

### **Project Report**

### **CS3006** Parallel and Distributed Computing

### **Project Title**

Comparison of Serial and Parallel Sorting of Records in a Large Dataset

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## **Comparison between Process And Threads**

### Introduction

Our application allows the user to sort a large dataset of student records on the basis of any attribute they choose. We have developed two separate versions of the application, one is a serial version and the other is a parallel version, we also compared the applications to analyse the time taken for different sizes of the dataset, using a graph.

### **Methodology**

First we run the **generatecsv.py** and give the N row size of the csv file and it will create a csv file with our defined attributes, we won't actually be running this file since we would need to create multiple large files which would be costly so we have created some files already and stored them in the **datasets** folder which we will be using.

The project can be executed in 2 different ways, we could either run it through the shellscript **runall.sh** which automates(and doesn't take any user input) the process of running both serial and parallel versions of our application on various datasets of different sizes then records the time taken for each and plots a graph to show the results

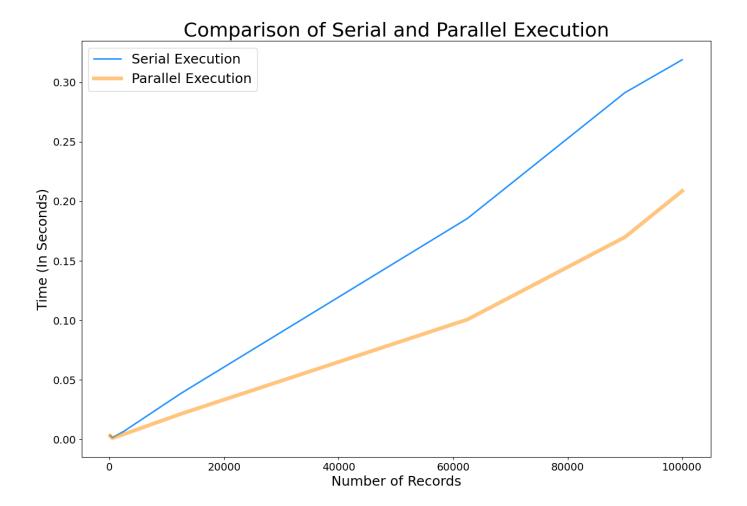
Alternatively we could run each program separately through the command line which would give us the time taken for the whole application to run on a single dataset (whose path we would hardcode near the top of the sortcsv.cpp file in the variable FILEPATH) as well as the time taken for each thread and the chunk allocated to each thread.

For the serial version, we used mergesort to sort the the data on the basis of a user selected attribute, and for the parallel version we used the OpenMP API to parallelise the mergesort algorithm with the help of **#pragma omp task**, which allows us to easily implement parallelism in recursive code and then we used shell scripting to automate the process of running both the parallel and serial versions of the application on a range of datasets, and it stores the time required to run each algorithm for each file in a csv file, after the algorithm is run on the range of datasets, the csv file is used by a Python program to generate a line graph for both versions of the applications. This graph can be observed more accurately at runtime but an image of this graph can be seen in this report.



The project can be <u>viewed on Github</u>
[https://github.com/AhmedMahmood19/pdc-project]

# Graph



### Results

The results we would achieve by running our program from **runall.sh** is that it will sort some pre-made datasets of varying sizes in serial and also in parallel, record their execution time and run **graph.py** to plot a line graph of (number of records) against (execution time) for both serial and parallel execution, which is shown above.

Alternatively by running our serial and parallel programs from the command line it will allow us to choose an attribute, on the basis of which the data will be sorted, then it displays the runtime in the terminal and it also creates the sorted csv file in the **scripts** folder but only in the parallel application do we also get a thread log(which shows which thread was allocated which chunk of data and how long it took to operate on it) which is stored in the **parallel** folder.

#### Dataset containing 100,000 records before sorting:

A	В	C	D	E	F	G	Н
Student ID	First Name	Last Name	CNIC	Email	Phone Number	Credit Hours	
11K-9001	Karina	Smith	36243-5068765-8	matthew04@gmail.com	+92 5661492883	38	3
07K-4734	Andre	Rodriguez	98575-2143558-7	john53@gmail.com	+92 4662795290	58	2.1
11K-1540	Kimberly	Wells	38001-8212432-8	andrewortiz@gmail.com	+92 6998976524	74	2.
15K-8372	Russell	Kennedy	81159-1003102-3	troy78@gmail.com	+92 1078372269	21	2.
49K-4969	Sandra	Rice	22842-0370638-7	david33@gmail.com	+92 3892232299	31	2.
99K-5237	Connie	Watson	89455-4410799-1	luisreed@gmail.com	+92 8581211820	91	2.
82K-7351	Chelsea	Thomas	71496-7464787-9	andrewfreeman@gmail.com	+92 0791776010	19	2.
95K-2844	Eddie	Duarte	82527-5237829-5	donna04@gmail.com	+92 5900603801	39	2
83K-0923	Sandra	Petersen	14655-3890425-0	mercerleslie@gmail.com	+92 3188221465	115	2.
72K-5282	Joel	Hines	87085-9294723-2	parkdeanna@gmail.com	+92 9320145771	33	2.
22K-8217	Rebecca	Aguilar	73150-3841382-4	smithpaul@gmail.com	+92 5644265177	25	3.
35K-7047	Kaylee	Ryan	45251-2765541-2	uvasquez@gmail.com	+92 9042048880	20	2.
79K-7457	Bonnie	Martinez	34184-6211470-1	oscar02@gmail.com	+92 2976420174	75	:
65K-1698	Betty	Yoder	96985-9572769-8	aaronfoster@gmail.com	+92 9690823038	117	3.
58K-9966	Daniel	Williams	34032-0182363-9	ojones@gmail.com	+92 3846134808	100	
59K-7287	Paul	Holland	58973-0071289-7	tsellers@gmail.com	+92 3870657886	64	2
97K-7408	Michael	Mccov	65822-4432347-2	joannaparsons@gmail.com	+92 1982718955	65	
51K-2454	Tina	Garner	98945-8880973-9	alexanderbenjamin@gmail.com	+92 4394061158	52	
26K-0467	Sandra	Haynes	99810-9848062-8	jordanjeffrey@gmail.com	+92 4589492689	29	
32K-8904	Thomas	Parks	28153-5276659-7	kevin43@gmail.com	+92 3923296430	86	
45K-7454	Michael	Bell	19748-2255489-8	jamesmichael@gmail.com	+92 2387971890	64	
93K-9244	Kristina	Bailey	28599-7237174-5	dperkins@gmail.com	+92 0990887874	71	_
04K-2031	Matthew	Campbell	26789-1039645-2	shawnelliott@gmail.com	+92 0015551895	34	
20K-6597	Timothy	Joseph	77721-8785367-2	evansjason@gmail.com	+92 2233770407	49	_
86K-4741	Michael	Ashley	52223-7347751-3	hjohnson@gmail.com	+92 0211034587	130	_
82K-6413	Derek	Davis	54204-3792879-2	tnunez@gmail.com	+92 2034790644	97	
72K-1887	Anna	Compton	60697-4881215-0	dorseysamuel@gmail.com	+92 1159466123	99	
00K-6076	David	Lambert	71046-8396905-9	ann50@gmail.com	+92 0956889073	53	
03K-6267	Ryan	Anderson	61976-6287984-7	imitchell@gmail.com	+92 6706728233	37	_
58K-3534	Kathy	Webb	57220-8028430-0	andrew25@gmail.com	+92 3219569290	114	_
48K-8576	Elizabeth	Edwards	80186-2809392-4	csnyder@gmail.com	+92 1665058679	122	
93K-1657	Elizabeth	Johnson	38429-4774399-3	lisagreen@gmail.com	+92 2683783984	60	
29K-3153	Jessica	Perez	42235-7161888-7	april99@gmail.com	+92 9186149379	92	
32K-7248	Joseph	Jensen	25026-3079462-9	parkerbrett@gmail.com	+92 8003962384	47	
33K-1992	Carly	West	31365-0075452-0	jacobthompson@gmail.com	+92 5003902384	76	
34K-6096	Stephen	Holmes	99463-1864468-3	donna36@gmail.com	+92 4748267917	95	
42K-2985	Brittany	Weeks	97880-4838761-9	msantos@gmail.com	+92 7881393418	84	_
42K-2905	Dilitary	*veeks	37000-4030701-9	msanos@gman.com	1 32 7001333410	04	

The command line when running the serial application:

```
~/Repos/pdc-project | master | cd serial
~/Repos/pdc-project/serial master g++ sortcsv.cpp -o sortcsv.out
~/Repos/pdc-project/serial master !2 ./sortcsv.out
:::Choose the attribute to sort by, enter the corresponding option number:::
Option No. : Attribute
          : Student ID
1
          : First Name
2
          : Last Name
3
          : CNIC
4
          : Email
5
         : Phone Number
6
         : Credit Hours
7
         : CGPA
Time Taken: 0.277052%
```

The command line when running the parallel application:

```
~/Repos/pdc-project | master !2 | cd parallel
~/Repos/pdc-project/parallel master !2 g++ -fopenmp sortcsv.cpp -o sortcsv.out
~/Repos/pdc-project/parallel master !2 ./sortcsv.out
:::Choose the attribute to sort by, enter the corresponding option number:::
Option No. : Attribute
          : Student ID
          : First Name
1
2
          : Last Name
3
          : CNIC
          : Email
          : Phone Number
          : Credit Hours
          : CGPA
Time Taken: 0.178455%
```

### Dataset after sorting in serial(start and end of sorted file shown, please zoom in to see clearly): Since we chose option 0 for both applications, it will sort on the basis of Student ID

OK.0026   Okready   Okre	1 Student ID	First Name	Last Name	CNIC	Email	Phone Number	Credit Hours C	GPA	99964	99K-9676	Cindy	Reed		qsnyder@gmail.com	+92 5865685608	37	3.43
500-00025   Directors   Barker   S8821-02529867   Kaltyrikm@gmail.com   +92 25918969505   118   3.61   99950   9996-691   John   Smith   90455-6684673   Talays?gmail.com   +92 2598597456   70   2.51   99950   9996-691   John   Smith   90455-6684673   Talays?gmail.com   +92 2598597456   70   2.51   99950   9996-691   John   Smith   90455-66846737   Talays?gmail.com   +92 2598597456   70   2.51   99950   9996-6997   Carla   Carder   4759-92215454   Ettryperacing.gmail.com   +92 2774297020   47   3.57   70	2 00K-0003	Joshua					92										3.72
Solic-Order	3 00K-0018	Joanna	Preston	16696-5325280-7	charles76@gmail.com	+92 6913000575	56	3.77	99966	99K-9683	Christopher	Wilson	78184-6266847-6	wkelley@gmail.com	+92 4141731119	69	2.37
Octoops	4 00K-0025	Christian	Barker	53821-0252968-7	kaitlynkim@gmail.com	+92 2501995935	118	3.61	99967	99K-9687	Ronald	Cameron	70311-5625512-7	esilva@gmail.com	+92 9718337697	87	3.2
5 OK-0045   Swah   Parsons   79/08/98/08/10   Parsons   79/08/98/08/08/07   Carlar   Carlar   45/79/92/2543-6   terryparciag/gmal.com   +92 776558/4671   124   3.71	5 00K-0026	Jennifer	Roberts	83938-9522082-2	qlang@gmail.com	+92 8318694854	109	3.84	99968	99K-9691	John	Smith	90456-2664873-7	haley37@gmail.com	+92 8094893429	68	3.71
00.0005  Edward   Thomas   1757-4164701.0   morrowkeninggmal.com   +92 788800053   72   3.2	6 00K-0029	Katherine	Gomez	99721-9702287-0	powersheather@gmail.com	+92 2558579456	70	2.51	99969	99K-9695	Heather	Reilly	90564-6909426-3	gcooper@gmail.com	+92 5774207020	47	3.57
Doctoropies   Microlas Forts	7 00K-0043	Sarah	Parsons	79038-9691638-9	rayryan@gmail.com	+92 6053638040	39	3.1	99970	99K-9697	Carla	Carter	45759-9212543-6	terrygarcia@gmail.com	+92 7726364671	124	3.71
10000076   Nicholas   Frost   70498-7015299-7   andradesustining-granal com   +92 902444576   44   2.83   99973   998-873   Cody   Adams   52169-521634-5   beliantification   +92 90374055-1   3.4   3.96   12 00000767   12 00	8 00K-0051	Edward	Thomas	17571-4164701-0	morrowkevin@gmail.com	+92 7011578446	65	3.11	99971	99K-9701	Christina	Curtis	94503-8601745-3	paulporter@gmail.com	+92 7438690253	72	3.2
10 000-0036 Rathrym Fvans 10117-68649371 daniel8t@gmail.com +92 086493636 111 3.1 99975 999-749 U.s.s Martinez 2800-71862-76 kelleywilliam@gmail.com +92 026593498 11.3 1. 3.1 99975 999-749 U.s.s Martinez 2800-71862-76 kelleywilliam@gmail.com +92 026593498 12. 3.6 99975 999-749 W.s.s Martinez 2800-71862-76 kelleywilliam@gmail.com +92 026593498 12. 3.6 99975 999-749 W.s.s Martinez 2800-71862-76 kelleywilliam@gmail.com +92 026593498 12. 3.6 99975 999-749 W.s.s Martinez 2800-71862-76 kelleywilliam@gmail.com +92 0265934989 12. 3.6 99977 999-75 3. 3.4 99977 999-75 3. 3.4 99977 999-75 3. 3.4 99977 999-75 6 kelleywilliam@gmail.com +92 0569896973 45. 3.4 99979 999-75 6 kelleywilliam@gmail.com +92 0569896973 45. 3.4 99997 999-75 6 kelleywilliam. Martinez 2800-7569504 have kelleywilliam. Martinez 2800-756974 Advance 2800-756974 Advance 2800-756974 Advance 2800-756974 Advance 2800-756974 Advance 2800-756974 4 kelleywilliam. Martinez 2800-756974 4 kelleywilliam. Martinez 2800-756974 4 kelleywilliam. Martinez 2800-756974 4 kelleywilliam. Have 2800-756974 4 kelleywilliam. Martinez 2800-756974 4 kelleywilliam. Have 2800-756974 4 kelleywilli	9 00K-0053	Alexis	Waters	99122-5384944-3	james55@gmail.com	+92 7888298849	103	3.19	99972	99K-9724	Mary	Suarez	24053-6165306-6	steven16@gmail.com	+92 3578810326	129	2
2 00K-0052   Kathryn   Evans   10117-6854597-0   mbownan@gmail.com   +92 0056959368   52 09   3 00K-0058   Robert   Baue   69210-300478-8   Josepher   2 0.67	10 00K-0068	Nicholas	Frost	70498-7015299-7	andradeaustin@gmail.com	+92 9042444576	44	2.83	99973	99K-9725	Gary	Wong	24221-0189126-2	benjamin62@gmail.com	+92 9020724251	34	3.69
3 00K-0094   Robert   Bauer   69210-3004789.3   robert02@gmail.com   +92 0065934897   72 3.67   99976   90K-9753   30F-0090   200500000000000000000000000000000000	11 00K-0076	Timothy	Norris	96025-8464314-1	daniel81@gmail.com	+92 2883077758	104	3.95	99974	99K-9731	Cody	Adams	52169-2916245-0	kelleywilliam@gmail.com	+92 1810067571	108	2.62
4 OK-0058   Cheryl   Ortiz   21023-2997409-6   brian2/0@gmail.com   +92 472800086   53 3.96   99978   OK-0752   Ok-0725   Ok	12 00K-0082	Kathryn	Evans	10117-6854597-0	mbowman@gmail.com	+92 0045469336	111	3.1	99975	99K-9741	Lisa	Martinez	43804-2716422-6	christine32@gmail.com	+92 8222255468	58	2.69
5 OK.0050   Donald   Delacritz   67967-2597381-5   https://genal.com	13 00K-0084	Robert	Bauer	69210-3004788-3	robert62@gmail.com	+92 0065934087	72	3.67	99976	99K-9743	Jeffery	Pham	19766-1852117-7	xryan@gmail.com	+92 4087230892	35	3.3
	14 00K-0088	Cheryl	Ortiz	21023-2992469-6	brian20@gmail.com	+92 4728906086	53	3.96	99977	99K-9753	Jamie	Moreno	90733-1370396-8	vanessalynch@gmail.com	+92 5039227250	57	2.3
17   0K-0129   Jennifer   Wilcox   81511-957500-9   littledeut@gmail.com   +92 092292379   47   2.22   99980   99987   99981   99987   99981   99987   99988   99987   99988   99987   99988	15 00K-0090	Donald	Delacruz	67967-2597381-5	hlopez@gmail.com	+92 6644873987	57	2.98	99978	99K-9763	Jennifer	Odom	26668-9482039-4	stevenwilliams@gmail.com	+92 6058959793	45	3.49
8	16 00K-0124	Nicole	Shannon	86090-1932288-1	tfritz@gmail.com	+92 2138375934	72	3.34	99979	99K-9765	Gregory	Jacobson	88329-0558109-5	kevin64@gmail.com	+92 3763510274	66	3.27
90 KV-0147   Frank   Francis   29169-6946381-3   michelle64@gmail.com   +92 f18269913   107   2.33   99987   99K-9773   John   Baker   89782-7896556-9   jamesbarnes@gmail.com   +92 f182697175   100   2.53   99981   99K-9774   Michael   Alexander   12688-3042965-2   archyrlose@gmail.com   +92 f182697175   100   2.53   99981   99K-9776   Cody   Lopez   64602-2036425-2   archyrlose@gmail.com   +92 f182697189   113   3.32   2.76   99981   99K-9776   Cody   Lopez   64602-2036425-2   archyrlose@gmail.com   +92 f1826971879   92   2.76   99981   99K-9776   Cody   Lopez   64602-2036425-2   archyrlose@gmail.com   +92 f1826992   50   3.48   2.76   6.76	17 00K-0129	Jennifer	Wilcox	81511-9575060-9	littledavid@gmail.com	+92 0922292379	47	2.22	99980	99K-9767	Adriana	Salazar	41486-0198108-1	jamesclark@gmail.com	+92 9116620205	68	3.93
20K-0150   Cornor   Watts   83591-3827040-4   Carlyn5&@gmail.com   +92 7829957175   100   2.53   99983   99K-9776   Cody   Lopez   Cody   L	18 00K-0131	Angela	Henry	89505-3755552-4	sharonrivera@gmail.com	+92 3465302006	93	3.53	99981	99K-9769	James	Watson	24491-0790700-6	richardlutz@gmail.com	+92 3420556084	59	2.8
1	19 00K-0147	Frank	Francis	29169-6945381-3	michelle64@gmail.com	+92 6118269913	107	2.33	99982	99K-9773	John	Baker	89782-7898556-9	jamesbarnes@gmail.com	+92 1481674673	104	2.25
22 OK-0161 Melanie Smith 20134-4696525-8 geraldjones@gmail.com +92 7596748739 92 2.76 99985 99K-9810 Stephen Malone 96810-3416733-4 gallen@gmail.com +92 9259598714 55 3.28 24 OK-0177 Daniel Garcia 1634-2129903-4 mayrswyre@gmail.com +92 7696222242 83 3.73 99987 99K-8910 Courtney Santiago 6539-6388702-2 pearvoll@gmail.com +92 7999452670 66 3.65 265 OK-0215 Manuel Green 72962-6437054-5 jimmy45@gmail.com +92 1384405038 25 3.83 99987 99K-8910 Courtney Santiago 6539-6388702-2 pearvoll@gmail.com +92 19995501 50 2.86 265 OK-0215 Manuel Green 72962-6437054-5 jimmy45@gmail.com +92 1384405038 25 3.83 99988 99K-8927 Kerry Campbell 6954-0524351-5 christopher/5@gmail.com +92 1384405038 25 3.83 99989 99K-8927 Kerry Campbell 6954-0524351-5 christopher/5@gmail.com +92 1384405038 25 3.83 9998 99K-8927 Kerry Campbell 6954-0524351-5 christopher/5@gmail.com +92 1495650533 101 3.2 28 0K-023 Allison Cole 84071-3130022-3 masondonald@gmail.com +92 8781486008 61 3.34 99990 99K-8939 Julie Joseph 12505-1085030-7 wadams@gmail.com +92 7646313615 35 22 0 0K-0235 Elizabeth Gonzalez 3042-8874515-6 nandersen@gmail.com +92 774500447 20 2.46 99992 99K-8967 Kelli Jackson 55240-7060361-9 melindamsaong/gmail.com +92 87896946774 130 3.91 0 0K-0255 Mikayla Moss 73024-6856729-9 guyhouston@gmail.com +92 9212955147 63 3.6 99993 99K-8987 Kelli Jackson 55240-7060361-9 melindamsaong/gmail.com +92 7896946774 130 3.91 0 0K-0255 Mikayla Moss 73024-6856729-9 guyhouston@gmail.com +92 140675944 42 2.41 99995 99K-9910 Kelli Jackson 55240-7060361-9 melindamsaong/gmail.com +92 140675944 42 2.41 99995 99K-9910 Kelli Jackson 55240-7060361-9 melindamsaong/gmail.com +92 140675944 43 2.41 99995 99K-9910 Kelli Jackson 55240-7060361-9 melindamsaong/gmail.com +92 1406769471-1 melindamsaong/gmail.com +92 140606004 59 3.52 3.52 300 0K-0230 Kerneth Odom 1978-937406-8 gregovysantos@gmail.com +92 140606004 59 3.52 3.52 300 0K-0230 Kerneth Odom 1978-937406-8 gregovysantos@gmail.com +92 12475533 40 3.85 99999 99K-9997 99K-9910 Kelli David Kramer 81275-4873758-3 klylerboven@gmail.c	20 00K-0150	Connor	Watts	83591-3827040-4	carolyn56@gmail.com	+92 7829957175	100	2.53	99983	99K-9774	Michael	Alexander	12668-3042965-2	amyfowler@gmail.com	+92 0285071489	113	3.32
23   0K-0176   Richard   Greves   94655-5815755-3   https://doi.org/10.1001/	21 00K-0159	Paige	Robinson	98058-3897689-9	april16@gmail.com	+92 2637699708	73	3.24	99984	99K-9776	Cody	Lopez	64602-2036425-2	charles16@gmail.com	+92 3189562692	50	3.48
24 OK-0217 Daniel Garcia 16344-1229803-4 manysawyer@gmail.com +92 1896381164 37 2.39 99987 99K-8981 Courtney Santiago 6539-6388702-2 pcarrol@gmail.com +92 1919193501 50 2.86 OK-0215 Manuel Green 72962-643705-6 jimmy45@gmail.com +92 190505250 77 3.87 26 OK-0215 Manuel Green 73072-1883774-5 christopher76@gmail.com +92 190505250 77 3.87 3.87 26 OK-0221 Kimberly Lewis 73072-1883774-5 christopher76@gmail.com +92 6921031254 67 2.45 99920 99K-9827 Kerry Campbell 69554-0524351-7 inchasquirm@gmail.com +92 1645505353 101 3.2 99920 90K-0235 Carla Russell Gill-1680983-3 jessica62/gmail.com +92 784313615 35 29 0K-0235 Elizabeth Gonzalez 90342-8874515-6 nandersen@gmail.com +92 6745006447 20 2.46 99929 99K-9827 Werdy Lewis 24420-27870364 William Flores 2258-2485729-9 guyhouston@gmail.com +92 6745006447 20 2.46 99992 99K-9869 Kelli Jackson 55240-7060361-9 melindamsahas@gmail.com +92 8744666750 92 2.59 0K-0235 Mikayla Moss 73024-6856279-5 katrinasanchez@gmail.com +92 49832993636 77 3.84 99994 99K-9985 Christina Hood 61510-2304262-4 griffithbenjamin@gmail.com +92 1804667594 44 2.41 99995 99K-9985 Christina Hood 61510-2304262-4 griffithbenjamin@gmail.com +92 1804607594 45 2.74 0K-0291 Dwayne Larsen 43707-2868819 blant72@gmail.com +92 124755323 40 3.85 99999 99K-9939 PS-9939 PS	22 00K-0161	Melanie	Smith	20134-4696525-8	geraldjones@gmail.com	+92 7596748739	92	2.76	99985	99K-9780	Stephen	Malone	96810-3416733-4	gallen@gmail.com	+92 9259598714	55	3.28
Solution   Color   C	23 00K-0176	Richard	Graves	94655-5815755-3	hughesmarilyn@gmail.com	+92 7669222242	83	3.73	99986	99K-9808	Gina	Lynch	26207-8728177-2	jacobstevens@gmail.com	+92 3099452670	66	3.65
26 OK-0221   Kimberly   Lewis   73072-1083774-5   christopher F@gmail.com   492 8921031254   87   2.45   9998   994.8827   kerry   Campbell   69554-0524551-7   nicholasquim@gmail.com   492 1646313615   35   2   2   0   0   0   0   0   0   0   0	24 00K-0177	Daniel	Garcia	16344-2129803-4	marysawyer@gmail.com	+92 4886381164	37	2.39	99987	99K-9810	Courtney	Santiago	65390-6388702-2	pcarroll@gmail.com	+92 7199193501	50	2.86
27 OK-0232   Allison   Cole   \$4071-3130022-3   masondonatd@gmail.com   +92 8781.486008   61   3.34   99990   99K-9867   Ocrey   Welch   16337.239305-2   manda97@gmail.com   +92 898988779   48   2.55	25 00K-0215	Manuel	Green	72962-6437054-5	jimmy45@gmail.com	+92 1384405038	25	3.83	99988	99K-9816	Brittany	Huang	29232-7963918-4	christina35@gmail.com	+92 5970606250	77	3.87
28 OK-0233	26 00K-0221	Kimberly	Lewis	73072-1083774-5	christopher76@gmail.com	+92 6921031254	87	2.45	99989	99K-9827	Kerry	Campbell	69554-0524351-7	nicholasquinn@gmail.com	+92 1645505353	101	3.2
29 OK-0235 Elizabeth Gonzalez 90342-8874515-6 nandersen@gmail.com +92 6745906447 20 2.46 99992 99K-9895 (kelli Jackson 55240-7060361-9 melindamason@gmail.com +92 927696750 92 2.59 3.50 0K-0255 Mikayla Moss 73024-6856279-5 katrinsasnchez@gmail.com +92 9212955147 63 3.6 99993 99K-9895 (hristina hood 61510-2304262-4 hood 998-6995 (hristina hood 61510-2304262-4 hood 61510-2304262-4 hood 998-6995 (hristina hood 61510-230426-4 hood 9	27 00K-0232	Allison	Cole	84071-3130022-3	masondonald@gmail.com	+92 8781486008	61	3.34	99990	99K-9839	Julie	Joseph	12505-1085030-7	wadams@gmail.com	+92 7646313615	35	2
50   OK-0243   William   Flores   32/289-2485729-9   guyhouston@gmail.com   +92 92/2955147   63   3.6   99993   99K-9893   Wendy   Lewis   24420-2787036-4   thomasshaw@gmail.com   +92 78966946774   130   3.91     31   OK-0256   Heid   Martinez   31021-1760599-9   jennifetrbav@gmail.com   +92 149075944   44   2.41   99995   99K-9914   David   Kramer   81275-8487378-8   griffethenjamin@gmail.com   +92 149480369048   66   3.12     32   OK-028   Kenneth   Odom   19785-9379406-8   gregorysantos@gmail.com   +92 1124755323   40   3.85   99995   99K-9914   David   Kramer   81275-8487378-8   3.61     34   OK-0291   Dwayne   Larsen   43707-2866819-3 brian72@gmail.com   +92 128141033   72   2.74     35   OK-0304   Sarah   Romero   85235-7227591-9   taylormarin@gmail.com   +92 8281198603   112   3.52   99997   99K-9912   David   Kramer   81275-8487378-8   3.61     35   OK-0306   Holly   Trujillo   29020-3197771-6   taylortarara@gmail.com   +92 233676311   119   2.3   99999   99K-9914   David   Romero   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311   119   2.3   492 233676311	28 00K-0233	Carla	Russell	61911-6860983-3	jessica92@gmail.com	+92 7354737153	119	3.82	99991	99K-9867	Corey	Welch	16337-2393050-2	amanda97@gmail.com	+92 9892988779	48	2.55
31 OK-0255 Mikayla Moss 73024-6856279-5 katrinasanchez@gmail.com +92 48932793536 77 3.84 99994 99K-9985 Christina Hood 61510-2304262-4 griffithbenjamin@gmail.com +92 480369048 66 3.12 32 0K-0251 Heid Martinez 31021-1760599-9 Inerifetray@gmail.com +92 140075934 44 2.41 99995 99K-9914 David Kramer 81275-4873758-3 lylerbowen@gmail.com +92 1250026904 59 3.56 3.56 30K-0291 Dwayne Larsen 43707-2866819-3 brian72@gmail.com +92 6287923428 52 2.83 99997 99K-9912 Driven Ballery 48450-4025687-3 wwoodward@gmail.com +92 1250026904 59 3.56 0K-0304 Nov.0304 Final Properties of the Properties of th	29 00K-0235	Elizabeth	Gonzalez	90342-8874515-6	nandersen@gmail.com	+92 6745906447	20	2.46	99992	99K-9869	Kelli	Jackson	55240-7060361-9	melindamason@gmail.com	+92 8744666750	92	2.59
32 OK-0261 Held Martinez 31021-176059-9 jenniferbray@gmail.com +92 1540675944 44 2.41 99995 99K-9914 David Kramer 81275-4873758-3 [ylerboxen@gmail.com +92 120026094 59 3.56 40K-0291 Dwayne Larsen 4707-2866819-3 brian72@gmail.com +92 26792328 40 3.85 99997 99K-9912 Eric Bailey 48450-4025867-3 anasomorphism +92 120026094 59 3.56 3.50 40K-0291 Dwayne Larsen 4707-2866819-3 brian72@gmail.com +92 687923428 35 0K-0304 Sarah Romero 85235-7227591-9 taylormartin@gmail.com +92 8218198603 112 3.52 99998 99K-9932 Angela Wong 35632-6767246-3 qyasquez@gmail.com +92 4987183790 45 3.2 99996 Holly Trujillo 29020-3197771-6 taylortararegmail.com +92 8385278675 43 3.38 100000 99K-998 kevin Allen 53006-4313585-0 pricevalerie@gmail.com +92 0389600267 60 3.25 80 0K-0304 Michelle Carlson 35348-0808223-5 qclark@gmail.com +92 3466038723 90 3.15 100000 99K-998 kyle Rice S3801-0000417-5 hartmanlesile@gmail.com +92 299674988 90 2.88	30 00K-0243	William	Flores	32268-2485729-9	guyhouston@gmail.com	+92 9212955147	63	3.6	99993	99K-9893	Wendy	Lewis	24420-2787036-4	thomasshaw@gmail.com	+92 7896946774	130	3.91
33 OK-0289 Kenneth Odom 19785-9379406-8 gregorysantos@gmail.com +92 1124755323 40 3.85 99996 99K-9919 Christine Ballard 45042-5611618-2 ana58@gmail.com +92 1200026094 59 3.56 34 OK-0291 Dwayne Larsen 43707-2866819-3 brian72@gmail.com +92 6287923428 35 2.83 99997 99K-9922 Eric Balley 48450-4025687-3 www.odward/@gmail.com +92 297183790 45 3.25 0K-0304 Sarah Romero 85235-727279-19 taylormatrin@gmail.com +92 233676311 119 2.3 99999 99K-9974 Deanna Jones 50041-0470477-4 stanleydeborah@gmail.com +92 0673782651 102 3.15 37 OK-0310 Debra Snyder 62140-1679477-1 mary22@gmail.com +92 3885278676 43 3.38 100000 99K-998 Kevin Allen 53006-4313585-0 pricevalerie@gmail.com +92 0389600267 60 3.25 38 0K-0314 Michelle Carlson 35348-0808223-5 qclark@gmail.com +92 3466038723 90 3.15 100001 99K-9987 Kyle Rice 53801-0030417-5 hartmanleslie@gmail.com +92 2996749988 90 2.88	31 00K-0255	Mikayla	Moss	73024-6856279-5	katrinasanchez@gmail.com	+92 4932793636	77	3.84	99994	99K-9895	Christina	Hood	61510-2304262-4	griffithbenjamin@gmail.com	+92 4480369048	66	3.12
34         OK-0291         Dwayne         Larsen         43707-2866819-3         brian72@gmail.com         +92 6287923428         35         2.83         99997         99K-9932         Eric         Balley         48450-4025687-3         owoodward@gmail.com         +92 4697183700         45         3.2           35 0K-0304         Sarah         Romero         85235-727519-19         studylormartin@gmail.com         +92 2818198603         112         3.52         99999         99K-9933         Angela         Womp         35632-6767246-3         qvasquez@gmail.com         +92 3014876414         107         35.5333676311         119         2.3         99999         99K-9933         Deanna         Jones         500K-01-0470477-4         Stanleydeborah@gmail.com         +92 0673782551         102         3.15           36 0K-0314         Michelle         Carlson         3548-0808223-5         G2140-1679477-1         mary2@gmail.com         +92 3466038723         90         3.15         100001         99K-9997         Kyle         Rice         53801-0030417-5         partural realler@gmail.com         +92 2996749988         90         2.88	32 00K-0261	Heidi	Martinez	31021-1760599-9	jenniferbray@gmail.com	+92 5140675944	44	2.41	99995	99K-9914	David	Kramer	81275-4873758-3	tylerbowen@gmail.com	+92 1254141033	72	2.74
55 OK-0304   Sarah   Romero   85238-7227591-9   taylormartin@gmail.com   492 8218198603   112   3.52   99998   99K-9993   Angela   Wong   3632-6767246-3 (yasquae/a@mail.com   492 3233657656311   119   2.3   99999   99K-9994   Deanna   Jones   50041-0470477-4   stanleydeborah@gmail.com   492 66737826551   102   3.15   37 OK-0313   Debra   Sryder   62140-1679477-1   mary/22/gmail.com   492 3885278676   43   3.38   100000   99K-9988   Kevin   Allen   S006-4313885-0   pricevalerie@gmail.com   492 0886600267   60   3.25   38   OK-0314   Michelle   Carlson   35348-0808223-5   qclark@gmail.com   492 3486038723   90   3.15   100000   99K-9987   Kyle   Rice   53801-0030417-5   hartmartiesle@gmail.com   492 2996749988   90   2.88	33 00K-0289	Kenneth	Odom	19785-9379406-8	gregorysantos@gmail.com	+92 1124755323	40	3.85	99996	99K-9919	Christine	Ballard	45042-5611618-2	ana58@gmail.com	+92 1200026094	59	3.56
36 OK-0306 Holty Trujillo 2920:3197771-6 taylortara@gmail.com +92 3233676311 119 2.3 99999 99K-9974 Deanna Jones 50041-0470477-4 stanleydeborah@gmail.com +92 0673782651 102 3.15 37 OK-0313 Debra Snyder 62140-1679477-1 mary22@gmail.com +92 3865278676 43 3.38 100000 99K-998 Kevin Alien 53006-4313585-0 pricevalerie@gmail.com +92 0389600267 60 3.25 38 OK-0314 Michelle Carlson 35348-0808223-5 qclark@gmail.com +92 3466038723 90 3.15 100001 99K-9997 Kyle Rice 53801-0030417-5 hartmanleslie@gmail.com +92 2996749988 90 2.88	34 00K-0291	Dwayne	Larsen	43707-2866819-3	brian72@gmail.com	+92 6287923428	35	2.83	99997	99K-9922	Eric	Bailey	48450-4025687-3	owoodward@gmail.com	+92 4697183790	45	
37 OK-0313 Debra         Snyder         62140-1679477-1 mary22@gmall.com         +92 3895278676         43         3.38         100000 99K-9988 Kevin         Allen         53006-4313585-0 pricevalerie@gmall.com         +92 0389500267         60         3.25           38 OK-0314 Michelle         Carlson         35348-0808223-5 qclark@gmail.com         +92 3466033723         90         3.15         100001 99K-9997         Kyle         Rice         53801-0030417-5 hartmanlesile@gmail.com         +92 2996749988         90         2.88	35 00K-0304	Sarah	Romero	85235-7227591-9	taylormartin@gmail.com	+92 8218198603	112	3.52	99998	99K-9933	Angela	Wong	35632-6767246-3	qvasquez@gmail.com	+92 3014876414	107	3.55
37 OK-0313 Debra         Sryder         62140-1679477-1 mary22@gmail.com         +92 3895278676         43 3.38         100000 99K-9988 Kevin         Klein         Allen         53006-4313585-0 pricevalerie@gmail.com         +92 0389600267         60 3.25           38 OK-0314 Michelle         Carlson         35348-0808223-5 qclark@gmail.com         +92 3466038723         90 3.15         100001 99K-9997         Kyle         Rice         53801-0030417-5 hartmanleslie@gmail.com         +92 2996749988         90 2.88	36 00K-0306	Holly	Trujillo	29202-3197771-6	taylortara@gmail.com	+92 3233676311	119	2.3	99999	99K-9974	Deanna	Jones	50041-0470477-4	stanleydeborah@gmail.com	+92 0673782651	102	3.15
38 0K-0314 Michelle Carlson 35348-0808223-5 qclark@gmail.com +92 3466038723 90 3.15 100001 99K-9997 Kyle Rice 53801-0030417-5 hartmanleslie@gmail.com +92 2996749988 90 2.88	37 00K-0313	Debra				+92 3885278676	43	3.38	100000	99K-9988	Kevin	Allen	53006-4313585-0	pricevalerie@gmail.com	+92 0389600267	60	3.25
	38 00K-0314	Michelle	Carlson	35348-0808223-5	qclark@gmail.com	+92 3466038723	90	3.15	100001	99K-9997	Kyle	Rice	53801-0030417-5	hartmanleslie@gmail.com	+92 2996749988	90	2.88
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# **Dataset after sorting in parallel**(start and end of sorted file shown, please zoom in to see clearly):

										1	_					
1 Student ID			CNIC	Email	Phone Number	or count i recure	CGPA	99964	99K-9676	Cindy	Reed		qsnyder@gmail.com	+92 5865685608	37	3.43
		Curtis		loriballard@gmail.com	+92 3267714395	92	3.23	99965	99K-9682	Danielle	Bryant		matthewadams@gmail.com	+92 7810597692	70	3.72
3 00K-0018	Joanna			charles76@gmail.com	+92 6913000575	56	3.77	99966	99K-9683	Christopher	Wilson		wkelley@gmail.com	+92 4141731119	69	2.37
	Christian	Barker	53821-0252968-7	kaitlynkim@gmail.com	+92 2501995935	118	3.61	99967	99K-9687	Ronald	Cameron		esilva@gmail.com	+92 9718337697	87	3.2
5 00K-0026	Jennifer	Roberts		qlang@gmail.com	+92 8318694854	109	3.84	99968	99K-9691	John	Smith		haley37@gmail.com	+92 8094893429	68	3.71
		Gomez		powersheather@gmail.com	+92 2558579456	70	2.51	99969	99K-9695	Heather	Reilly		gcooper@gmail.com	+92 5774207020	47	3.57
	Sarah			rayryan@gmail.com	+92 6053638040	39	3.1	99970	99K-9697	Carla	Carter		terrygarcia@gmail.com	+92 7726364671	124	3.71
	Edward	Thomas	17571-4164701-0	morrowkevin@gmail.com	+92 7011578446	65	3.11	99971	99K-9701	Christina	Curtis		paulporter@gmail.com	+92 7438690253	72	3.2
9 00K-0053	Alexis			james55@gmail.com	+92 7888298849	103	3.19	99972	99K-9724	Mary	Suarez		steven16@gmail.com	+92 3578810326	129	2
10 00K-0068	Nicholas	Frost	70498-7015299-7	andradeaustin@gmail.com	+92 9042444576	44	2.83	99973	99K-9725	Gary	Wong		benjamin62@gmail.com	+92 9020724251	34	3.69
11 00K-0076	Timothy	Norris	96025-8464314-1	daniel81@gmail.com	+92 2883077758	104	3.95	99974	99K-9731	Cody	Adams		kelleywilliam@gmail.com	+92 1810067571	108	2.62
12 00K-0082	Kathryn	Evans	10117-6854597-0	mbowman@gmail.com	+92 0045469336	111	3.1	99975	99K-9741	Lisa	Martinez		christine32@gmail.com	+92 8222255468	58	2.69
13 00K-0084	Robert	Bauer	69210-3004788-3	robert62@gmail.com	+92 0065934087	72	3.67	99976	99K-9743	Jeffery	Pham		xryan@gmail.com	+92 4087230892	35	3.3
14 00K-0088	Cheryl	Ortiz	21023-2992469-6	brian20@gmail.com	+92 4728906086	53	3.96	99977	99K-9753	Jamie	Moreno		vanessalynch@gmail.com	+92 5039227250	57	2.3
15 00K-0090	Donald	Delacruz	67967-2597381-5	hlopez@gmail.com	+92 6644873987	57	2.98	99978	99K-9763	Jennifer	Odom	26668-9482039-4	stevenwilliams@gmail.com	+92 6058959793	45	3.49
16 00K-0124	Nicole	Shannon	86090-1932288-1	tfritz@gmail.com	+92 2138375934	72	3.34	99979	99K-9765	Gregory	Jacobson	88329-0558109-5	kevin64@gmail.com	+92 3763510274	66	3.27
17 00K-0129	Jennifer	Wilcox	81511-9575060-9	littledavid@gmail.com	+92 0922292379	47	2.22	99980	99K-9767	Adriana	Salazar		jamesclark@gmail.com	+92 9116620205	68	3.93
18 00K-0131	Angela	Henry	89505-3755552-4	sharonrivera@gmail.com	+92 3465302006	93	3.53	99981	99K-9769	James	Watson	24491-0790700-6	richardlutz@gmail.com	+92 3420556084	59	2.8
19 00K-0147	Frank	Francis	29169-6945381-3	michelle64@gmail.com	+92 6118269913	107	2.33	99982	99K-9773	John	Baker		jamesbarnes@gmail.com	+92 1481674673	104	2.25
20 00K-0150	Connor	Watts	83591-3827040-4	carolyn56@gmail.com	+92 7829957175	100	2.53	99983	99K-9774	Michael	Alexander	12668-3042965-2	amyfowler@gmail.com	+92 0285071489	113	3.32
21 00K-0159	Paige	Robinson	98058-3897689-9	april16@gmail.com	+92 2637699708	73	3.24	99984	99K-9776	Cody	Lopez	64602-2036425-2	charles16@gmail.com	+92 3189562692	50	3.48
22 00K-0161	Melanie	Smith	20134-4696525-8	geraldjones@gmail.com	+92 7596748739	92	2.76	99985	99K-9780	Stephen	Malone		gallen@gmail.com	+92 9259598714	55	3.28
23 00K-0176	Richard	Graves	94655-5815755-3	hughesmarilyn@gmail.com	+92 7669222242	83	3.73	99986	99K-9808	Gina	Lynch	26207-8728177-2	jacobstevens@gmail.com	+92 3099452670	66	3.65
24 00K-0177	Daniel	Garcia	16344-2129803-4	marysawyer@gmail.com	+92 4886381164	37	2.39	99987	99K-9810	Courtney	Santiago	65390-6388702-2	pcarroll@gmail.com	+92 7199193501	50	2.86
25 00K-0215	Manuel	Green	72962-6437054-5	jimmy45@gmail.com	+92 1384405038	25	3.83	99988	99K-9816	Brittany	Huang		christina35@gmail.com	+92 5970606250	77	3.87
26 00K-0221	Kimberly	Lewis	73072-1083774-5	christopher76@gmail.com	+92 6921031254	87	2.45	99989	99K-9827	Kerry	Campbell	69554-0524351-7	nicholasquinn@gmail.com	+92 1645505353	101	3.2
27 00K-0232	Allison	Cole	84071-3130022-3	masondonald@gmail.com	+92 8781486008	61	3.34	99990	99K-9839	Julie	Joseph		wadams@gmail.com	+92 7646313615	35	2
28 00K-0233	Carla	Russell	61911-6860983-3	jessica92@gmail.com	+92 7354737153	119	3.82	99991	99K-9867	Corey	Welch	16337-2393050-2	amanda97@gmail.com	+92 9892988779	48	2.55
	Elizabeth	Gonzalez	90342-8874515-6	nandersen@gmail.com	+92 6745906447	20	2.46	99992	99K-9869	Kelli	Jackson		melindamason@gmail.com	+92 8744666750	92	2.59
30 00K-0243	William	Flores	32268-2485729-9	guyhouston@gmail.com	+92 9212955147	63	3.6	99993	99K-9893	Wendy	Lewis		thomasshaw@gmail.com	+92 7896946774	130	3.91
	Mikayla	Moss	73024-6856279-5	katrinasanchez@gmail.com	+92 4932793636	77	3.84	99994	99K-9895	Christina	Hood		griffithbenjamin@gmail.com	+92 4480369048	66	3.12
32 00K-0261	Heidi	Martinez	31021-1760599-9	jenniferbray@gmail.com	+92 5140675944	44	2.41	99995	99K-9914	David	Kramer		tylerbowen@gmail.com	+92 1254141033	72	2.74
33 00K-0289	Kenneth	Odom	19785-9379406-8	gregorysantos@gmail.com	+92 1124755323	40	3.85	99996	99K-9919	Christine	Ballard	45042-5611618-2	ana58@gmail.com	+92 1200026094	59	3.56
	Dwayne	Larsen	43707-2866819-3	brian72@gmail.com	+92 6287923428	35	2.83	99997	99K-9922	Eric	Bailey		owoodward@gmail.com	+92 4697183790	45	3.2
35 00K-0304	Sarah	Romero	85235-7227591-9	taylormartin@gmail.com	+92 8218198603	112	3.52	99998	99K-9933	Angela	Wong		qvasquez@gmail.com	+92 3014876414	107	3.55
36 00K-0306	Holly	Trujillo	29202-3197771-6	taylortara@gmail.com	+92 3233676311	119	2.3	99999	99K-9974	Deanna	Jones	50041-0470477-4	stanleydeborah@gmail.com	+92 0673782651	102	3.15
37 00K-0313	Debra	Snyder	62140-1679477-1	mary22@gmail.com	+92 3885278676	43	3.38	100000	99K-9988	Kevin	Allen	53006-4313585-0	pricevalerie@gmail.com	+92 0389600267	60	3.25
	Michelle			qclark@gmail.com	+92 3466038723	90	3.15		99K-9997	Kyle	Rice	53801-0030417-5	hartmanleslie@gmail.com	+92 2996749988	90	2.88
			00750 0110101 0	<u> </u>	00.0005005404	0.0		*****								
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#### Thread log created after sorting in parallel:

```
parallel > 🖹 threadlog.txt
         Thread 2 took 0.000001s to merge the chunk from index 0 to 6 of size 7
         Thread 2 took 0.000001s to merge the chunk from index 0 to 12 of size 13
        Thread 2 took 0.000001s to merge the chunk from index 0 to 24 of size 25
        Thread 2 took 0.000003s to merge the chunk from index 0 to 48 of size 49
        Thread 2 took 0.000005s to merge the chunk from index 0 to 97 of size 98
         Thread 2 took 0.000010s to merge the chunk from index 0 to 195 of size 196
        Thread 2 took 0.000020s to merge the chunk from index 0 to 390 of size 391
        Thread 1 took 0.000330s to merge the chunk from index 6250 to 12499 of size 6250
        Thread 2 took 0.000039s to merge the chunk from index 0 to 781 of size 782
        Thread 2 took 0.000078s to merge the chunk from index 0 to 1562 of size 1563
        Thread 2 took 0.000156s to merge the chunk from index 0 to 3124 of size 3125
        Thread 2 took 0.000311s to merge the chunk from index 0 to 6249 of size 6250
        Thread 1 took 0.000681s to merge the chunk from index 0 to 12499 of size 12500
        Thread 1 took 0.001385s to merge the chunk from index 0 to 24999 of size 25000
        Thread 3 took 0.002838s to merge the chunk from index 0 to 49999 of size 50000
        Thread 0 took 0.005893s to merge the chunk from index 0 to 99999 of size 100000
```

### Conclusion

The results above(specifically the graph) lead us to conclude that as the size of the dataset (Number of Records in the dataset) increases, the benefits of parallel programming become more visible and apparent since the runtime of the parallel application rised slowly compared to that of the serial application. Especially in this era of "Big Data", where the size of data available and required to be processed is rapidly increasing, it would be highly beneficial to parallelize sorting, since it's such an essential subprocess in many processes, so more time can be spent on actually using this data then it is spent processing it.