### CIS6930: Programming on Massive Parallel Systems

### **GPU Project 2: A better version of SDH computing program**

### Submitted by - Ghalib Saleem

I have decided to implement the algorithm 3 from the paper, Algorithms and Framework for Computing 2-body Statistics on GPUs by Napath Pitaksirianan, Zhila Nouri, and Yi-Cheng Tu for the implementation of this project. The paper describes a series of techniques for achieving high performance in dealing with a group of problems that share similar computing patterns as the SDH problem.

#### **Algorithm 3: SDH** with Output Privatization

```
Local Var: t (Thread id), b (Block id)
Global Var: B (Block size), M (total number of blocks)
 1: SHMOut \leftarrow Initialize shared memory to zero
 2: reg \leftarrow the t-th datum of b-th input data block
 3: for i = b + 1 to M do
      R \leftarrow the i-th input data block loaded to cache
      syncthreads()
      for j = 0 to B do
 6:
 7:
         d \leftarrow \text{DisFunction}(req, R[j])
 8:
         atomicAdd(SHMOut[d], 1)
      end for
 9:
10: end for
11: L \leftarrow the b-th input data block loaded to cache
12: syncthreads()
13: for i = t + 1 to B do
      d \leftarrow \text{DisFunction}(reg, L[i])
      atomicAdd(SHMOut[d], 1)
15:
16: end for
17: syncthreads()
18: Output[b][t] \leftarrow SHMOut[t]
```

The reason I chose the Algorithm 3 is the use of shared memory for the values of distance function. As we all know shared memory is faster than the local memory and Global memory and has lower latency. The privatization algorithm creates a private copy of the output and stores it so it tends to be utilized by the subset of threads.

After completion and execution of my code, the minimum total running time of the kernel for three execution with different input that I was able to achieve is:

**Note:** - GPU Old is Brute force and GPU Algo 3 is result of privatization.

# Output 1

Number of Samples: 10000	<b>Bucket Width:</b> 1000	Block Size: 64
Kernel ti	<b>me:</b> 93.46391 ms	

**************************************							
Running time for GPU Old version: 0.000010							
00:	16288	108733	275806 I	501165	767139		
05:	1061461	1367080	1678079	1979292	2259514		
10:	2510674	2730531	2906757	3039978	3120712		
15:	3146650	3112938	3027899	2882944	2685905		
20:	2426248	2110178	1743897	1356172	1021851		
25:	749569	530258	358306	230657	138568		
30:	76914	39502 İ	19368 İ	8666 İ	3661 İ		
35:	1254	326	50	10	Θ '		
35: T:49995		326			Θ '		
T:49995	*******			10	0		
T:49995 ******** Running	**************************************	' ****** GPU version: 0.000016	50   Algo 3*********	10	********		
T:49995 ******** Running	**************************************	' ****** GPU version: 0.000016 108733	50   Algo 3************************************	10   ************************************	**************************************		
T:49995 ******** Running 00: 05:	******************** time for GPU new 16288   1061461	******* GPU version: 0.000016 108733   1367080	50   Algo 3************************************	10   ********** 501165   1979292	**************************************		
T:49995 ******** Running 00: 05: 10:	**************************************	************** GPU version: 0.000016 108733   1367080   2730531	50   Algo 3************************************	10   ************************************	**************************************		
T:49995 ******** Running 00: 05: 10: 15:	******************** time for GPU new 16288   1061461	******* GPU version: 0.000016 108733   1367080	50   Algo 3************************************	10   ********** 501165   1979292	**************************************		
T:49995	******************* time for GPU new 16288   1061461   2510674   3146650	************** GPU version: 0.000016 108733   1367080   2730531   3112938	50   Algo 3***********  275806   1678079   2906757   3027899	501165   1979292   3039978   2882944	**************************************		
********* Running 00: 05: 10: 15: 20:	****************** time for GPU new  16288   1061461   2510674   3146650   2426248	******************* GPU version: 0.000016 108733   1367080   2730531   3112938   2110178	50   Algo 3**********  275806   1678079   2906757   3027899   1743897	501165   1979292   3039978   2882944   1356172	**************************************		
**************************************	****************** time for GPU new  16288   1061461   2510674   3146650   2426248   749569	**************************************	275806   1678079   2906757   3027899   1743897   358306	501165   1979292   3039978   2882944   1356172   230657	**************************************		

# Output 2

Number of Samples: 10000	<b>Bucket Width:</b> 500	Block Size: 32			
Kernel time: 74,97648 ms					

		****** GPU	Old ********	*******	*******
inning t	time for GPU Old	version: 0.000008			
0:	2076 l	14212	37870 l	70863 I	113190
5:	162616	219792	281373	348231	418908
0:	492542	568919	643293	723787	799933
5:	878146	953657	1025635	1097551	1161963
9:	1225131	1285543	1340874	1389657	1435607
5:	1471150	1505326	1534652	1554499	1566213
9:	1574002	1572648	1562633	1550305	1527753
5:	1500146	1463004	1419940	1372128	1313777
9:	1249134	1177114	1097835	1012343	920271
5:	823626	723835	632337	548947	472904
9:	405296	344273	289347	240911	197652
5:	160654	129093	101564	78499	60069 j
0:	44360	32554	23054	16448	11533
5:	7835 İ	5295	3371	2289	1372
	804	450	222	104	34
: : :499956 :*****	16   900 ********	8   ******* GPU	2	104   0   *********	0
0: 5: T:499956 ******	16   900 ********	8 <b>j</b>	2	о ј	0
0: 5: T:499950 ******* unning t	16   900 ******************* time for GPU new	8   ****************** GPU version: 0.000016	2   Algo 3********	о ј	
0: 5: T:499950 ******* unning t	16   900 ********	8   ******* GPU	2	0 <b> </b> **********	_0 ' ************************************
0: 5: T:499950 ******* unning t 0: 5:	16   900 **************** time for GPU new 2076	8   ***************** GPU version: 0.000016 14212	2   Algo 3************************************	0   ************************************	
0: 5: T:499950 ******* unning t 0: 5:	16   900 *************** time for GPU new 2076   162616	8   ***************** GPU version: 0.000016 14212   219792	2   Algo 3************************************	0   ************************************	**************************************
0: 5: 7:499956 ******* unning t 0: 5:	16   900 *************** time for GPU new 2076   162616   492542	8   ***************** GPU version: 0.000016 14212   219792   568919	2   Algo 3************************************	0   ************************************	**************************************
0: 5: T:499956 ******	16   900 *************** time for GPU new 2076   162616   492542   878146	8   ****************** GPU version: 0.000016 14212   219792   568919   953657	2   Algo 3************************************	0   ************************************	**************************************
:: :499956 ******* inning t	16   900 **************** time for GPU new 2076   162616   492542   878146   1225131	8   ****************** GPU version: 0.000016 14212   219792   568919   953657   1285543	2   Algo 3************************************	0   ************************************	**************************************
0: 5: T:499956 ******* unning t 0: 5: 0: 5:	16   900 **************** time for GPU new 2076   162616   492542   878146   1225131   1471150	8   ******************* GPU version: 0.000016 14212   219792   568919   953657   1285543   1505326	2   Algo 3************************************	0   ************************************	113190   418908   799933   1161963   1435607   1566213
0: 5: T:499956 ******* unning t 0: 5: 0: 5:	16   900 ****************** time for GPU new 2076   162616   492542   878146   1225131   1471150   1574002	8   ******************* GPU version: 0.000016 14212   219792   568919   953657   1285543   1505326   1572648	2   Algo 3************************************	70863   348231   723787   1097551   1389657   1554499   1550305	113190   418908   799933   1161963   1435607   1566213   1527753
0: 5: 7:499956 ******** unning t 0: 5: 0: 5: 0: 5:	16   900 ******************* time for GPU new 2076   162616   492542   878146   1225131   1471150   1574002   1500146	8   ************************************	2   Algo 3************************************	70863   348231   723787   1097551   1389657   1554499   1550305   1372128	113190   418908   799933   1161963   1435607   1566213   1527753   1313777
9: 5: T:499956 ******** unning 1 9: 5: 9: 5: 9: 5: 9: 5:	16   000  *********** time for GPU new  2076   162616   492542   878146   1225131   1471150   1574002   1500146   1249134	8   ************************************	2   Algo 3************************************	70863   348231   723787   1097551   1389657   1554499   1550305   1372128   1012343	113190   418908   799933   1161963   1435607   1566213   1527753   1313777   920271
9: 5: T:499956 ******** unning 1 9: 5: 9: 5: 9: 5: 9: 5:	16   000  ************ time for GPU new  2076   162616   492542   878146   1225131   1471150   1574002   1500146   1249134   823626   405296   160654	8    ***********************************	2   Algo 3**********  37870   281373   643293   1025635   1340874   1534652   1562633   1419940   1097835   632337   289347   101564	70863   348231   723787   1097551   1389657   1554499   1550305   1372128   1012343   548947   240911   78499	113190   418908   799933   1161963   1435607   1566213   1527753   1313777   920271   472904   197652   60069
9: 5: 7:499956 ******** unning 1 9: 5: 9: 5: 9: 5: 9: 5:	16   0000  ****************  time for GPU new  2076   162616   492542   878146   1225131   1471150   1574002   1500146   1249134   823626   405296   160654   44360	8    ***********************************	2   Algo 3***********  37870   281373   643293   1025635   1340874   1534652   1562633   1419940   1097835   632337   289347   101564   23054	70863   348231   723787   1097551   1389657   1554499   1550305   1372128   1012343   548947   240911   78499   16448	113190   418908   799933   1161963   1435607   1566213   1527753   1313777   920271   472904   197652   60069   11533
0: 5: 7:499956 ******** unning 1 0: 5: 0: 5: 0: 5: 0: 5:	16   9000  ****************  time for GPU new  2076   162616   492542   878146   1225131   1471150   1574002   1500146   1249134   823626   405296   160654   44360   7835	8    ***********************************	2   Algo 3**********  37870   281373   643293   1025635   1340874   1534652   1562633   1419940   1097835   632337   289347   101564   23054   3371	70863   348231   723787   1097551   1389657   1554499   1550305   1372128   1012343   548947   240911   78499   16448   2289	113190   418908   799933   1161963   1435607   156213   1527753   1313777   920271   472904   197652   60069   11533   1372
9: 5: 7:499956 ******** unning 1 9: 5: 9: 5: 9: 5: 9: 5:	16   0000  ****************  time for GPU new  2076   162616   492542   878146   1225131   1471150   1574002   1500146   1249134   823626   405296   160654   44360	8    ***********************************	2   Algo 3***********  37870   281373   643293   1025635   1340874   1534652   1562633   1419940   1097835   632337   289347   101564   23054	70863   348231   723787   1097551   1389657   1554499   1550305   1372128   1012343   548947   240911   78499   16448	113190   418908   799933   1161963   1435607   1566213   1527753   1313777   920271   472904   197652   60069   11533

# Output 3

Number of Samples: 100000	<b>Bucket Width:</b> 1000	Block Size: 64			
Kernel time: 6902,37646 ms					

(base)	ghalibsaleem@Ghal	lib-linux:~/Documer	nts/USF/Cuda/proj2	-ghalibsaleem\$ ./te	st 100000 1000 64	
*****	*******	****** GPL	J Old ********	*******	*****	
Running time for GPU Old version: 0.000010						
00.	1640200	10043000	27544100 L	E0026016	76700011	
00: 05:	1640289   106121559	10843080   136910632	27544198   167848146	50026816   197868797	76708211   225955796	
10:	251328500	273244161	291068479	304327905 l	312470075	
15:	315193417	312331390	303639589	289084180	268815791	
20:	242887739	211519683	174891328	135536901	101644679	
25:	74102047	52073269	34966533	22219570	13192634	
30:	7249346	3683809	1759328	789152	317736	
35:	109694	29703	5342	491	5	
T:4999	9950000					
				*******	******	
Running	g time for GPU nev	version: 0.000050	)			
00:	1640289	10843080	27544198	50026816	76708211	
05:	106121559	136910632	167848146	197868797	225955796	
10:	251328500	273244161	291068479	304327905	312470075	
15:	315193417	312331390	303639589	289084180	268815791	
20:	242887739	211519683	174891328	135536901	101644679	
25:	74102047	52073269	34966533	22219570	13192634	
30:	7249346	3683809	1759328	789152	317736	
35:	109694	29703	5342	491	5	
1:4999	9950000					
	k***Time to genera	ate:: 6902.37646 ms	*****			