

Database HW3 report

2.1.1

Reference : <https://segmentfault.com/a/1190000008131735>

我的 7.sql

```
mysql> source 7.sql
ERROR:
Failed to open file '7.sql', error: 2
mysql> source brian/7.sql
+-----+-----+-----+
| position | champion_name | max_kda |
+-----+-----+-----+
| DUO_CARRY | Shaco          | 19.0000 |
| DUO_SUPPORT | Janna          | 3.8330 |
| JUNGLE     | Ivern          | 3.8764 |
| MID        | Ivern          | 3.7015 |
| TOP        | Sona           | 3.1538 |
+-----+-----+-----+
5 rows in set, 104 warnings (23.31 sec)

mysql> source brian/7.sql
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| id | select_type | table | partitions | type | possible_keys | key | key_len | ref | rows | filtered | Extra |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| 1 | PRIMARY | <derived4> | NULL | ALL | NULL | NULL | NULL | NULL | 1817575 | 100.00 | Using where; Using temporary; Using filesort |
| 1 | PRIMARY | C | NULL | eq_ref | PRIMARY | PRIMARY | 4 | new3_t.champion_id | 1 | 100.00 | NULL |
| 1 | PRIMARY | <derived2> | NULL | ref | <auto_key0> | <auto_key0> | 15 | new3_t.kda | 10 | 100.00 | NULL |
| 4 | DERIVED | P | NULL | ALL | PRIMARY | NULL | NULL | NULL | 1817575 | 100.00 | Using temporary; Using filesort |
| 4 | DERIVED | S | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.p.player_id | 1 | 100.00 | NULL |
| 2 | DERIVED | <derived3> | NULL | ALL | NULL | NULL | NULL | NULL | 1817575 | 72.90 | Using where; Using temporary; Using filesort |
| 3 | DERIVED | P | NULL | ALL | PRIMARY | NULL | NULL | NULL | 1817575 | 100.00 | Using temporary; Using filesort |
| 3 | DERIVED | S | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.p.player_id | 1 | 100.00 | NULL |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
5 rows in set, 1 warning (0.00 sec)
```

Karl 7.sql

```
mysql> source karl/7.sql
+-----+-----+-----+
| position | champion_name | kda |
+-----+-----+-----+
| DUO_CARRY | Shaco          | 19.0000 |
| DUO_SUPPORT | Janna          | 3.8330 |
| JUNGLE     | Ivern          | 3.8764 |
| MID        | Ivern          | 3.7015 |
| TOP        | Sona           | 3.1538 |
+-----+-----+-----+
5 rows in set (26.36 sec)

mysql> source karl/7.sql
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| id | select_type | table | partitions | type | possible_keys | key | key_len | ref | rows | filtered | Extra |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| 1 | PRIMARY | <derived2> | NULL | ALL | NULL | NULL | NULL | NULL | 744315 | 100.00 | Using where; Using filesort |
| 1 | PRIMARY | <derived> | NULL | ref | <auto_key0> | <auto_key0> | 30 | grp.position.grp.sum_kda | 10 | 100.00 | Using index |
| 5 | DERIVED | <derived> | NULL | ALL | NULL | NULL | NULL | NULL | 744315 | 100.00 | Using temporary; Using filesort |
| 7 | DERIVED | par | NULL | ALL | PRIMARY | NULL | NULL | NULL | 1817575 | 40.95 | Using where; Using temporary; Using filesort |
| 7 | DERIVED | champ | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.par.champion_id | 1 | 100.00 | NULL |
| 7 | DERIVED | stat | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.par.player_id | 1 | 100.00 | NULL |
| 2 | DERIVED | par | NULL | ALL | PRIMARY | NULL | NULL | NULL | 1817575 | 40.95 | Using where; Using temporary; Using filesort |
| 2 | DERIVED | champ | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.par.champion_id | 1 | 100.00 | NULL |
| 2 | DERIVED | stat | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.par.player_id | 1 | 100.00 | NULL |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
9 rows in set, 1 warning (0.00 sec)
```

Yao 7.sql

```
mysql> source yao/7.sql
+-----+-----+-----+
| position | champion_name | kda |
+-----+-----+-----+
| DUO_CARRY | Shaco          | 19.0000 |
| DUO_SUPPORT | Janna          | 3.8330 |
| JUNGLE     | Ivern          | 3.8764 |
| MID        | Ivern          | 3.7015 |
| TOP        | Sona           | 3.1538 |
+-----+-----+-----+
5 rows in set (11.50 sec)

mysql> source yao/7.sql
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| id | select_type | table | partitions | type | possible_keys | key | key_len | ref | rows | filtered | Extra |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| 1 | PRIMARY | <derived2> | NULL | ALL | NULL | NULL | NULL | NULL | 1192510 | 90.00 | Using where; Using temporary; Using filesort |
| 1 | PRIMARY | C | NULL | eq_ref | PRIMARY | PRIMARY | 4 | info.champion_id | 1 | 100.00 | NULL |
| 2 | DERIVED | P | NULL | ALL | PRIMARY | NULL | NULL | NULL | 1817575 | 65.41 | Using where; Using temporary; Using filesort |
| 2 | DERIVED | S | NULL | eq_ref | PRIMARY | PRIMARY | 4 | hw1.p.player_id | 1 | 100.00 | NULL |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
4 rows in set, 1 warning (0.00 sec)
```

我的跟 karl 助教的 explain 差異不大 但我只用 8 個 select 而 karl 助教用 9 個 select。

Yao 助教則是只用了 4 個 select 完成。

Type 性能比較: ALL < index < range ~ index_merge < ref < eq_ref < const < system

從上面可以知道，用越多 ALL type 會越慢。

並且在 extra 用到 Using temporary,using filesort 也很耗時

還有如果 **filter** 比例越低 這個 **select** 規模越小越快。

以上決定了 yao 的 query 效率較高。

2.1.2

我的 optimizer_trace:

首先先看時間

```
mysql> source brian/6.sql
+-----+-----+
| position | champion_name |
+-----+-----+
| DUO_CARRY | Caitlyn       |
| DUO_SUPPORT | Thresh       |
| JUNGLE     | Lee Sin      |
| MID        | Ahri         |
| TOP        | Riven        |
+-----+-----+
5 rows in set (15.45 sec)
```

然後把 `optimizer_trace` 的 json 打開發現有點長，所以複製到 mac OS 存成 json 檔再用 VScode 開啟，然後因為要符合直立式螢幕，所以有些行我手動縮排。

1. *Journal of the American Medical Association*, 1997; 277: 1001-1005.

無意義的行數我先不複製

這些都弄好後，json 如下

```

1 select T1.position,C.champion_name
2 from(
3     select t1.position,max(t1.cnt) as max_cnt
4     from(select P.position,P.champion_id,count(*) cnt
5          from participant as P, match_info as M
6          where M.duration between 2400 and 3000 and P.match_id=M.match_id
7          group by P.position ,P.champion_id
8          order by cnt desc
9     )as t1
10    group by t1.position
11 )as T1,
12 (
13     select P.position,P.champion_id,count(*) cnt
14     from participant as P, match_info as M
15     where M.duration between 2400 and 3000 and P.match_id=M.match_id
16     group by P.position ,P.champion_id
17     order by cnt desc
18 )as T2,
19 champ as C
20 where T1.position=T2.position and T1.max_cnt=T2.cnt and C.champion_id=T2.champion_id and T1.position != "DUO"
21        and T1.position != "SOLO" and T1.position != "NONE"
22 order by T1.position | {
23     "steps": [
24         {
25             "join_preparation": {
26                 "select#": 1,
27                 "steps": [
28                     {
29                         "join_preparation": {
30                             "select#": 2,
31                             "steps": [
32                                 {
33                                     "join_preparation": {
34                                         "select#": 3,
35                                         "steps": [
36                                             {
37                                                 "expanded_query":
38                                                 /* select#3 */
39                                                 select 'P`.`position` AS `position`,
40                                                         'P`.`champion_id` AS `champion_id`,count(0) AS `cnt`
41                                                         from `participant` `P` join `match_info` `M`
42                                                         where (('M`.`duration` between 2400 and 3000)
43                                                                and ('P`.`match_id` = `M`.`match_id`))
44                                                         group by 'P`.`position`,`P`.`champion_id` order by `cnt` desc"
45                                             }
46                                         ]
47                                     },
48                                 },
49                             {
50                                 "derived": {
51                                     "table": " `t1`",
52                                     "select#": 3,
53                                     "materialized": true
54                                 }
55                             },
56                             {
57                                 "expanded_query": "/* select#2 */
58                                                         select `t1`.`position` AS `position`,max(`t1`.`cnt`) AS `max_cnt`
59                                                         from (
60                                                             /* select#3 */
61                                                             select 'P`.`position` AS `position`,`P`.`champion_id` AS `champion_id`,count(0) AS `cnt`
62                                                             from `participant` `P` join `match_info` `M`
63                                                             where (('M`.`duration` between 2400 and 3000) and ('P`.`match_id` = `M`.`match_id`))
64                                                             group by 'P`.`position`,`P`.`champion_id` order by `cnt` desc) `t1`
65                                                             group by `t1`.`position`"
66                                 }
67                             ]
68                         },
69                     },
70                 {
71                     "join_preparation": {
72                         "select#": 4,
73                         "steps": [
74                             {
75                                 "expanded_query": "/* select#4 */
76                                                         select 'P`.`position` AS `position`,`P`.`champion_id` AS `champion_id`,count(0) AS `cnt`
77                                                         from `participant` `P` join `match_info` `M`
78                                                         where (('M`.`duration` between 2400 and 3000)
79                                                                and ('P`.`match_id` = `M`.`match_id`)) group by 'P`.`position`,`P`.`champion_id`
80                                                         order by `cnt` desc"
81                             }
82                         ]
83                     },
84                 },
85                 {
86                     "derived": {
87                         "table": " `T1`",
88                         "select#": 2,
89                         "materialized": true
90                     }
91                 },
92                 {
93                     "derived": {
94                         "table": " `T2`",
95                         "select#": 4,
96                         "materialized": true
97                     }
98                 },
99                 {
100                     "expanded_query":

```

```

101 expanded_query:
102     /* select#1 */
103     select 'T1'.position AS 'position', 'C'.champion_name AS 'champion_name'
104     from (
105         /* select#2 */
106         select 't1'.position AS 'position', max('t1'.cnt) AS 'max_cnt'
107         from (
108             /* select#3 */
109             select 'P'.position AS 'position', 'P'.champion_id AS 'champion_id', count(0) AS 'cnt'
110             from 'participant' 'P' join 'match_info' 'M'
111             where (('M'.duration` between 2400 and 3000)
112                   and ('P'.match_id` = 'M'.match_id'))
113             group by 'P'.position, 'P'.champion_id
114             order by `cnt` desc) `t1`
115         group by `t1`.position) `T1`
116
117         join (
118             /* select#4 */
119             select 'P'.position AS 'position', 'P'.champion_id AS 'champion_id', count(0) AS 'cnt'
120             from 'participant' 'P' join 'match_info' 'M'
121             where (('M'.duration` between 2400 and 3000) and ('P'.match_id` = 'M'.match_id'))
122             group by 'P'.position, 'P'.champion_id order by `cnt` desc) `T2` join 'champ' `C`
123             where (('T1'.position` = 'T2'.position')
124                   and ('T1'.max_cnt` = 'T2'.cnt')
125                   and ('C'.champion_id` = 'T2'.champion_id')
126                   and ('T1'.position` <> 'DUO')
127                   and ('T1'.position` <> 'SOLO')
128                   and ('T1'.position` <> 'NONE'))
129             order by 'T1'.position"
130     )
131 }
132 },
133 {
134     "join_optimization": {
135         "select#": 1,
136         "steps": [
137             {
138                 "join_optimization": {
139                     "select#": 2,
140                     "steps": [
141                         {
142                             "join_optimization": {
143                                 "select#": 3,
144                                 "steps": [
145                                     {
146                                         "condition_processing": {
147                                             "condition": "WHERE",
148                                             "original_condition": "((('M'.duration` between 2400 and 3000)
149                                                                 and ('P'.match_id` = 'M'.match_id'))",
150                                             "steps": [
151                                                 {
152                                                     "transformation": "equality_propagation",
153                                                     "resulting_condition": "((('M'.duration` between 2400 and 3000)
154                                                                 and multiple equal('P'.match_id`, 'M'.match_id'))"
155                                                 },
156                                                 {
157                                                     "transformation": "constant_propagation",
158                                                     "resulting_condition": "((('M'.duration` between 2400 and 3000)
159                                                                 and multiple equal('P'.match_id`, 'M'.match_id'))"
160                                                 },
161                                                 {
162                                                     "transformation": "trivial_condition_removal",
163                                                     "resulting_condition": "((('M'.duration` between 2400 and 3000)
164                                                                 and multiple equal('P'.match_id`, 'M'.match_id'))"
165                                                 }
166                                             ]
167                                         },
168                                     },
169                                 ],
170                             "substitute_generated_columns": {
171                                 {
172                                 },
173                             },
174                             "table_dependencies": [
175                                 {
176                                     "table": "'participant' `P`",
177                                     "row_may_be_null": false,
178                                     "map_bit": 0,
179                                     "depends_on_map_bits": [
180                                     ]
181                                 },
182                                 {
183                                     "table": "'match_info' `M`",
184                                     "row_may_be_null": false,
185                                     "map_bit": 1,
186                                     "depends_on_map_bits": [
187                                     ]
188                                 }
189                             ]
190                         },
191                     ],
192                 },
193                 "ref_optimizer_key_uses": [
194                     {
195                         "table": "'participant' `P`",
196                         "field": "match_id",
197                         "equals": "'M'.match_id",
198                         "null_rejecting": false
199                     },
200                     {
201                         "table": "'match_info' `M`",

```

```

201         "field": "match_id",
202         "equals": "`P`.`match_id`",
203         "null_rejecting": false
204     }
205 }
206 },
207 {
208     "rows_estimation": [
209     {
210         "table": "`participant` `P`",
211         "table_scan": {
212             "rows": 1817575,
213             "cost": 6376
214         }
215     },
216     {
217         "table": "`match_info` `M`",
218         "table_scan": {
219             "rows": 182186,
220             "cost": 545
221         }
222     }
223 ]
224 },
225 {
226     "considered_execution_plans": [
227     {
228         "plan_prefix": [
229         ],
230         "table": "`match_info` `M`",
231         "best_access_path": {
232             "considered_access_paths": [
233             {
234                 "access_type": "ref",
235                 "index": "PRIMARY",
236                 "usable": false,
237                 "chosen": false
238             },
239             {
240                 "rows_to_scan": 182186,
241                 "access_type": "scan",
242                 "resulting_rows": 20241,
243                 "cost": 36982,
244                 "chosen": true
245             }
246         ]
247     },
248     "condition_filtering_pct": 100,
249     "rows_for_plan": 20241,
250     "cost_for_plan": 36982,
251     "rest_of_plan": [
252     {
253         "plan_prefix": [
254             "`match_info` `M`"
255         ],
256         "table": "`participant` `P`",
257         "best_access_path": {
258             "considered_access_paths": [
259             {
260                 "access_type": "ref",
261                 "index": "match_id",
262                 "rows": 9.953,
263                 "cost": 241750,
264                 "chosen": true
265             },
266             {
267                 "rows_to_scan": 1817575,
268                 "access_type": "scan",
269                 "using_join_cache": true,
270                 "buffers_needed": 1,
271                 "resulting_rows": 1.82e6,
272                 "cost": 7.36e9,
273                 "chosen": false
274             }
275         ]
276     },
277     "condition_filtering_pct": 100,
278     "rows_for_plan": 201458,
279     "cost_for_plan": 278732,
280     "chosen": true
281     }
282 ]
283 },
284 {
285     "plan_prefix": [
286     ],
287     "table": "`participant` `P`",
288     "best_access_path": {
289         "considered_access_paths": [
290         {
291             "access_type": "ref",
292             "index": "match_id",
293             "usable": false,
294             "chosen": false
295         },
296         {
297             "rows_to_scan": 1817575,
298             "access_type": "scan",
299             "resulting_rows": 1.82e6,
300             "cost": 369891,

```

```

301         "chosen": true
302     }
303 }
304 },
305 "condition_filtering_pct": 100,
306 "rows_for_plan": 1.82e6,
307 "cost_for_plan": 369891,
308 "pruned_by_cost": true
309 }
310 ]
311 },
312 {
313     "attaching_conditions_to_tables": [
314         "original_condition": "({'P`.`match_id` = `M`.`match_id`
315                                and ('M`.`duration` between 2400 and 3000))",
316         "attached_conditions_computation": [
317         ],
318         "attached_conditions_summary": [
319             {
320                 "table": "`match_info` `M`",
321                 "attached": "(`M`.`duration` between 2400 and 3000)"
322             },
323             {
324                 "table": "`participant` `P`",
325                 "attached": null
326             }
327         ]
328     ],
329     {
330     },
331     {
332         "clause_processing": {
333             "clause": "ORDER BY",
334             "original_clause": "`cnt` desc",
335             "items": [
336                 {
337                     "item": "count(0)"
338                 }
339             ],
340             "resulting_clause_is_simple": false,
341             "resulting_clause": "`cnt` desc"
342         },
343     },
344     {
345         "clause_processing": {
346             "clause": "GROUP BY",
347             "original_clause": "`P`.`position`, `P`.`champion_id`",
348             "items": [
349                 {
350                     "item": "`P`.`position`"
351                 },
352                 {
353                     "item": "`P`.`champion_id`"
354                 }
355             ],
356             "resulting_clause_is_simple": false,
357             "resulting_clause": "`P`.`position`, `P`.`champion_id`"
358         },
359     },
360     {
361         "refine_plan": [
362             {
363                 "table": "`match_info` `M`"
364             },
365             {
366                 "table": "`participant` `P`"
367             }
368         ]
369     }
370 ],
371 },
372 {
373     "substitute_generated_columns": {
374     },
375 },
376 {
377     "table_dependencies": [
378         {
379             "table": "`t1`",
380             "row_may_be_null": false,
381             "map_bit": 0,
382             "depends_on_map_bits": [
383             ]
384         }
385     ],
386 },
387 {
388     "rows_estimation": [
389         {
390             "table": "`t1`",
391             "table_scan": {
392                 "rows": 201458,
393                 "cost": 10082
394             }
395         }
396     ],
397 },
398 {
399     "considered_execution_plans": [
400     {

```

```

401     "plan_prefix": [
402     ],
403     "table": " `t1` ",
404     "best_access_path": {
405         "considered_access_paths": [
406             {
407                 "rows_to_scan": 201458,
408                 "access_type": "scan",
409                 "resulting_rows": 201458,
410                 "cost": 50375,
411                 "chosen": true,
412                 "use_tmp_table": true
413             }
414         ]
415     },
416     "condition_filtering_pct": 100,
417     "rows_for_plan": 201458,
418     "cost_for_plan": 50375,
419     "sort_cost": 201458,
420     "new_cost_for_plan": 251832,
421     "chosen": true
422 }
423 ],
424 },
425 {
426     "attaching_conditions_to_tables |
427
428

```

可以看到一個 select 下面還有 subselect，並且 select #4,5,8,9 各重複兩次，這就是造成時間為 17sec 的原因

karl:

助教的 json 看起來很短

先來看看執行時間

```

mysql> source karl/6.sql
+-----+-----+
| position | champion_name |
+-----+-----+
| DUO_CARRY | Caitlyn |
| DUO_SUPPORT | Thresh |
| JUNGLE | Lee Sin |
| MID | Ahri |
| TOP | Riven |
+-----+-----+
5 rows in set (15.46 sec)

```

Json:

```

1  || explain
2  select final.position, champ.champion_name
3  from
4  (
5      select list.position, list.champion_id
6      from
7      (
8          select position, champion_id, count(champion_id) as cnt
9          from
10         (
11             select match_id
12             from match_info
13             where duration >= 2400 and duration <= 3000
14         ) as dur_match,
15         (
16             select match_id, champion_id, position
17             from participant
18             where position = 'TOP' or position = 'MID' or position = 'JUNGLE'
19             or position = 'DUO_CARRY' or position = 'DUO_SUPPORT'
20         ) as par
21         where par.match_id = dur_match.match_id
22         group by position, champion_id
23         order by cnt desc
24     ) as list,
25     (
26         select grp_pos_champ.position, max(grp_pos_champ.cnt) as cnt
27         from
28         (
29             select position, champion_id, count(champion_id) as cnt
30             from
31             (
32                 select match_id
33                 from match_info
34                 where duration >= 2400 and duration <= 3000
35             ) as dur_match,
36             (
37                 select match_id, champion_id, position
38                 from participant
39                 where position = 'TOP' or position = 'MID' or position = 'JUNGLE'
40                 or position = 'DUO_CARRY' or position = 'DUO_SUPPORT'
41             ) as par
42             where par.match_id = dur_match.match_id
43             group by position, champion_id
44             order by cnt desc
45         ) as grp_pos_champ
46         group by grp_pos_champ.position
47     ) as tmp
48     where list.position = tmp.position
49     and list.cnt = tmp.cnt
50 ) as final, champ
51 where final.champion_id = champ.champion_id
52 order by final.position | {
53     "steps": [
54     {
55         "join_preparation": {
56             "select#": 1,
57             "steps": [
58             {
59                 "join_preparation": {
60                     "select#": 2,
61                     "steps": [
62                     {
63                         "join_preparation": {
64                             "select#": 3,
65                             "steps": [
66                             {
67                                 "join_preparation": {
68                                     "select#": 4,
69                                     "steps": [
70                                     {
71                                         "expanded_query": "/* select#4 */ select `match_info`.`match_id` AS `match_id` from "
72                                     }
73                                     ]
74                                 }
75                             ],
76                             "select#": 4,
77                             "merged": true
78                         }
79                     ],
80                     "select#": 5,
81                     "steps": [
82                     {
83                         "expanded_query": "/* select#5 */ select `participant`.`match_id` AS `match_id`, `par`"
84                     }
85                     ],
86                     "select#": 5,
87                     "merged": true
88                 }
89             ],
90             "select#": 5,
91             "steps": [
92             {
93                 "expanded_query": "/* select#5 */ select `participant`.`match_id` AS `match_id`, `par`"
94             }
95             ],
96             "select#": 5,
97             "merged": true
98         }
99     ],
100     {

```



```

101         "expanded_query": "/* select#3 */ select `participant`.`position` AS `position`,`participan
102     }
103 }
104 },
105 },
106 {
107     "join_preparation": {
108         "select#": 6,
109         "steps": [
110             {
111                 "join_preparation": {
112                     "select#": 7,
113                     "steps": [
114                         {
115                             "join_preparation": {
116                                 "select#": 8,
117                                 "steps": [
118                                     {
119                                         "expanded_query": "/* select#8 */ select `match_info`.`match_id` AS `match_id`
120                                     }
121                                 ]
122                             }
123                         },
124                         {
125                             "join_preparation": {
126                                 "select#": 9,
127                                 "steps": [
128                                     {
129                                         "expanded_query": "/* select#9 */ select `participant`.`match_id` AS `match_id`
130                                     }
131                                 ]
132                             }
133                         },
134                         {
135                             "derived": {
136                                 "table": "``,`dur_match`",
137                                 "select#": 8,
138                                 "merged": true
139                             }
140                         },
141                         {
142                             "derived": {
143                                 "table": "``,`par`",
144                                 "select#": 9,
145                                 "merged": true
146                             }
147                         },
148                     ]
149                 }
150             }
151         ]
152     }
153 },
154 {
155     "derived": {
156         "table": "` `grp_pos_champ`",
157         "select#": 7,
158         "materialized": true
159     }
160 },
161 {
162     "expanded_query": "/* select#6 */ select `grp_pos_champ`.`position` AS `position`,max(`grp_
163 }
164 ]
165 }
166 },
167 {
168     "derived": {
169         "table": "` `list`",
170         "select#": 3,
171         "materialized": true
172     }
173 },
174 {
175     "derived": {
176         "table": "` `tmp`",
177         "select#": 6,
178         "materialized": true
179     }
180 },
181 {
182     "expanded_query": "/* select#2 */ select `list`.`position` AS `position`,`list`.`champion_id` AS
183 }
184 ]
185 }
186 },
187 {
188     "derived": {
189         "table": "``,`final`",
190         "select#": 2,
191         "merged": true
192     }
193 },
194 {
195     "expanded_query": "/* select#1 */ select `list`.`position` AS `position`,`champ`.`champion_name` AS `ch
196 },
197 {
198     "transformations_to_nested_joins": {
199         "transformations": [
200             "JOIN_condition_to_WHERE",

```

```

201         "parenthesis_removal"
202     ],
203     "expanded_query": "/* select#7 */ select `participant`.`position` AS `position`,`participant`.`champ:
204 }
205 },
206 {
207     "transformations_to_nested_joins": {
208         "transformations": [
209             "JOIN_condition_to_WHERE",
210             "parenthesis_removal"
211         ],
212         "expanded_query": "/* select#3 */ select `participant`.`position` AS `position`,`participant`.`champ:
213     }
214 },
215 {
216     "transformations_to_nested_joins": {
217         "transformations": [
218             "JOIN_condition_to_WHERE",
219             "parenthesis_removal"
220         ],
221         "expanded_query": "/* select#1 */ select `list`.`position` AS `position`,`champ`.`champion_name` AS `
222

```

可以看到其實 select #4,5,8,9 也都重複兩次 寫法跟我的很像
 所以得出來的時間才會差不多

Yao:

```

mysql> source yao/6.sql
+-----+-----+
| position | ANY_VALUE(c.champion_name) |
+-----+-----+
| DUO_CARRY | Annie |
| DUO_SUPPORT | Annie |
| JUNGLE | Annie |
| MID | Annie |
| TOP | Annie |
+-----+-----+
5 rows in set (5.77 sec)

```

時間只需 1/3

但答案在 Ver 14.14 Distrib 5.7.30, for Linux (x86_64) using 是錯的

應該是 any_value()的問題

Query 也不能在 Ver 14.14 Distrib 5.6.21, for osx10.8 (x86_64)環境下跑

```

1 | explain
2 | SELECT info.position, ANY_VALUE(c.champion_name)
3 | FROM
4 | (
5 |     SELECT p.champion_id, p.position, COUNT(*) as appear
6 |     FROM participant as p, match_info as m
7 |     WHERE p.position != 'NONE'
8 |     AND p.position != 'DUO'
9 |     AND p.position != 'BOT'
10 |    AND p.position != 'SOLO'
11 |    AND m.duration BETWEEN 2400 AND 3000
12 |    AND m.match_id = p.match_id
13 |    GROUP BY p.champion_id, p.position
14 |    ORDER BY appear DESC
15 | ) as info, champ as c
16 | WHERE c.champion_id = info.champion_id
17 | GROUP BY info.position | {
18 |     "steps": [
19 |         {
20 |             "join_preparation": {
21 |                 "select#": 1,
22 |                 "steps": [
23 |                     {
24 |                         "join_preparation": {
25 |                             "select#": 2,
26 |                             "steps": [
27 |                                 {
28 |                                     "expanded_query": "/* select#2 */ select 'p'.champion_id AS 'champion_id', 'p'.position AS 'position'"
29 |                                 }
30 |                             ]
31 |                         }
32 |                     }
33 |                 ],
34 |                 "derived": {
35 |                     "table": " `info` ",
36 |                     "select#": 2,
37 |                     "materialized": true
38 |                 }
39 |             },
40 |             "expanded_query": "/* select#1 */ select 'info'.position AS 'position', any_value('c'.champion_name) AS 'champion_name'"
41 |         ]
42 |     },
43 |     {
44 |         "join_optimization": {
45 |             "select#": 1,
46 |             "steps": [
47 |                 {
48 |                     "join_optimization": {
49 |                         "select#": 2,
50 |                         "steps": [
51 |                             {
52 |                                 "condition_processing": {
53 |                                     "condition": "WHERE",
54 |                                     "original_condition": "((('p'.position <> 'NONE') and ('p'.position <> 'DUO') and ('p'.position <> 'BOT') and ('p'.position <> 'SOLO')) and (m.duration >= 2400 and m.duration <= 3000 and m.match_id = p.match_id))",
55 |                                     "steps": [
56 |                                         {
57 |                                             "transformation": "equality_propagation",
58 |                                             "resulting_condition": "((('p'.position <> 'NONE') and ('p'.position <> 'DUO') and ('p'.position <> 'BOT') and ('p'.position <> 'SOLO')) and (m.duration >= 2400 and m.duration <= 3000 and m.match_id = p.match_id))"
59 |                                         },
60 |                                         {
61 |                                             "transformation": "constant_propagation",
62 |                                             "resulting_condition": "((('p'.position <> 'NONE') and ('p'.position <> 'DUO') and ('p'.position <> 'BOT') and ('p'.position <> 'SOLO')) and (m.duration >= 2400 and m.duration <= 3000 and m.match_id = p.match_id))"
63 |                                         },
64 |                                         {
65 |                                             "transformation": "trivial_condition_removal",
66 |                                             "resulting_condition": "((('p'.position <> 'NONE') and ('p'.position <> 'DUO') and ('p'.position <> 'BOT') and ('p'.position <> 'SOLO')) and (m.duration >= 2400 and m.duration <= 3000 and m.match_id = p.match_id))"
67 |                                         }
68 |                                     ]
69 |                                 }
70 |                             }
71 |                         ]
72 |                     }
73 |                 ],
74 |                 "substitute_generated_columns": {
75 |                 }
76 |             },
77 |             "table_dependencies": [
78 |                 {
79 |                     "table": "`participant` `p`",
80 |                     "row_may_be_null": false,
81 |                     "map_bit": 0,
82 |                     "depends_on_map_bits": [
83 |                     ]
84 |                 },
85 |                 {
86 |                     "table": "`match_info` `m`",
87 |                     "row_may_be_null": false,
88 |                     "map_bit": 1,
89 |                     "depends_on_map_bits": [
90 |                     ]
91 |                 }
92 |             ]
93 |         },
94 |         "ref_optimizer_key_uses": [
95 |             {
96 |                 "table": "`participant` `p`",
97 |                 "field": "match_id",
98 |             }
99 |         ]
100 |     }

```

```

101         "equals": "m"."match_id",
102         "null_rejecting": false
103     },
104     {
105         "table": "`match_info` `m`",
106         "field": "match_id",
107         "equals": "p"."match_id",
108         "null_rejecting": false
109     }
110 ]
111 },
112 {
113     "rows_estimation": [
114         {
115             "table": "`participant` `p`",
116             "table_scan": {
117                 "rows": 1817575,
118                 "cost": 6376
119             }
120         },
121         {
122             "table": "`match_info` `m`",
123             "table_scan": {
124                 "rows": 182186,
125                 "cost": 545
126             }
127         }
128     ]
129 },
130 {
131     "considered_execution_plans": [
132         {
133             "plan_prefix": [
134             ],
135             "table": "`match_info` `m`",
136             "best_access_path": {
137                 "considered_access_paths": [
138                     {
139                         "access_type": "ref",
140                         "index": "PRIMARY",
141                         "usable": false,
142                         "chosen": false
143                     },
144                     {
145                         "rows_to_scan": 182186,
146                         "access_type": "scan",
147                         "resulting_rows": 20241,
148                         "cost": 36982,
149                         "chosen": true
150                     }
151                 ]
152             },
153             "condition_filtering_pct": 100,
154             "rows_for_plan": 20241,
155             "cost_for_plan": 36982,
156             "rest_of_plan": [
157                 {
158                     "plan_prefix": [
159                         "`match_info` `m`"
160                     ],
161                     "table": "`participant` `p`",
162                     "best_access_path": {
163                         "considered_access_paths": [
164                             {
165                                 "access_type": "ref",
166                                 "index": "match_id",
167                                 "rows": 9.953,
168                                 "cost": 241750,
169                                 "chosen": true
170                             },
171                             {
172                                 "rows_to_scan": 1817575,
173                                 "access_type": "scan",
174                                 "using_join_cache": true,
175                                 "buffers_needed": 1,
176                                 "resulting_rows": 1.19e6,
177                                 "cost": 4.83e9,
178                                 "chosen": false
179                             }
180                         ]
181                     },
182                     "condition_filtering_pct": 65.61,
183                     "rows_for_plan": 132177,
184                     "cost_for_plan": 278732,
185                     "chosen": true
186                 }
187             ]
188         },
189         {
190             "plan_prefix": [
191             ],
192             "table": "`participant` `p`",
193             "best_access_path": {
194                 "considered_access_paths": [
195                     {
196                         "access_type": "ref",
197                         "index": "match_id",
198                         "usable": false,
199                         "chosen": false
200                     },

```

```

201         {
202             "rows_to_scan": 1817575,
203             "access_type": "scan",
204             "resulting_rows": 1.19e6,
205             "cost": 369891,
206             "chosen": true
207         }
208     ],
209     },
210     "condition_filtering_pct": 100,
211     "rows_for_plan": 1.19e6,
212     "cost_for_plan": 369891,
213     "pruned_by_cost": true
214 }
215 ]
216 },
217 {
218     "attaching_conditions_to_tables": {
219         "original_condition": "((`p`.`match_id` = `m`.`match_id`) and (`p`.`position` <> 'NONE'))",
220         "attached_conditions_computation": [
221             ],
222         "attached_conditions_summary": [
223             {
224                 "table": "`match_info` `m`",
225                 "attached": "(`m`.`duration` between 2400 and 3000)"
226             },
227             {
228                 "table": "`participant` `p`",
229                 "attached": "((`p`.`position` <> 'NONE') and (`p`.`position` <> 'DU0') and (`p`.`pos"
230             )
231         ]
232     }
233 },
234 {
235     "clause_processing": {
236         "clause": "ORDER BY",
237         "original_clause": "`appear` desc",
238         "items": [
239             {
240                 "item": "count(0)"
241             }
242         ],
243         "resulting_clause_is_simple": false,
244         "resulting_clause": "`appear` desc"
245     }
246 },
247 {
248     "clause_processing": {
249         "clause": "GROUP BY",
250         "original_clause": "`p`.`champion_id`,`p`.`position`",
251         "items": [
252             {
253                 "item": "`p`.`champion_id`"
254             },
255             {
256                 "item": "`p`.`position`"
257             }
258         ],
259         "resulting_clause_is_simple": false,
260         "resulting_clause": "`p`.`champion_id`,`p`.`position`"
261     }
262 },
263 {
264     "refine_plan": [
265         {
266             "table": "`match_info` `m`"
267         },
268         {
269             "table": "`participant` `p`"
270         }
271     ]
272 }
273 ]
274 }
275 },
276 {
277     "condition_processing": {
278         "condition": "WHERE",
279         "original_condition": "(`c`.`champion_id` = `info`.`champion_id`)",
280         "steps": [
281             {
282                 "transformation": "equality_propagation",
283                 "resulting_condition": "multiple equal(`c`.`champion_id`, `info`.`champion_id`)"
284             },
285             {
286                 "transformation": "constant_propagation",
287                 "resulting_condition": "multiple equal(`c`.`champion_id`, `info`.`champion_id`)"
288             },
289             {
290                 "transformation": "trivial_condition_removal",
291                 "resulting_condition": "multiple equal(`c`.`champion_id`, `info`.`champion_id`)"
292             }
293         ]
294     }
295 },
296 {
297     "substitute_generated_columns": {
298     }
299 },
300 {

```

```

301     "table_dependencies": [
302     {
303         "table": " `info\"",
304         "row_may_be_null": false,
305         "map_bit": 0,
306         "depends_on_map_bits": [
307         ]
308     },
309     {
310         "table": "`champ` `c`\"",
311         "row_may_be_null": false,
312         "map_bit": 1,
313         "depends_on_map_bits": [
314         ]
315     }
316     ],
317 },
318 {
319     "ref_optimizer_key_uses": [
320     {
321         "table": " `info\"",
322         "field": "champion_id",
323         "equals": "`c`.`champion_id`\"",
324         "null_rejecting": false
325     },
326     {
327         "table": " `info\"",
328         "field": "champion_id",
329         "equals": "`c`.`champion_id`\"",
330         "null_rejecting": false
331     },
332     {
333         "table": "`champ` `c`\"",
334         "field": "champion_id",
335         "equals": "`info`.`champion_id`\"",
336         "null_rejecting": false
337     }
338     ],
339 },
340 {
341     "rows_estimation": [
342     {
343         "table": " `info\"",
344         "table_scan": {
345             "rows": 132176,
346             "cost": 6618
347         },
348     },
349     {
350         "table": "`champ` `c`\"",
351         "table_scan": {
352             "rows": 138,
353             "cost": 1
354         }
355     }
356     ],
357 },
358 {
359     "considered_execution_plans": [
360     {
361         "plan_prefix": [
362         ],
363         "table": "`champ` `c`\"",
364         "best_access_path": {
365             "considered_access_paths": [
366             {
367                 "access_type": "ref",
368                 "index": "PRIMARY",
369                 "usable": false,
370                 "chosen": false
371             },
372             {
373                 "rows_to_scan": 138,
374                 "access_type": "scan",
375                 "resulting_rows": 138,
376                 "cost": 28.6,
377                 "chosen": true
378             }
379             ],
380         },
381         "condition_filtering_pct": 100,
382         "rows_for_plan": 138,
383         "cost_for_plan": 28.6,
384         "rest_of_plan": [
385         {
386             "plan_prefix": [
387                 "`champ` `c`"
388             ],
389             "table": " `info\"",
390             "best_access_path": {
391                 "considered_access_paths": [
392                 {
393                     "access_type": "ref",
394                     "index": "<auto_key0>",
395                     "rows": 957.8,
396                     "cost": 158611,
397                     "chosen": true
398                 },
399                 {
400                     "access_type": "ref",

```

```

401         "index": "<auto_key1>",
402         "rows": 957.8,
403         "cost": 158611,
404         "chosen": false
405     },
406     {
407         "rows_to_scan": 132176,
408         "access_type": "scan",
409         "using_join_cache": true,
410         "buffers_needed": 1,
411         "resulting_rows": 132176,
412         "cost": 3.65e6,
413         "chosen": false
414     }
415 ]
416 },
417 "condition_filtering_pct": 100,
418 "rows_for_plan": 132176,
419 | 4436 | 0 |
420

```

2-2-1

Phase 1 growing phase 在 18~68 行

Phase 2 shrinking phase 在 70~78 行

在 main 內讀入 write target, read target，用 `vector<int> regs` 一次存起在，
write target index 放在 `regs[0]`。

再把 `regs` 與整行 line 讀入 `threadfunc(reg, str)`。

Threadfunc 是用 VSmutex(type 為 shared_mutex) 的 vector 進行上鎖。
並在函數(threadfunc)內用 unique_lock 與 shared_lock 分別鎖住 write,read
target

算完後，assign 給 write target，最後進入 shrinking phase

我沒有用 semaphore，可能就是因為這樣 data2 才會出錯吧

```
1  #include<iostream>
2  #include<thread>
3  #include<fstream>
4  #include<cstring>
5  #include<stdio.h>
6  #include<cstdlib>
7  #include<vector>
8  #include <unistd.h>
9  #include<semaphore.h>
10 #include<shared_mutex>
11 using namespace std;
12 vector<shared_mutex*> VSshared_mutex;
13 vector<shared_mutex*> VXshared_mutex;
14 vector<int> a;
15 sem_t semaphore;
16 void threadfunc(vector<int> regs,string str){
17     //cout<<regs.size()<<endl;
18     //phase 1
19     unique_lock<shared_mutex> Xlock(*VSshared_mutex[regs[0]]);
20     //VXshared_mutex[regs[0]]->lock();
21     //VSshared_mutex[regs[0]]->lock();
22     //cout<<"locking X S $"<<regs[0]<<endl;
23     for(int i=1;i<regs.size();i++){
24         unique_lock<shared_mutex> Slock(*VSshared_mutex[regs[i]]);
25         //VSshared_mutex[regs[i]]->lock();
26         //cout<<"locking S $"<<regs[i]<<endl;
27     }
28     int ans = 0;
29     string tmp="";
30     int i=0;
31     for(;str[i]!=' ';i++){
32         tmp.push_back(str[i]);
33     }
34     tmp.erase(tmp.begin());
35     tmp = "";
36     bool sign=0;
37     i+=3;
38     for(;i<str.size();i++){
39         //cout<<"i="<<i<<endl;
40         if(str[i]!=' ')tmp.push_back(str[i]);
```



```

40         if (set[i] != 0) tmp.push_back(set[i]);
41     else{
42         //cout<<tmp<<" ";
43         if(tmp[0] == '$'){
44             tmp.erase(tmp.begin());
45             //cout<<"("<<a[stoi(tmp)]<<")"<<" ";
46             if(sign==0) ans += a[stoi(tmp)];
47             else ans-= a[stoi(tmp)];
48         }else if(tmp[0]>='0' and tmp[0]<='9'){
49             if(sign==0) ans += stoi(tmp);
50             else ans -= stoi(tmp);
51         }else if(tmp[0]=='+' or tmp[0]=='-'){
52             if(tmp[0]=='+')sign=0;
53             else sign=1;
54         }
55         tmp="";
56     }
57 }
58
59 if(tmp[0] == '$'){
60     tmp.erase(tmp.begin());
61     if(sign==0) ans += a[stoi(tmp)];
62     else ans-= a[stoi(tmp)];
63 }else if(tmp[0]>='0' and tmp[0]<='9'){
64     if(sign==0) ans += stoi(tmp);
65     else ans -= stoi(tmp);
66 }
67
68 a[regs[0]] = ans ;
69 //phase 2
70 //VXshared_mutex[regs[0]]->unlock();
71 VSshared_mutex[regs[0]]->unlock();
72 //cout<<"unlocking X S $"<<regs[0]<<endl;
73 for(int i=1;i<regs.size();i++){
74     VSshared_mutex[regs[i]]->unlock();
75     //cout<<"locking S $"<<regs[i]<<endl;
76 }
77
78 }
79

```

```

80  int main(int argc, char *argv[])
81  {
82      //fstream file;
83      fstream file_out;
84      //thread Thread[stoi(argv[0])];
85      //file.open("data/data3", ios::in);
86      file_out.open(argv[2], ios::out);
87      int n; cin >> n;
88      vector<thread *> Threadvector(stoi(argv[1]));
89
90      int in;
91      for(int i=0; i<n; i++){
92          cin >> in;
93          a.push_back(in);
94          shared_mutex *SMutex = new(shared_mutex);
95          VSshared_mutex.push_back(SMutex);
96          shared_mutex *XMutex = new(shared_mutex);
97          VXshared_mutex.push_back(XMutex);
98      }
99      string str;
100     vector<vector<int> > ReadWrite;
101     int counter = 0;
102     getline(cin, str);
103     while(getline(cin, str)){
104
105         //cout<<"str="<<str<<endl;
106         if(str=="") break;
107         vector<int> regs;
108         string tmp="";
109         int flag=0;
110         for(int i=0; i<str.length(); i++){
111             if(str[i]!=' ') tmp.push_back(str[i]);
112             else{
113                 if(tmp == "=" ) flag=1;
114                 else if(tmp[0] == '$'){
115                     tmp.erase(tmp.begin());
116                     int r = stoi(tmp);
117                     bool flag=0;

```

```

117         bool flag=0;
118         for(int i=0;i<regs.size();i++){
119             if(regs[i]==r)flag=1;
120         }
121         if(flag==0){
122             regs.push_back(stoi(tmp));
123             //cout<<tmp<<" ";
124         }
125     }
126     tmp="";
127 }
128 }
129 if(tmp[0] == '$'){
130     tmp.erase(tmp.begin());
131     regs.push_back(stoi(tmp));
132 }
133 Threadvector[counter++%stoi(argv[1])] = new thread(threadfunc,regs,str); // 這裡出問題
134 //threadfunc(regs,str);
135 ReadWrite.push_back(regs);
136 //cout<<"\n";
137 }
138 }
139 for(int i=0;i<stoi(argv[1]);i++){
140     Threadvector[i]->join();
141 }
142 for(int i=0;i<n;i++){
143     file_out<<"$"<<i<<" = "<<a[i]<<endl;
144 }
145 }
146 }
147 }
148 }

```

2-2-2

不同的 Thread 數時間都差不多

```
chenyusheng@140-113-68-206 hw3 % ./main 1 data_out < data/data2
totalTime = 2.66387
chenyusheng@140-113-68-206 hw3 % ./main 2 data_out < data/data2
totalTime = 2.68209
chenyusheng@140-113-68-206 hw3 % ./main 3 data_out < data/data2
totalTime = 3.2215
chenyusheng@140-113-68-206 hw3 % ./main 4 data_out < data/data2
totalTime = 3.42754
chenyusheng@140-113-68-206 hw3 % ./main 5 data_out < data/data2
totalTime = 3.06511
chenyusheng@140-113-68-206 hw3 % ./main 6 data_out < data/data2
totalTime = 3.35763
chenyusheng@140-113-68-206 hw3 % ./main 7 data_out < data/data2
totalTime = 3.16709
chenyusheng@140-113-68-206 hw3 % ./main 8 data_out < data/data2
totalTime = 3.34566
chenyusheng@140-113-68-206 hw3 % ./main 9 data_out < data/data2
totalTime = 2.85088
chenyusheng@140-113-68-206 hw3 % ./main 10 data_out < data/data2
totalTime = 2.94897
chenyusheng@140-113-68-206 hw3 % ./main 20 data_out < data/data2
totalTime = 3.36398
chenyusheng@140-113-68-206 hw3 % ./main 30 data_out < data/data2
totalTime = 3.43145
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 40 data_out < data/data2
totalTime = 2.90746
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 50 data_out < data/data2
totalTime = 3.99136
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 60 data_out < data/data2
totalTime = 3.0197
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 70 data_out < data/data2
totalTime = 3.1512
chenyusheng@140-113-68-206 hw3 % ./main 80 data_out < data/data2
totalTime = 3.8153
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 90 data_out < data/data2
totalTime = 3.46677
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 %
```

```
chenyusheng@140-113-68-206 hw3 % ./main 4 data_out < data/data2
totalTime = 3.42754
chenyusheng@140-113-68-206 hw3 % ./main 5 data_out < data/data2
totalTime = 3.06511
chenyusheng@140-113-68-206 hw3 % ./main 6 data_out < data/data2
totalTime = 3.35763
chenyusheng@140-113-68-206 hw3 % ./main 7 data_out < data/data2
totalTime = 3.16709
chenyusheng@140-113-68-206 hw3 % ./main 8 data_out < data/data2
totalTime = 3.34566
chenyusheng@140-113-68-206 hw3 % ./main 9 data_out < data/data2
totalTime = 2.85088
chenyusheng@140-113-68-206 hw3 % ./main 10 data_out < data/data2
totalTime = 2.94897
chenyusheng@140-113-68-206 hw3 % ./main 20 data_out < data/data2
totalTime = 3.36398
chenyusheng@140-113-68-206 hw3 % ./main 30 data_out < data/data2
totalTime = 3.43145
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 40 data_out < data/data2
totalTime = 2.90746
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 50 data_out < data/data2
totalTime = 3.99136
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 60 data_out < data/data2
totalTime = 3.0197
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 70 data_out < data/data2
totalTime = 3.1512
chenyusheng@140-113-68-206 hw3 % ./main 80 data_out < data/data2
totalTime = 3.8153
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 90 data_out < data/data2
totalTime = 3.46677
chenyusheng@140-113-68-206 hw3 % diff data_out data/data2_answer
chenyusheng@140-113-68-206 hw3 % ./main 90 data_out < data/data3
totalTime = 7418.89
chenyusheng@140-113-68-206 hw3 % ./main 80 data_out < data/data3
totalTime = 7384.83
chenyusheng@140-113-68-206 hw3 % ./main 50 data_out < data/data3
totalTime = 7411.9
chenyusheng@140-113-68-206 hw3 % ./main 40 data_out < data/data3
```

```
chenyusheng@140-113-68-206 hw3 % ./main 4 data_out < data/data3
totalTime = 7877.12
time = 12064204
chenyusheng@140-113-68-206 hw3 % diff data_out data/data3_answer
chenyusheng@140-113-68-206 hw3 % ./main 5 data_out < data/data3
totalTime = 7733.43
time = 11930896
chenyusheng@140-113-68-206 hw3 %
chenyusheng@140-113-68-206 hw3 % ./main 6 data_out < data/data3
totalTime = 7755.07
time = 11965980
chenyusheng@140-113-68-206 hw3 %
chenyusheng@140-113-68-206 hw3 % ./main 7 data_out < data/data3
totalTime = 7805.87
time = 12027632
chenyusheng@140-113-68-206 hw3 % ./main 8 data_out < data/data3
totalTime = 7837.76
time = 12126766
chenyusheng@140-113-68-206 hw3 % ./main 9 data_out < data/data3
totalTime = 8028.17
time = 12218750
chenyusheng@140-113-68-206 hw3 % ./main 10 data_out < data/data3
totalTime = 7746.67
time = 11982474
chenyusheng@140-113-68-206 hw3 % ./main 11 data_out < data/data3
totalTime = 7734.91
time = 11951977
chenyusheng@140-113-68-206 hw3 % ./main 12 data_out < data/data3
totalTime = 7737.52
time = 11937252
chenyusheng@140-113-68-206 hw3 %
```

2-2-3

