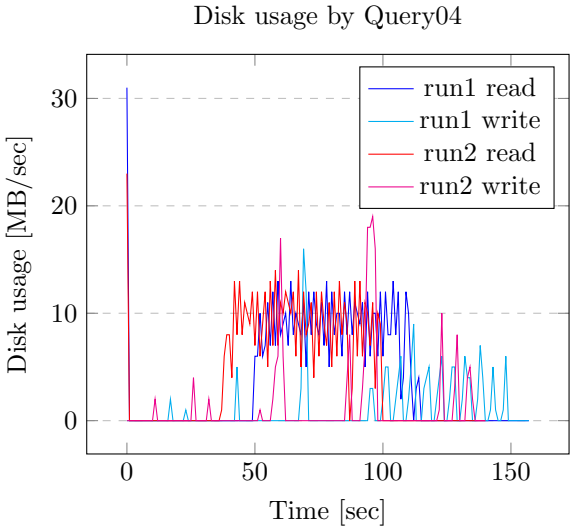


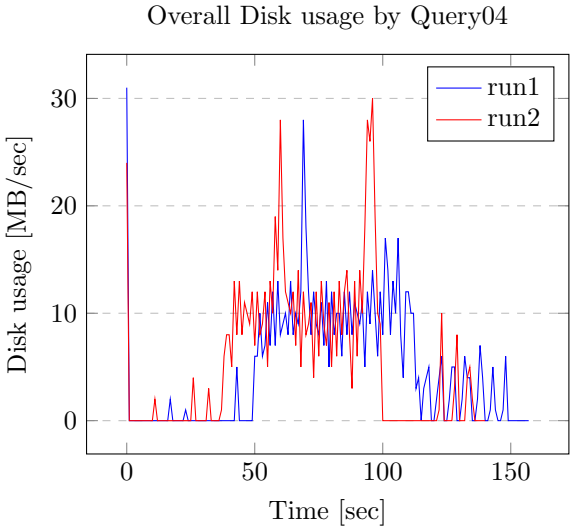
Load	Memory	Disk IO	Execution Time
7.55	27317.29 MB	5.15 MB/sec	149.50 sec

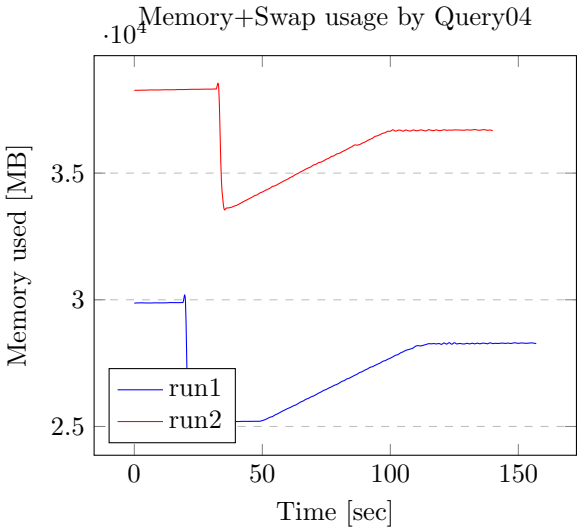
Table 46: Average Parametes over Runtime for Query04

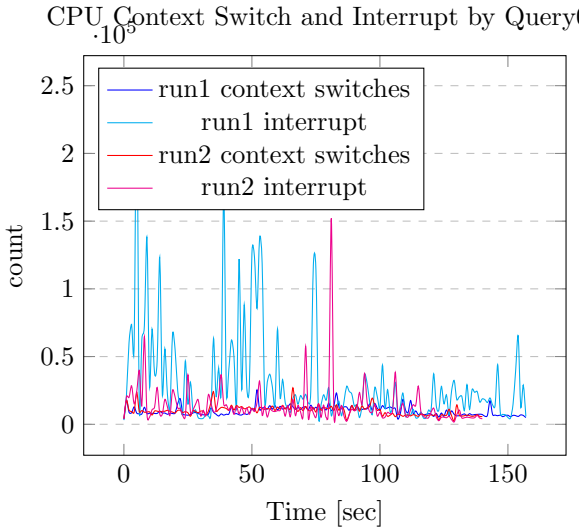






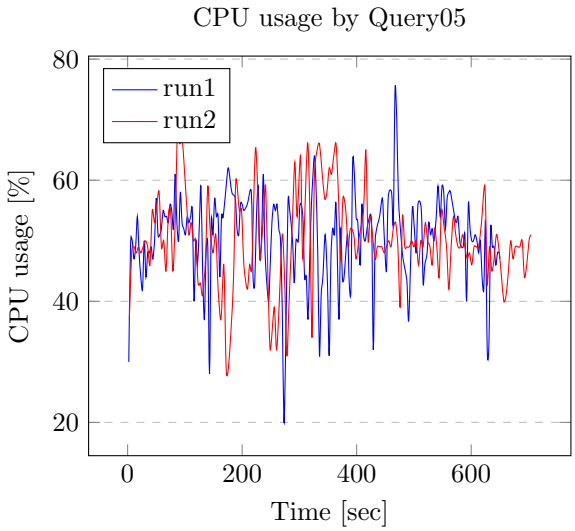


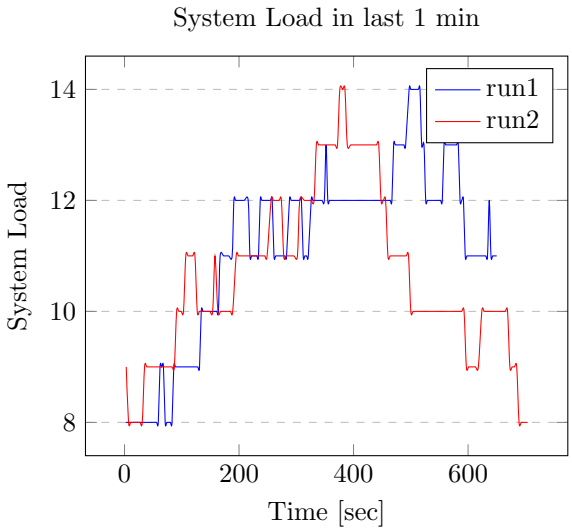


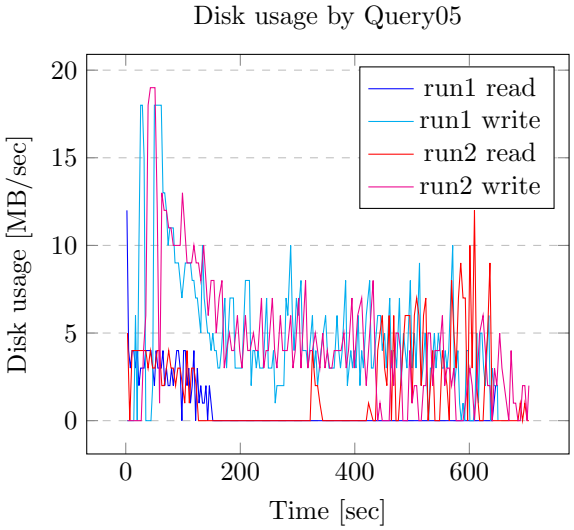


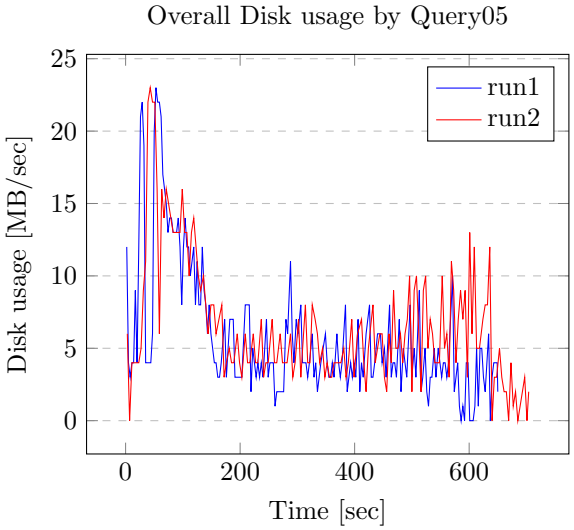
Load	Memory	Disk IO	Execution Time
11.55	36390.49 MB	6.37 MB/sec	622.50 sec

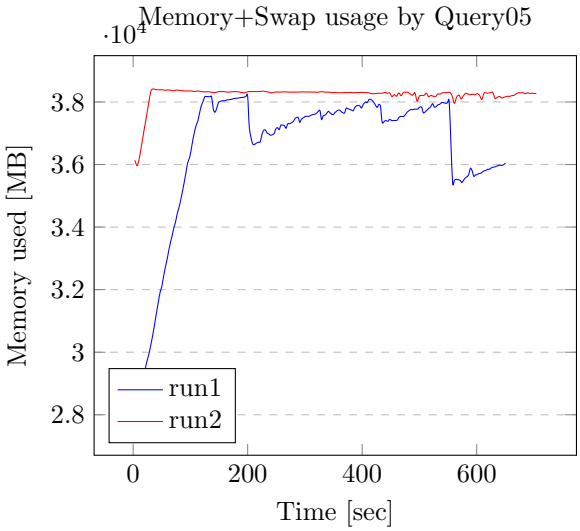
Table 47: Average Parametes over Runtime for Query05

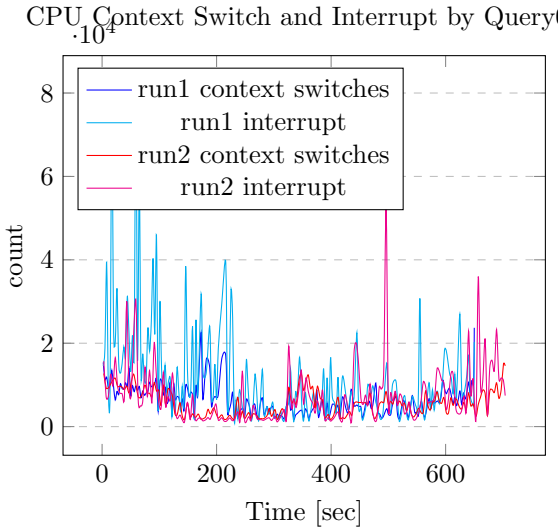






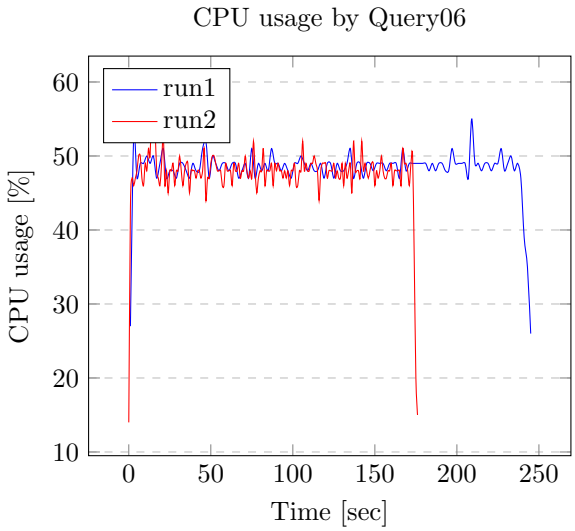


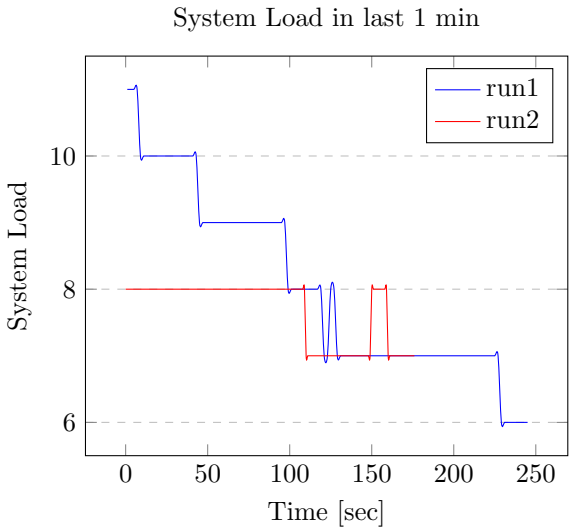


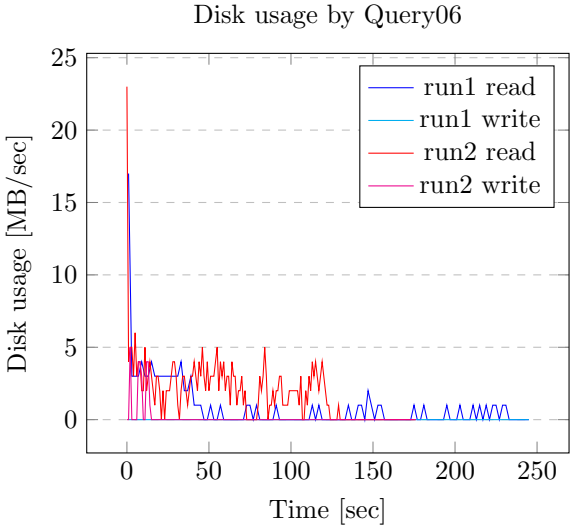


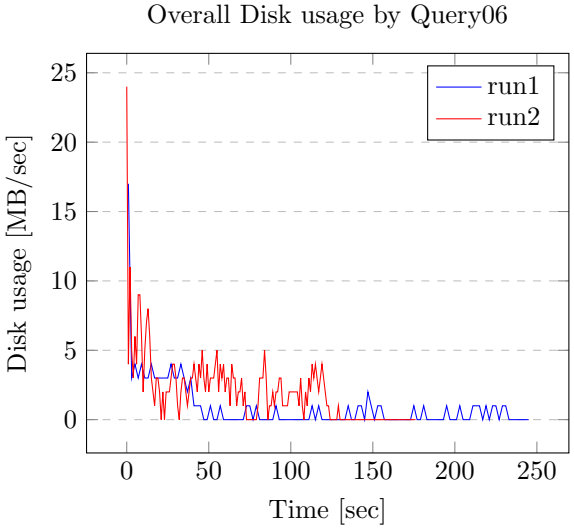
Load	Memory	Disk IO	Execution Time
8.47	24064.27 MB	1.36 MB/sec	211.50 sec

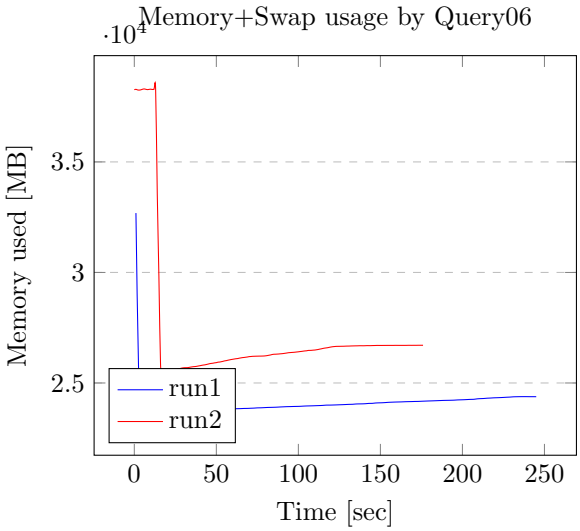
Table 48: Average Parametes over Runtime for Query06

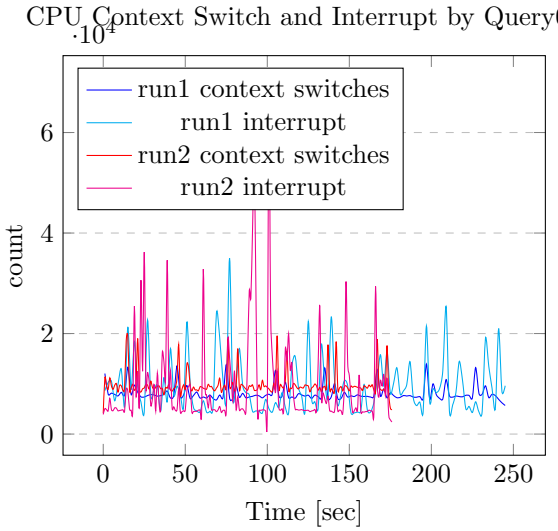






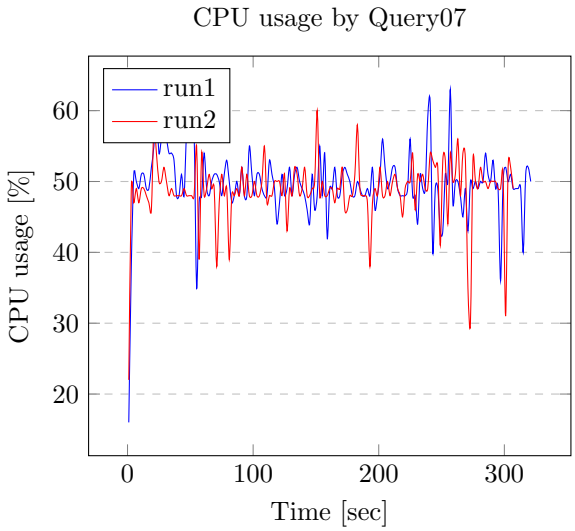


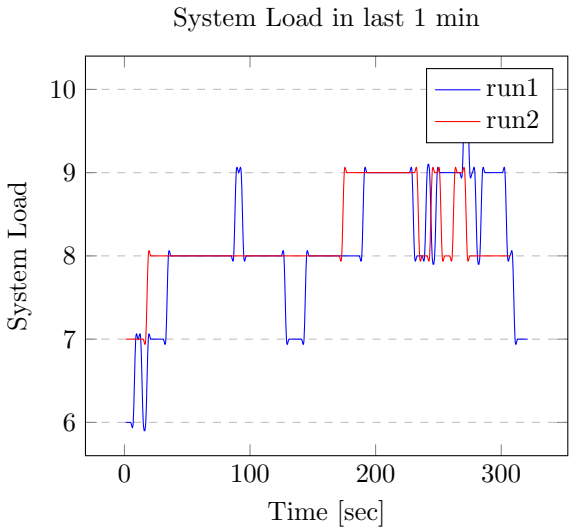


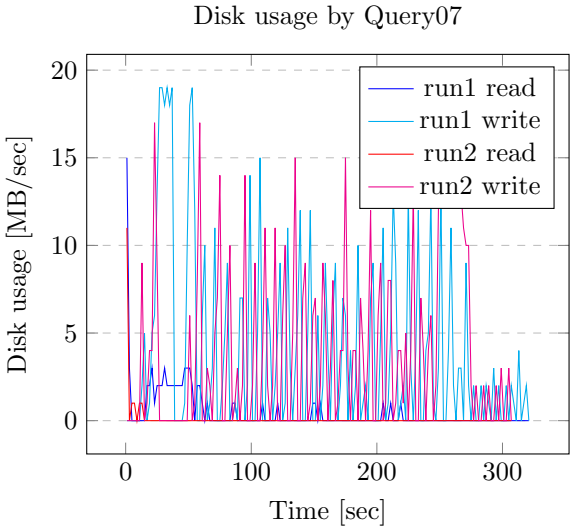


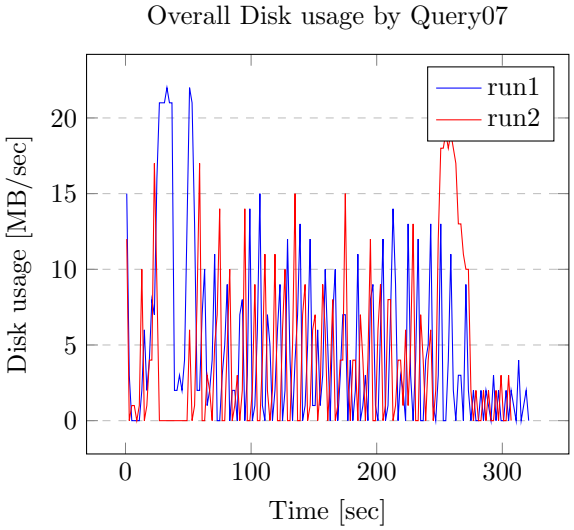
Load	Memory	Disk IO	Execution Time
8.61	28937.86 MB	5.18 MB/sec	315.00 sec

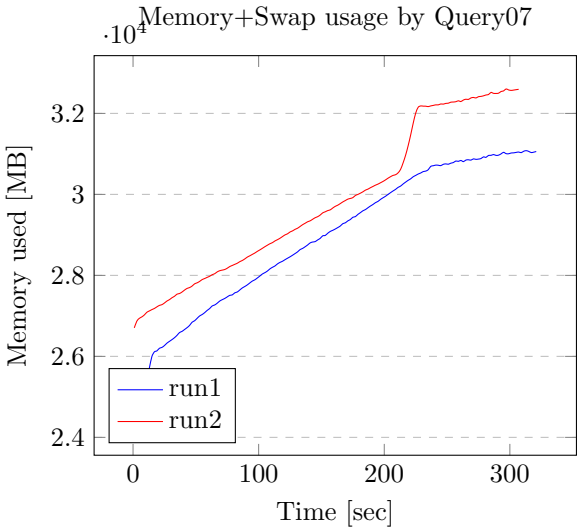
Table 49: Average Parametes over Runtime for Query07

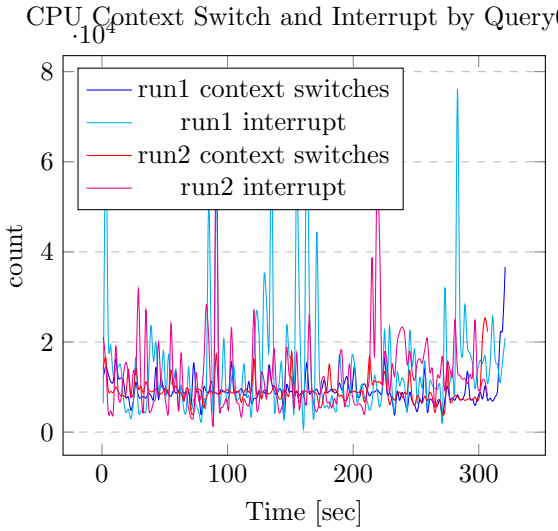






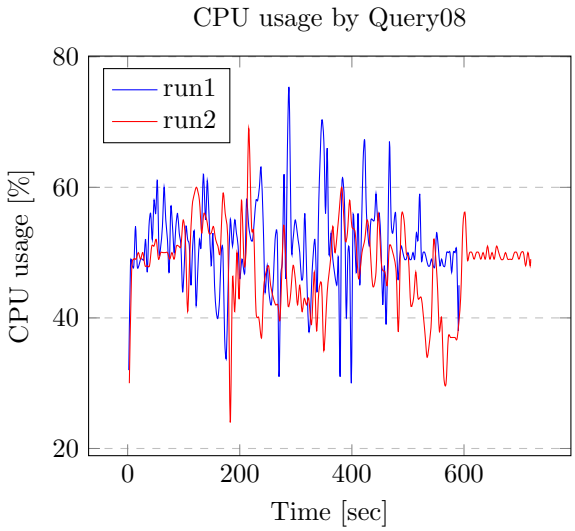


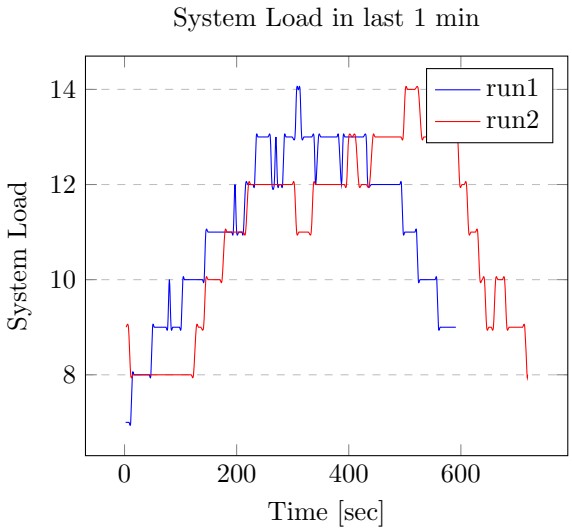


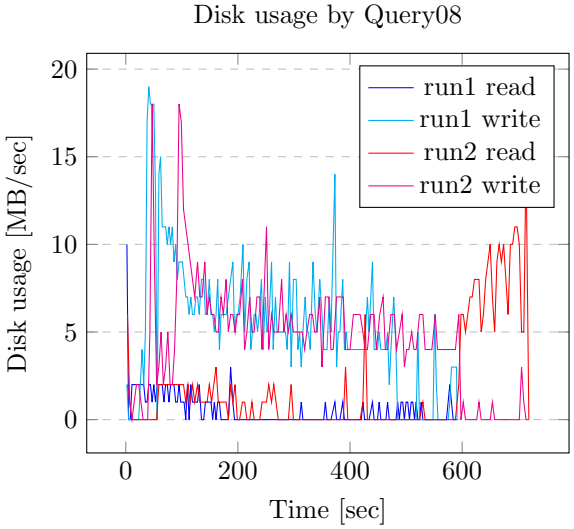


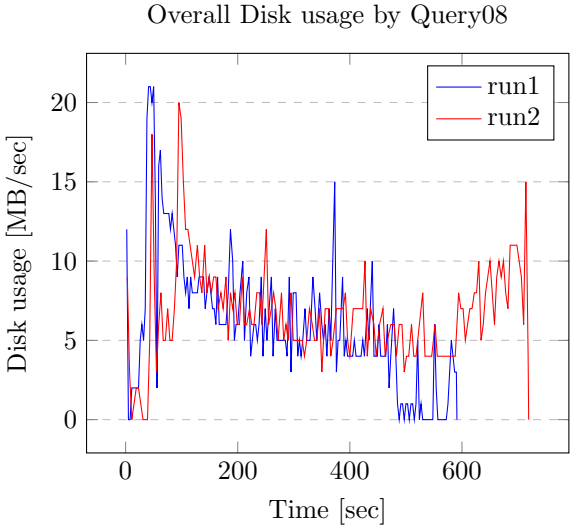
Load	Memory	Disk IO	Execution Time
11.46	36116.59 MB	6.40 MB/sec	605.50 sec

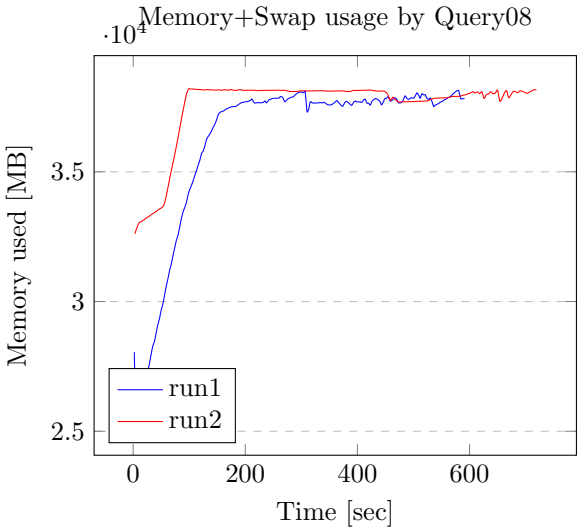
Table 50: Average Parametes over Runtime for Query08

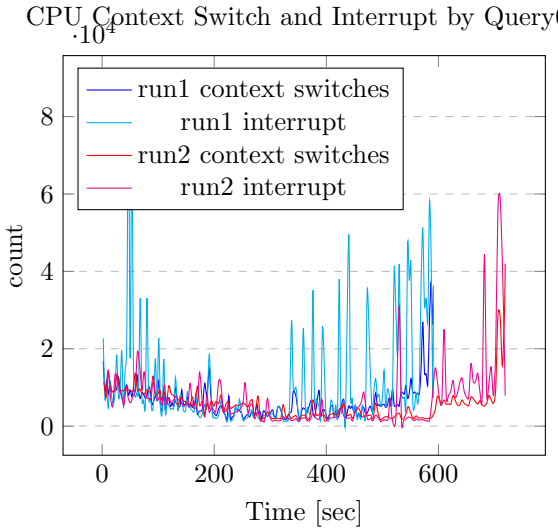






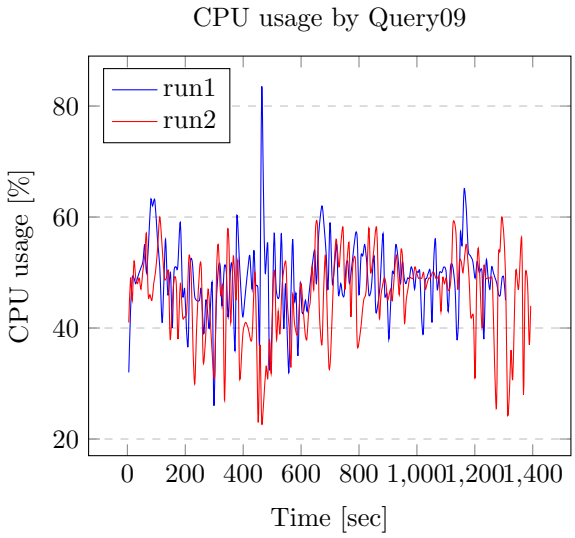


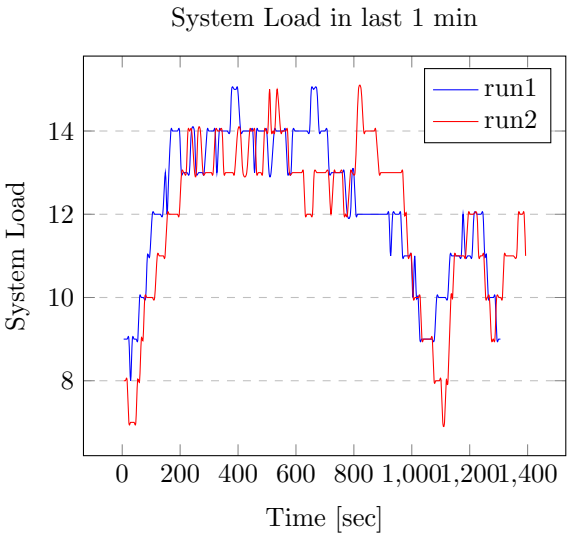


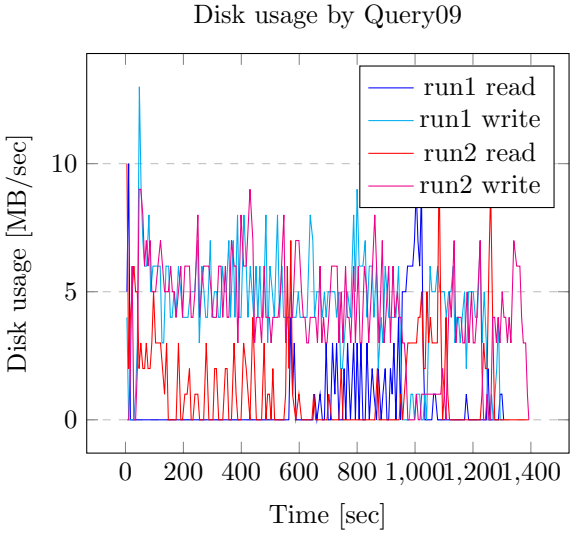


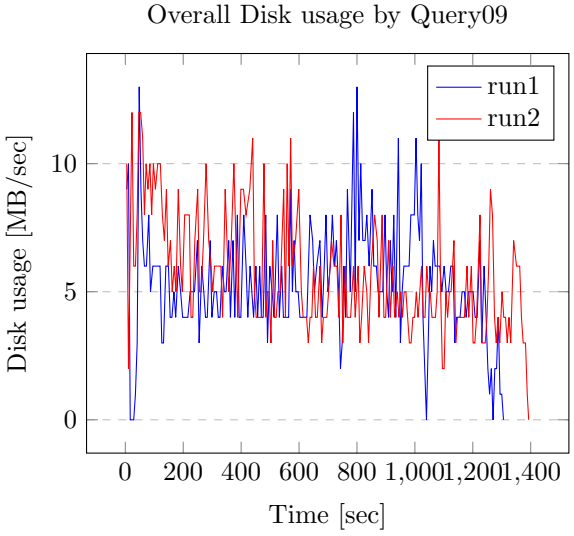
Load	Memory	Disk IO	Execution Time
12.66	36729.97 MB	5.74 MB/sec	1163.50 sec

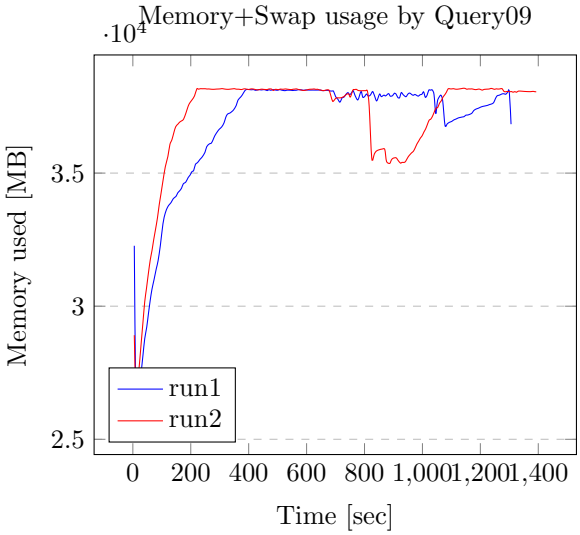
Table 51: Average Parametes over Runtime for Query09

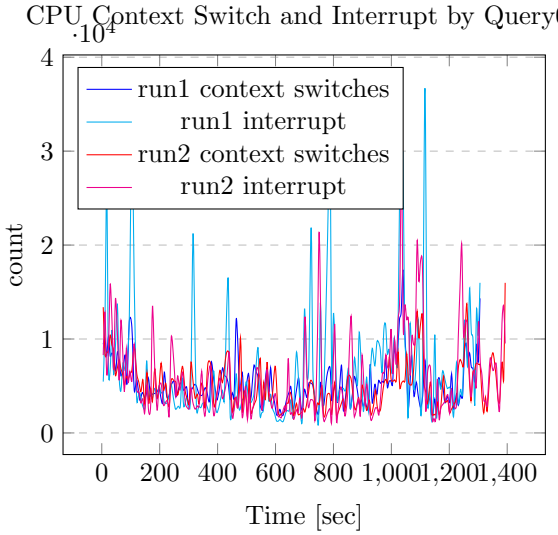






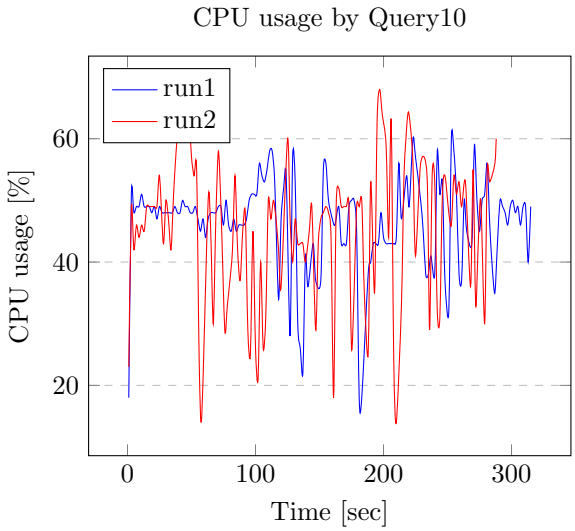


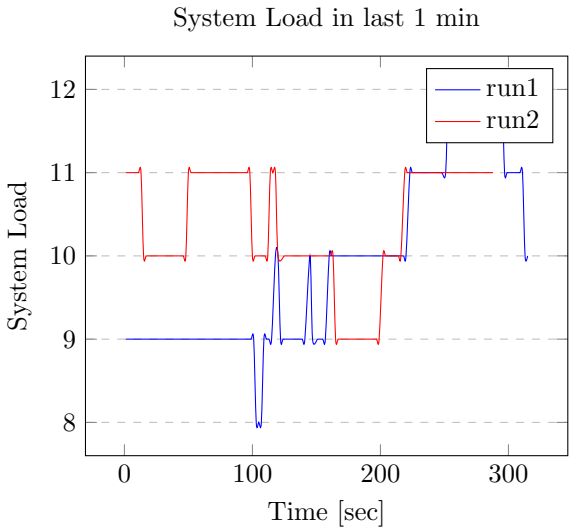


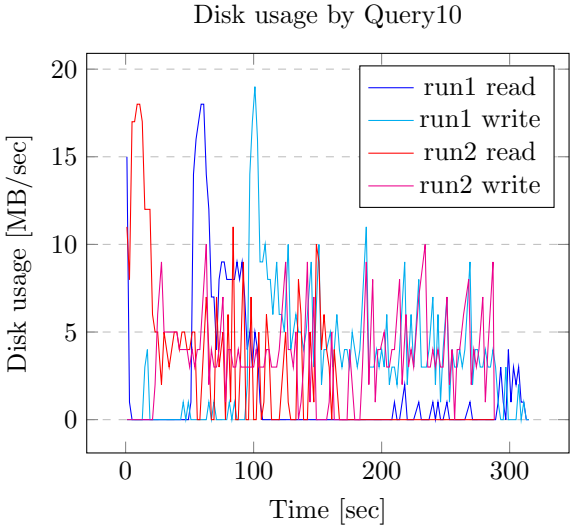


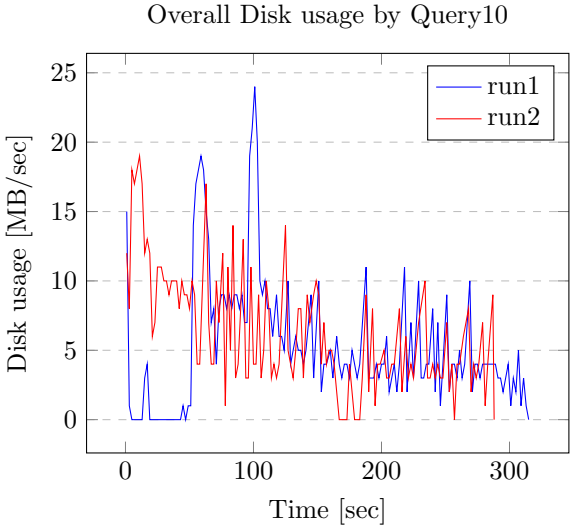
Load	Memory	Disk IO	Execution Time
10.38	37723.28 MB	5.74 MB/sec	278.50 sec

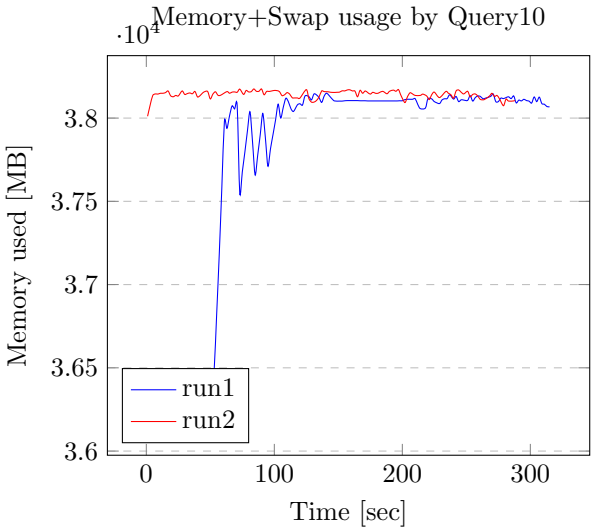
Table 52: Average Parametes over Runtime for Query10

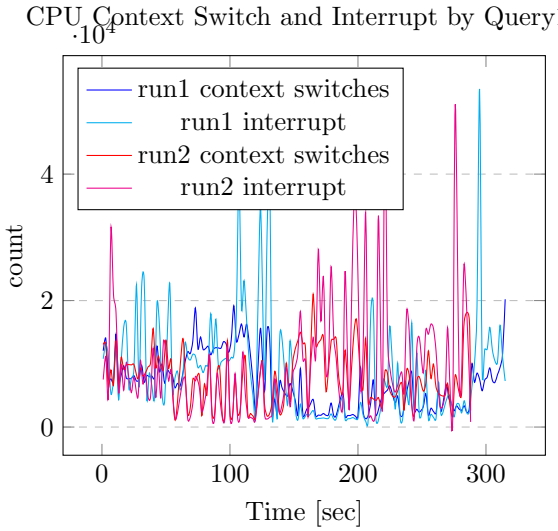






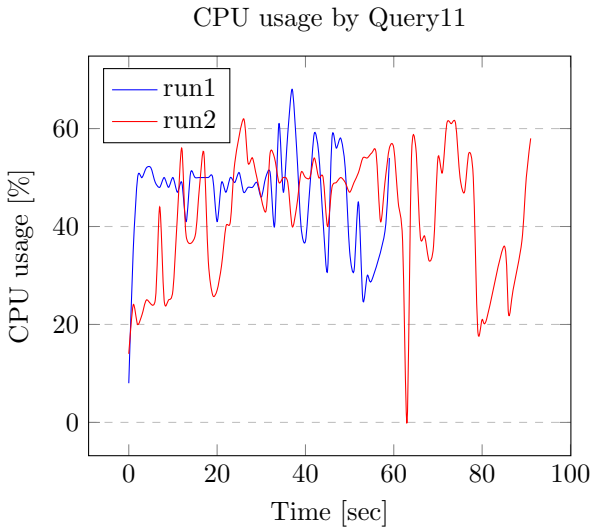


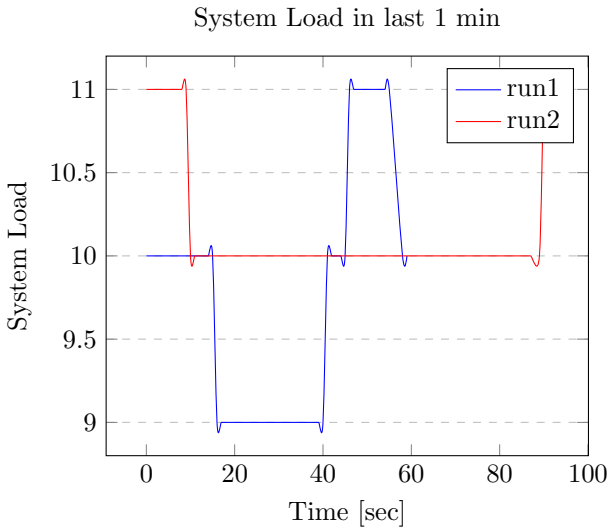


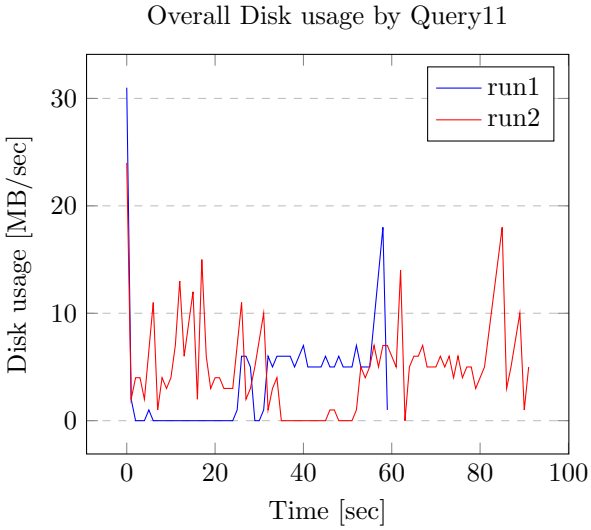


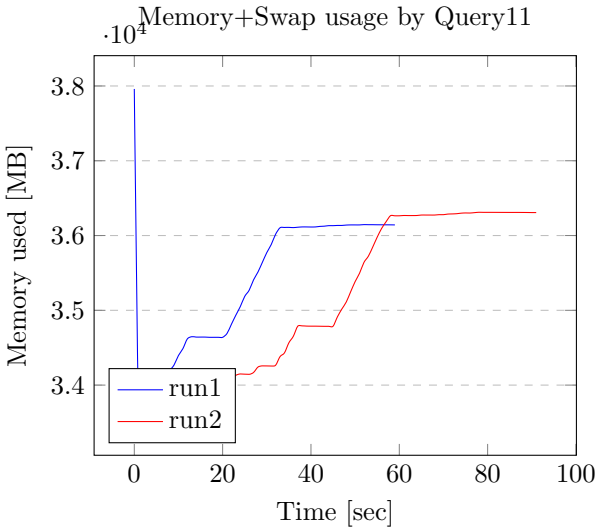
Load	Memory	Disk IO	Execution Time
10.20	35361.91 MB	3.87 MB/sec	71.00 sec

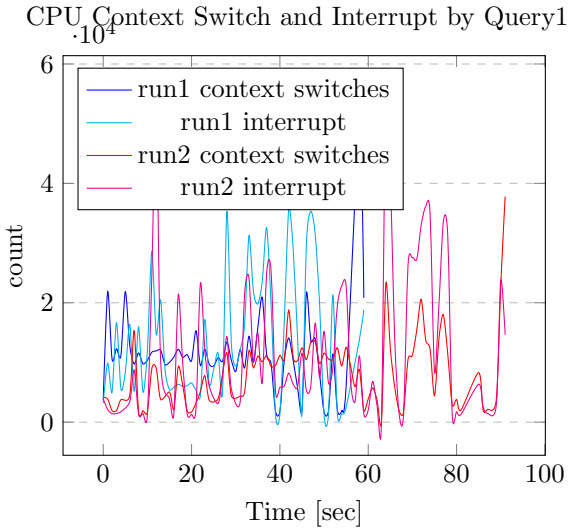
Table 53: Average Parametes over Runtime for Query11





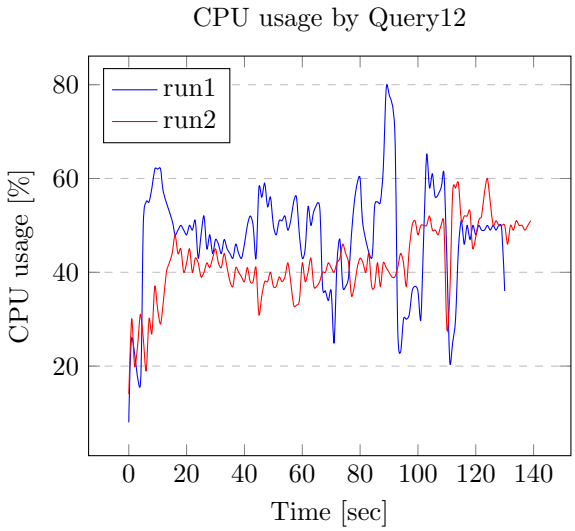


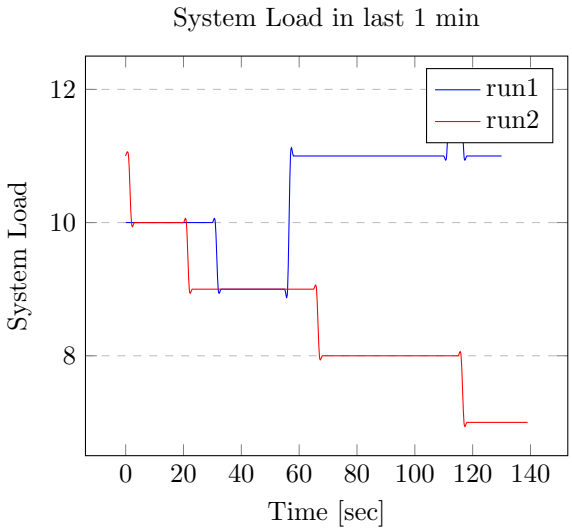


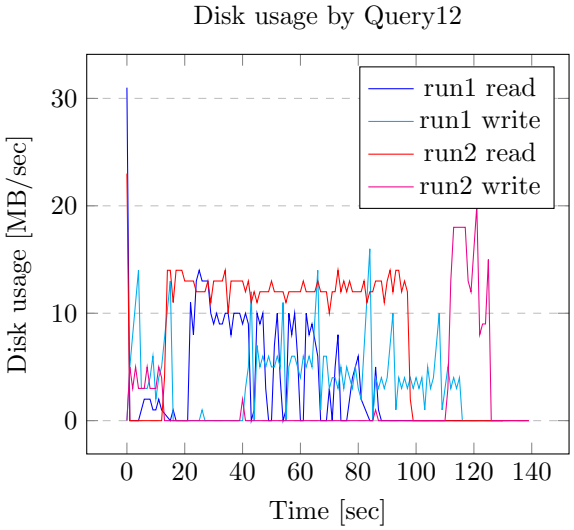


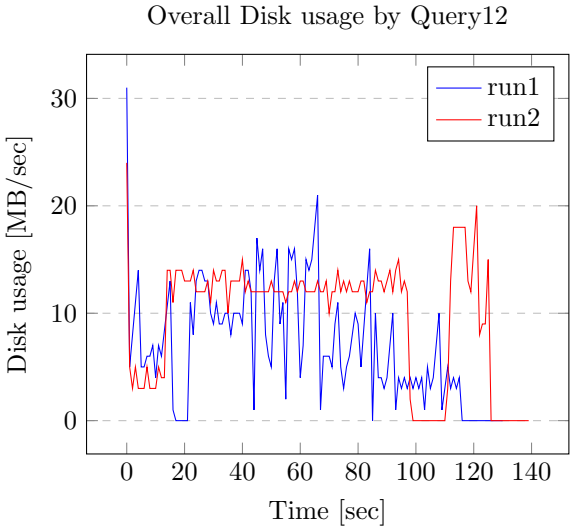
Load	Memory	Disk IO	Execution Time
10.94	36023.24 MB	7.27 MB/sec	130.50 sec

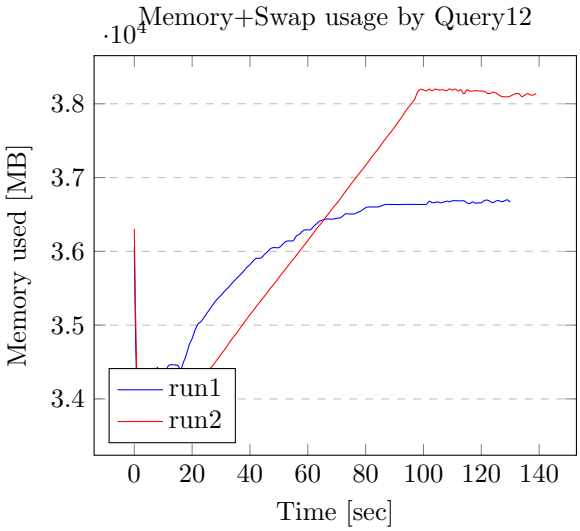
Table 54: Average Parametes over Runtime for Query12

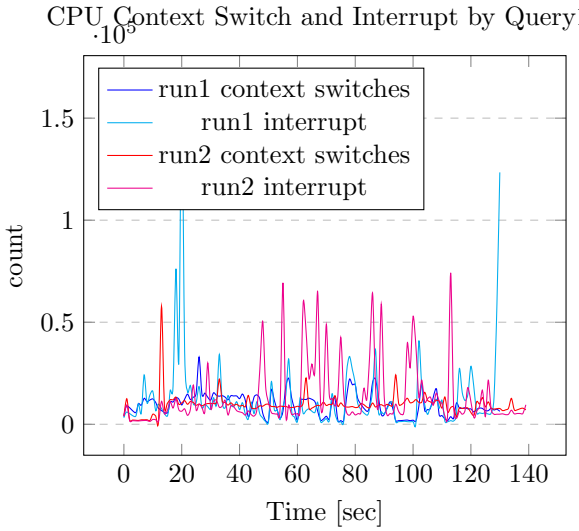






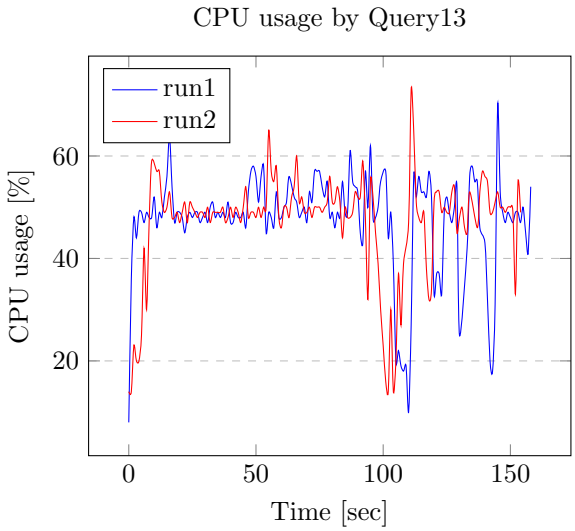


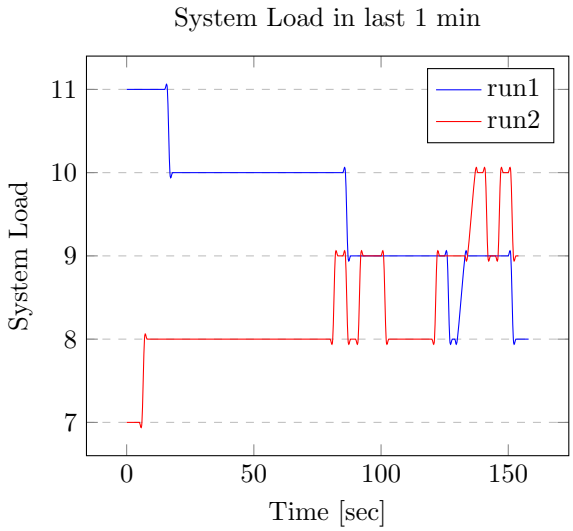


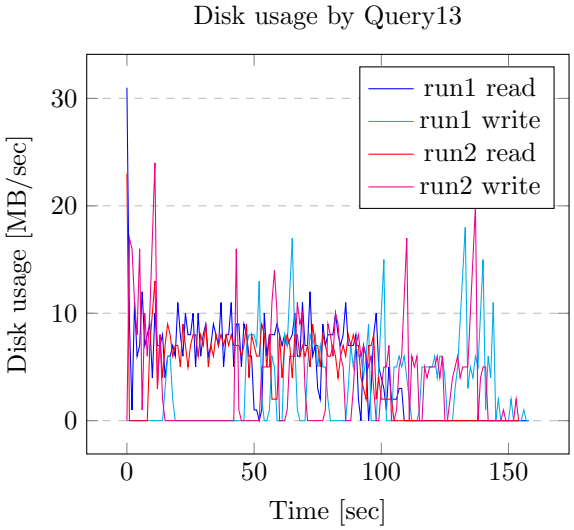


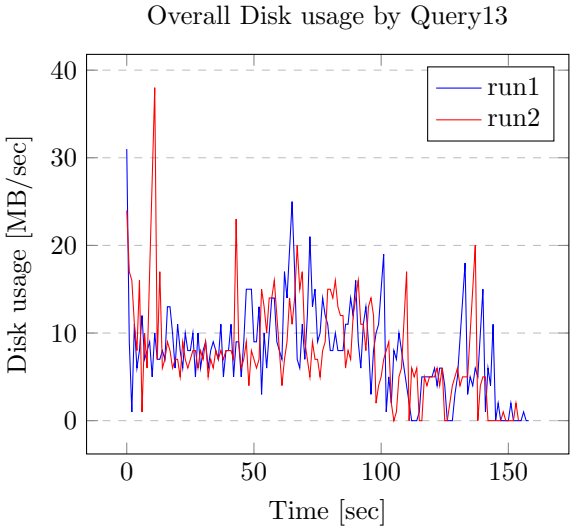
Load	Memory	Disk IO	Execution Time
10.08	37552.20 MB	8.16 MB/sec	152.50 sec

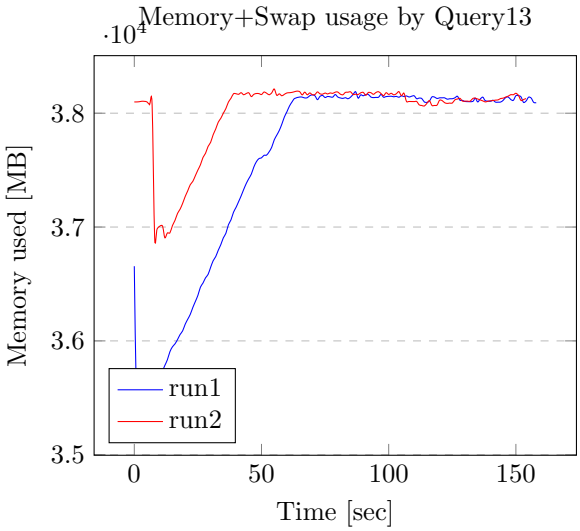
Table 55: Average Parametes over Runtime for Query13

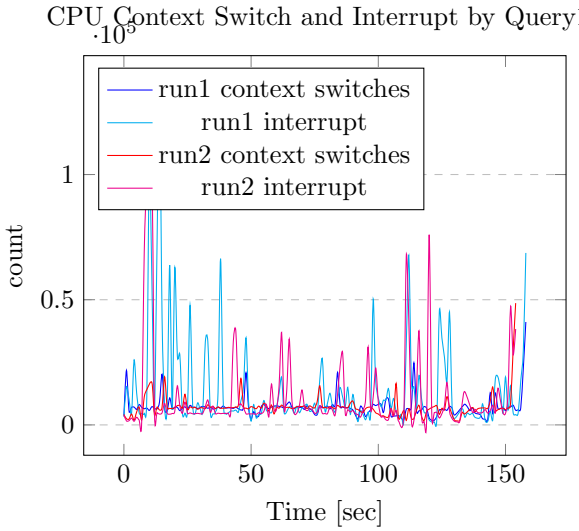






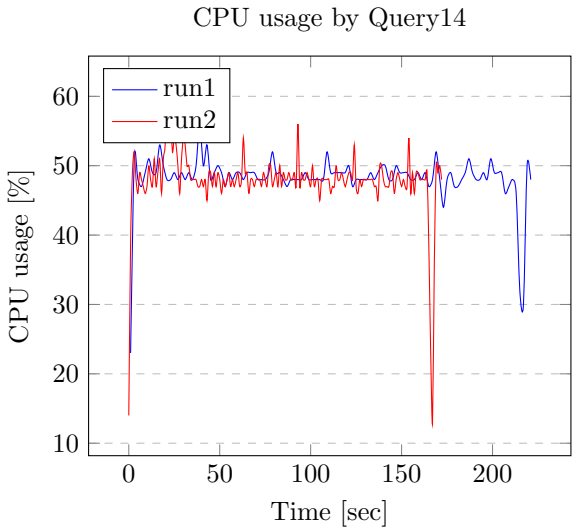


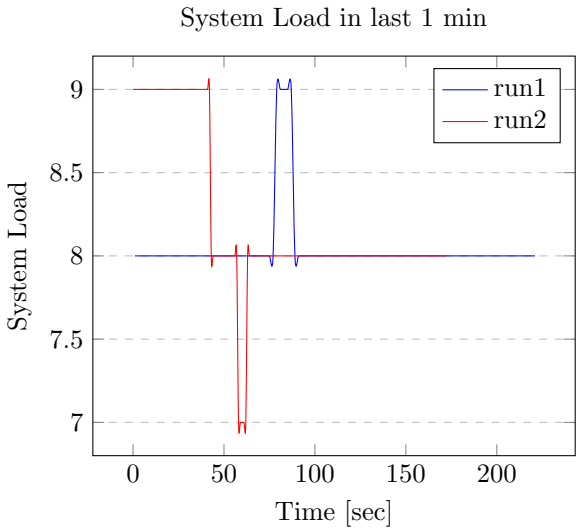


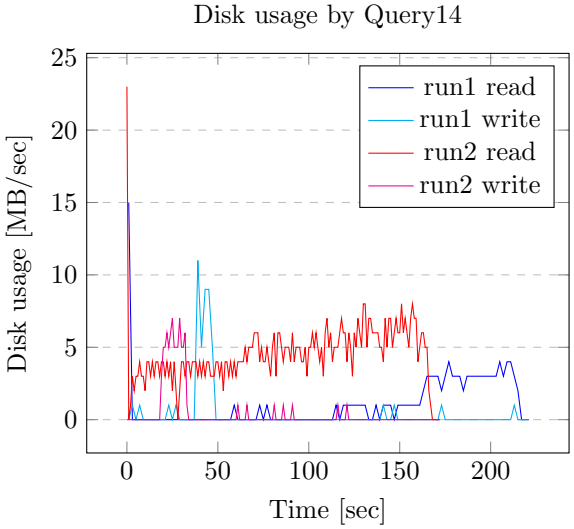


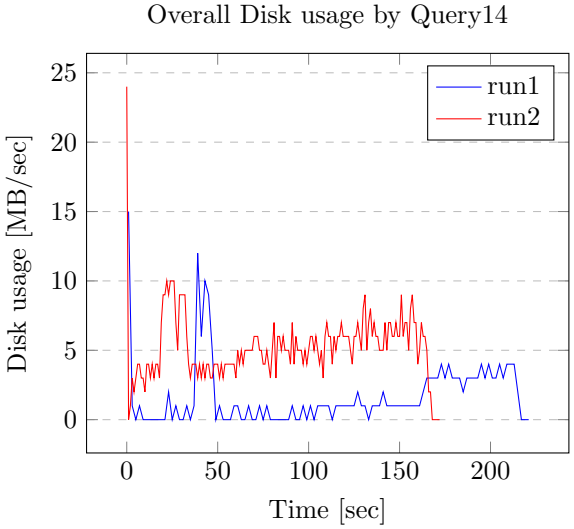
Load	Memory	Disk IO	Execution Time
8.43	37351.88 MB	2.17 MB/sec	197.50 sec

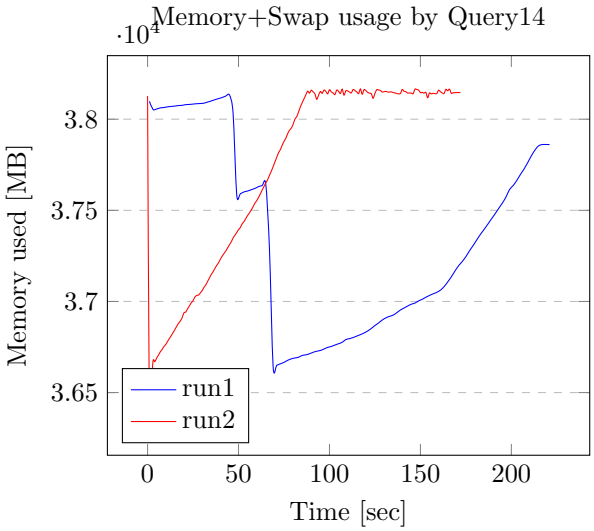
Table 56: Average Parametes over Runtime for Query14

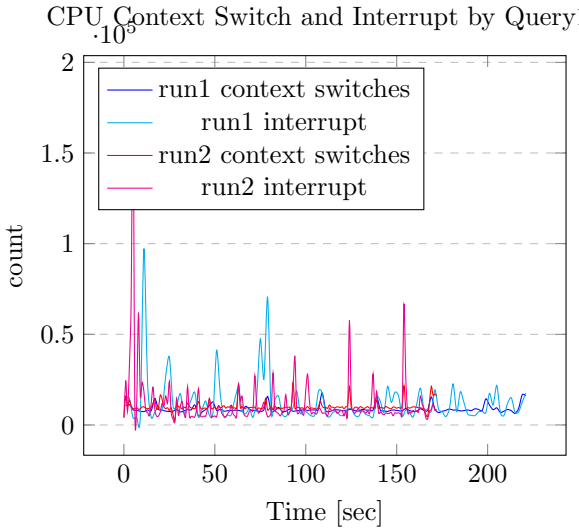






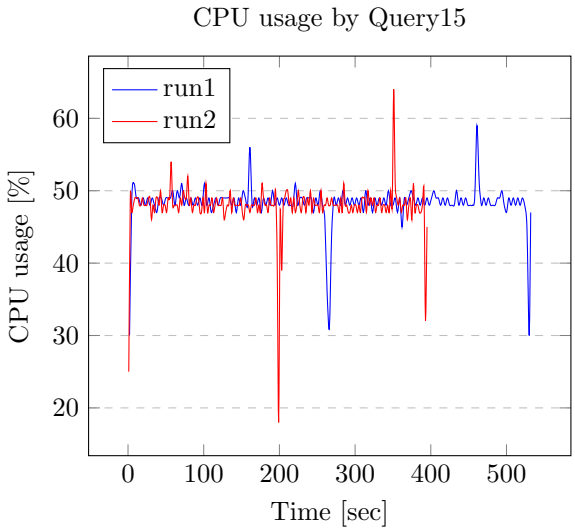


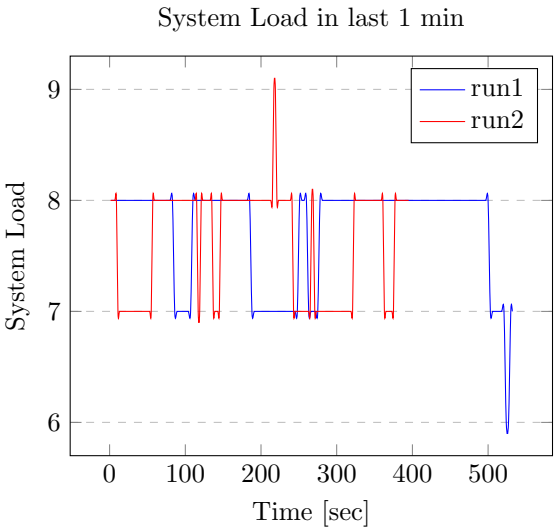


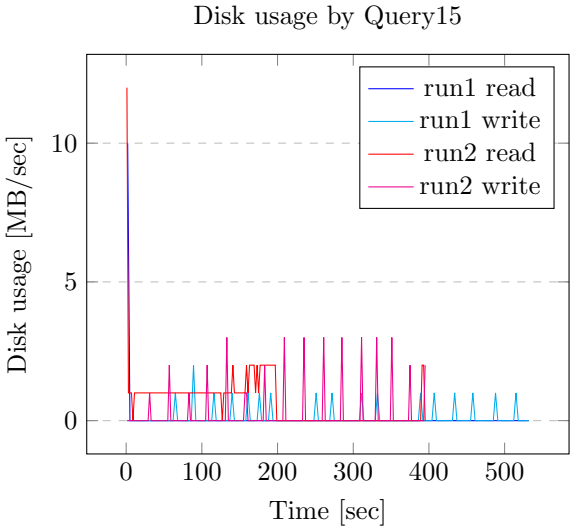


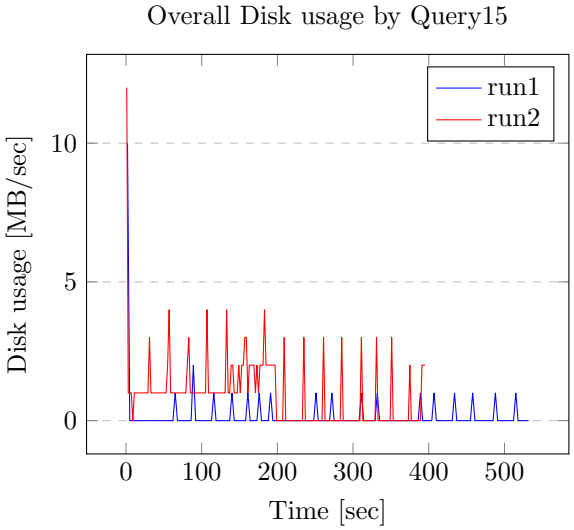
Load	Memory	Disk IO	Execution Time
8.27	35972.20 MB	0.31 MB/sec	464.50 sec

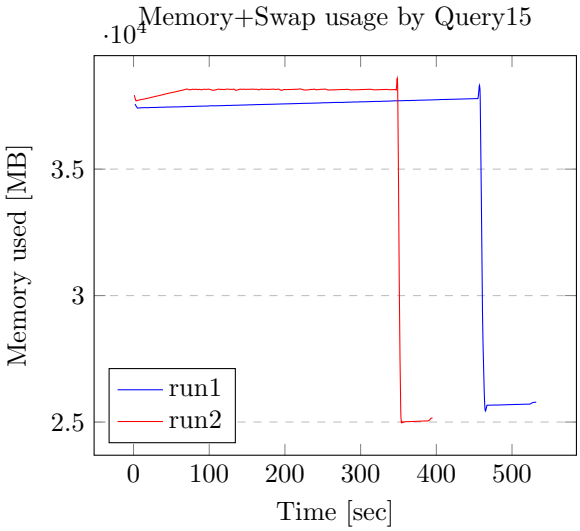
Table 57: Average Parametes over Runtime for Query15

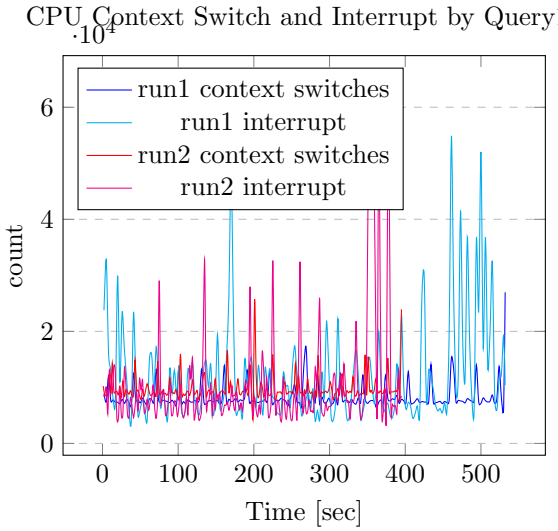






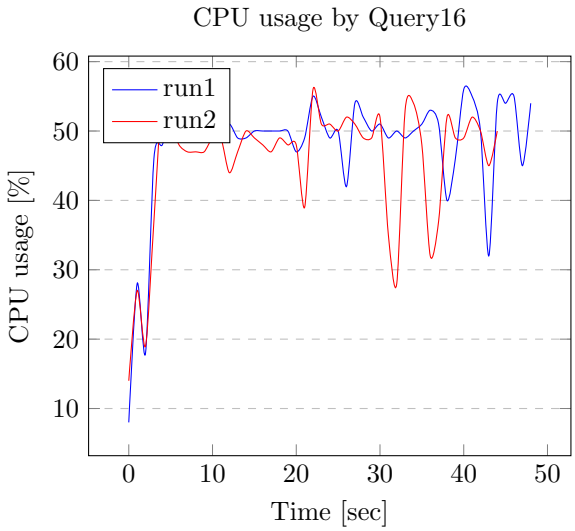


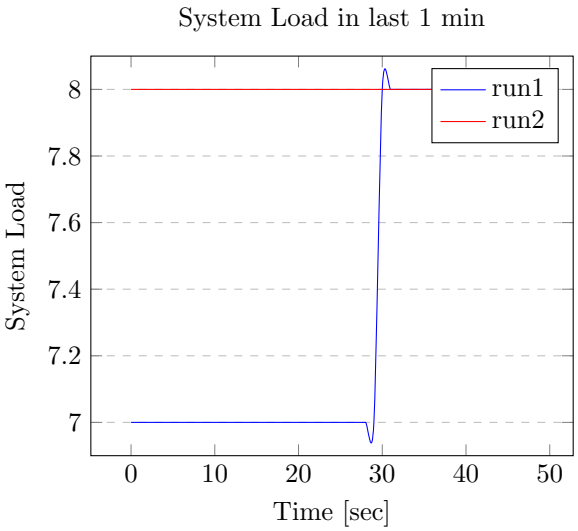


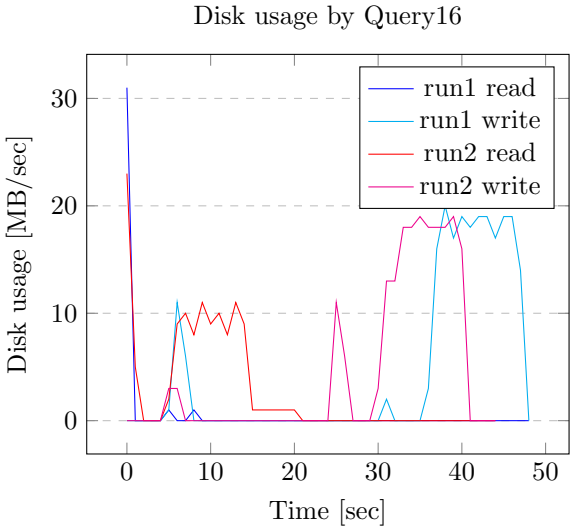


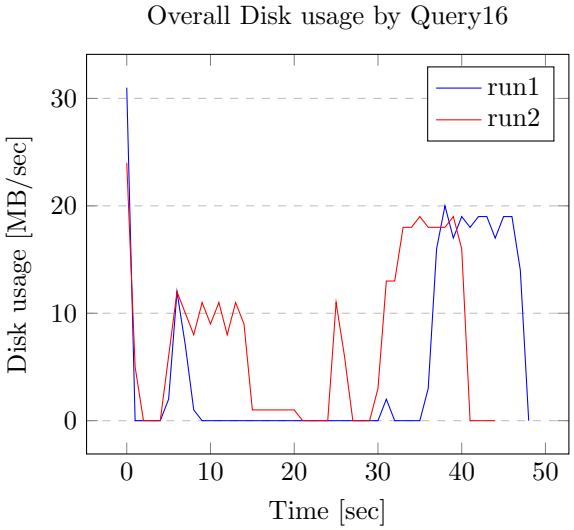
Load	Memory	Disk IO	Execution Time
7.83	26438.05 MB	5.46 MB/sec	47.00 sec

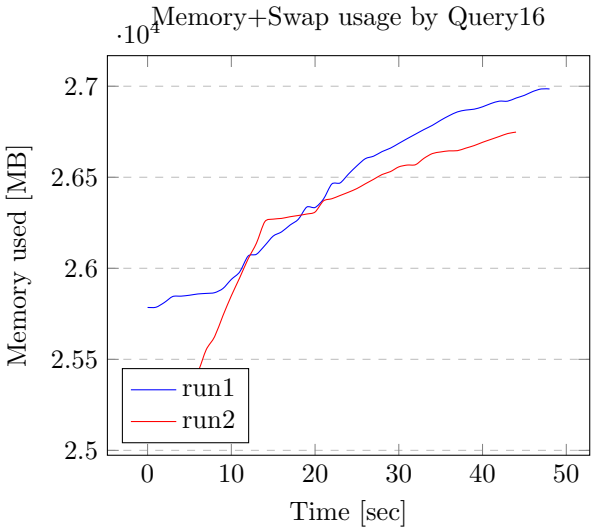
Table 58: Average Parametes over Runtime for Query16

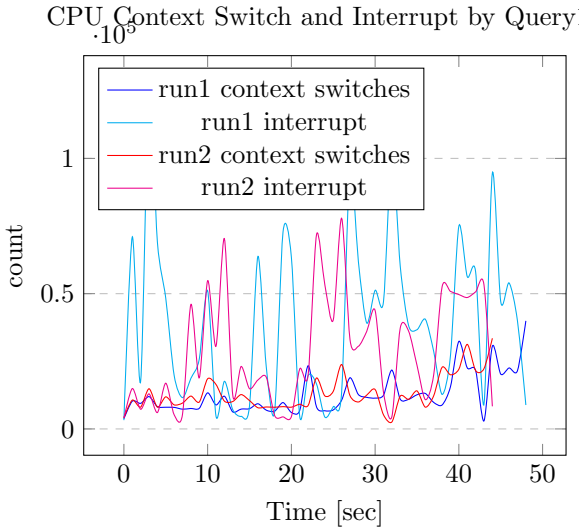






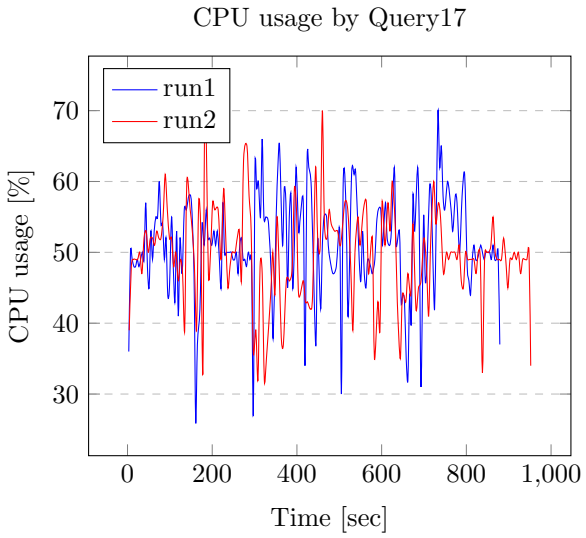


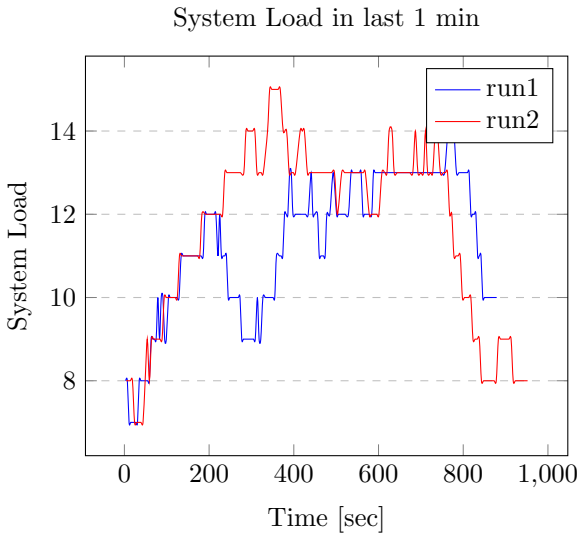


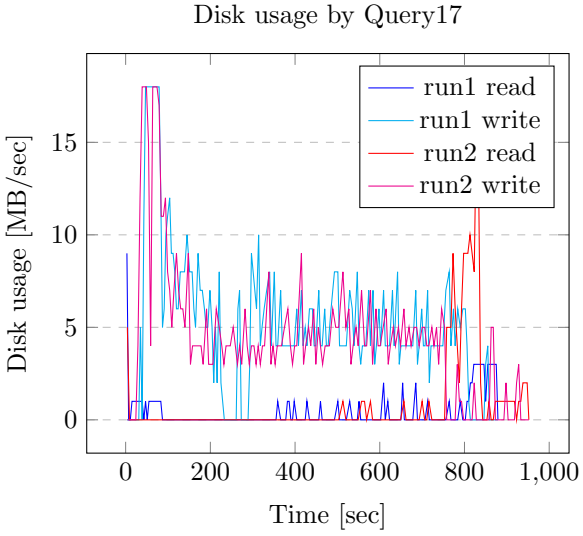


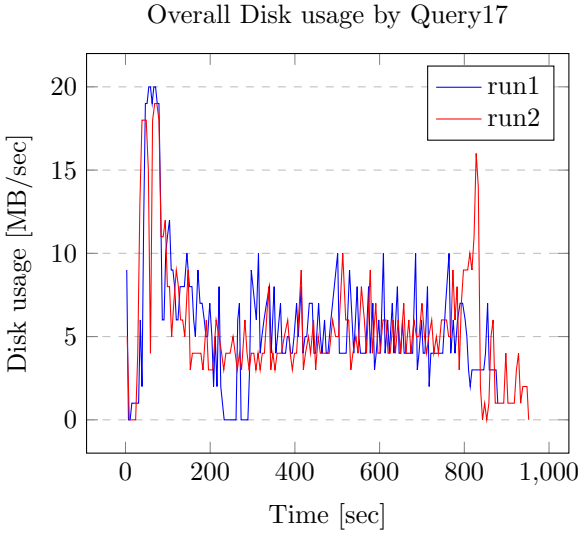
Load	Memory	Disk IO	Execution Time
11.74	35718.01 MB	6.00 MB/sec	811.00 sec

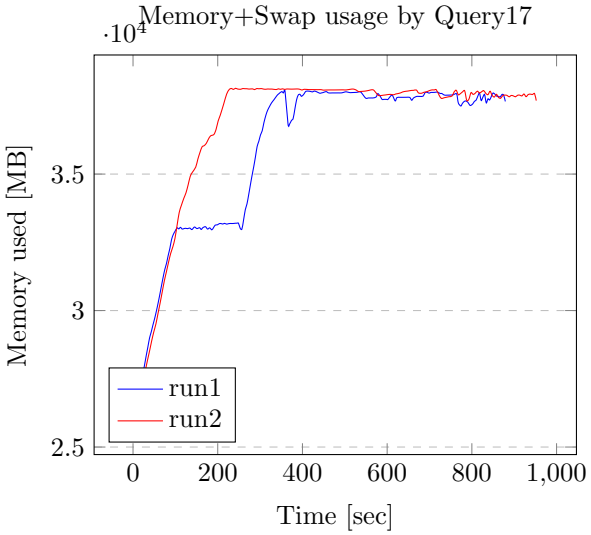
Table 59: Average Parametes over Runtime for Query17

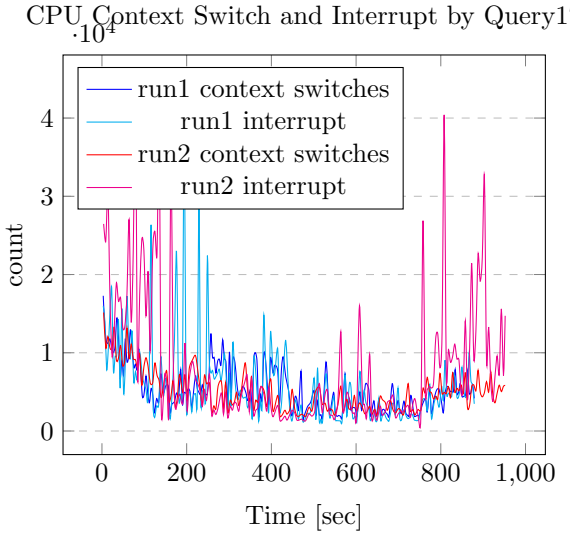






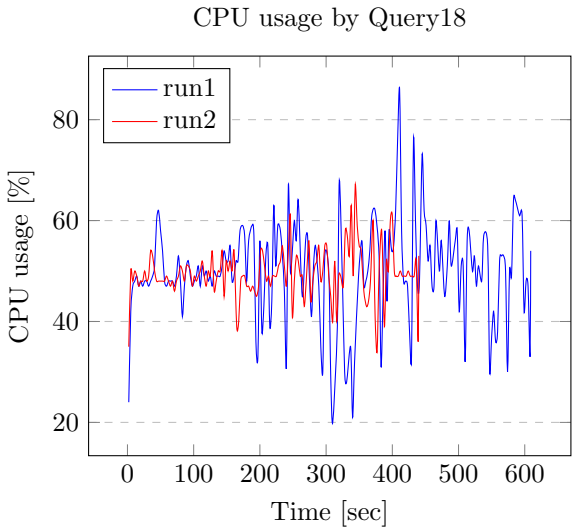


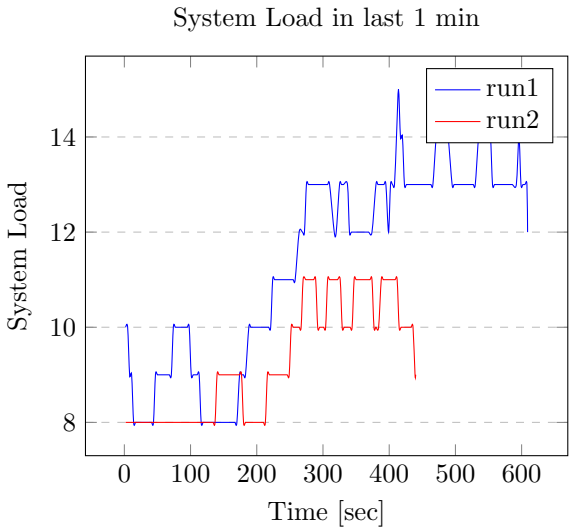


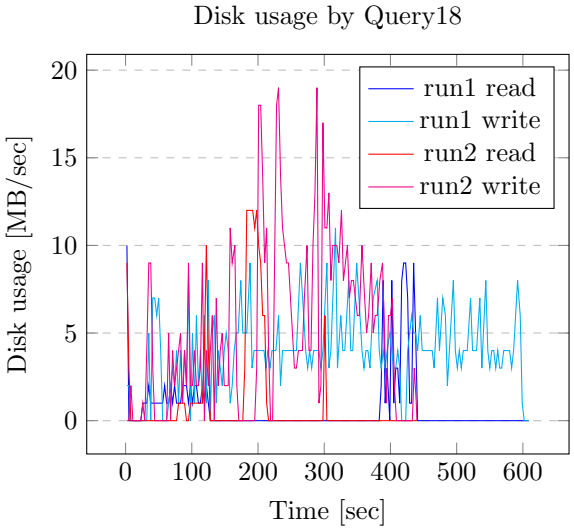


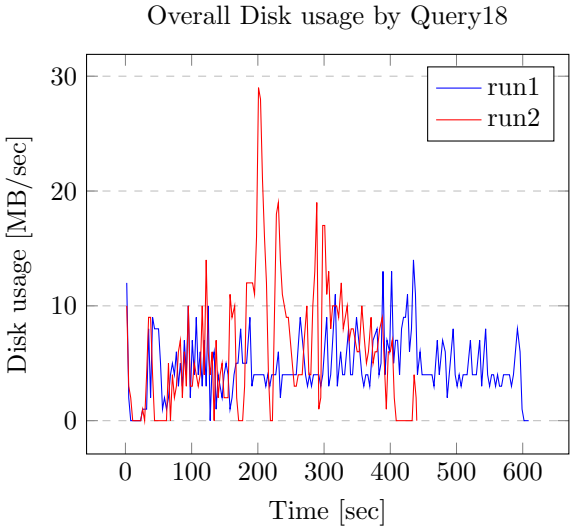
Load	Memory	Disk IO	Execution Time
11.82	30325.33 MB	5.10 MB/sec	494.50 sec

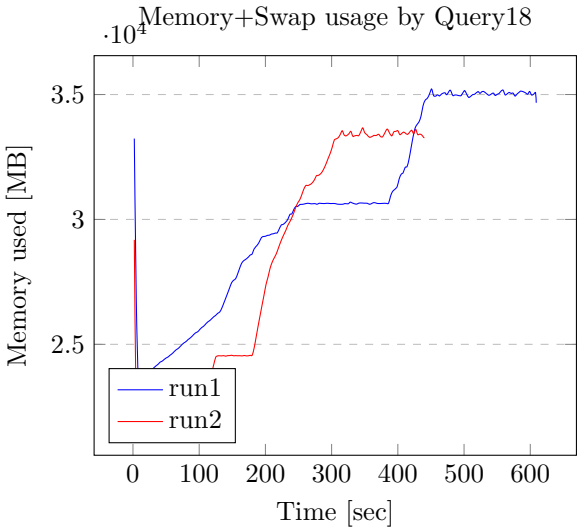
Table 60: Average Parametes over Runtime for Query18

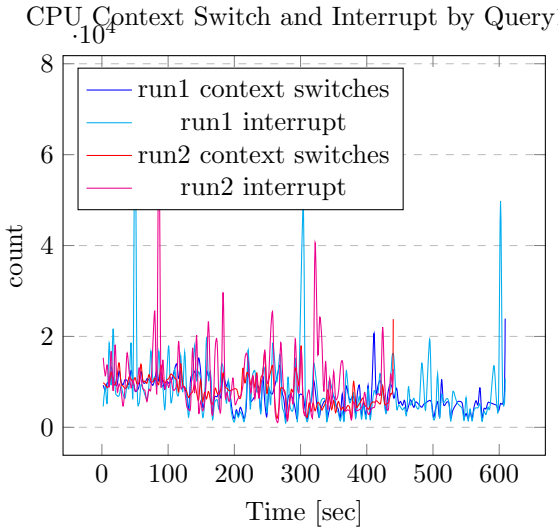






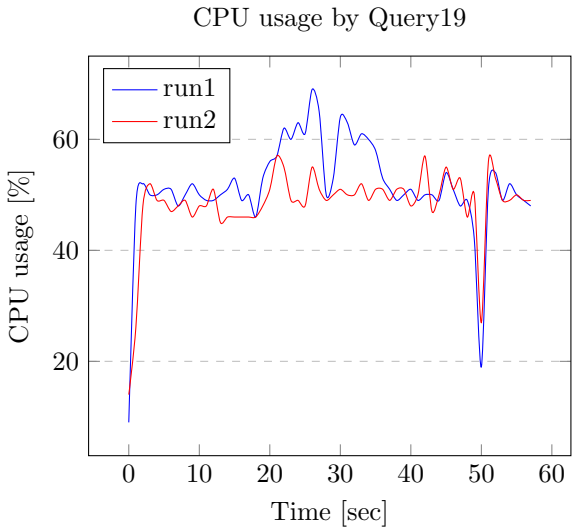


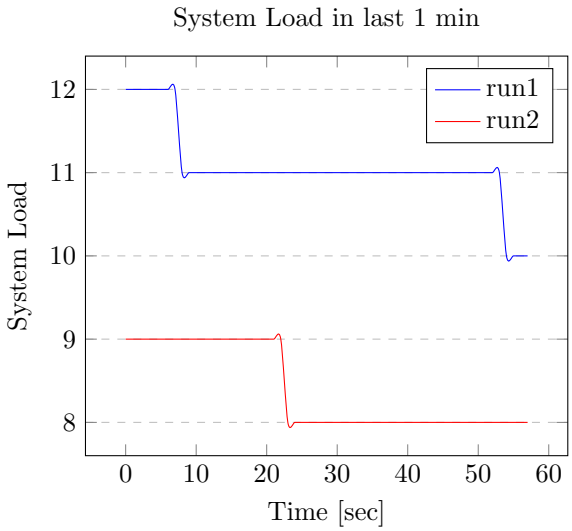


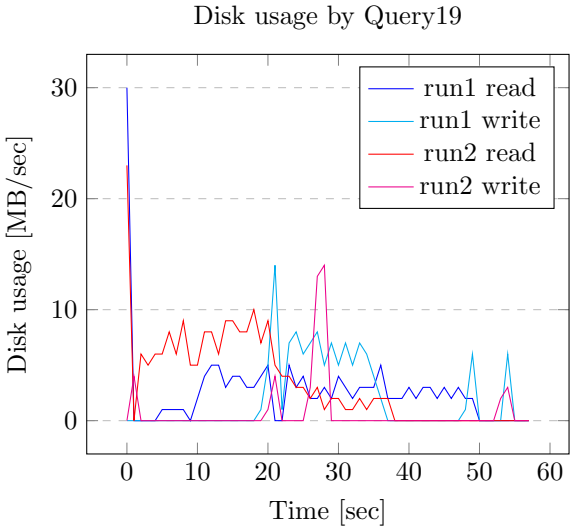


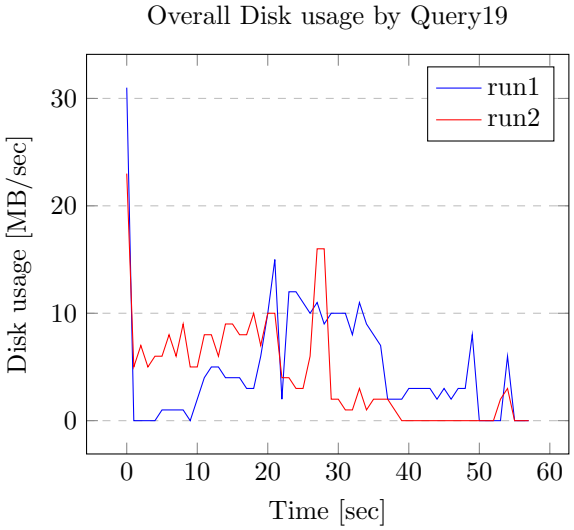
Load	Memory	Disk IO	Execution Time
11.49	26440.09 MB	5.30 MB/sec	58.00 sec

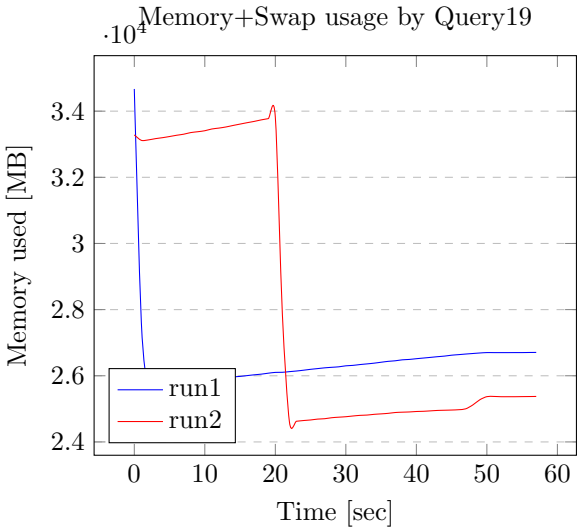
Table 61: Average Parametes over Runtime for Query19

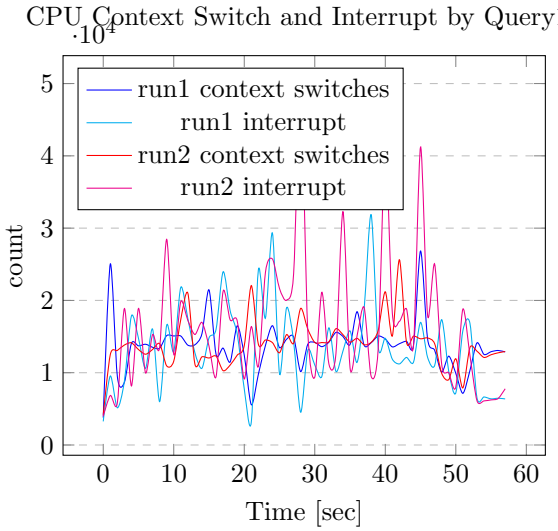






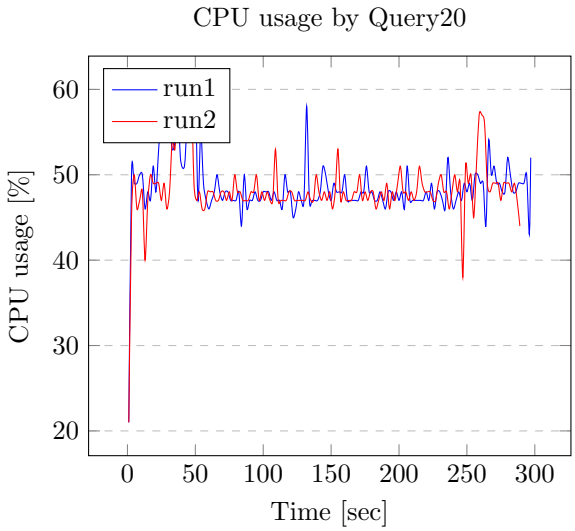


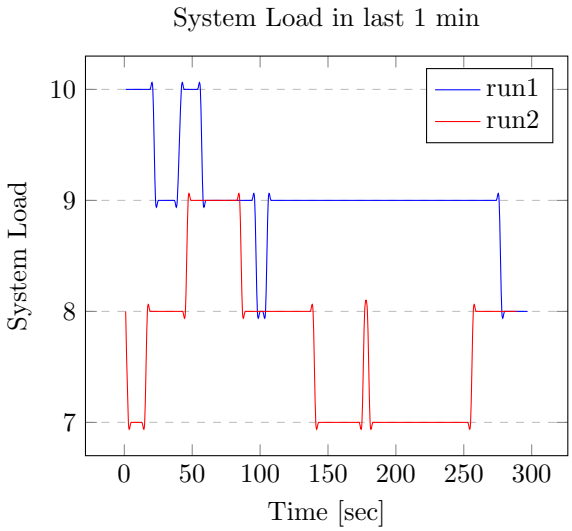


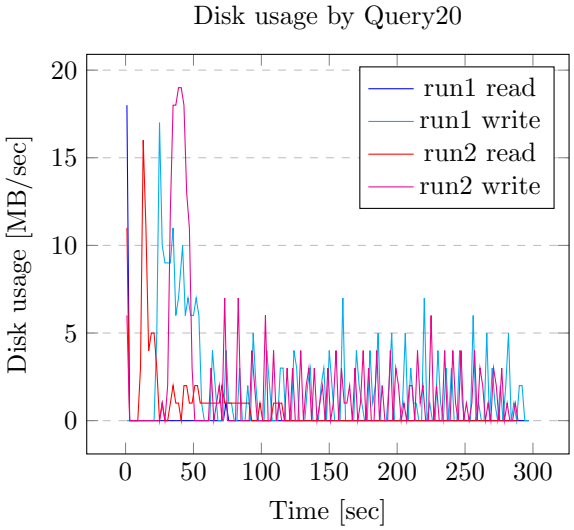


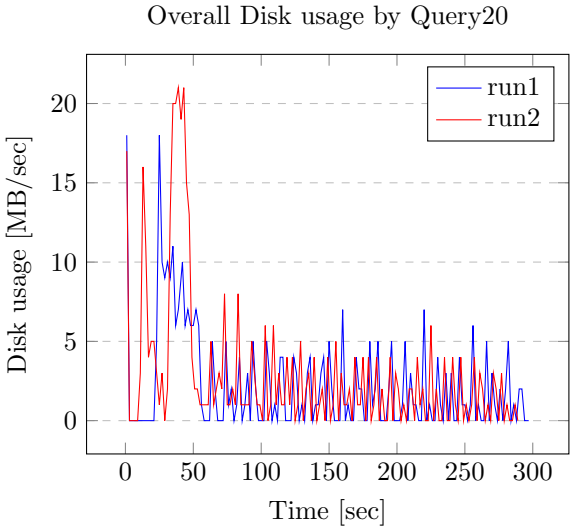
Load	Memory	Disk IO	Execution Time
9.52	27935.17 MB	2.71 MB/sec	293.50 sec

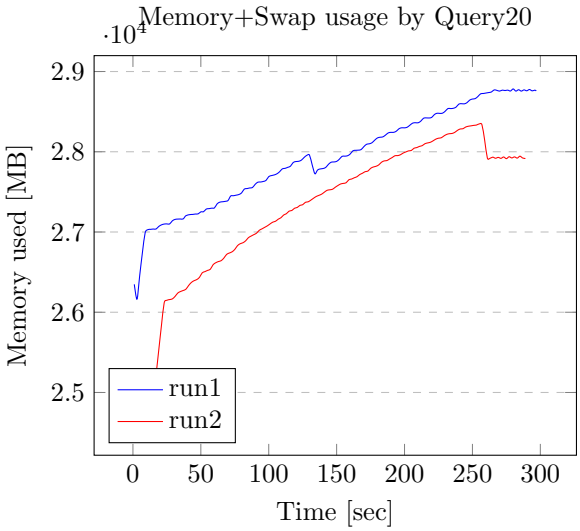
Table 62: Average Parametes over Runtime for Query20

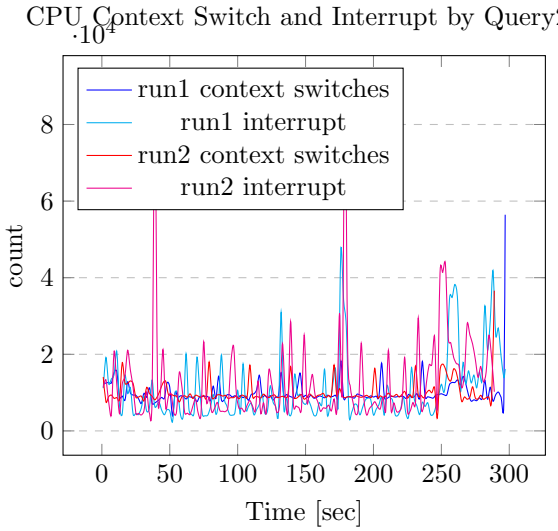






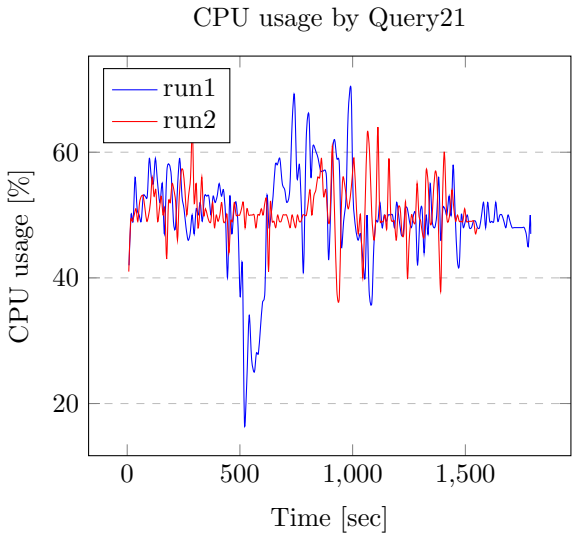


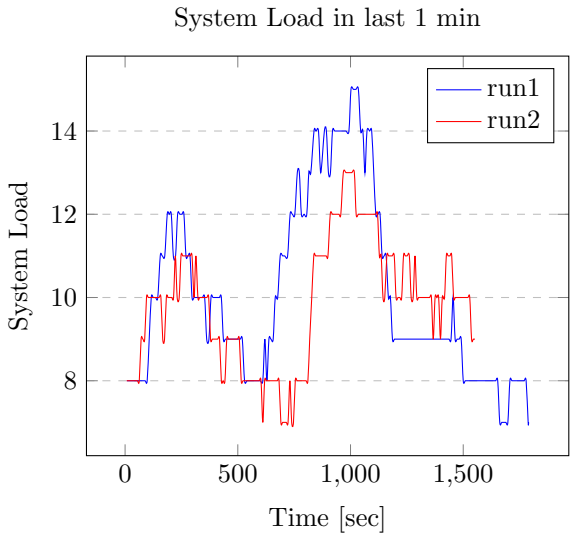


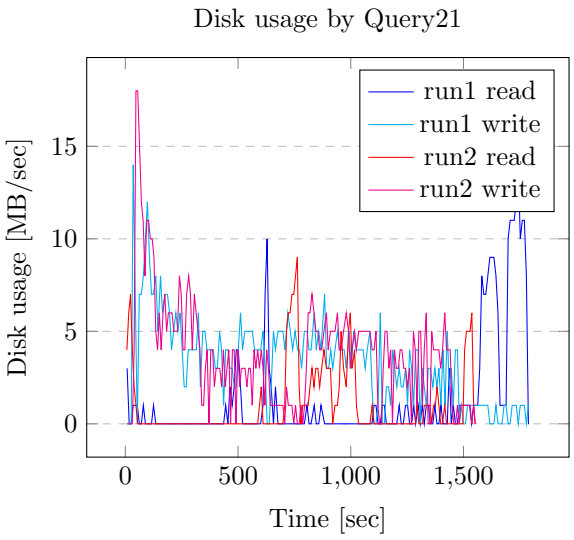


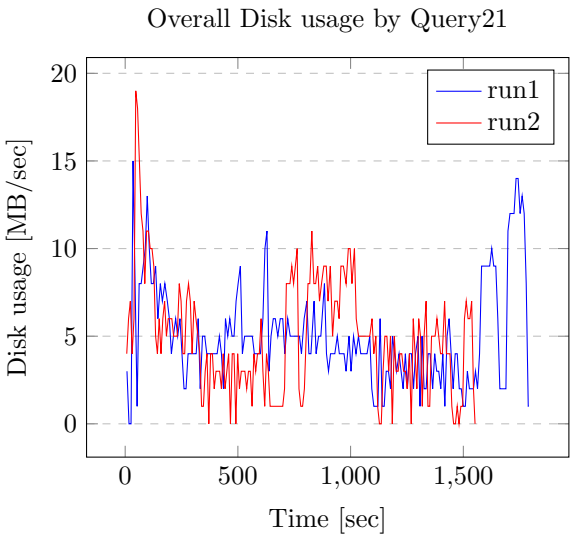
Load	Memory	Disk IO	Execution Time
10.51	37143.61 MB	5.52 MB/sec	1594.50 sec

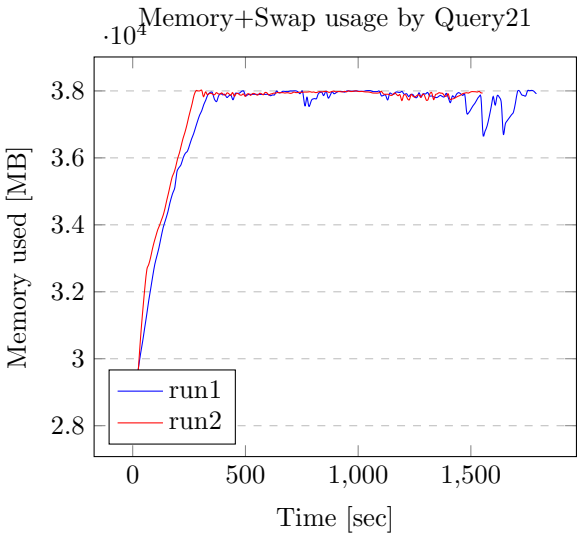
Table 63: Average Parametes over Runtime for Query21

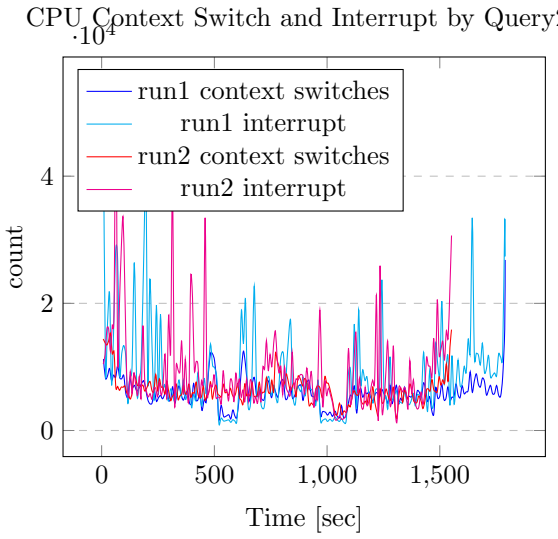






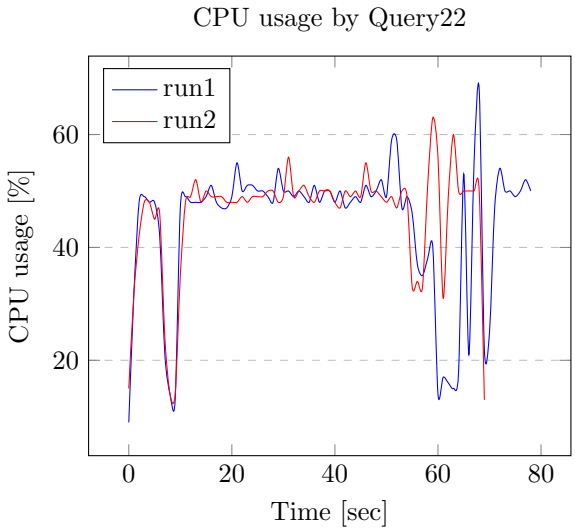


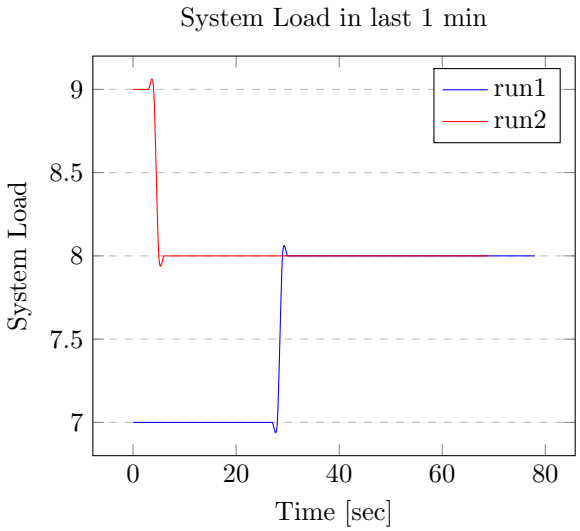


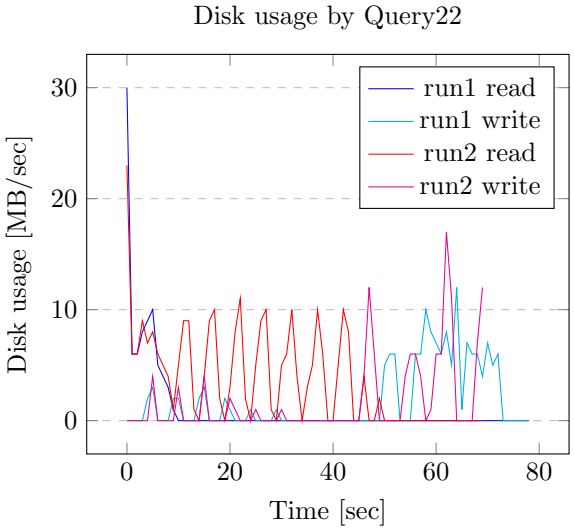


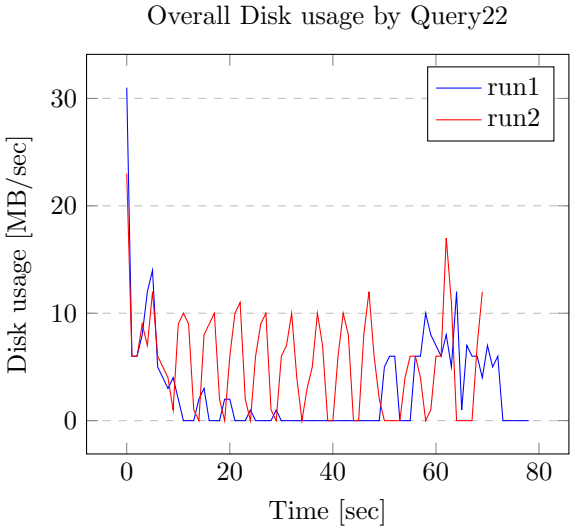
Load	Memory	Disk IO	Execution Time
8.17	37967.55 MB	3.23 MB/sec	74.50 sec

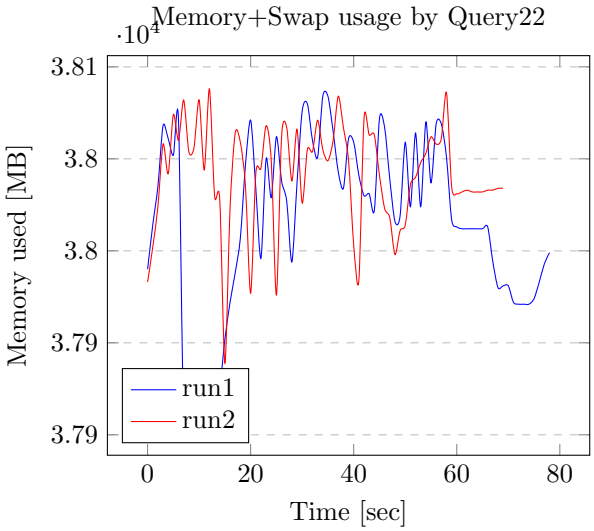
Table 64: Average Parametes over Runtime for Query22

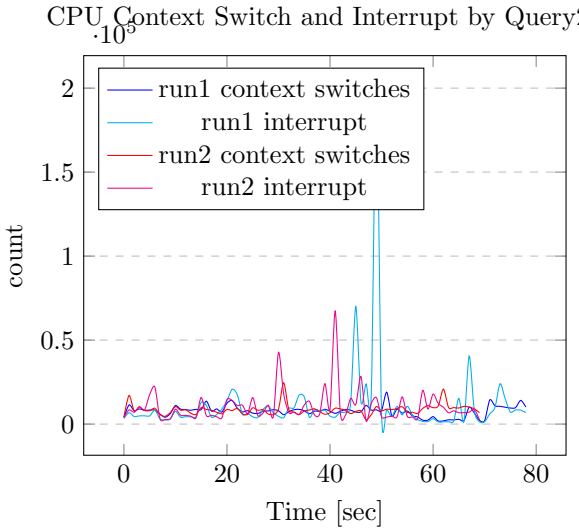










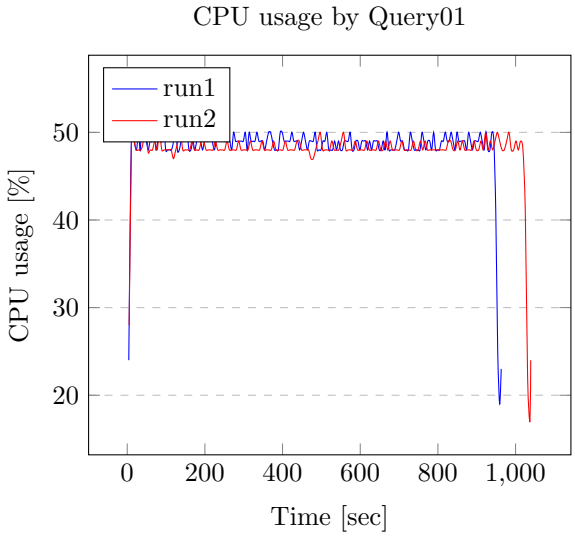


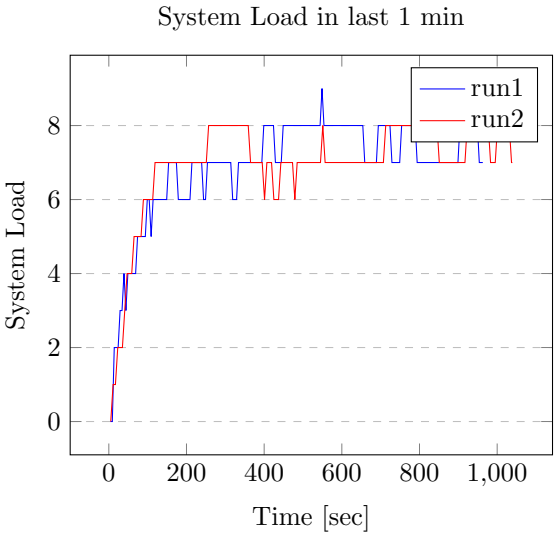
Load	Memory	Disk IO	Execution Time
7.39	38187.44 MB	3.23 MB/sec	1002.00 sec

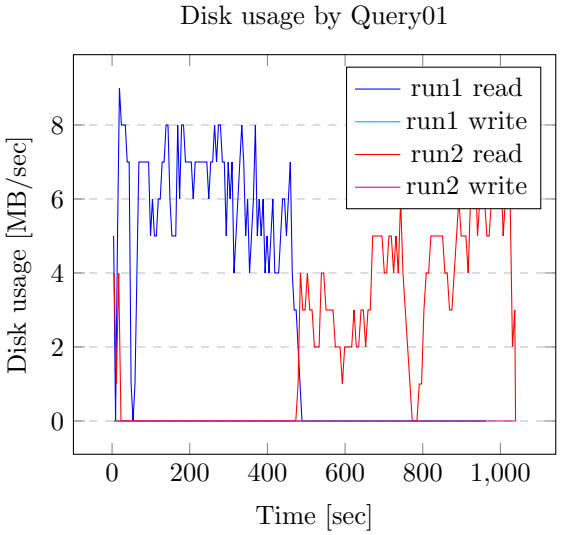
Table 65: Average Parametes over Runtime for Query01

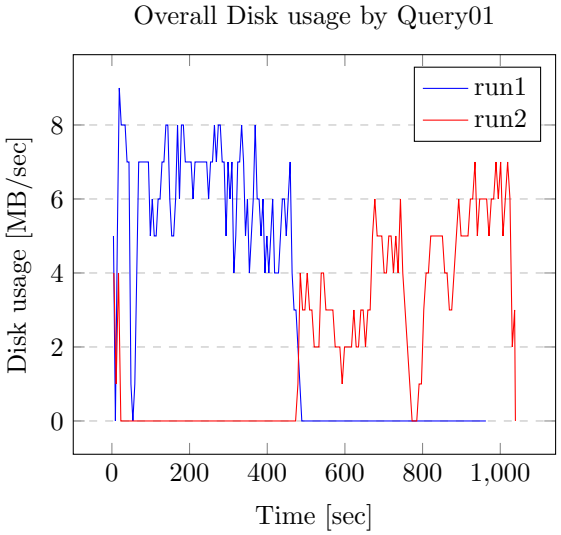
5.3 Spark and Avro

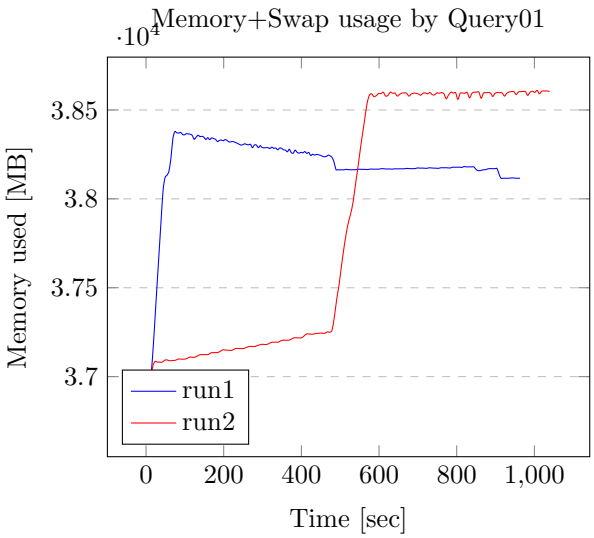
In some queries the first and the second run have massive diffrence. The run which uses more resources ends sooner so it can conclude other environment variables can effect on spark and avro integration. Creating files in avro format and load data from parquet format took 2030 seconds which is 6 time faster than postgres.

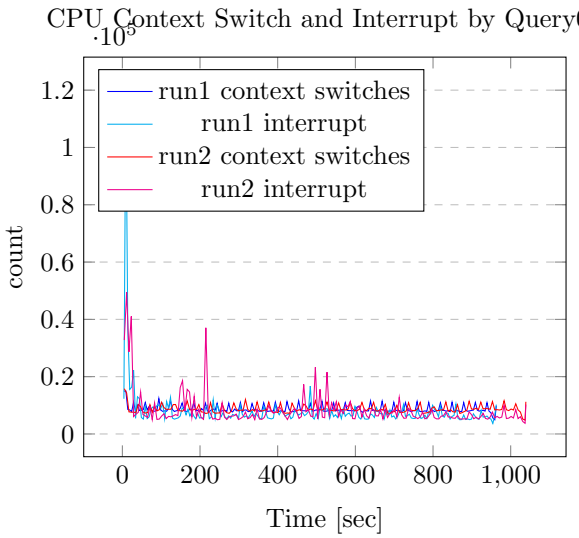






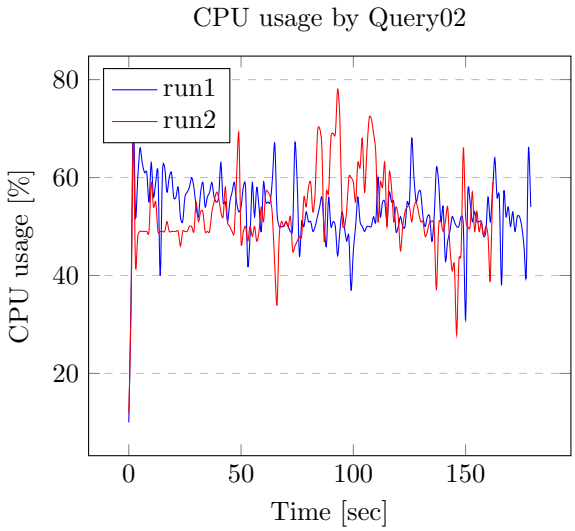


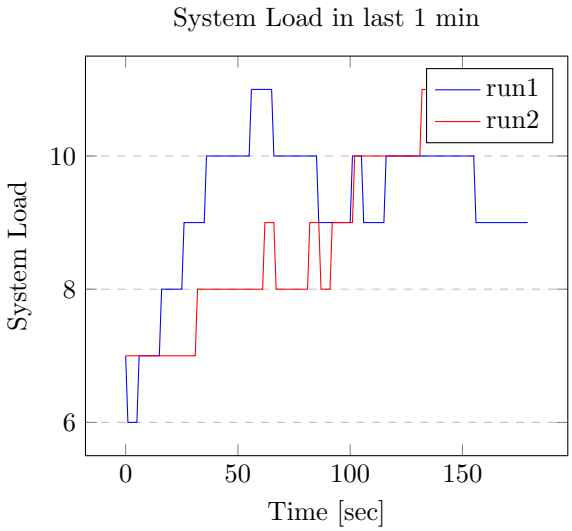


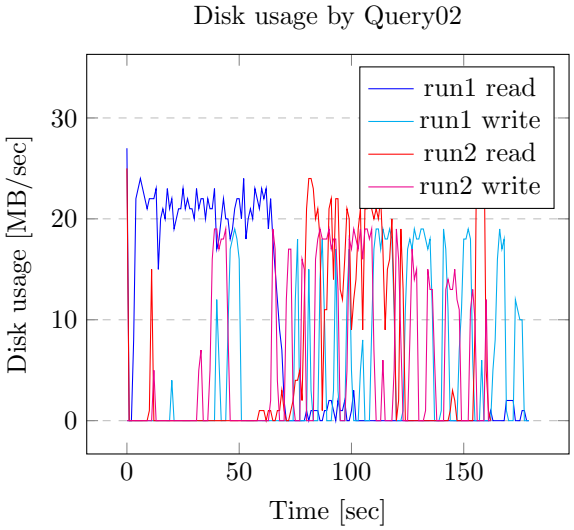


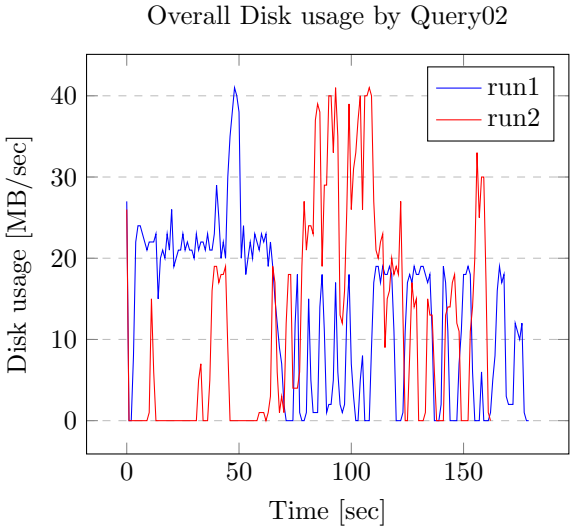
Load	Memory	Disk IO	Execution Time
9.84	38049.24 MB	13.78 MB/sec	171.50 sec

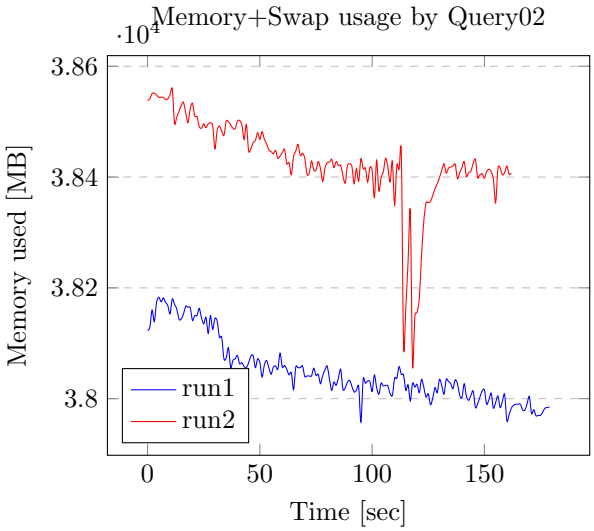
Table 66: Average Parametes over Runtime for Query02

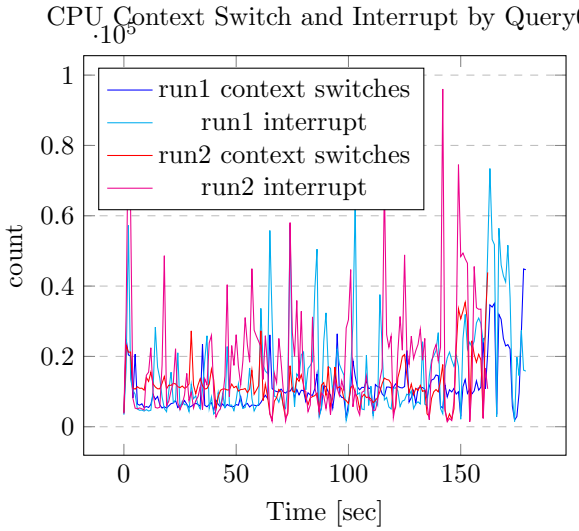






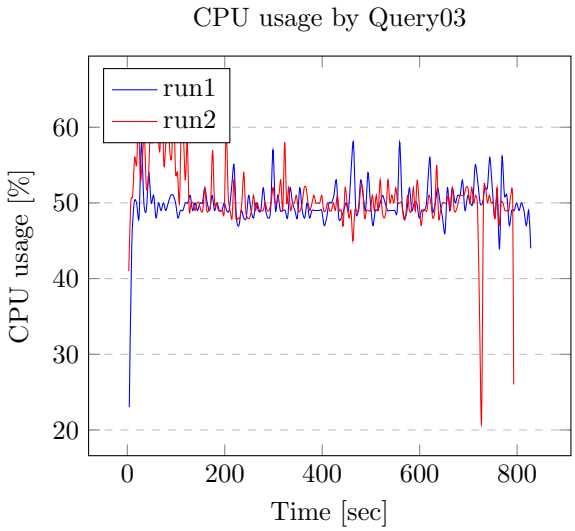


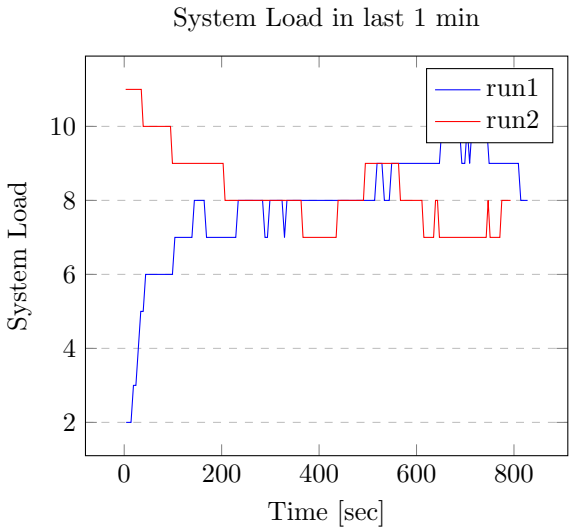


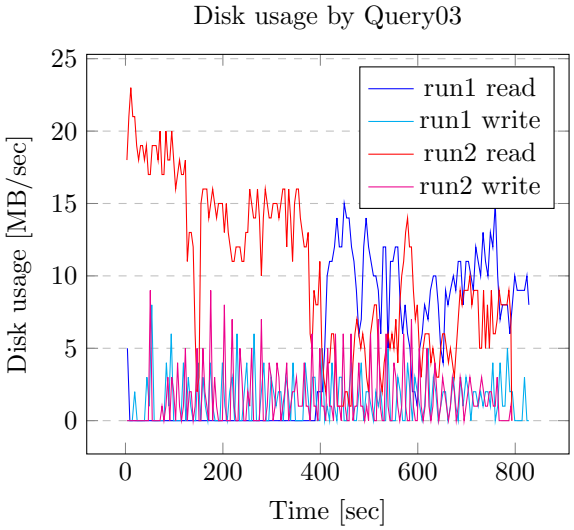


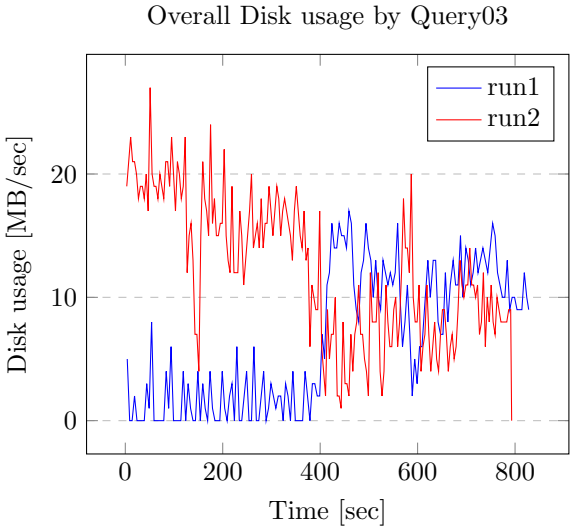
Load	Memory	Disk IO	Execution Time
8.39	38428.72 MB	6.91 MB/sec	809.00 sec

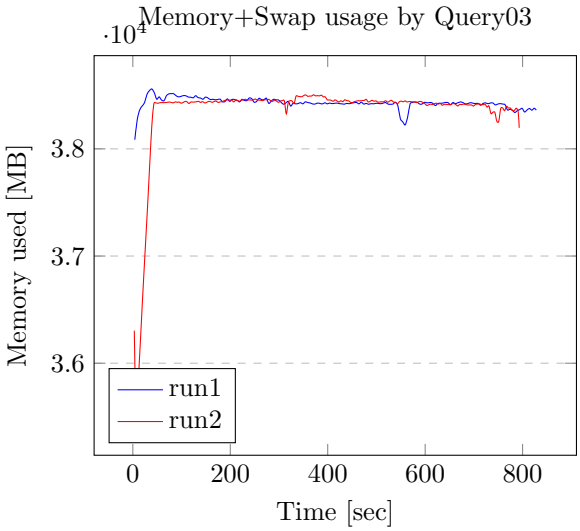
Table 67: Average Parametes over Runtime for Query03

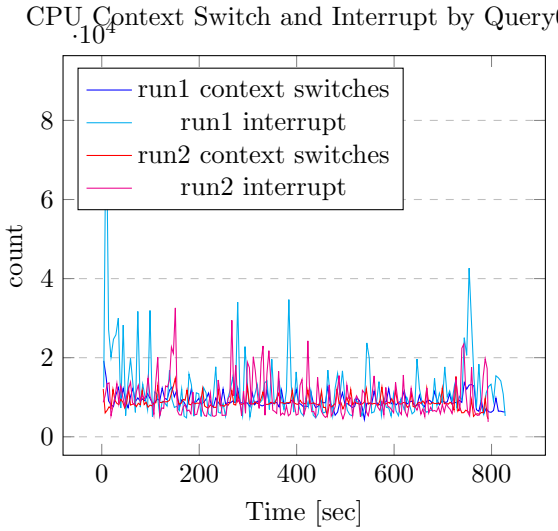








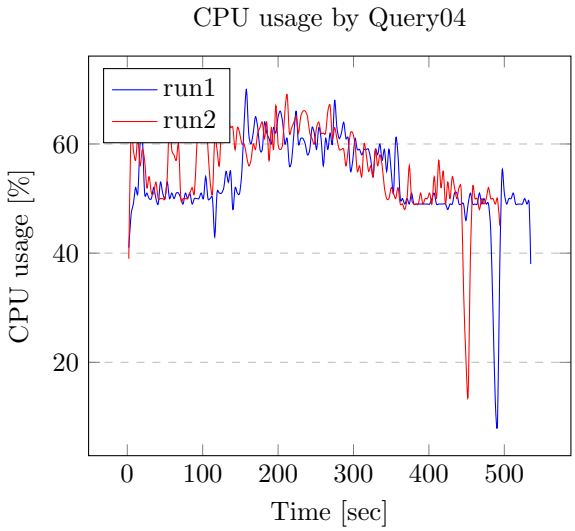


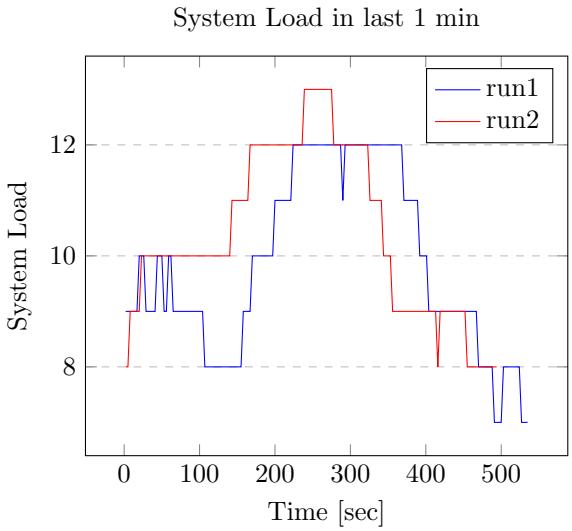


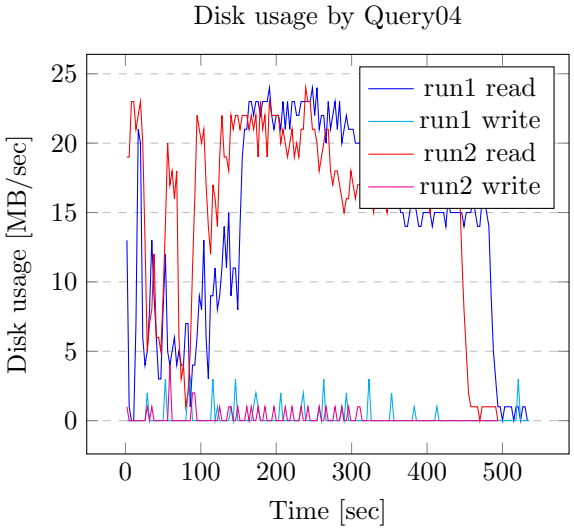
In this and previous Query execution, disk usage pattern for the first and second run are seemed reverted.

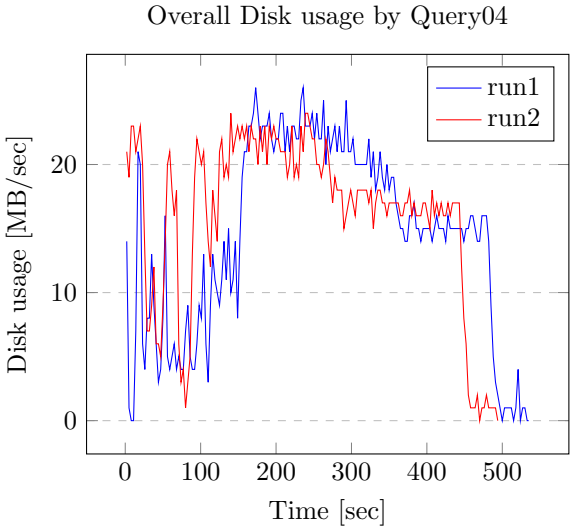
Load	Memory	Disk IO	Execution Time
10.30	37495.57 MB	14.88 MB/sec	515.50 sec

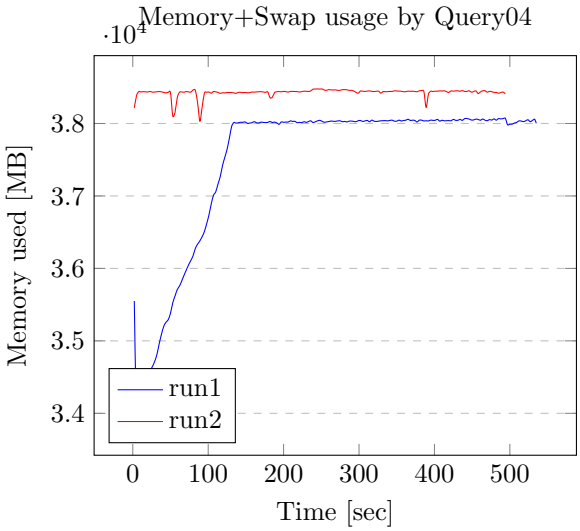
Table 68: Average Parametes over Runtime for Query04

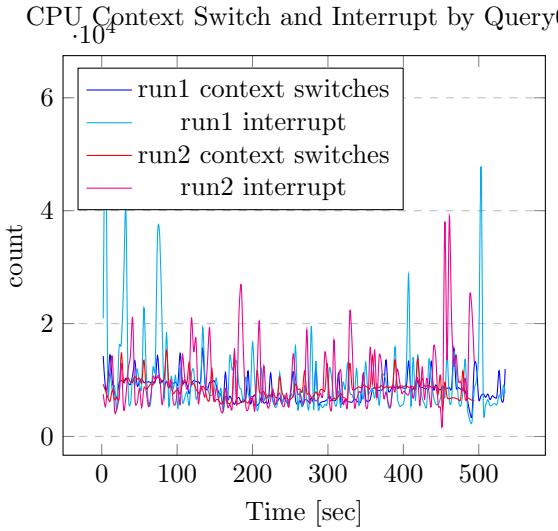






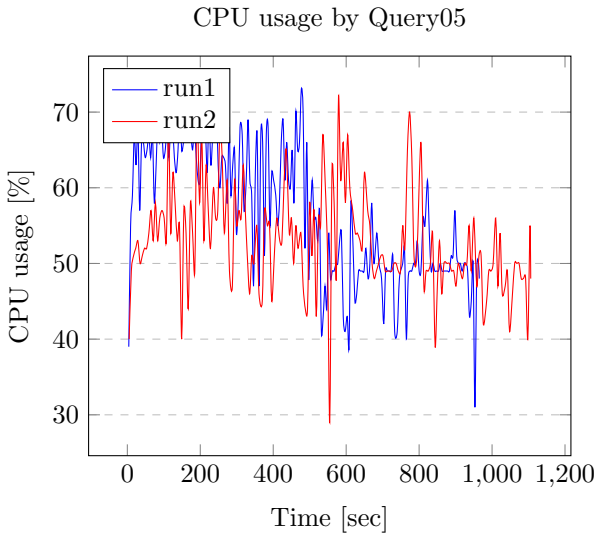


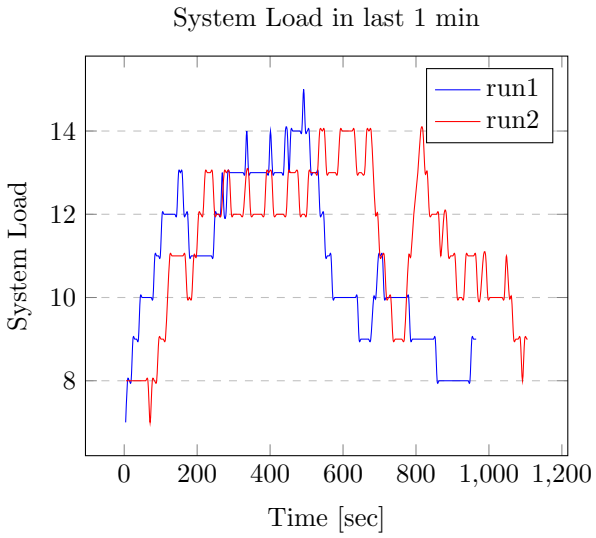


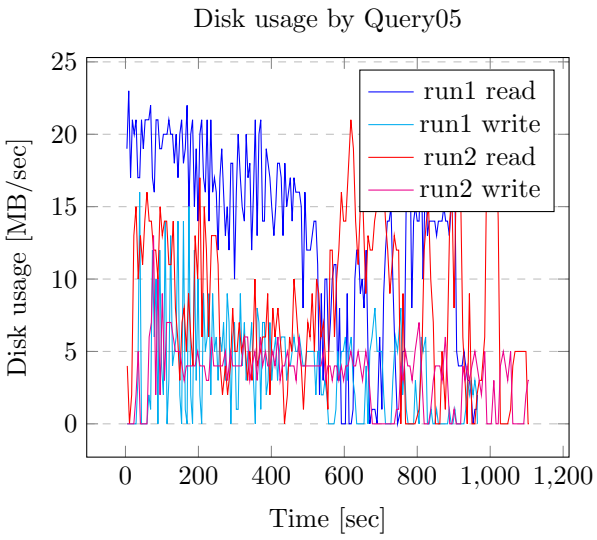


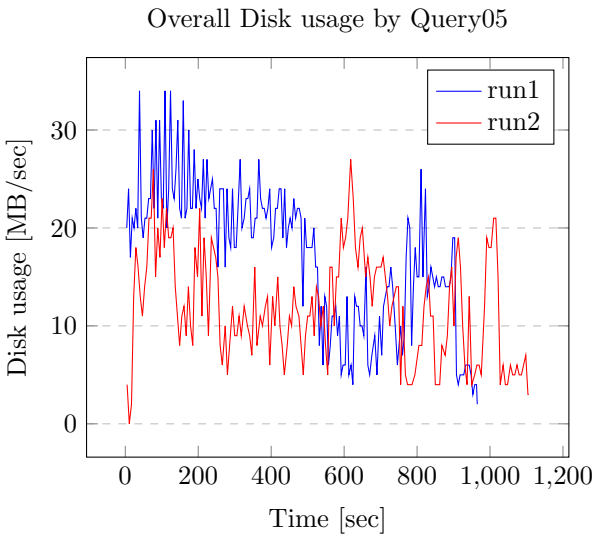
Load	Memory	Disk IO	Execution Time
11.42	38011.38 MB	17.81 MB/sec	994.00 sec

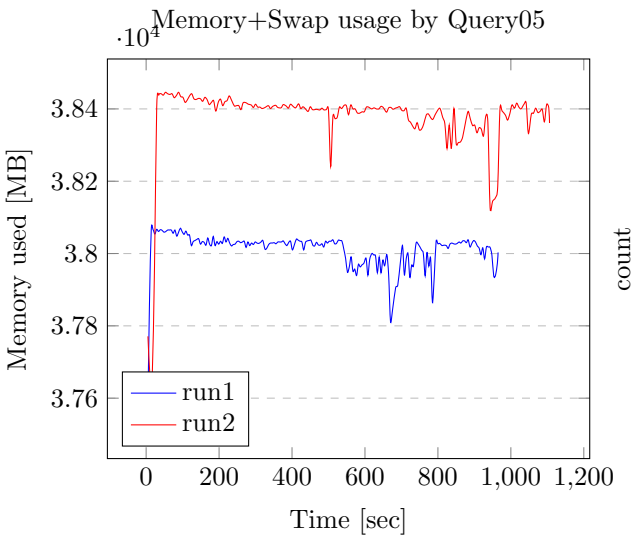
Table 69: Average Parametes over Runtime for Query05

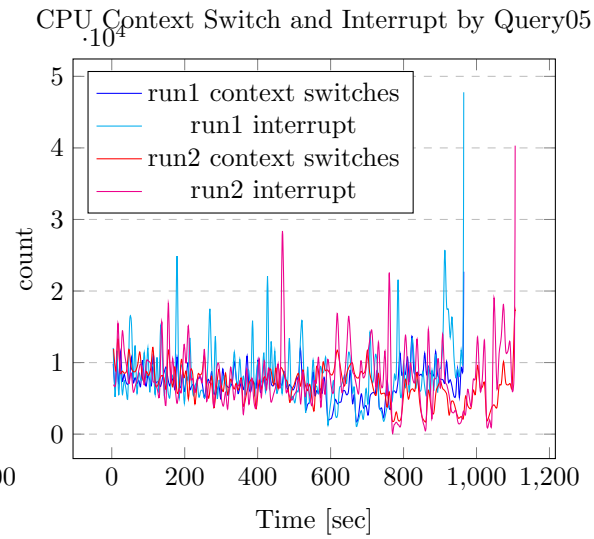






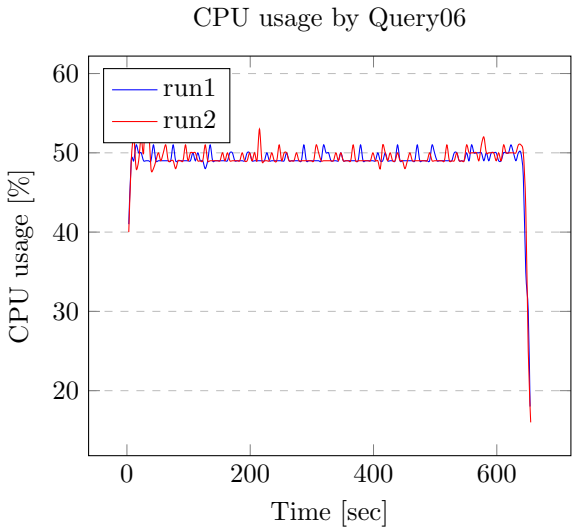


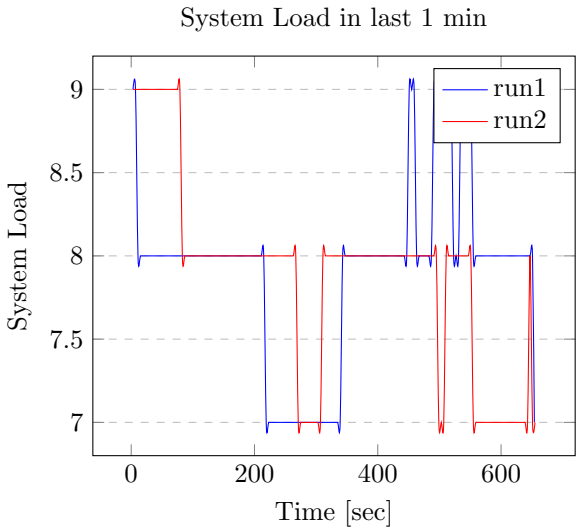


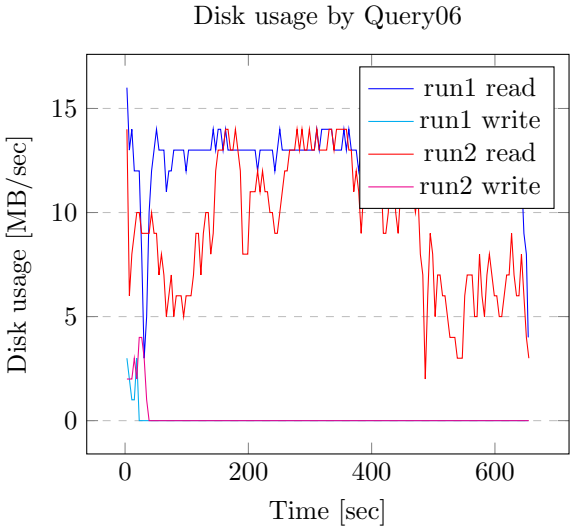


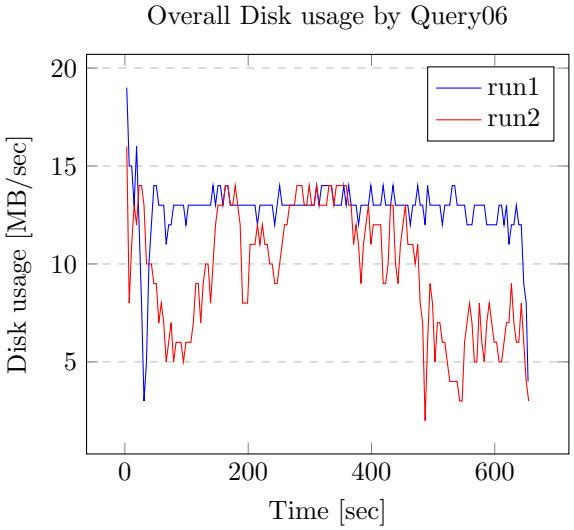
Load	Memory	Disk IO	Execution Time
8.29	38056.31 MB	13.30 MB/sec	655.50 sec

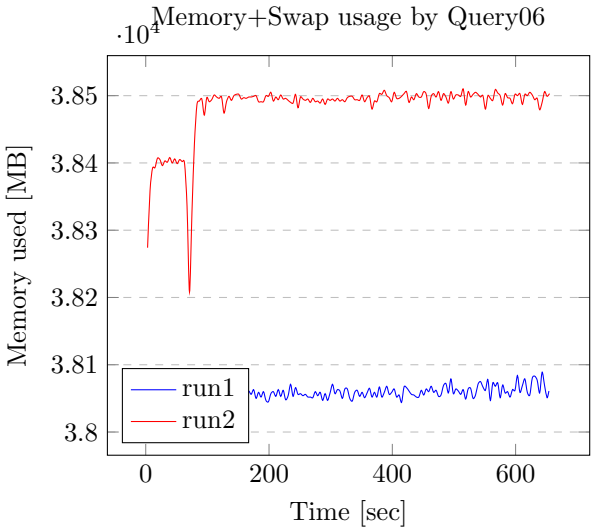
Table 70: Average Parametes over Runtime for Query06

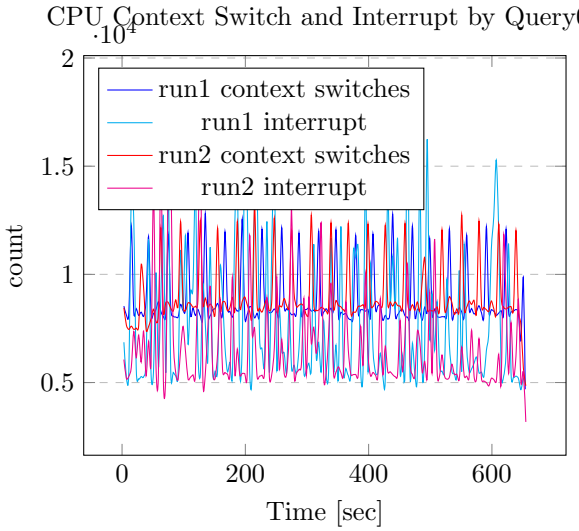






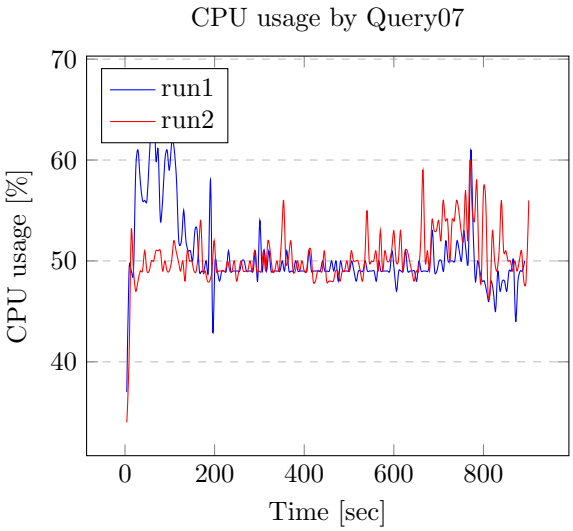


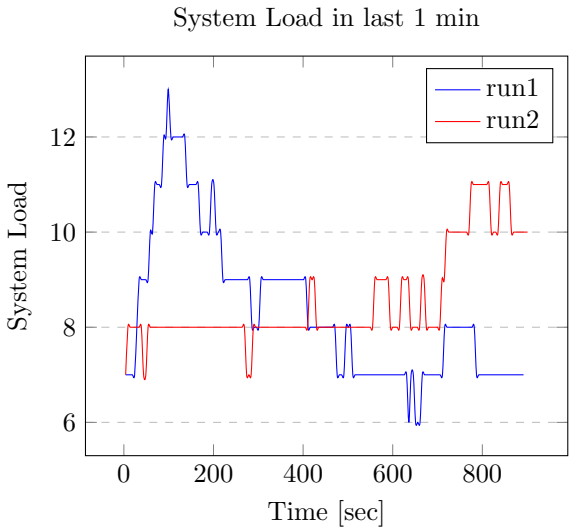


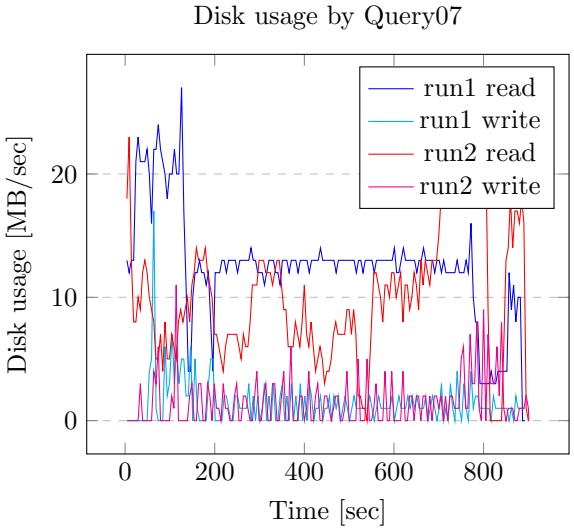


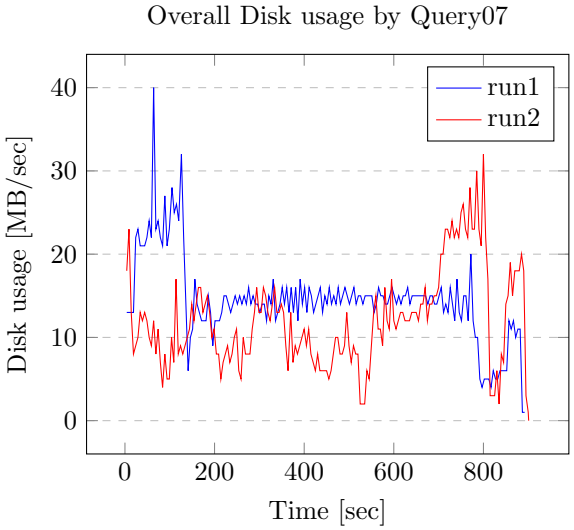
Load	Memory	Disk IO	Execution Time
8.84	37942.76 MB	14.97 MB/sec	895.50 sec

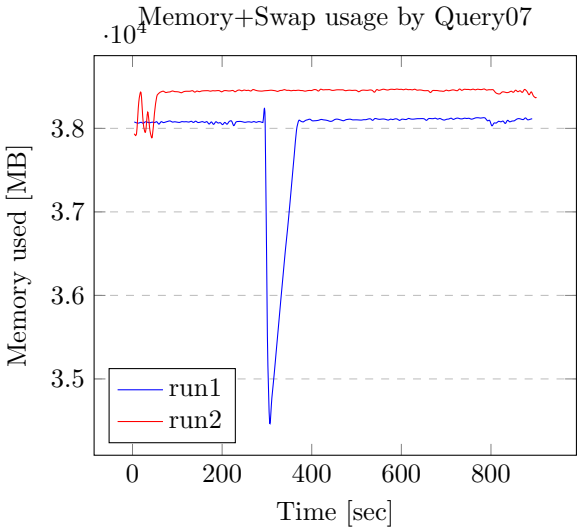
Table 71: Average Parametes over Runtime for Query07

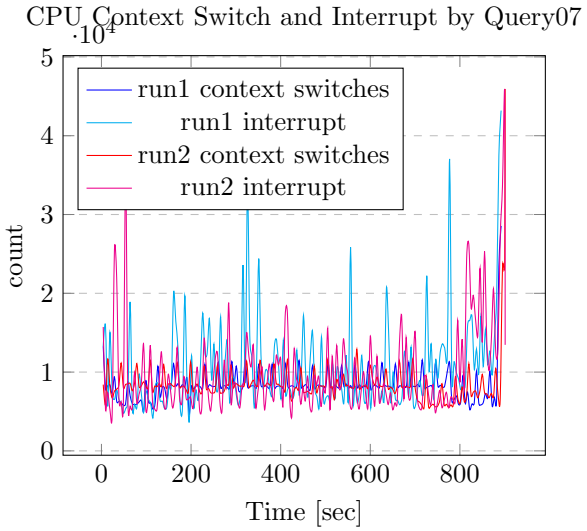






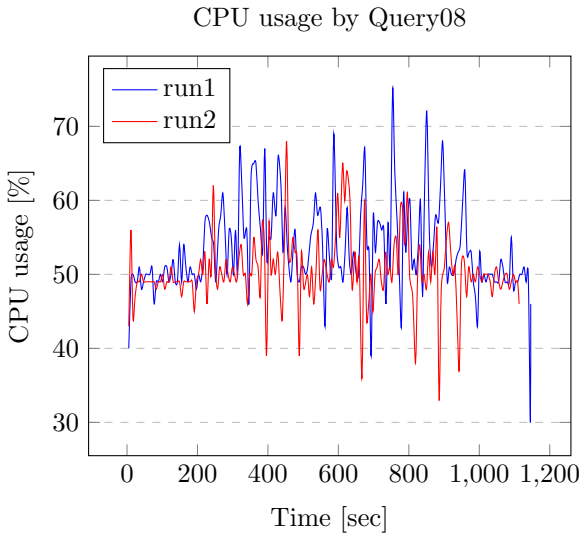


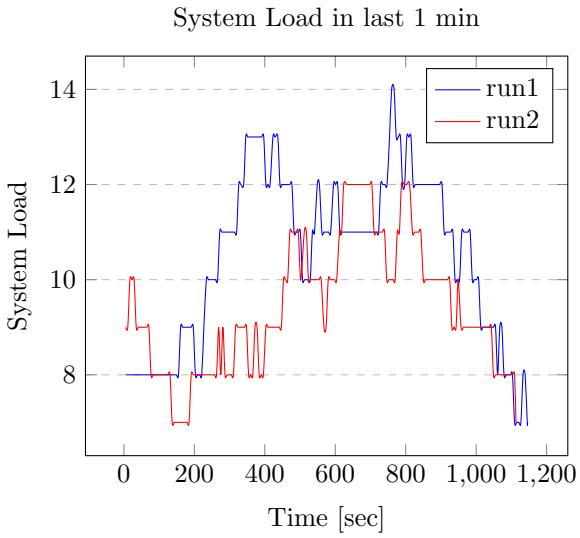


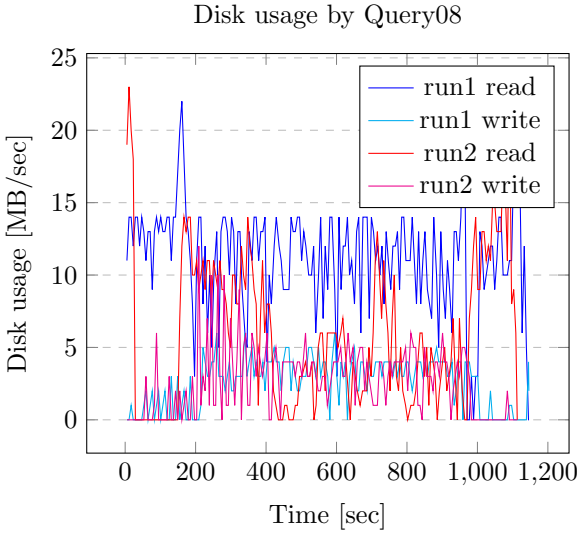


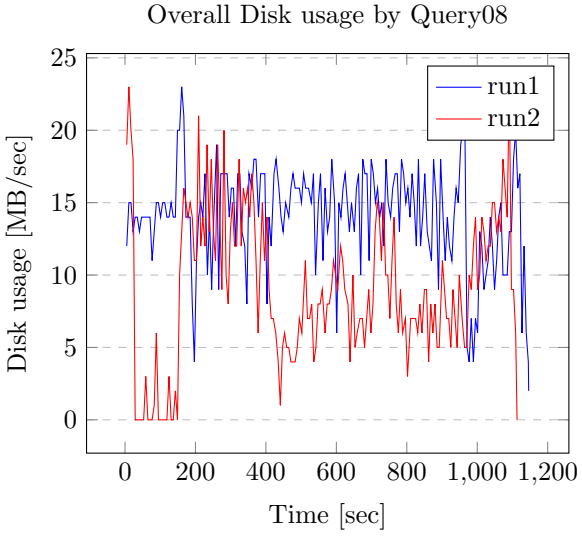
Load	Memory	Disk IO	Execution Time
10.89	38093.10 MB	14.59 MB/sec	1094.50 sec

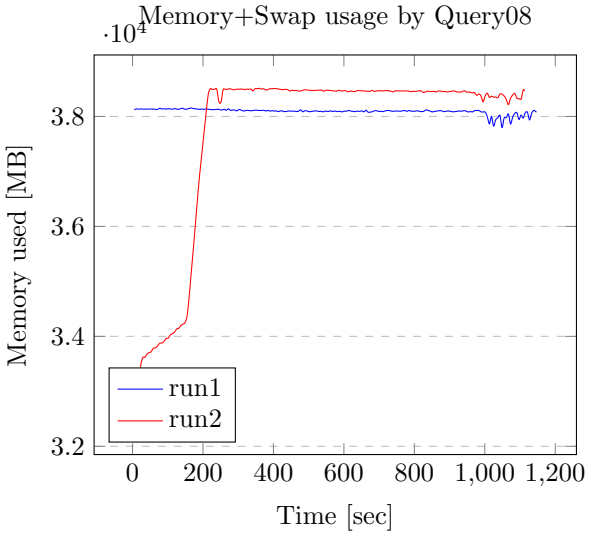
Table 72: Average Parametes over Runtime for Query08

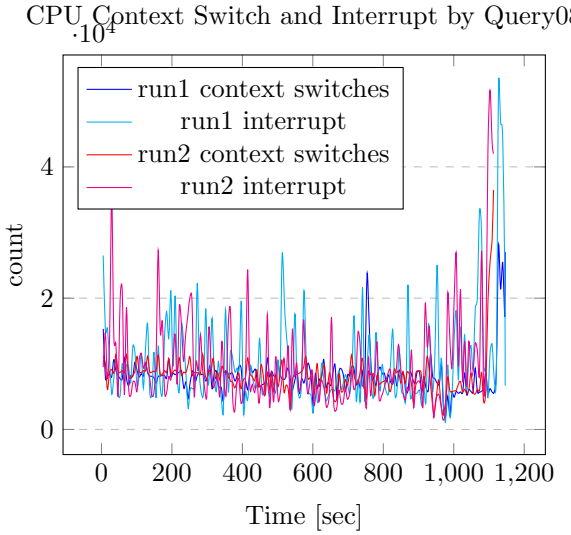






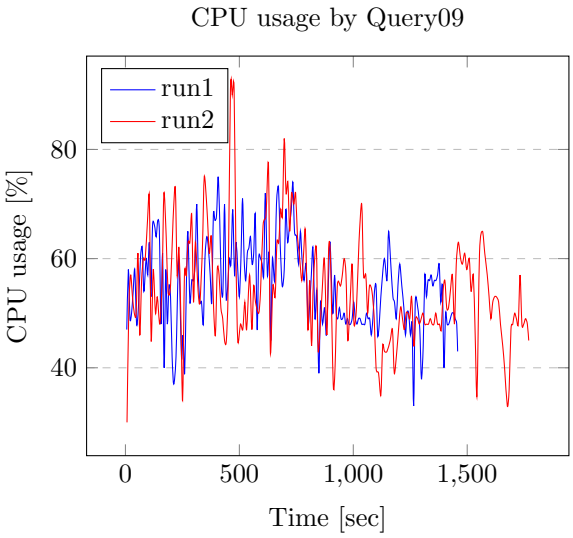


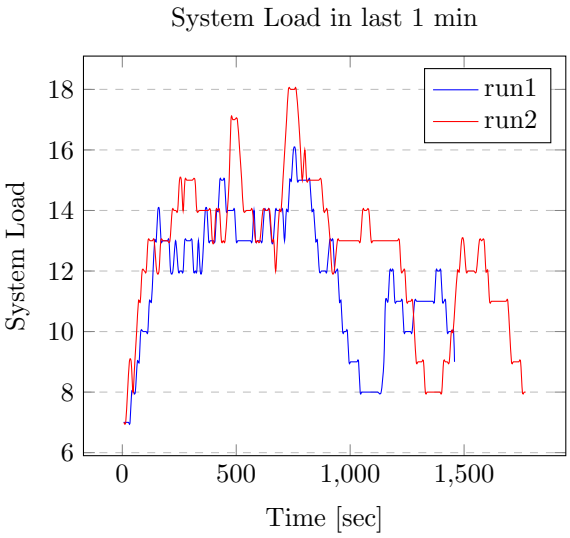


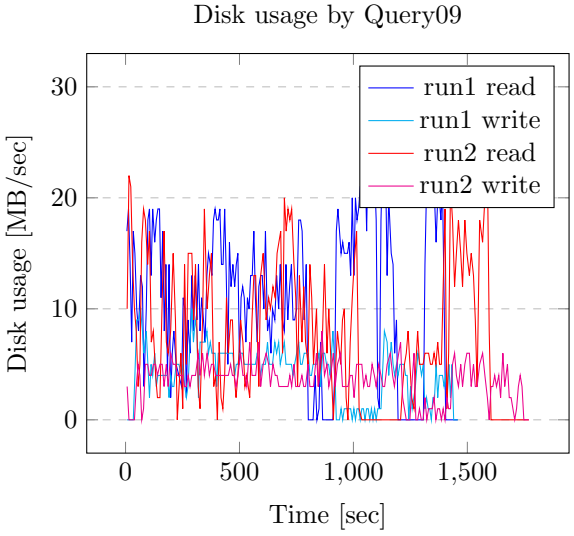


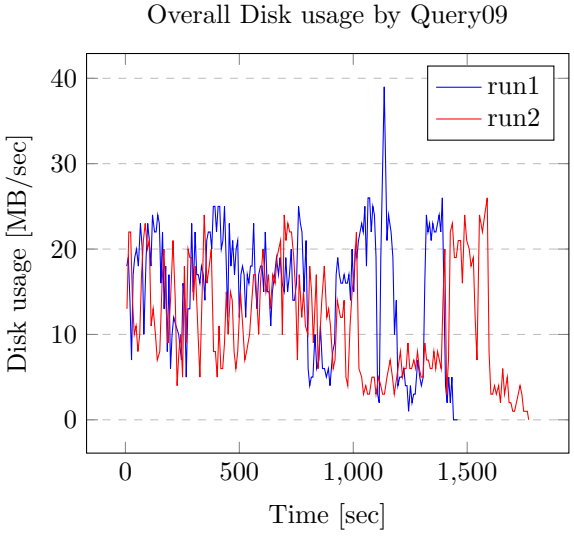
Load	Memory	Disk IO	Execution Time
12.32	34857.56 MB	16.04 MB/sec	1461.00 sec

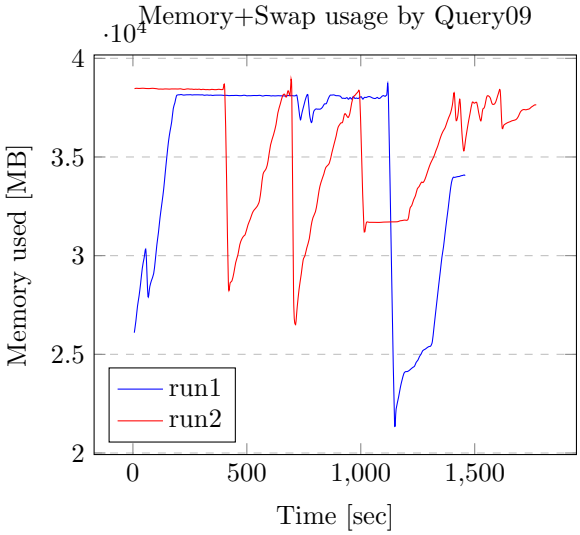
Table 73: Average Parametes over Runtime for Query09

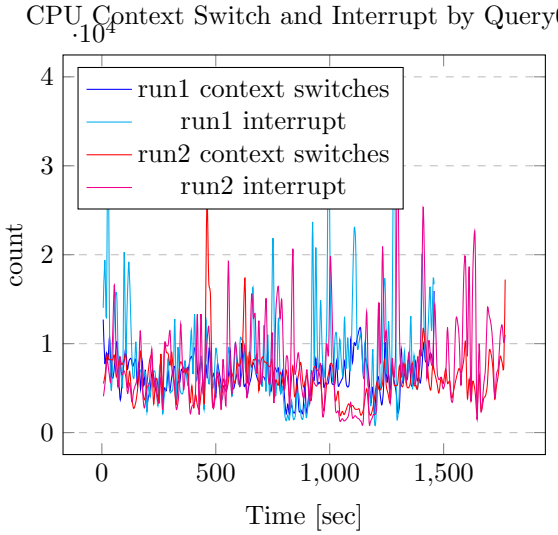






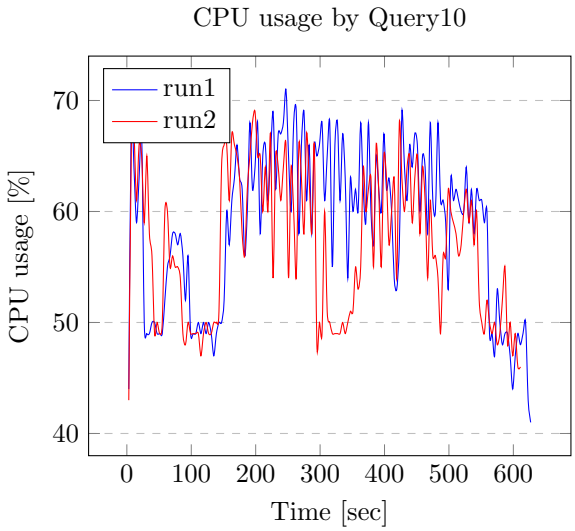


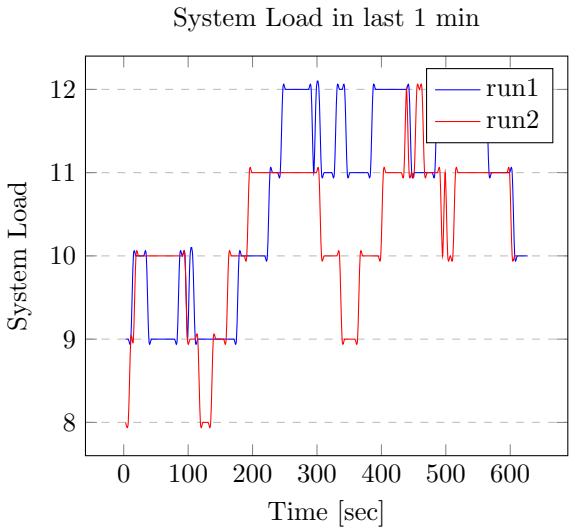


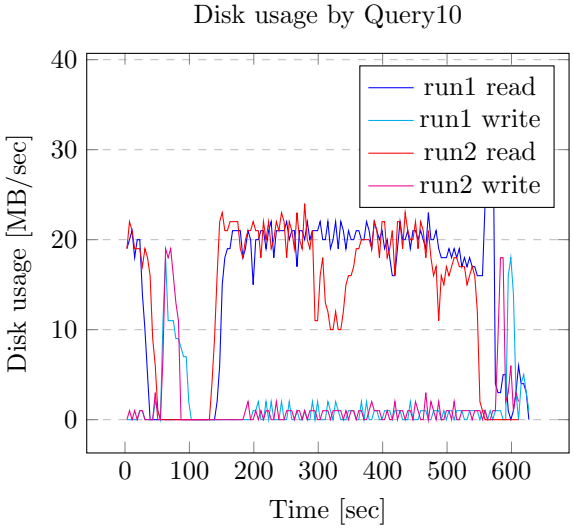


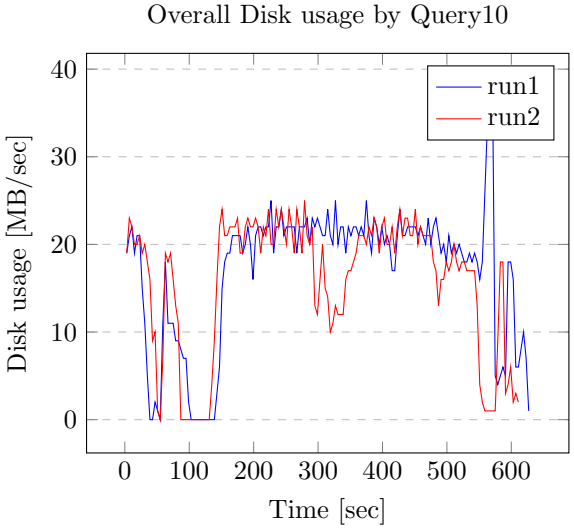
Load	Memory	Disk IO	Execution Time
11.22	37285.80 MB	17.30 MB/sec	620.00 sec

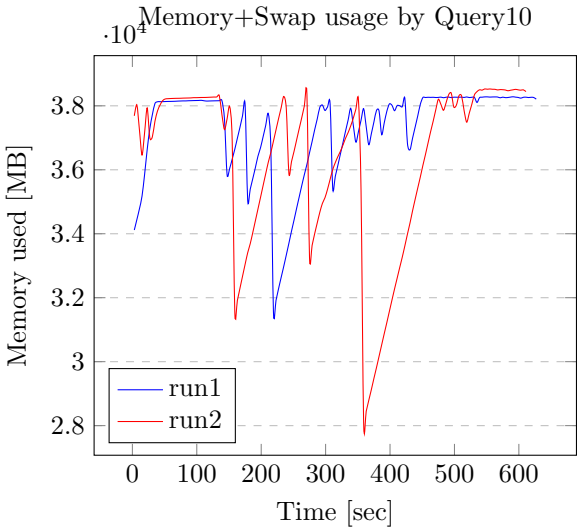
Table 74: Average Parametes over Runtime for Query10

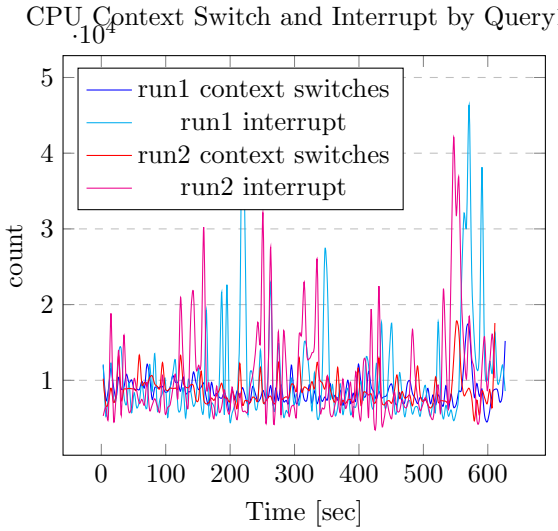






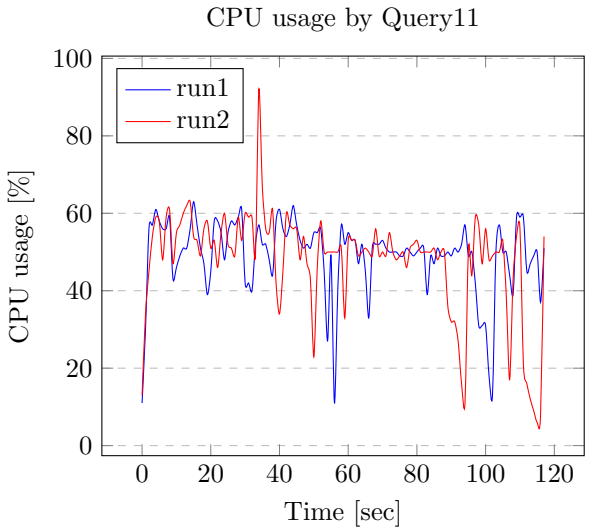


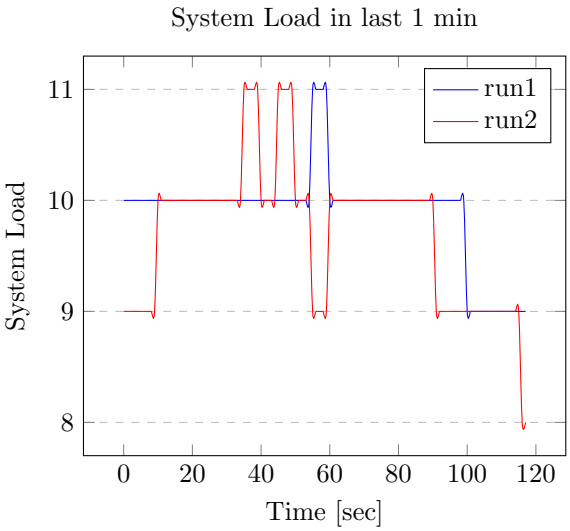


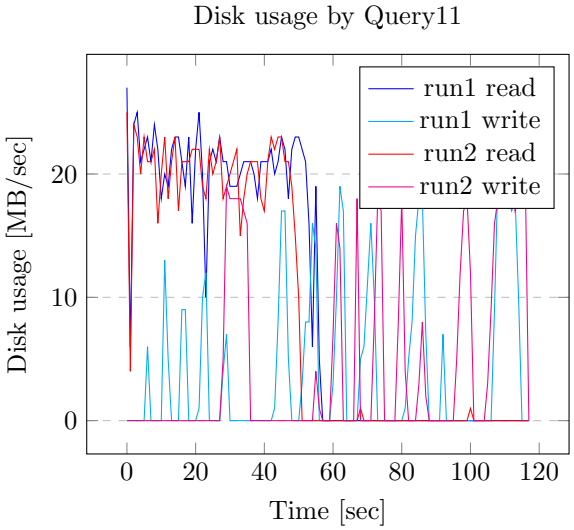


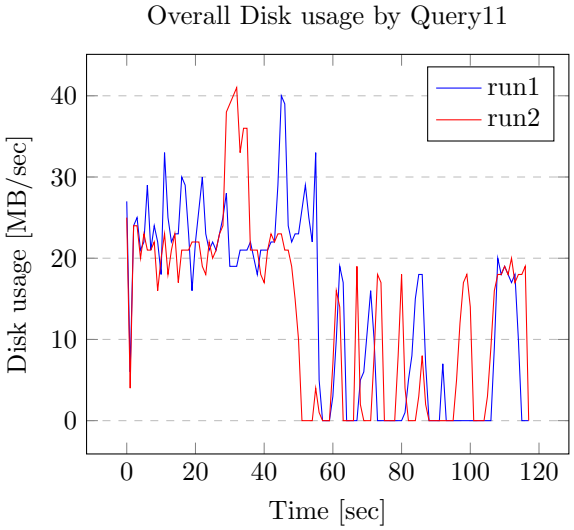
Load	Memory	Disk IO	Execution Time
10.36	35672.18 MB	14.29 MB/sec	118.00 sec

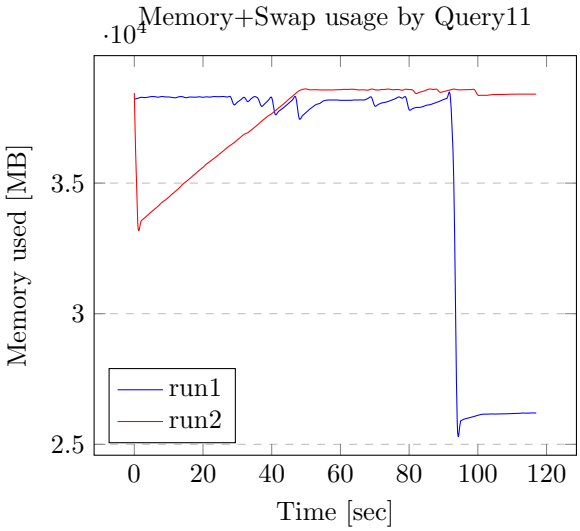
Table 75: Average Parametes over Runtime for Query11

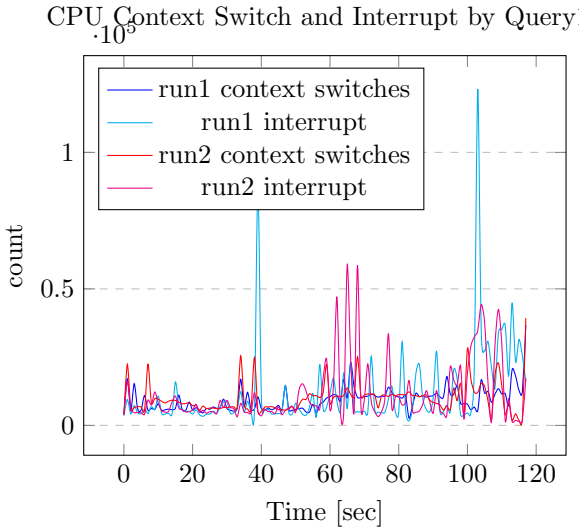






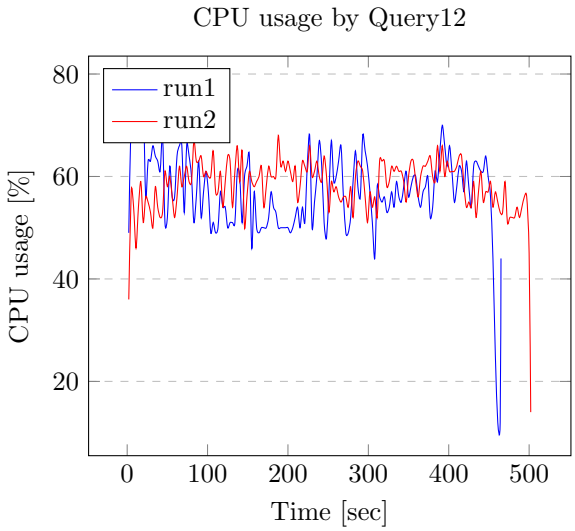


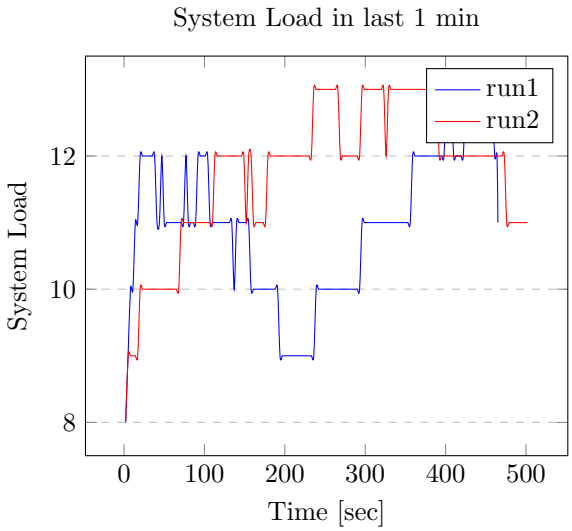


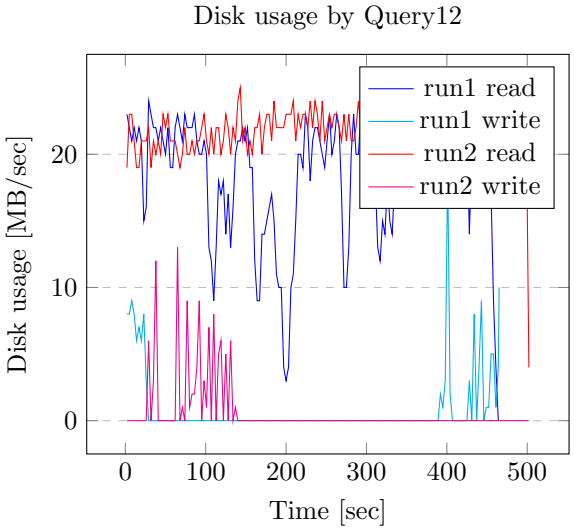


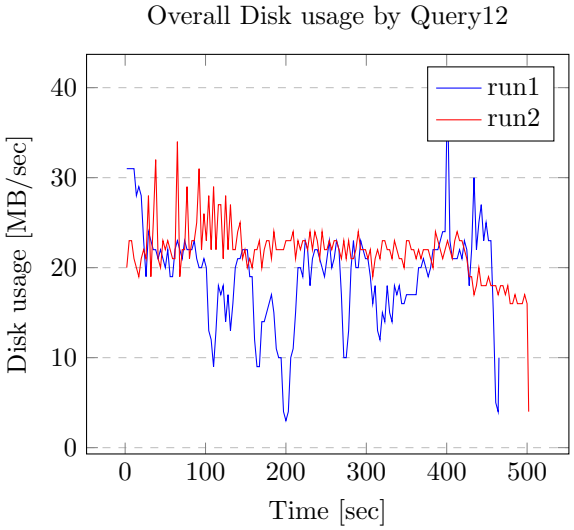
Load	Memory	Disk IO	Execution Time
11.46	34995.34 MB	19.67 MB/sec	484.50 sec

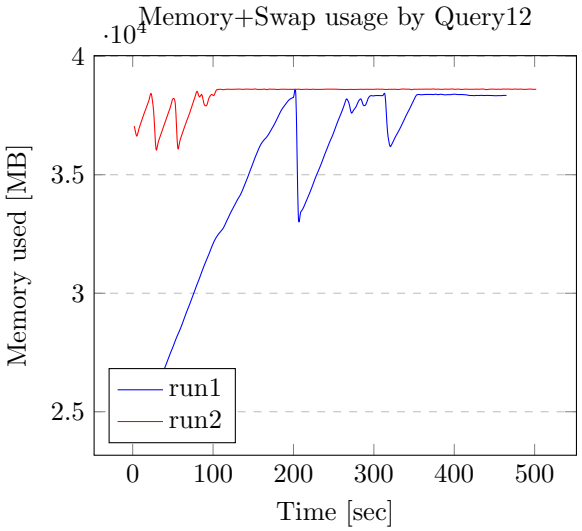
Table 76: Average Parametes over Runtime for Query12

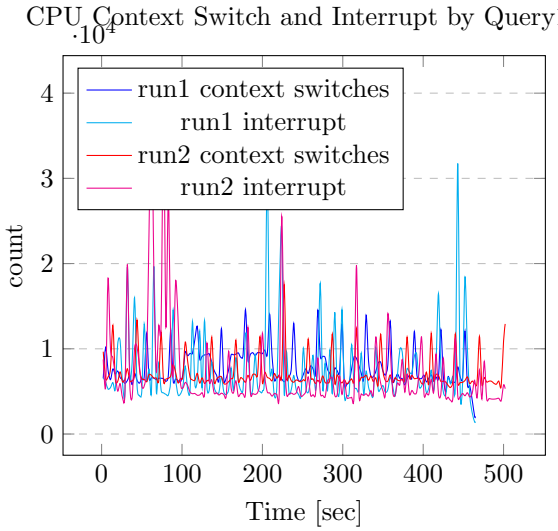






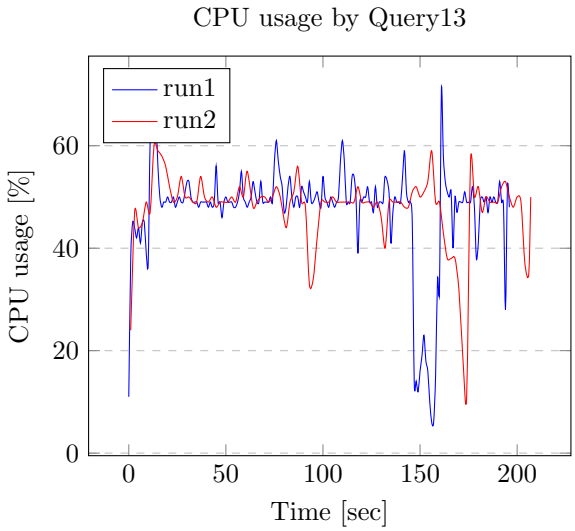


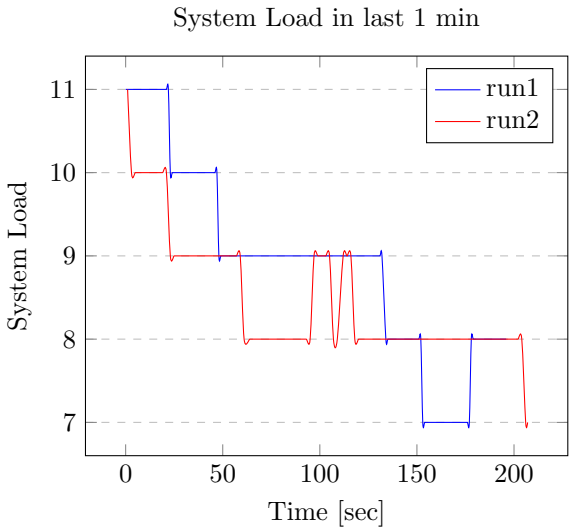


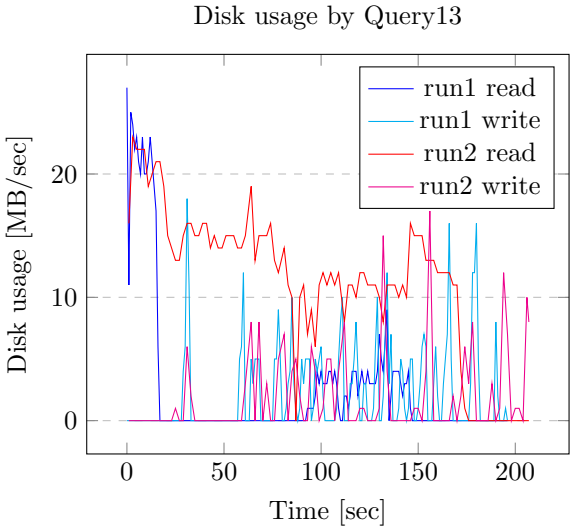


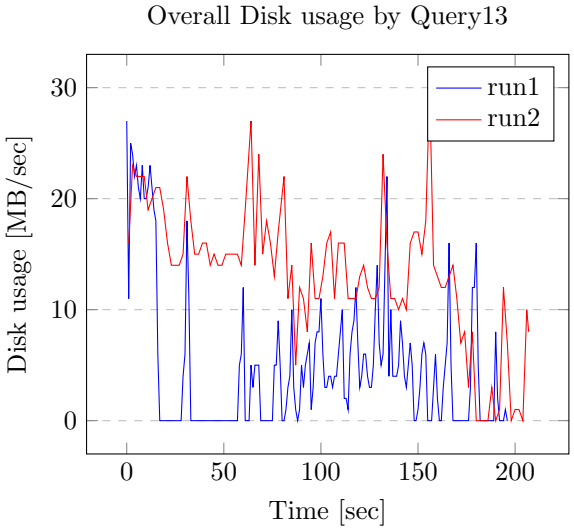
Load	Memory	Disk IO	Execution Time
9.49	37867.98 MB	5.13 MB/sec	200.50 sec

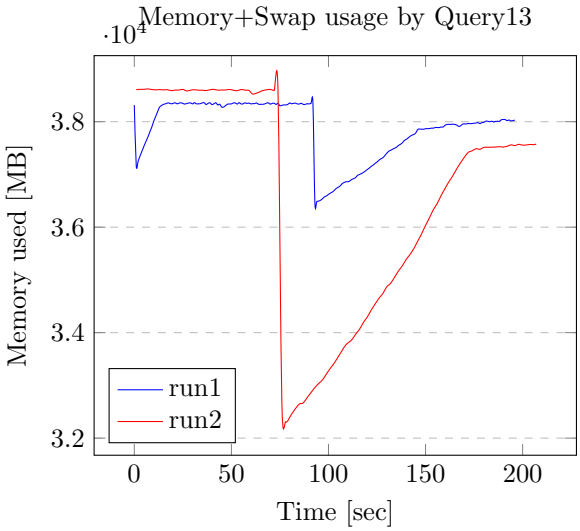
Table 77: Average Parametes over Runtime for Query13

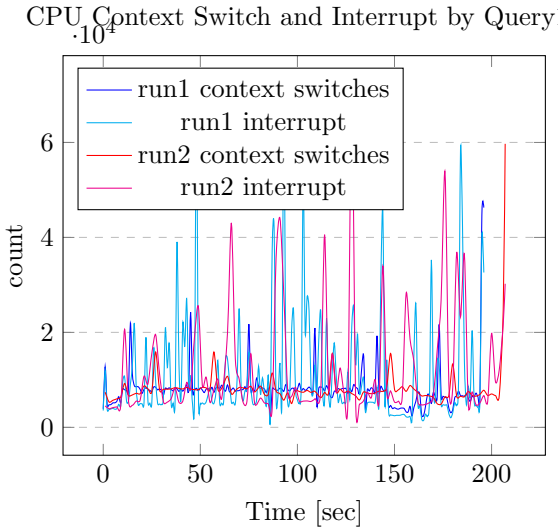






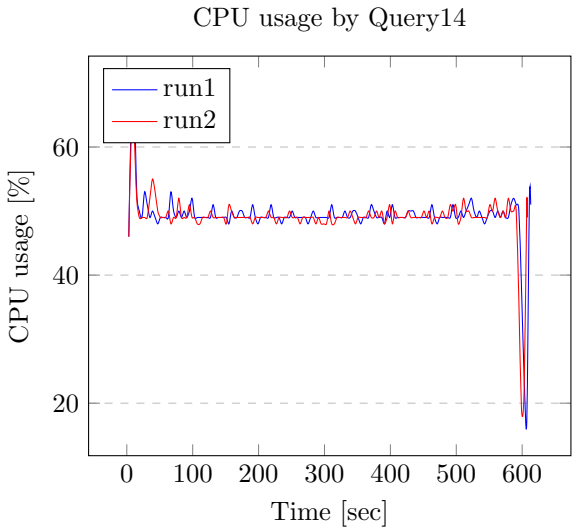


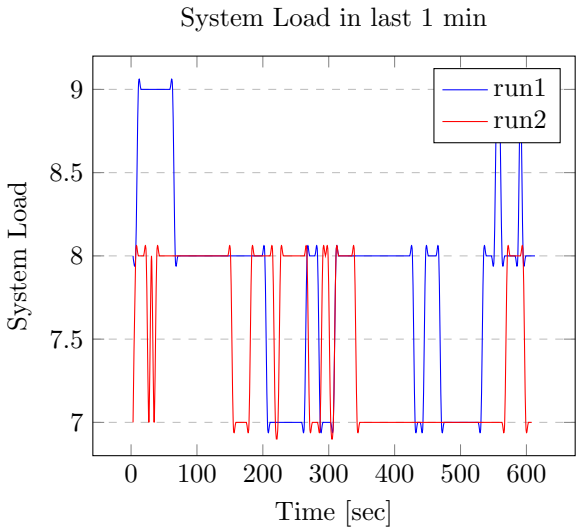


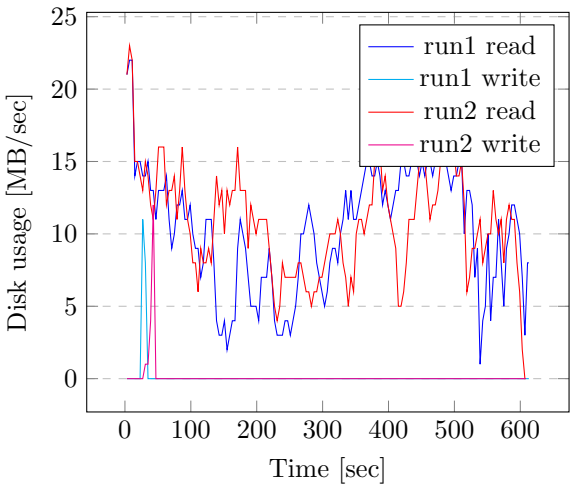


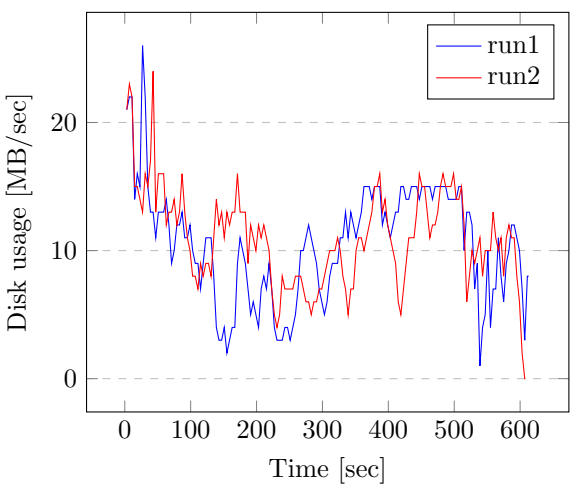
Load	Memory	Disk IO	Execution Time
8.36	34507.11 MB	11.06 MB/sec	611.50 sec

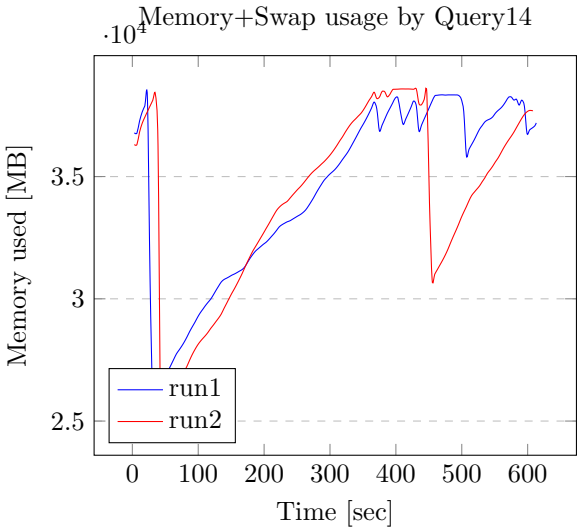
Table 78: Average Parametes over Runtime for Query14

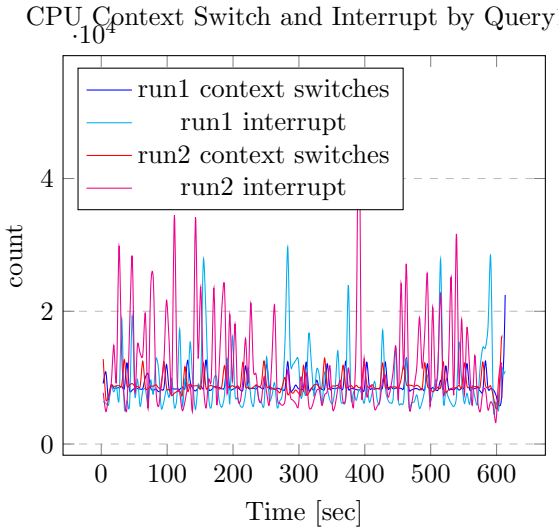






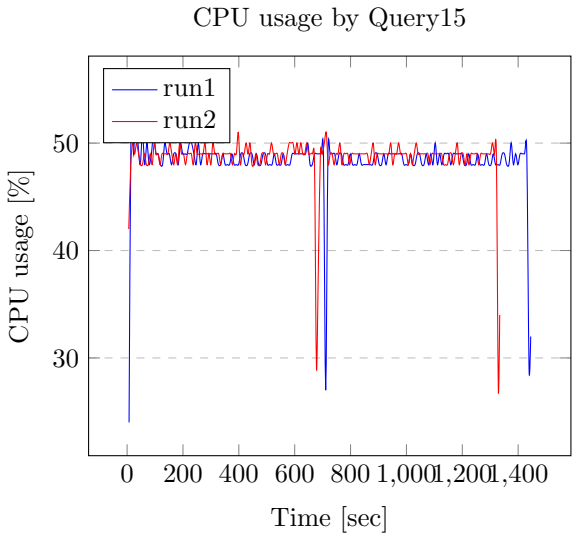


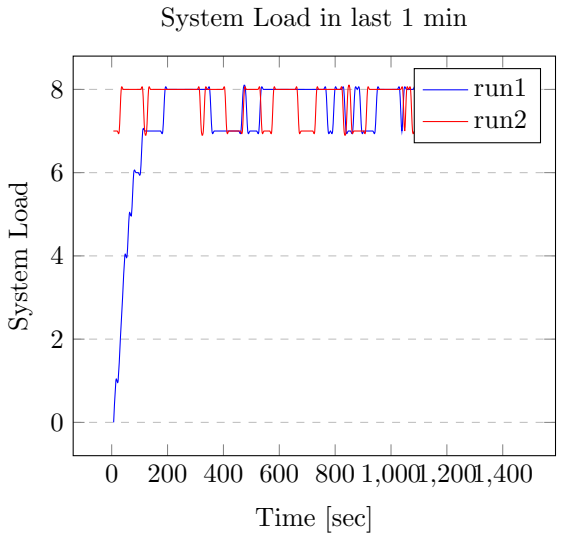


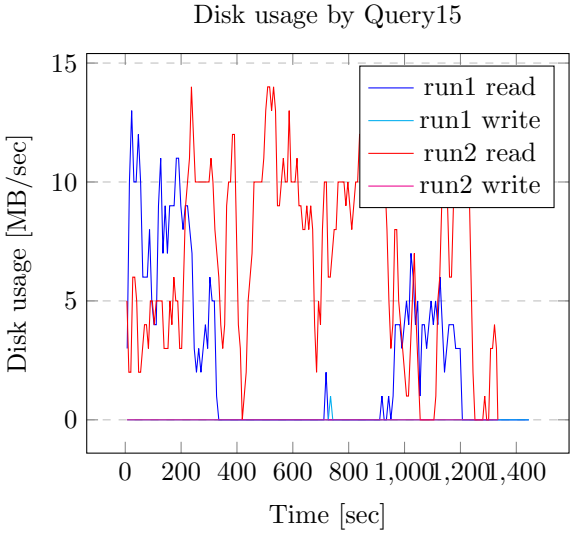


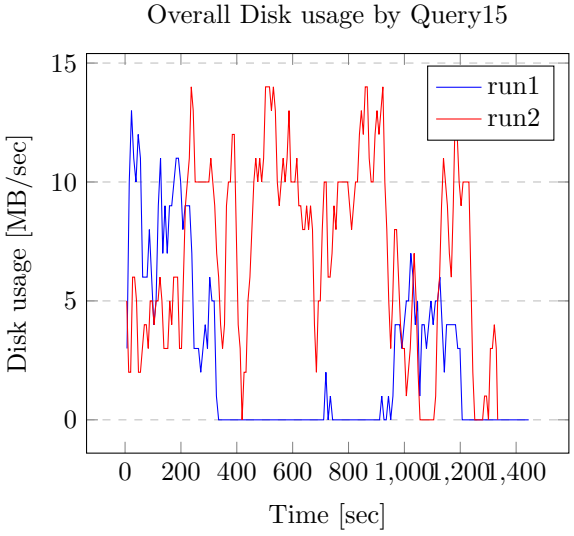
Load	Memory	Disk IO	Execution Time
7.81	38092.25 MB	2.63 MB/sec	1390.50 sec

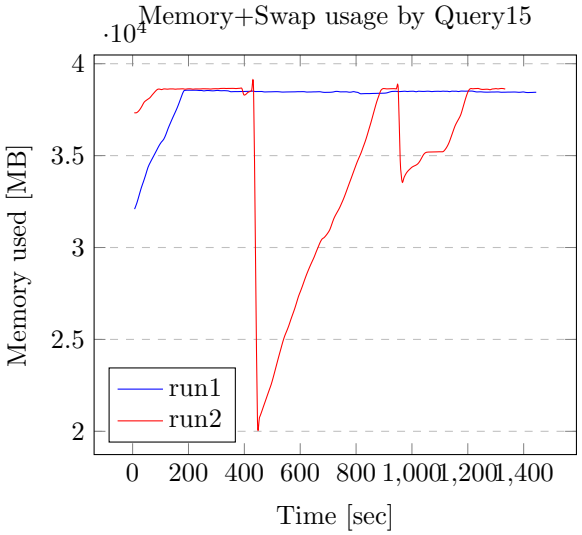
Table 79: Average Parametes over Runtime for Query15

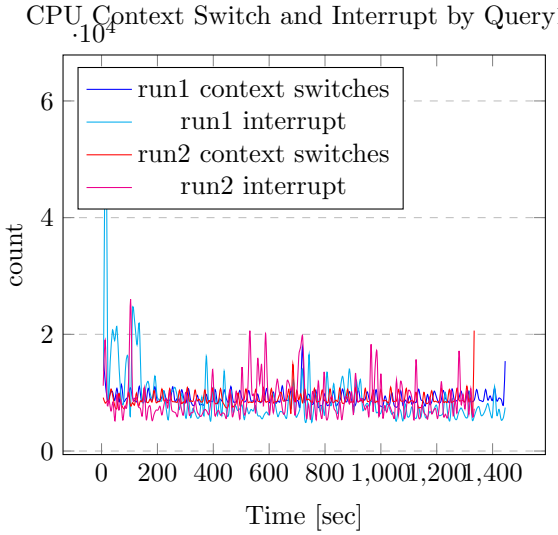






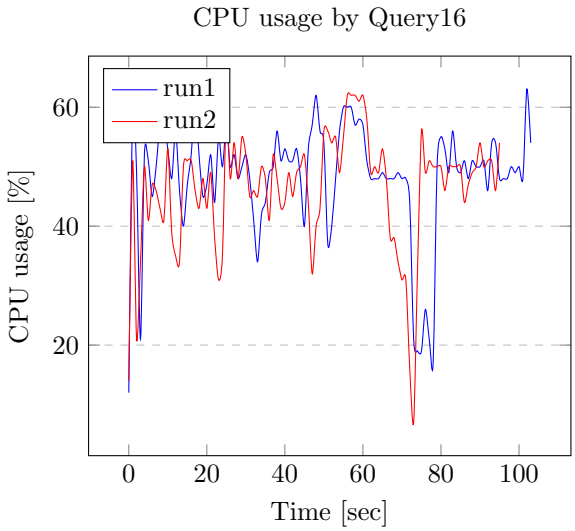


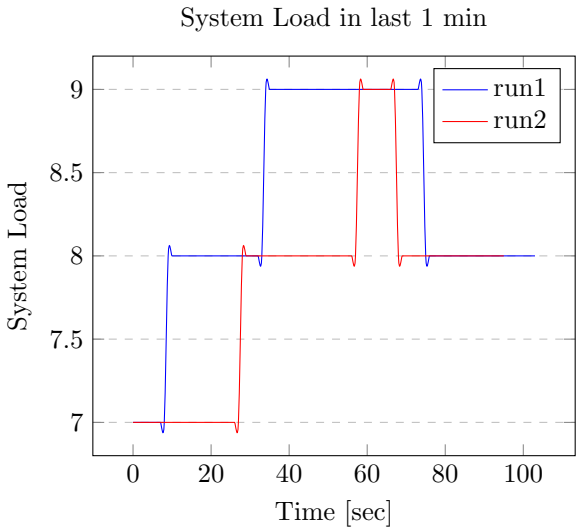


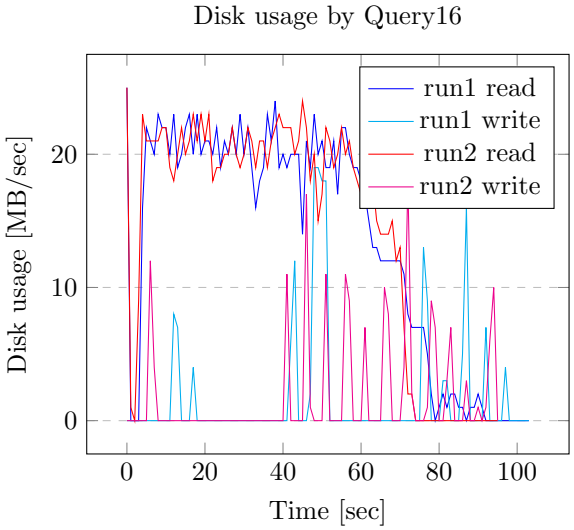


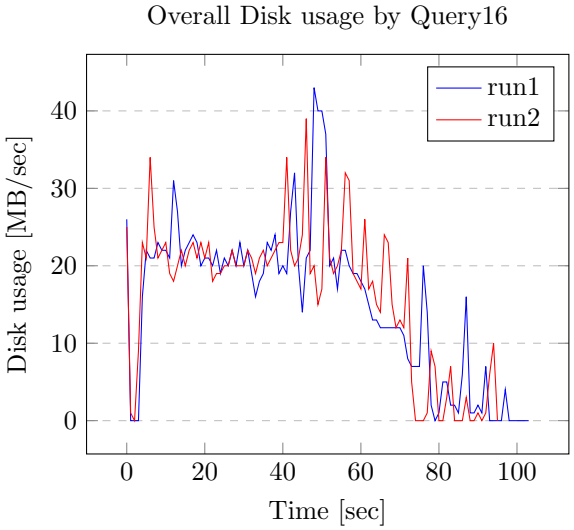
Load	Memory	Disk IO	Execution Time
8.94	38406.51 MB	15.50 MB/sec	100.00 sec

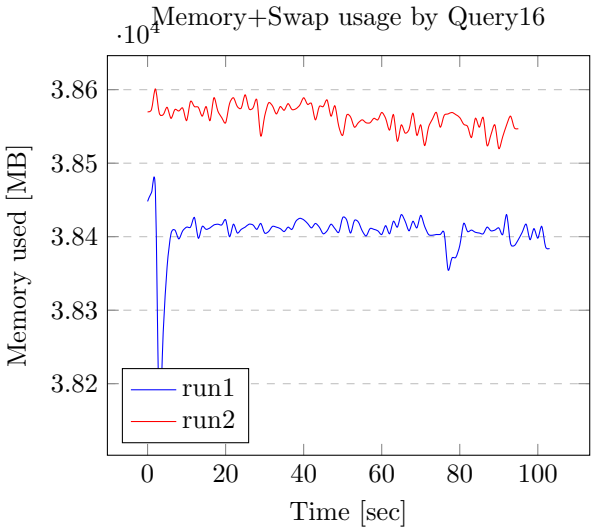
Table 80: Average Parametes over Runtime for Query16

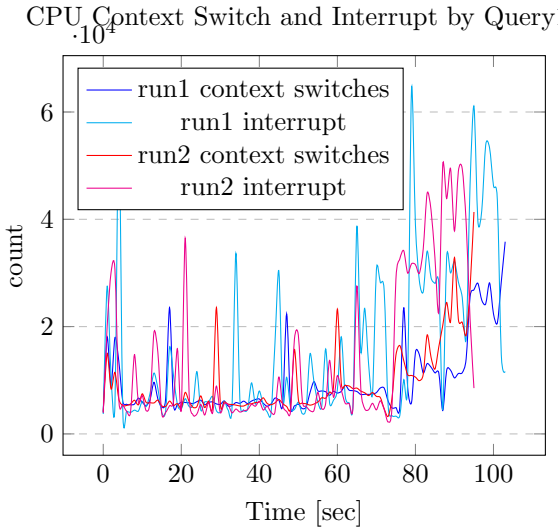






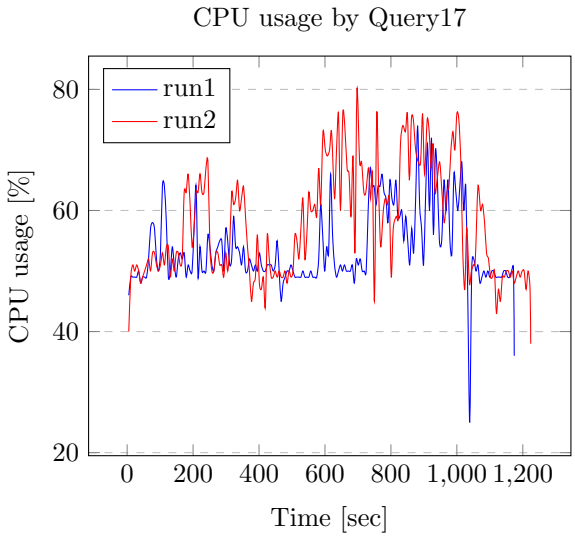


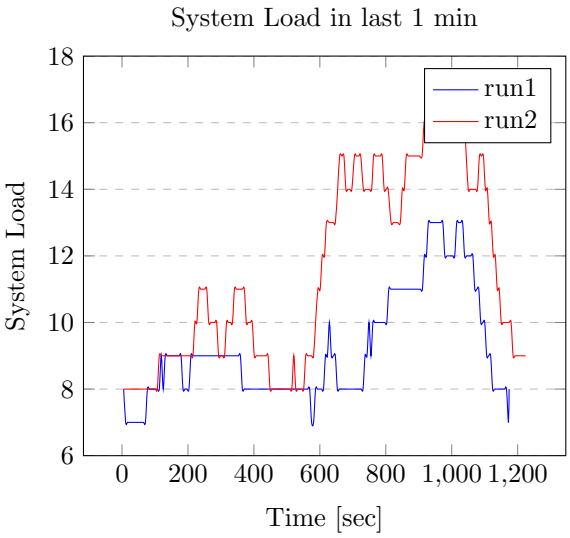


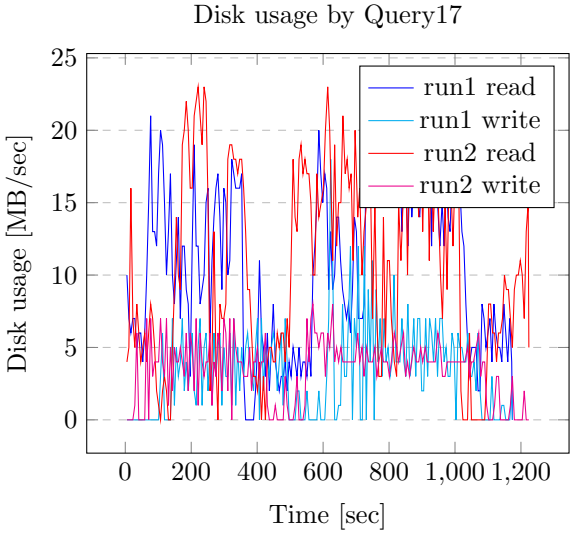


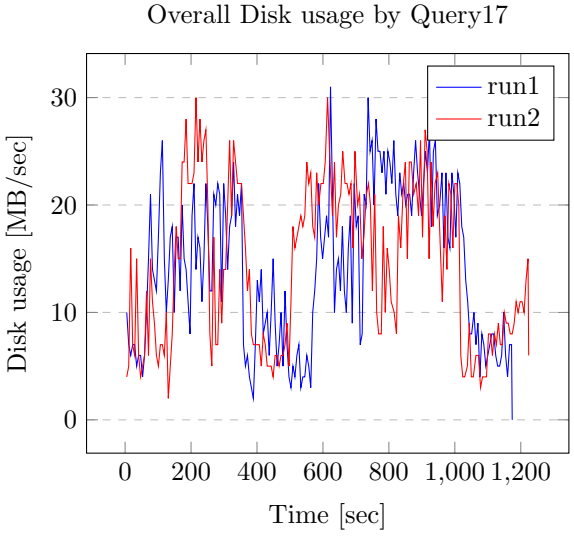
Load	Memory	Disk IO	Execution Time
9.71	33030.43 MB	14.94 MB/sec	1178.00 sec

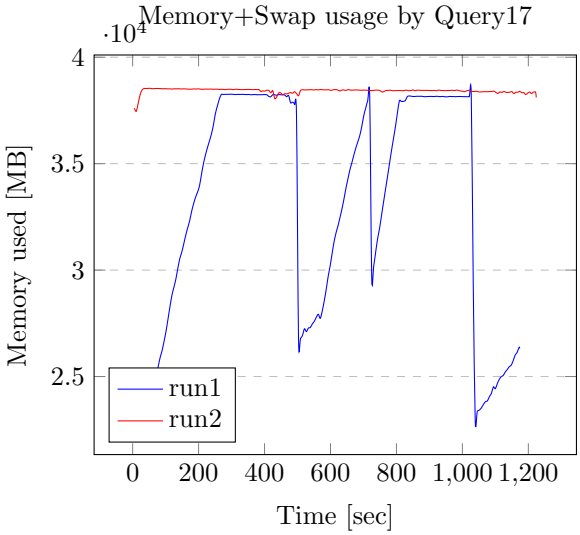
Table 81: Average Parametes over Runtime for Query17

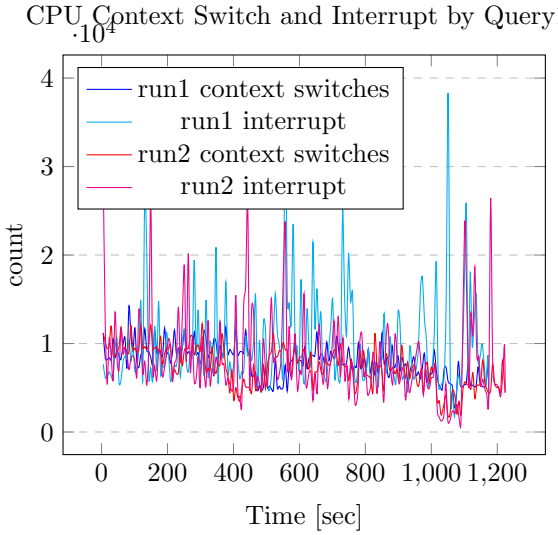






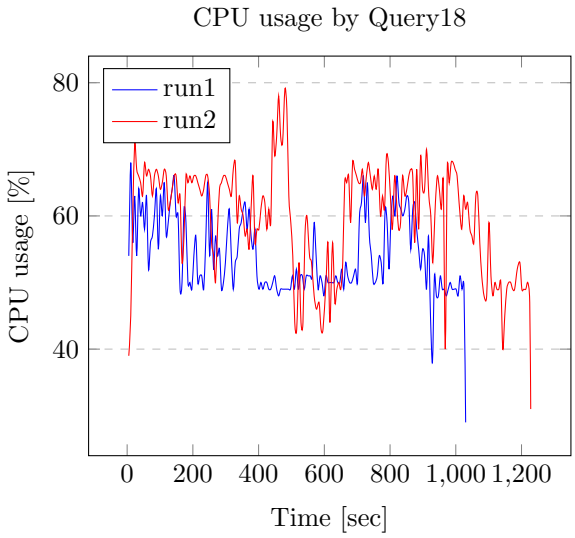


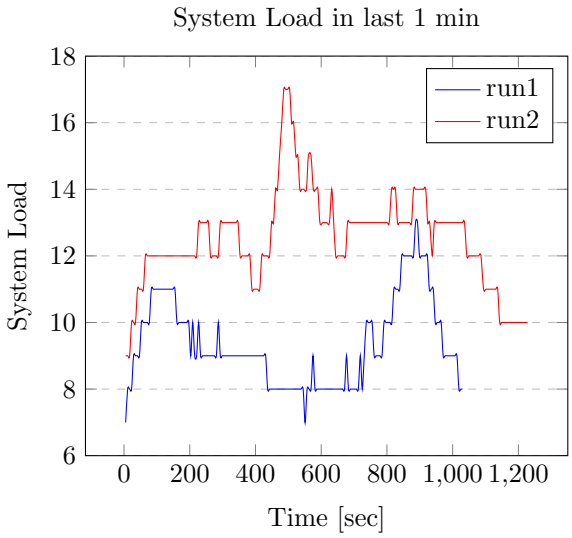


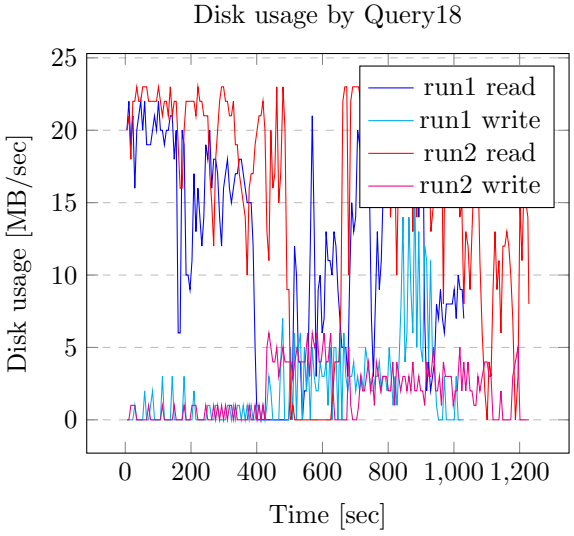


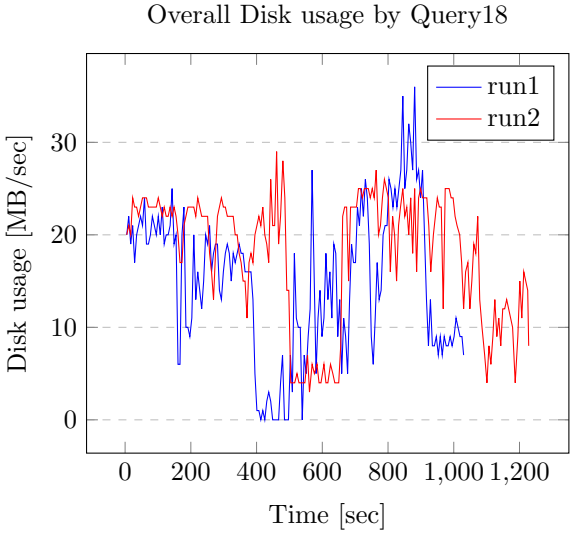
Load	Memory	Disk IO	Execution Time
9.86	33576.10 MB	15.39 MB/sec	1114.00 sec

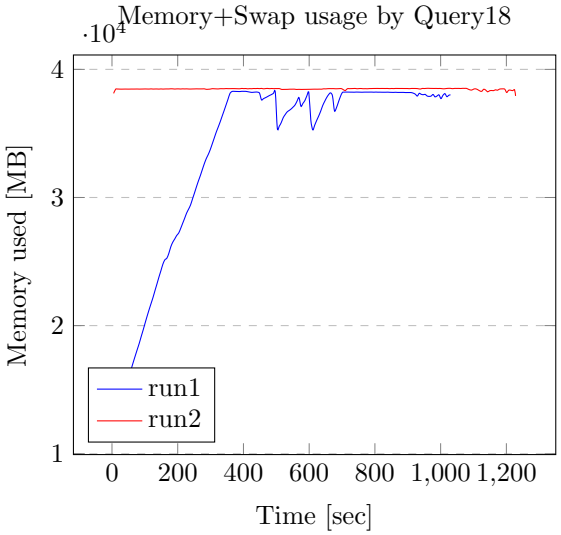
Table 82: Average Parametes over Runtime for Query18

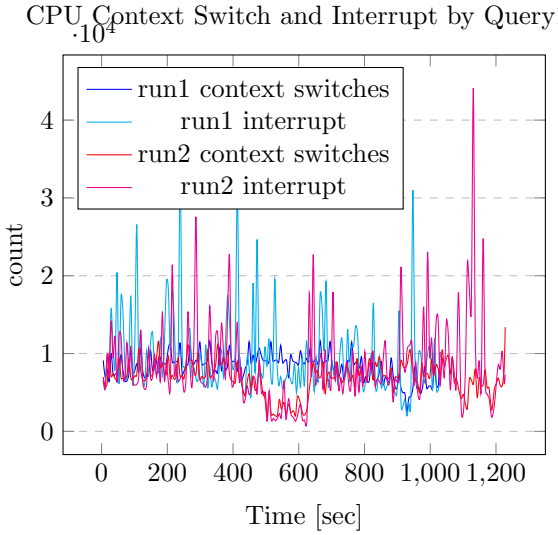






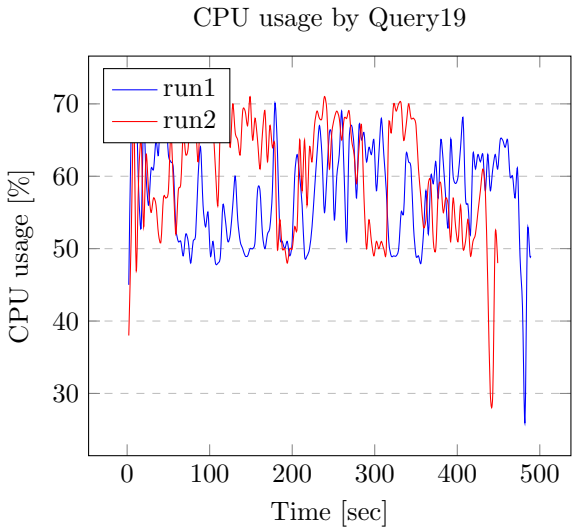


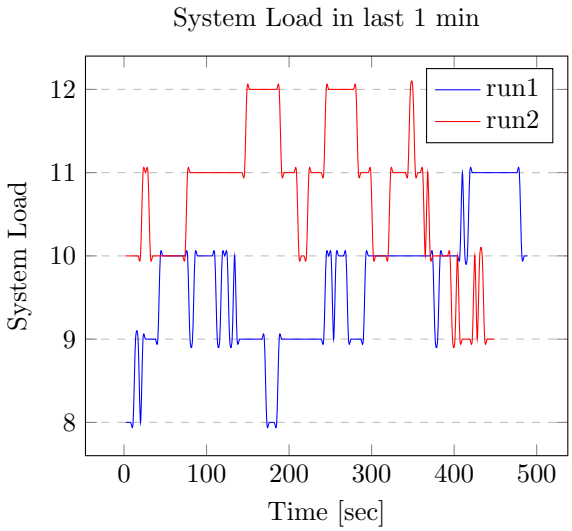


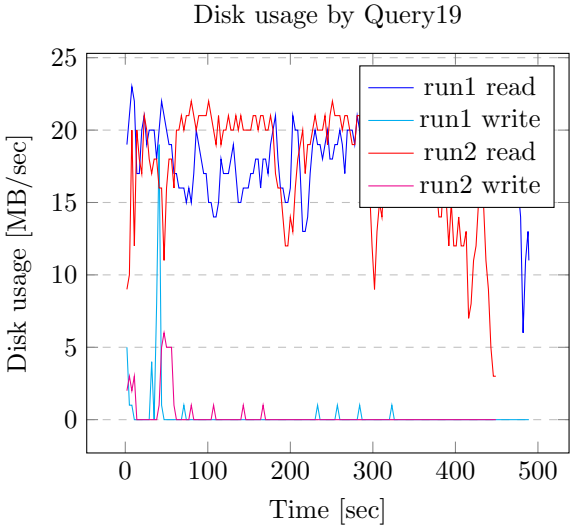


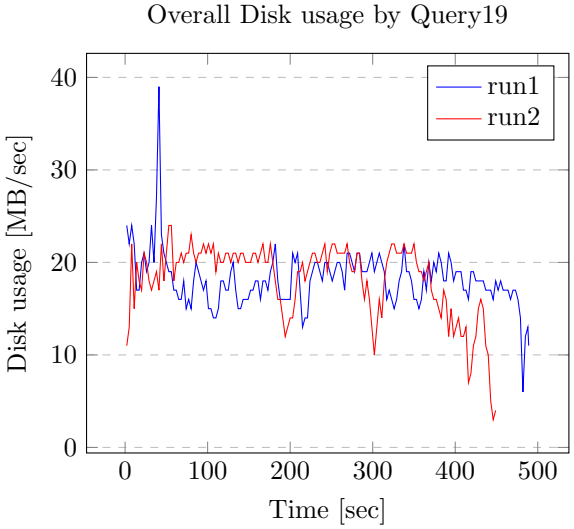
Load	Memory	Disk IO	Execution Time
10.13	36706.26 MB	18.64 MB/sec	470.00 sec

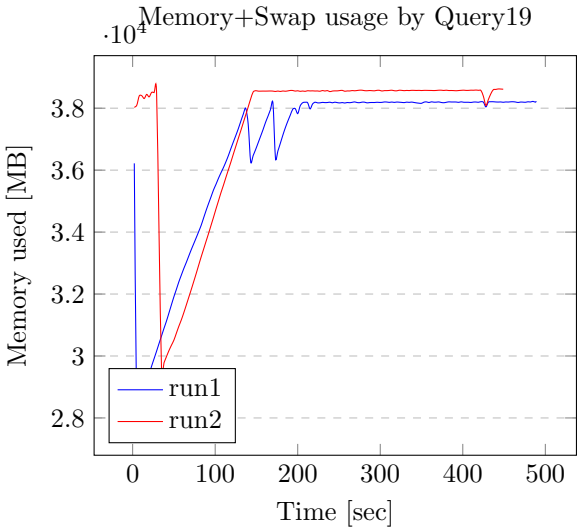
Table 83: Average Parametes over Runtime for Query19

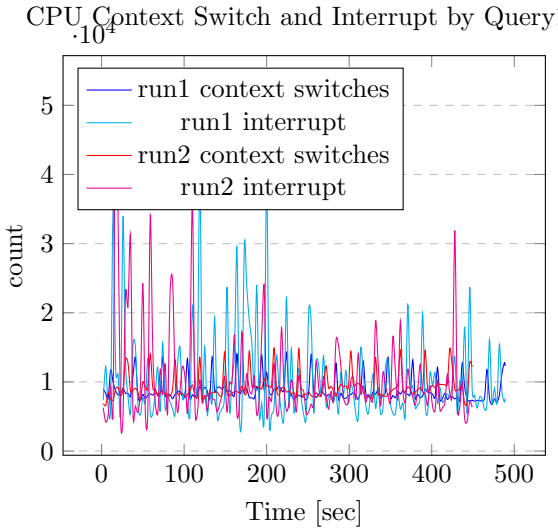






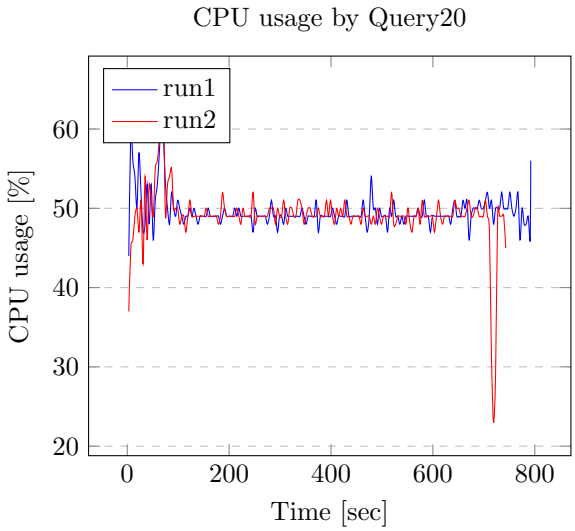


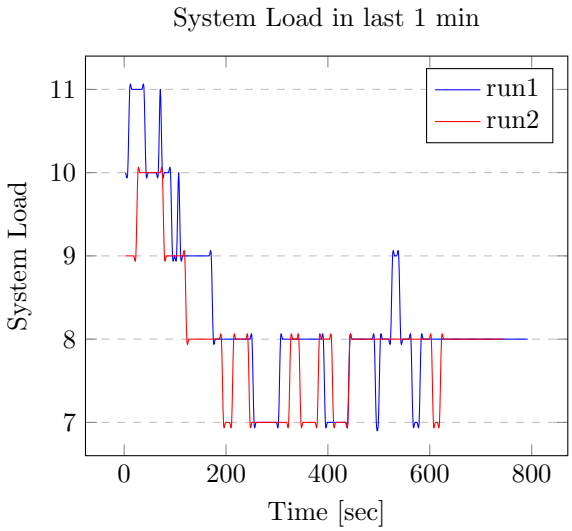


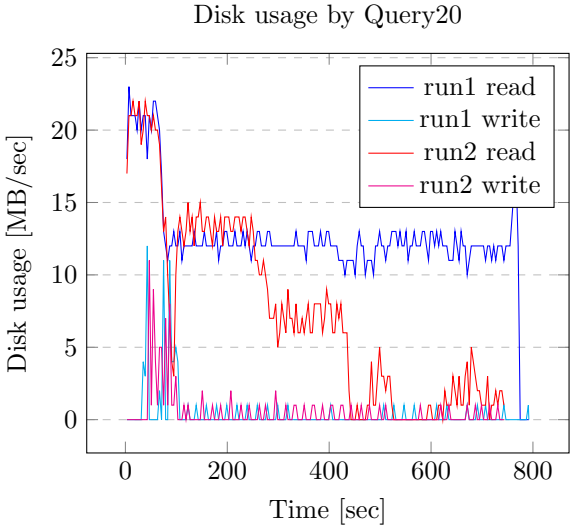


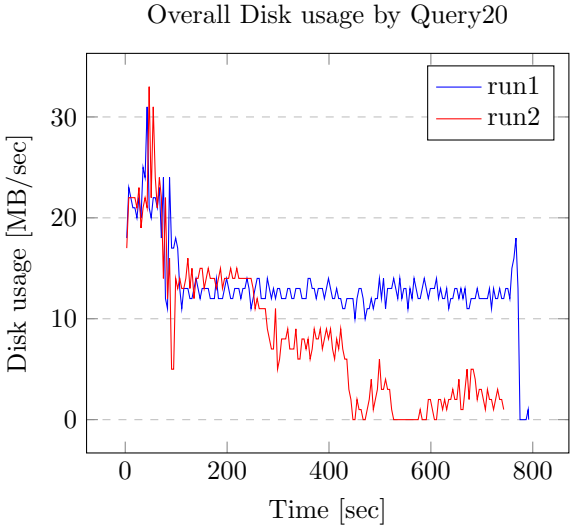
Load	Memory	Disk IO	Execution Time
8.74	38214.14 MB	13.77 MB/sec	768.50 sec

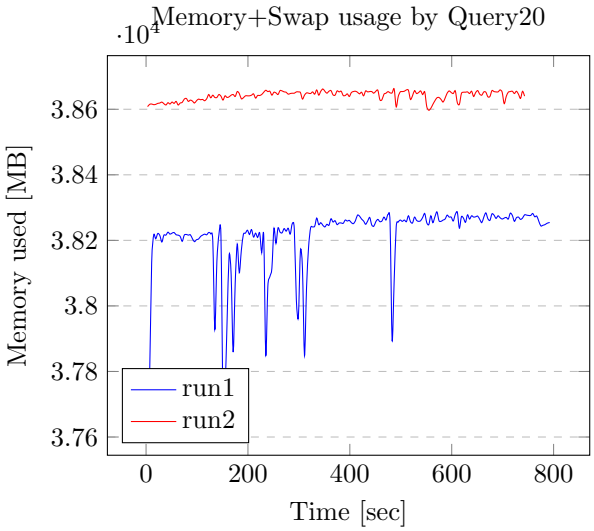
Table 84: Average Parametes over Runtime for Query20

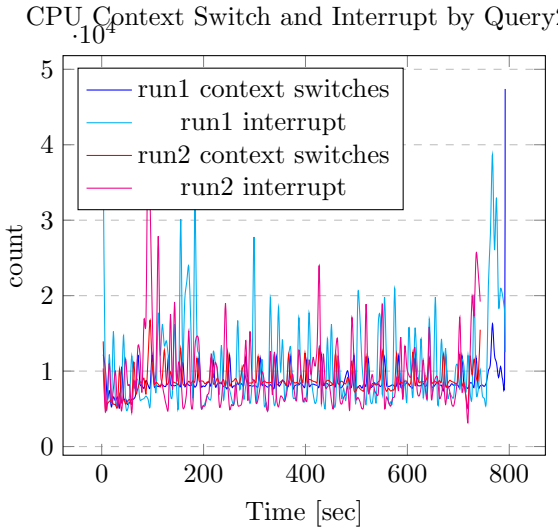






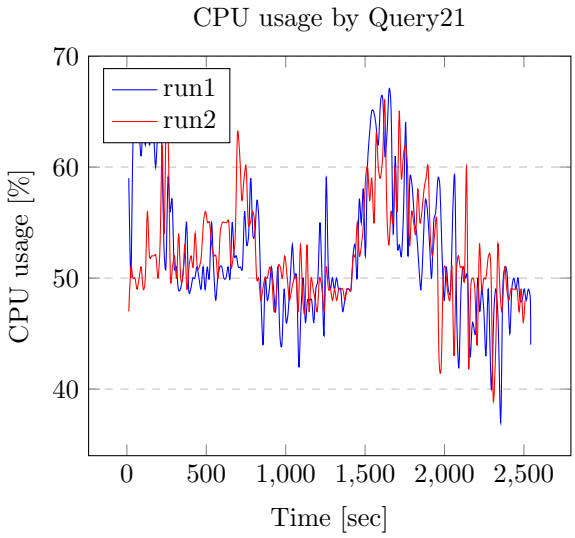


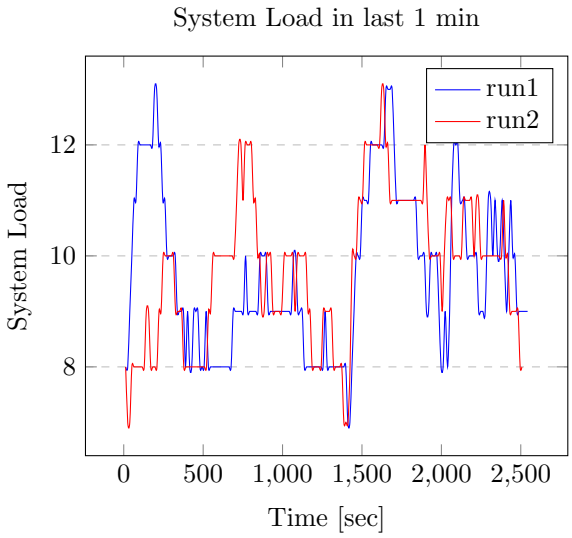


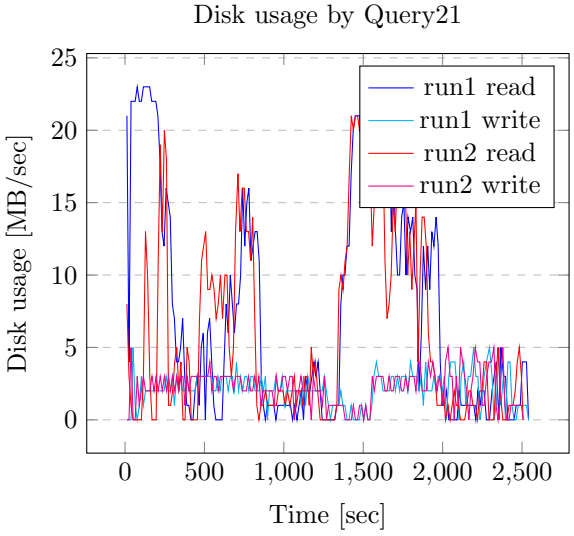


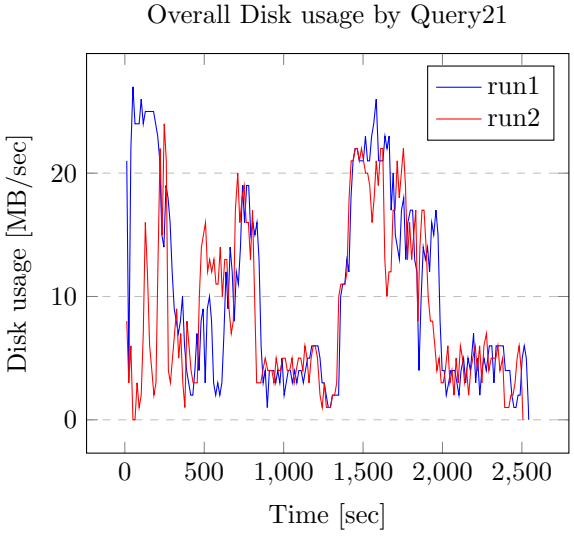
Load	Memory	Disk IO	Execution Time
10.26	38188.50 MB	10.81 MB/sec	2463.50 sec

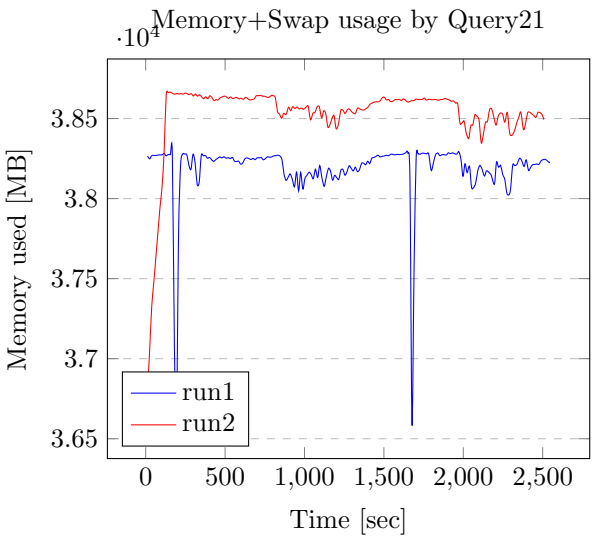
Table 85: Average Parametes over Runtime for Query21

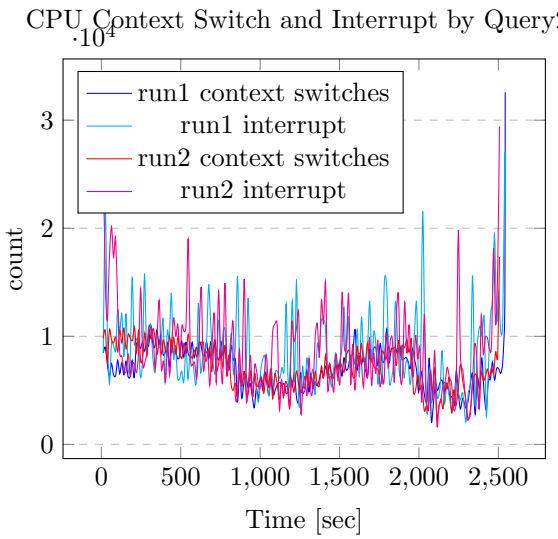






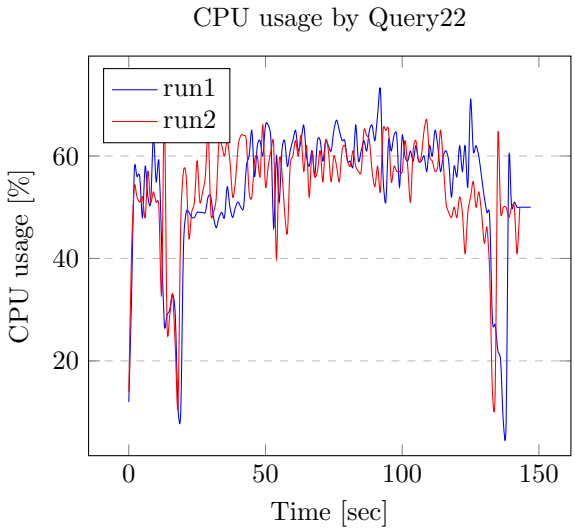


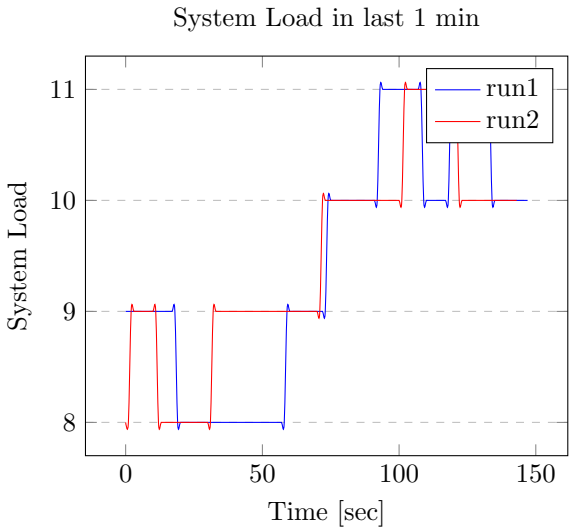


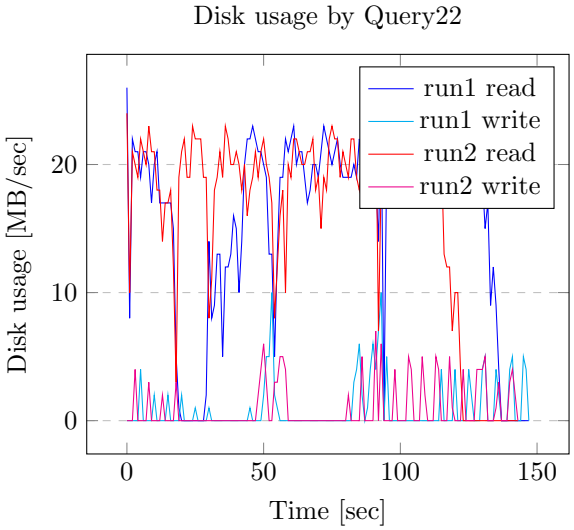


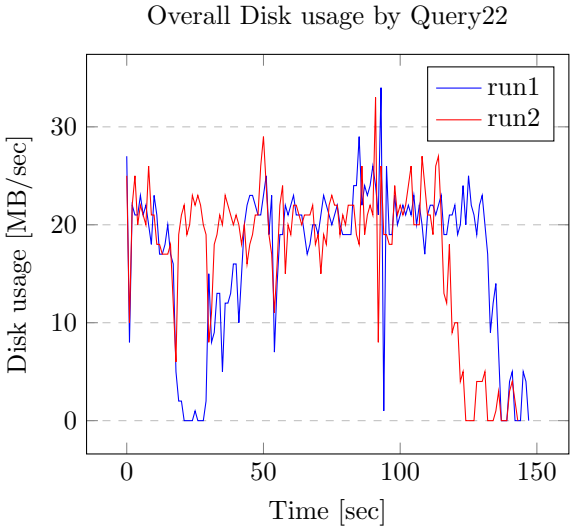
Load	Memory	Disk IO	Execution Time
9.97	38164.89 MB	17.12 MB/sec	146.00 sec

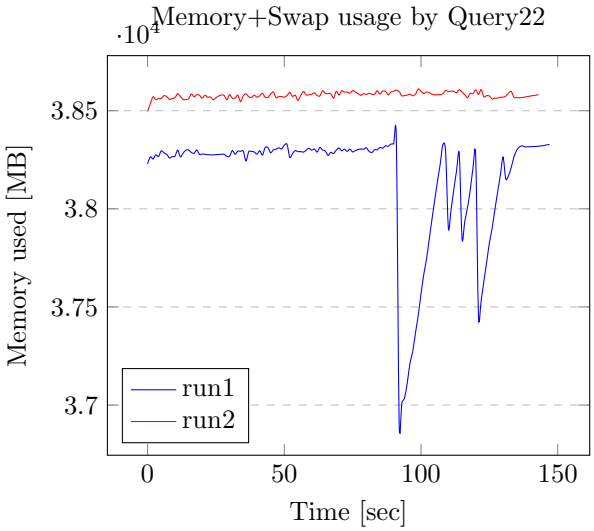
Table 86: Average Parametes over Runtime for Query22

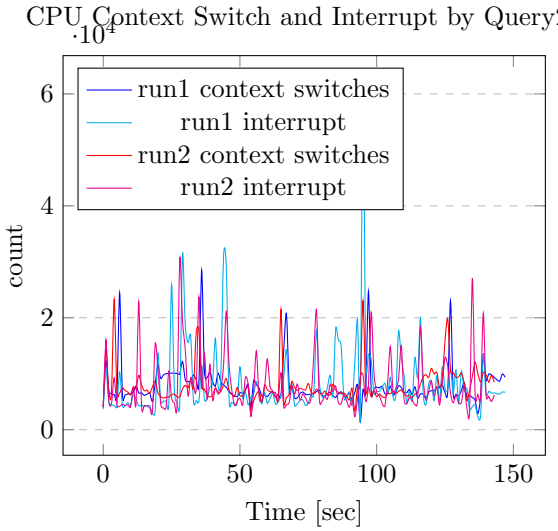








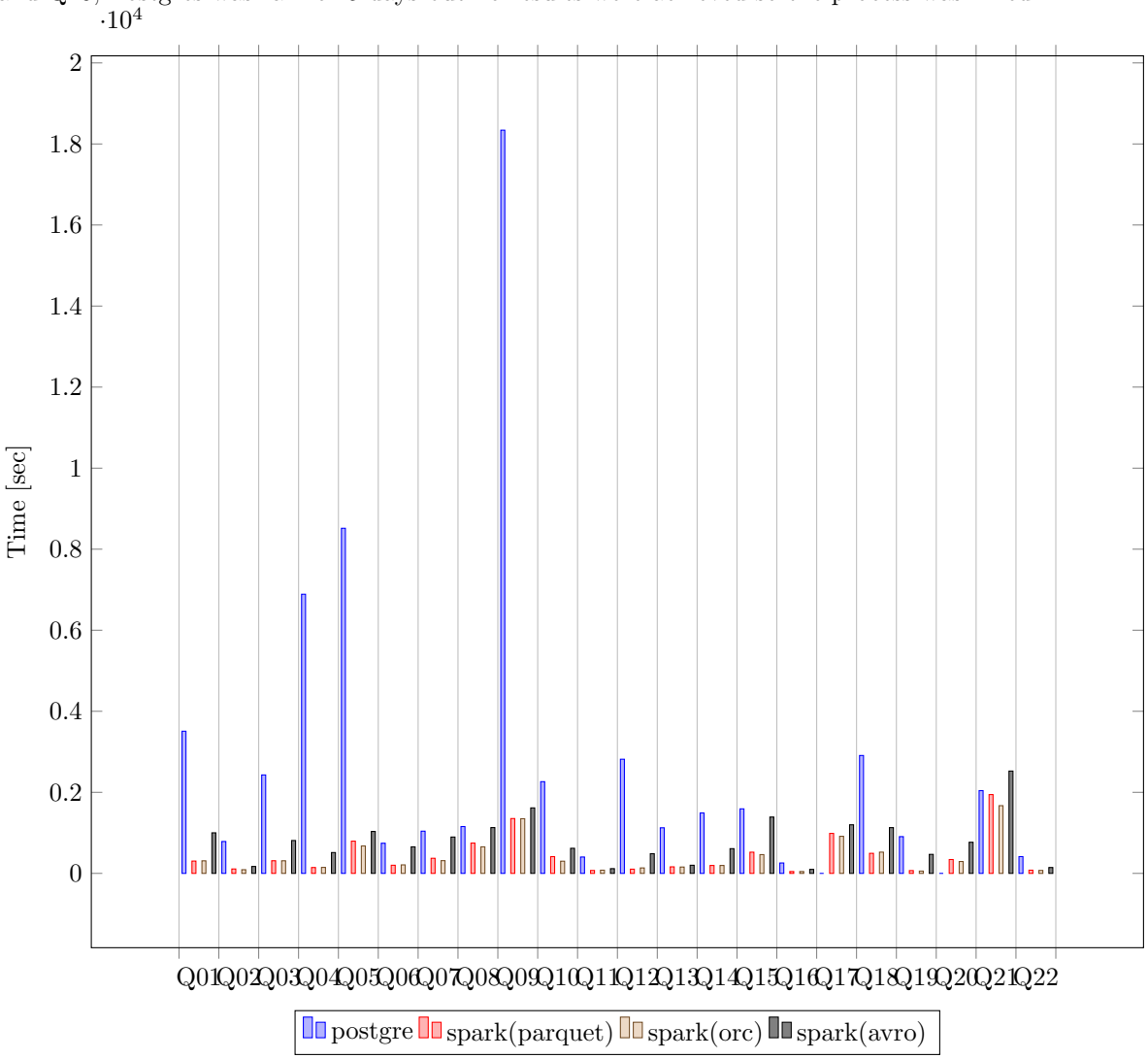




6 Compare DMBSs

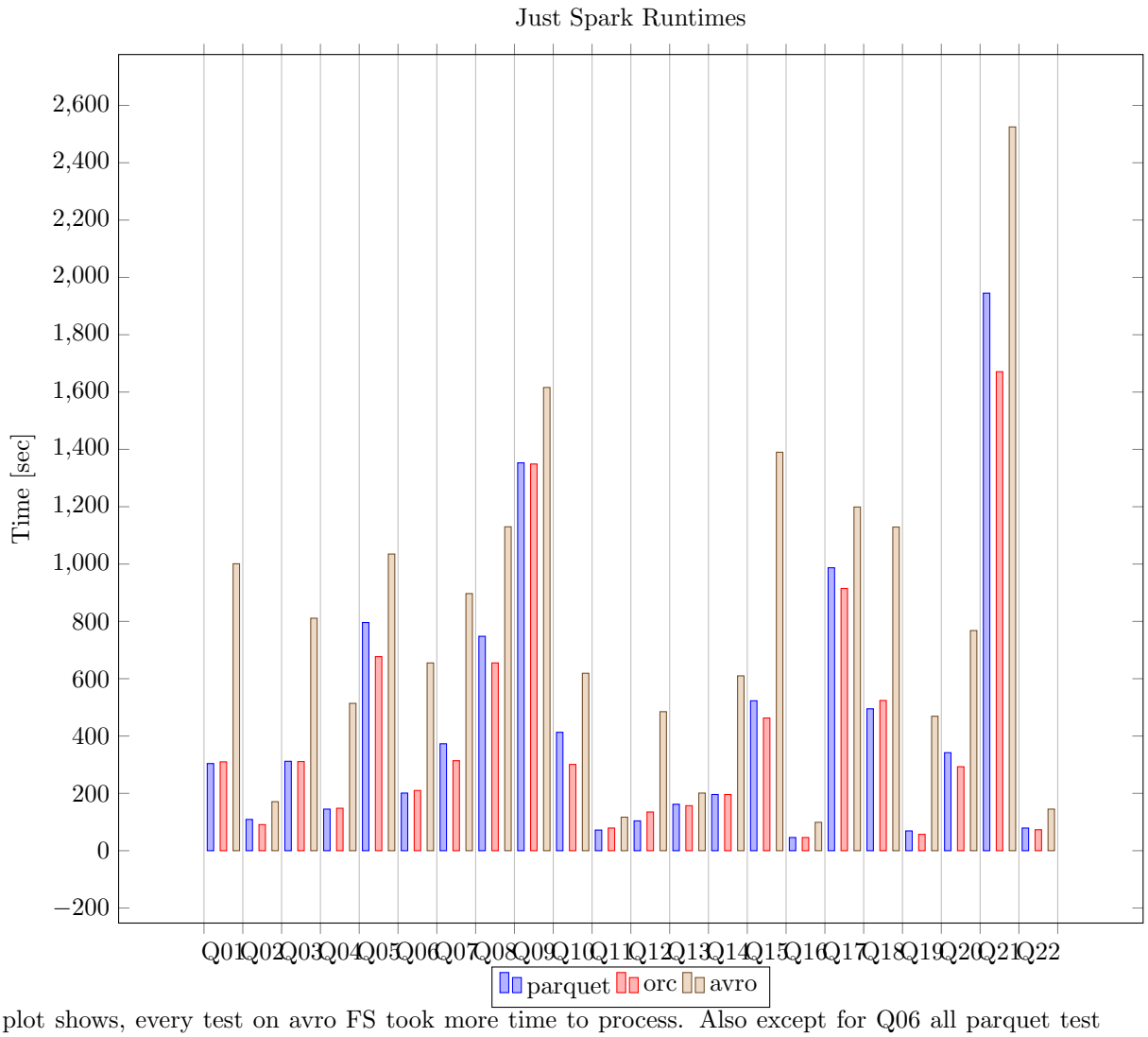
6.1 Runtime

Runtimes which are reported here in second are average of total execution time for first and second run. Almost in all queries Postgres took much more time to generating results (except fot query21). For Q17 and Q20, Postgres was ran for 5 days but no results were achieved so the process was killed.



Query num	postgre	spark(parquet)	spark(orc)	spark(avro)
Q01	3508	304	310	1001
Q02	787	109	91	171
Q03	2429	312	311	811
Q04	6888	145	148	514
Q05	8516	796	677	1035
Q06	744	201	210	655
Q07	1042	373	314	897
Q08	1156	748	655	1130
Q09	18340	1353	1349	1616
Q10	2263	413	301	619
Q11	404	72	79	117
Q12	2817	104	135	485
Q13	1125	162	157	201
Q14	1491	196	196	610
Q15	1592	523	463	1390
Q16	257	46	46	99
Q17	more than 546734	987	915	1199
Q18	2909	495	524	1129
Q19	907	69	57	469
Q20	more than 522760	342	293	768
Q21	2042	1945	1671	2525
Q22	414	79	73	145

Table 87: Runtimes in seconds



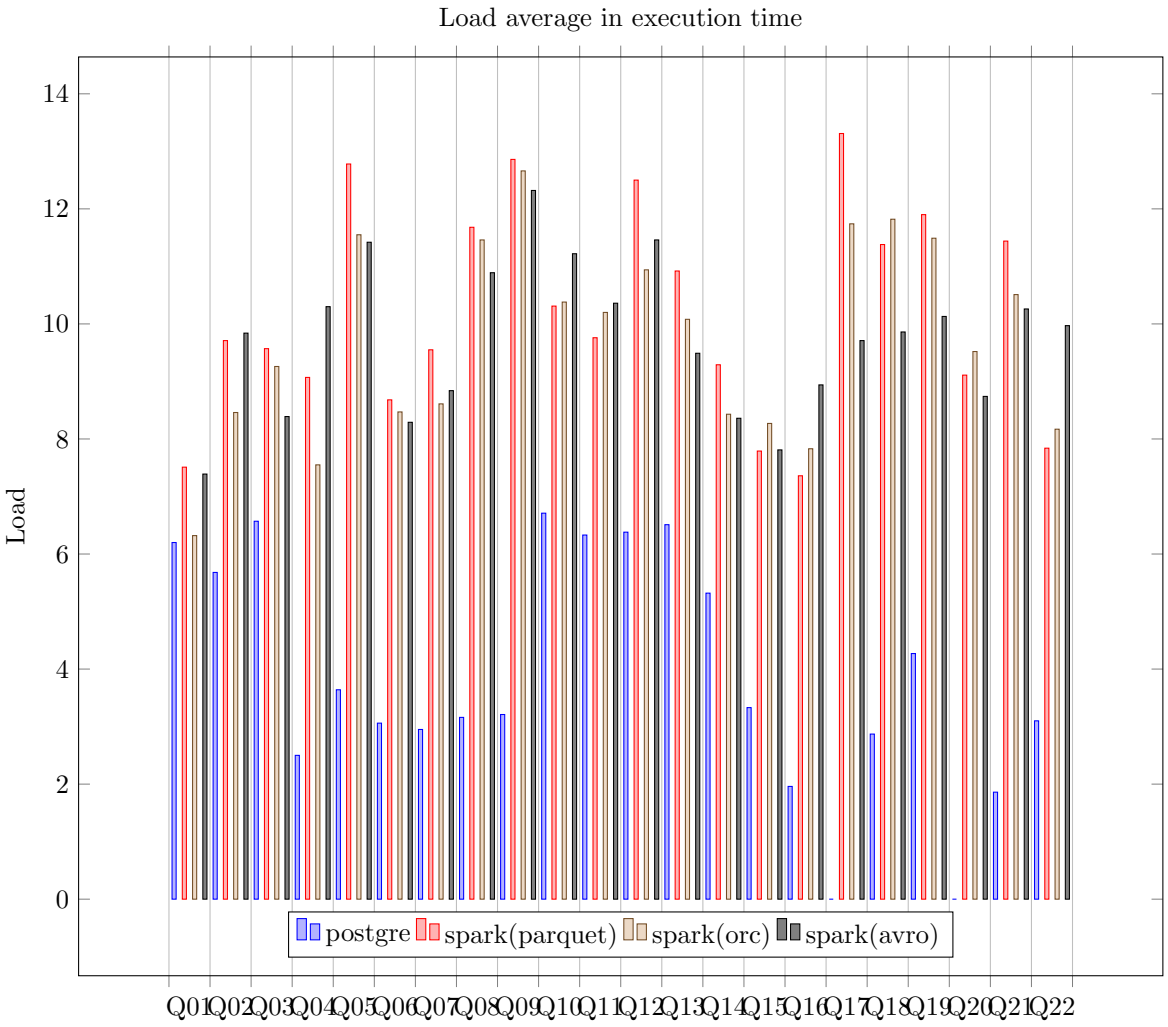
As plot shows, every test on avro FS took more time to process. Also except for Q06 all parquet test rans longer than orc.

Query num	postgre	spark(avro)	spark(orc)	spark(parquet)
Q01	6.20	7.39	6.32	7.51
Q02	5.68	9.84	8.46	9.71
Q03	6.57	8.39	9.26	9.57
Q04	2.50	10.30	7.55	9.07
Q05	3.64	11.42	11.55	12.78
Q06	3.06	8.29	8.47	8.68
Q07	2.95	8.84	8.61	9.55
Q08	3.16	10.89	11.46	11.68
Q09	3.21	12.32	12.66	12.86
Q10	6.71	11.22	10.38	10.31
Q11	6.33	10.36	10.20	9.76
Q12	6.38	11.46	10.94	12.50
Q13	6.51	9.49	10.08	10.92
Q14	5.32	8.36	8.43	9.29
Q15	3.33	7.81	8.27	7.79
Q16	1.96	8.94	7.83	7.36
Q17	-	9.71	11.74	13.31
Q18	2.87	9.86	11.82	11.38
Q19	4.27	10.13	11.49	11.90
Q20	-	8.74	9.52	9.11
Q21	1.86	10.26	10.51	11.44
Q22	3.10	9.97	8.17	7.84

Table 88: Runtimes in seconds

6.2 Load

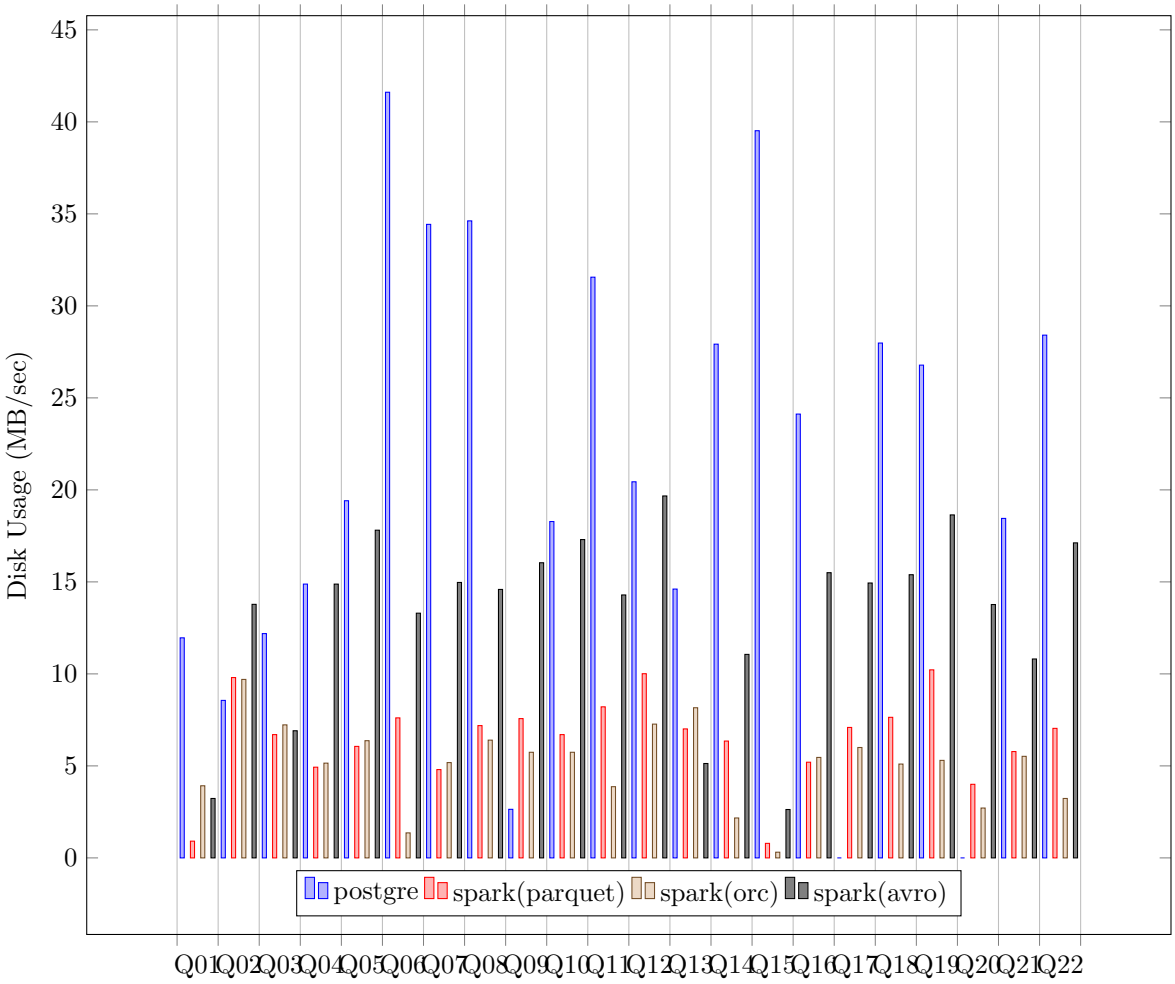
Load average for spark with parquet is higher than others and postgres has minimum load average.(maybe because it took longer than other tests). comparing orc tests and Avro tests doesnt get us concret result. Their load average are close together and sometime avro is higher and sometime vice versa.



6.3 Average Disk Usage

Unlike other parameters overall disk usage of postgres is higher the other in spite of long runtime. This is because postgres tries to persist everything on disk and correspond to join implementation in postgres DBMS (except the Q09, because Q09 takes too much time). Between spark tests avro has higher disk usage in spite of long runtime. According to queries disk usage plots, Spark reads file in format of avro more time than the other formats. Overall disk usage of parquet is slightly higher than orc. For orc tests, it seemed too much writing on disk is bottleneck. Unlike parquet and avro , it uses disk Almost just for reading, even after free memory reading from disk continues to load needed data.

Average Disk read and write

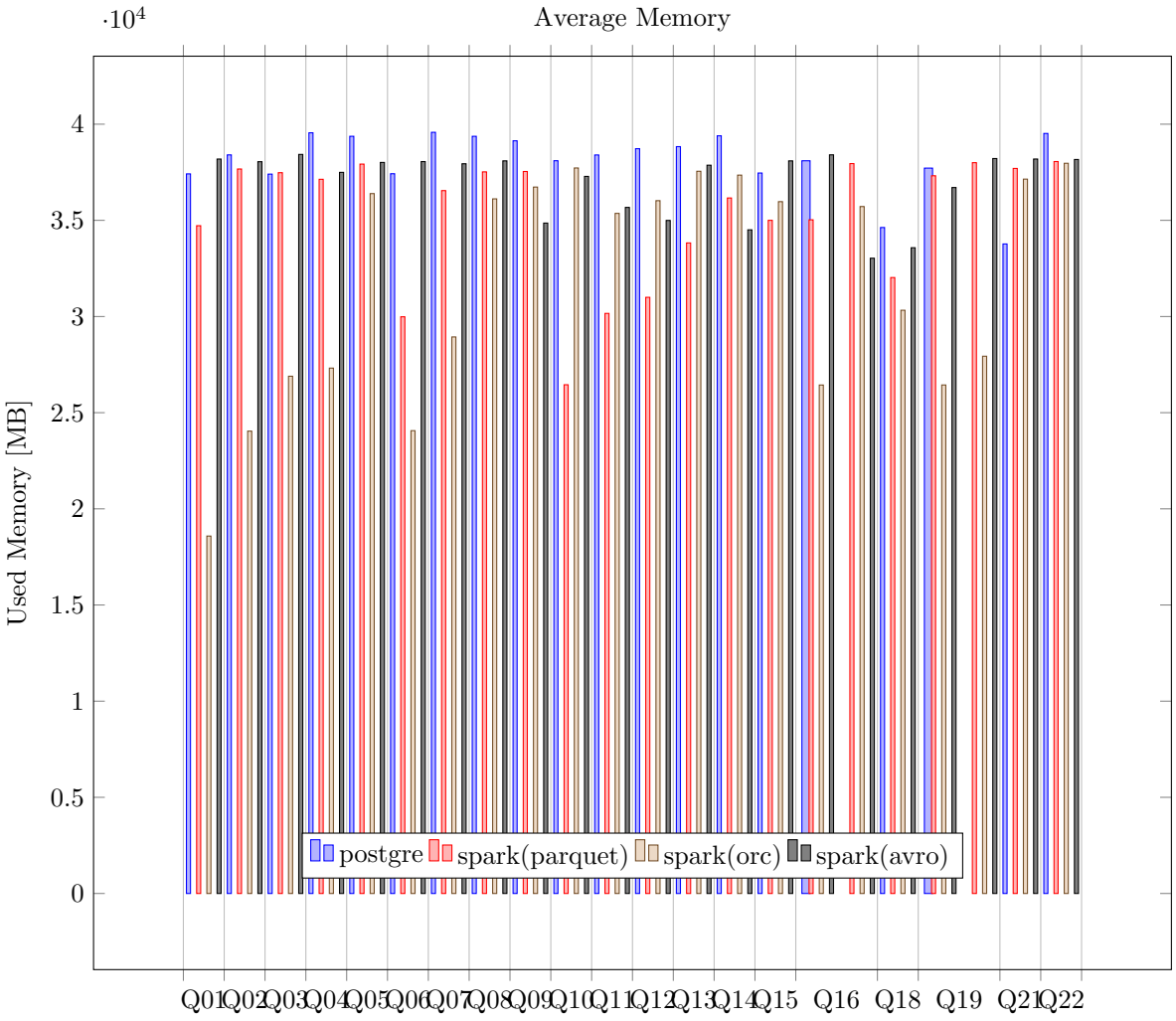


6.4 Memory

Memory average results are so close together that we cant make certain results. Except for orc format which seems use less memory than the others in some queries.
In all sparks tests with diffrent file formats no obvious diffrence can be seen. Just amount of reading from disk and freeing memory is variant among tests.
Overally spark uses memory much better than postgres and most effective parameter on spark function is reading less from disk. which avro makes it better than other file systems.
It seemed spark with avro free memory and load data more time than other spark runs.

Query num	postgre	spark(avro)	spark(orc)	spark(parquet)
Q01	11.96	3.23	3.92	0.91
Q02	8.56	13.78	9.70	9.80
Q03	12.19	6.91	7.23	6.70
Q04	14.88	14.88	5.15	4.93
Q05	19.41	17.81	6.37	6.06
Q06	41.61	13.30	1.36	7.61
Q07	34.43	14.97	5.18	4.80
Q08	34.62	14.59	6.40	7.19
Q09	2.64	16.04	5.74	7.57
Q10	18.28	17.30	5.74	6.70
Q11	31.56	14.29	3.87	8.21
Q12	20.44	19.67	7.27	10.01
Q13	14.61	5.13	8.16	7.01
Q14	27.92	11.06	2.17	6.35
Q15	39.52	2.63	0.31	0.79
Q16	24.12	15.50	5.46	5.20
Q17	-	14.94	6.00	7.09
Q18	27.98	15.39	5.10	7.64
Q19	26.78	18.64	5.30	10.22
Q20	-	13.77	2.71	4.00
Q21	18.45	10.81	5.52	5.78
Q22	28.41	17.12	3.23	7.04

Table 89: Average disk read and write (MB/sec)



Query num	postgre	spark(avro)	spark(orc)	spark(parquet)
Q01	37415.77	38187.44	18584.58	34721.47
Q02	38404.04	38049.24	24040.47	37669.72
Q03	37404.01	38428.72	26894.77	37478.01
Q04	39552.73	37495.57	27317.29	37134.43
Q05	39370.85	38011.38	36390.49	37925.04
Q06	37423.94	38056.31	24064.27	29986.37
Q07	39577.62	37942.76	28937.86	36546.44
Q08	39370.30	38093.10	36116.59	37520.41
Q09	39136.33	34857.56	36729.97	37540.41
Q10	38100.66	37285.80	37723.28	26451.74
Q11	38399.85	35672.18	35361.91	30161.78
Q12	38726.13	34995.34	36023.24	30997.83
Q13	38832.73	37867.98	37552.20	33825.26
Q14	39395.19	34507.11	37351.88	36162.94
Q15	37460.35	38092.25	35972.20	35000.78
Q16	38097.41	38406.51	26438.05	35028.55
Q17	-	33030.43	35718.01	37951.60
Q18	34627.95	33576.10	30325.33	32025.87
Q19	37715.97	36706.26	26440.09	37318.39
Q20	-	38214.14	27935.17	37999.16
Q21	33771.81	38188.50	37143.61	37699.89
Q22	39518.21	38164.89	37967.55	38057.87

Table 90: Average memory usage (MB)

7 Run Technical Details

7.1 Generate and Load Data and Queries

Data was created using dbgen by scale factor of 100 based on TPC-H standard. All data loaded from tbl format to postgres, parquet and orc in HDFS. Loading data to avro format was from parquet format. For loading data to hdfs, simple python script was wroted and submited to spark.
Queries Also edited under TPC-H circumstances.

7.2 Measurment Tools

we used Dstat for log system status. Dstat is a light system resource statistics recorder. After these data were collected, they were aggregated to generate proper plots and statistics to analyze them.
Simple python script was written for postgres to submit query through *psql*, measure executaion time and record resource status.
For spark, a supervisor app was devloped in scala and added hdfs support, system resource measurement tool and fixed some bugs. Complied supervisor app was submited to spark.

All codes including load scripts, queries and supervisor apps are pushed to corresponded repository.

Cafebazar company allowed some of their servers to be used for free in order to run these tests. Therefore no price has been reported in this report.