Lab 3 - Validating Linearizability of Lock-free Skiplists

- Group 18
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1. Measuring execution time

1.1 Measurement program

I modified the measurement program as follows for testing.

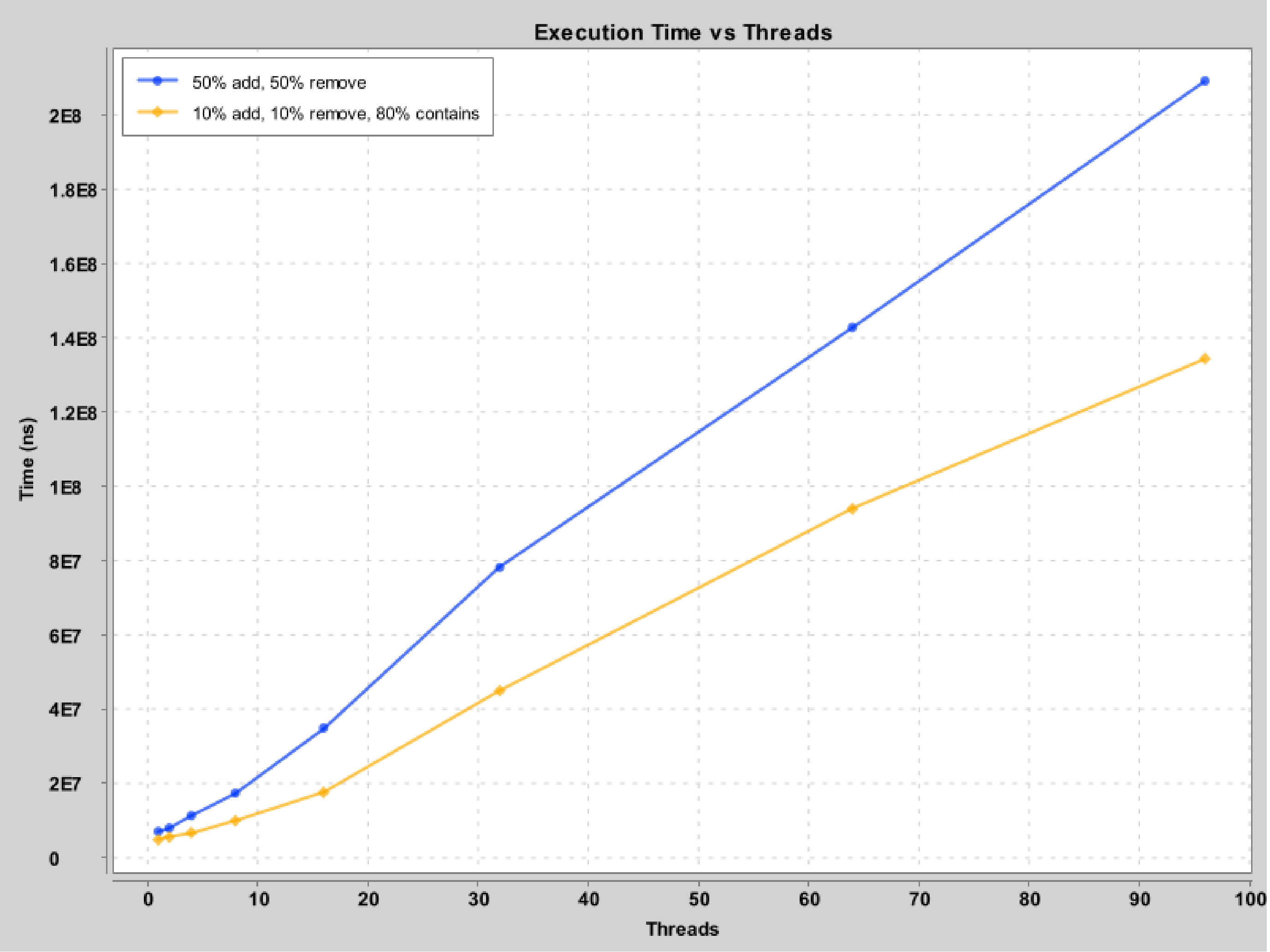
> java Main 2 Default Normal 4096 1:1:8 100000 20 50

Operations with 50% add & 50% remove seem to be slower.

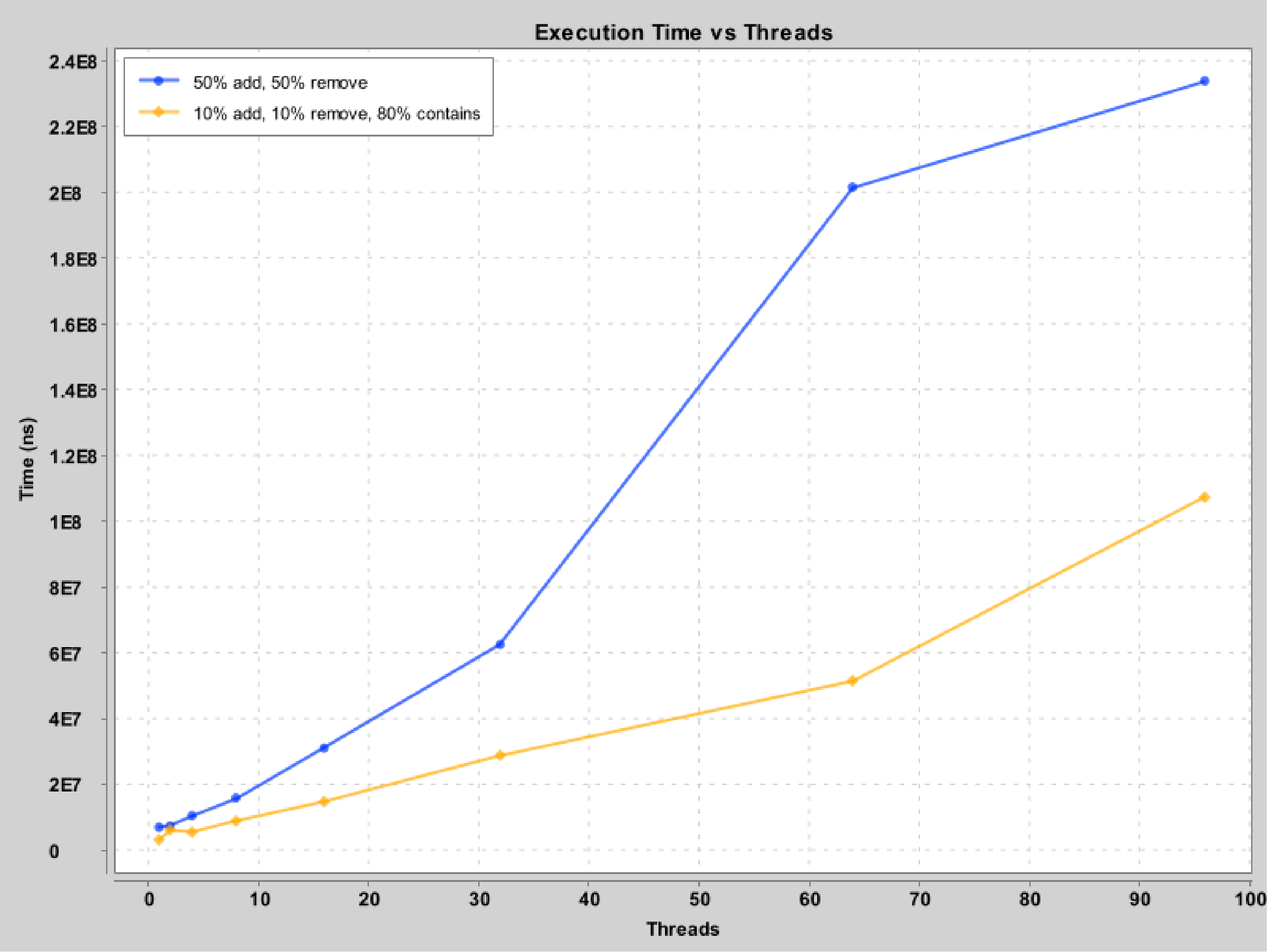
1.2 Dardel experiments

Source file:

- `src/Main.java` (Run on PDC)
- `plots/PDCPlot1.java` (Run on PDC)



- Fig above is the Normal Distribution.
- Fig below is the Uniform Distribution.



> Yes, they make sense.

> Uniform distribution is expected to be faster. In normal distribution, the concentration of operations in a small range of values causes contention being high and slows down performance.

> The 10:10:80 distribution should be faster than the 50:50 distribution because read-heavy workloads tend to have better performance in concurrent lock-free data structures like skip lists, as they involve less contention and fewer expensive operations.

2. Identify and validate linearization points

2.1 Identify linearization points

> Generally speaking, the locations of these points are around the successful or unsuccessful call.

> - `add()` : The linearization point is where the node is successfully inserted into the list with compareAndSet() or when it is determined that the node already exists.
> - `remove()` : The linearization point is where the node is marked logically deleted or when it is found that the node is already removed or doesn't exist.
> - `contains()` : The linearization point is when the element is found in the list or determined to not be present.

> Well, if described in my own words, I would say that capture it "before the return".

2.2 Develop a validation method

Source file:

- `src/Main.java`
- `src/log.java`

> `Log.validate` is implemented with the help of `HashSet` .

2.3. Locked time sampling

Source file:

- `src/Main.java`
- `src/LockFreeSkipListLocked.java`

> Though the locked version is more accurate, it introduces large delays, especially as the number of threads increases. The lock contention causes performance to degrade in multithreading scenarios.

2.4. Lock-free time sampling with local log

Source file:

- `src/Main.java`
- `src/LockFreeSkipListLocalLog.java`

2.5. Lock-free Time Sampling with Global Log

Source file:

- `src/Main.java`
- `src/LockFreeSkipListGlobalLog.java`

> The absence of locks means reduced contention and improved throughput. However, it brings some trade-offs in accuracy, particularly in the ordering of timestamps due to the lack of precise synchronization between threads.

2.5.Extra

Source file:

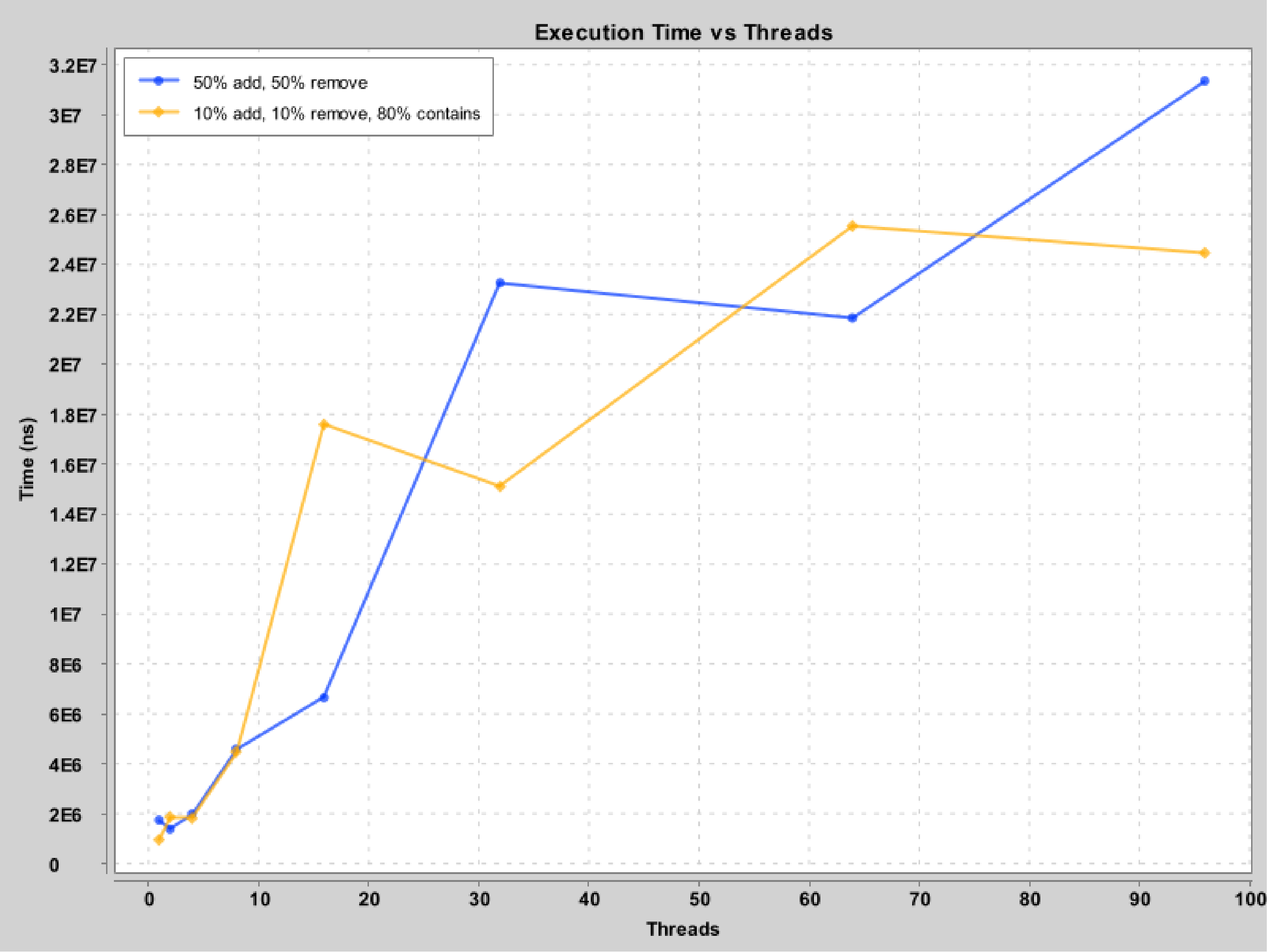
- `src/LockFreeQueue.java`

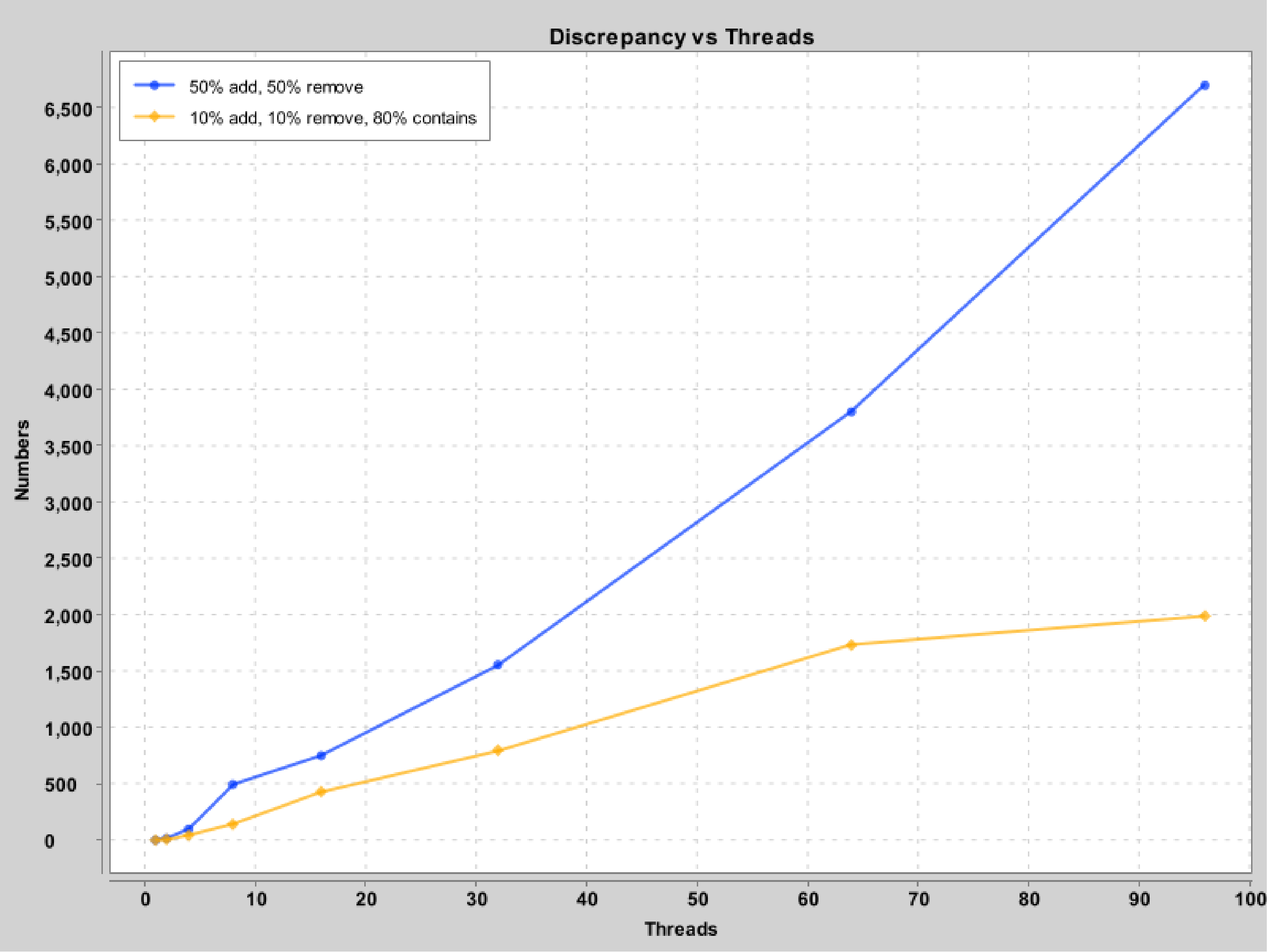
> Reference: HSLS Chapter 10 Page 237-238 LockFreeQueue.

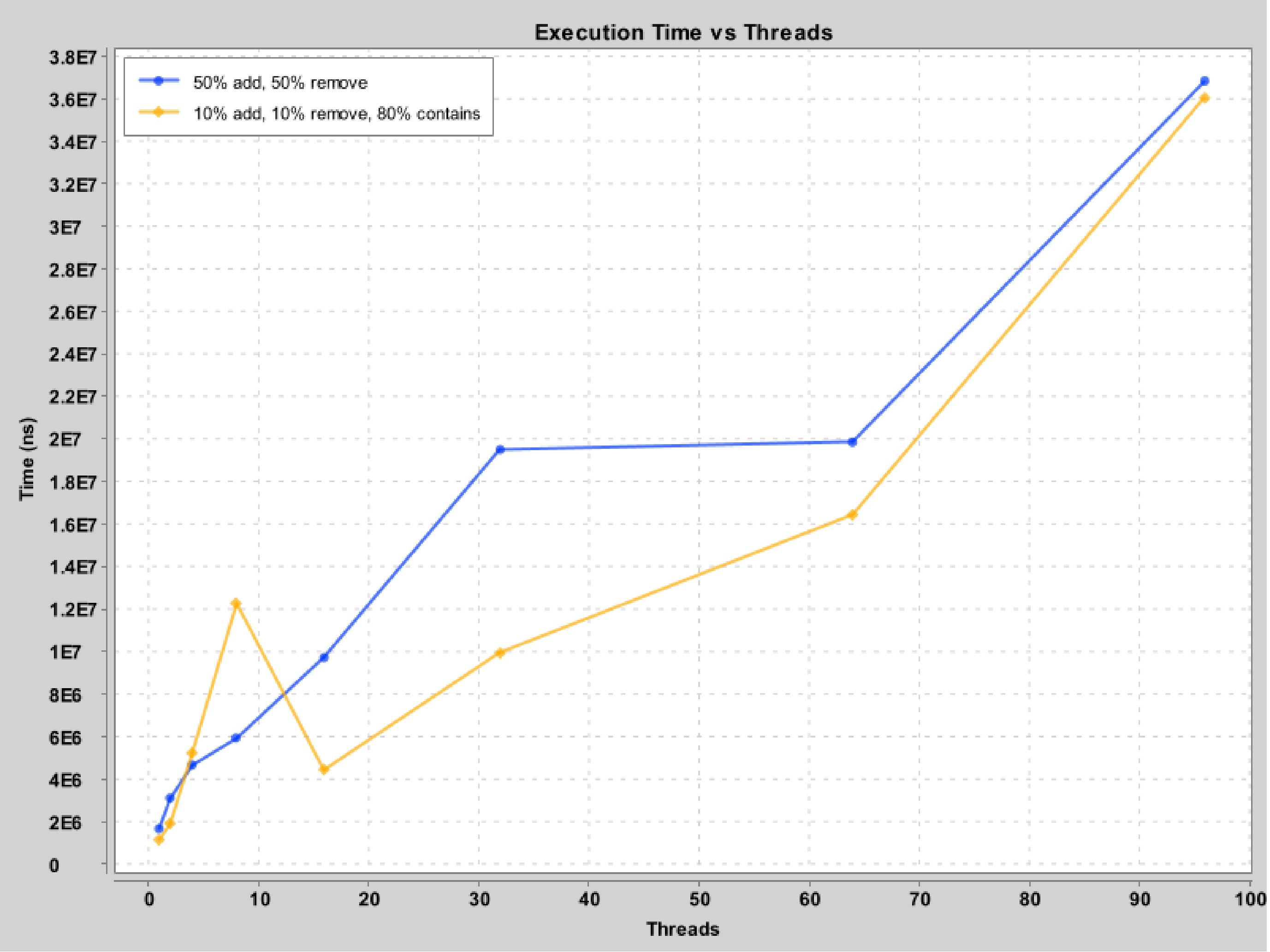
2.6. Dardel experiments

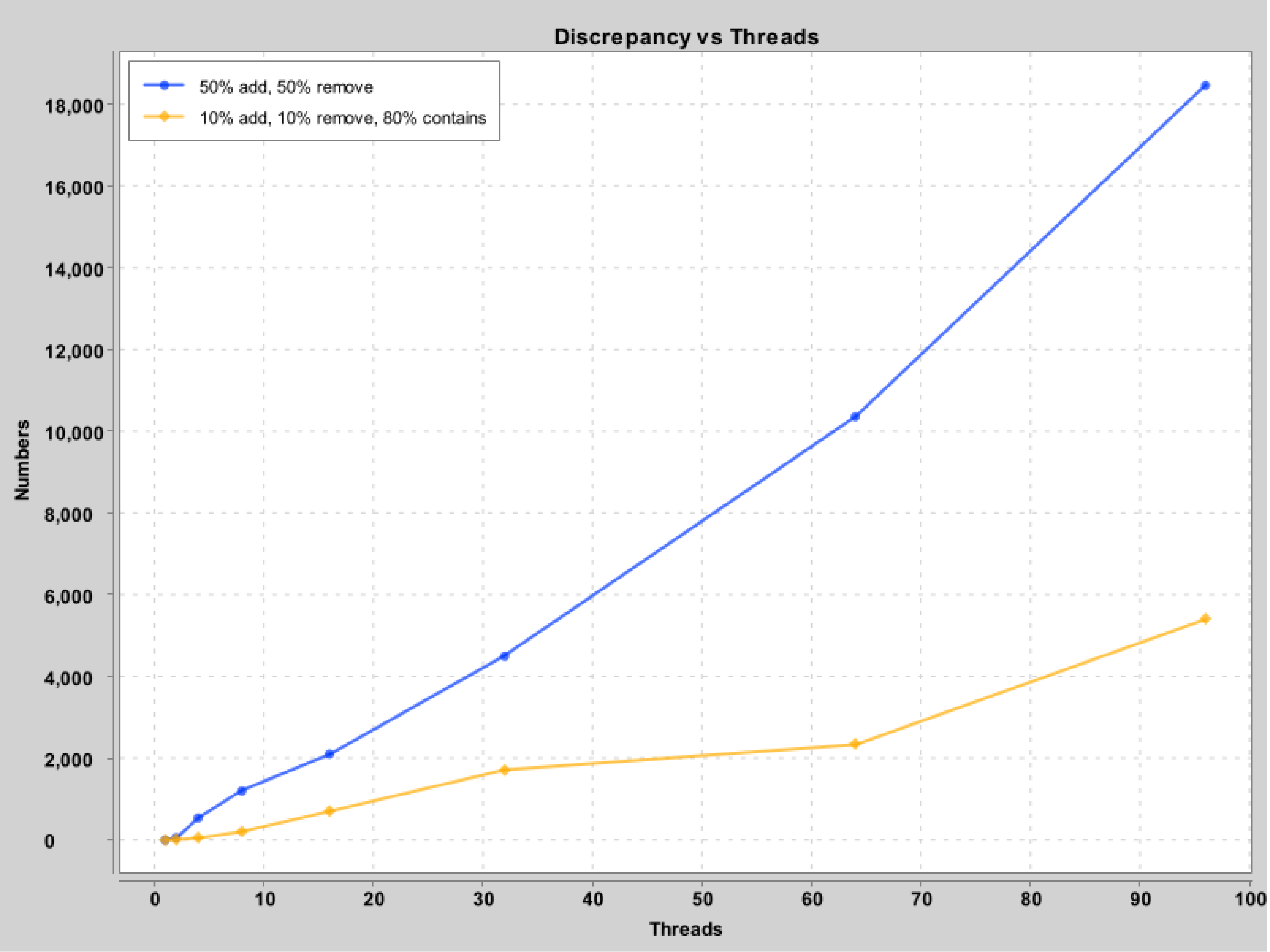
Source file:

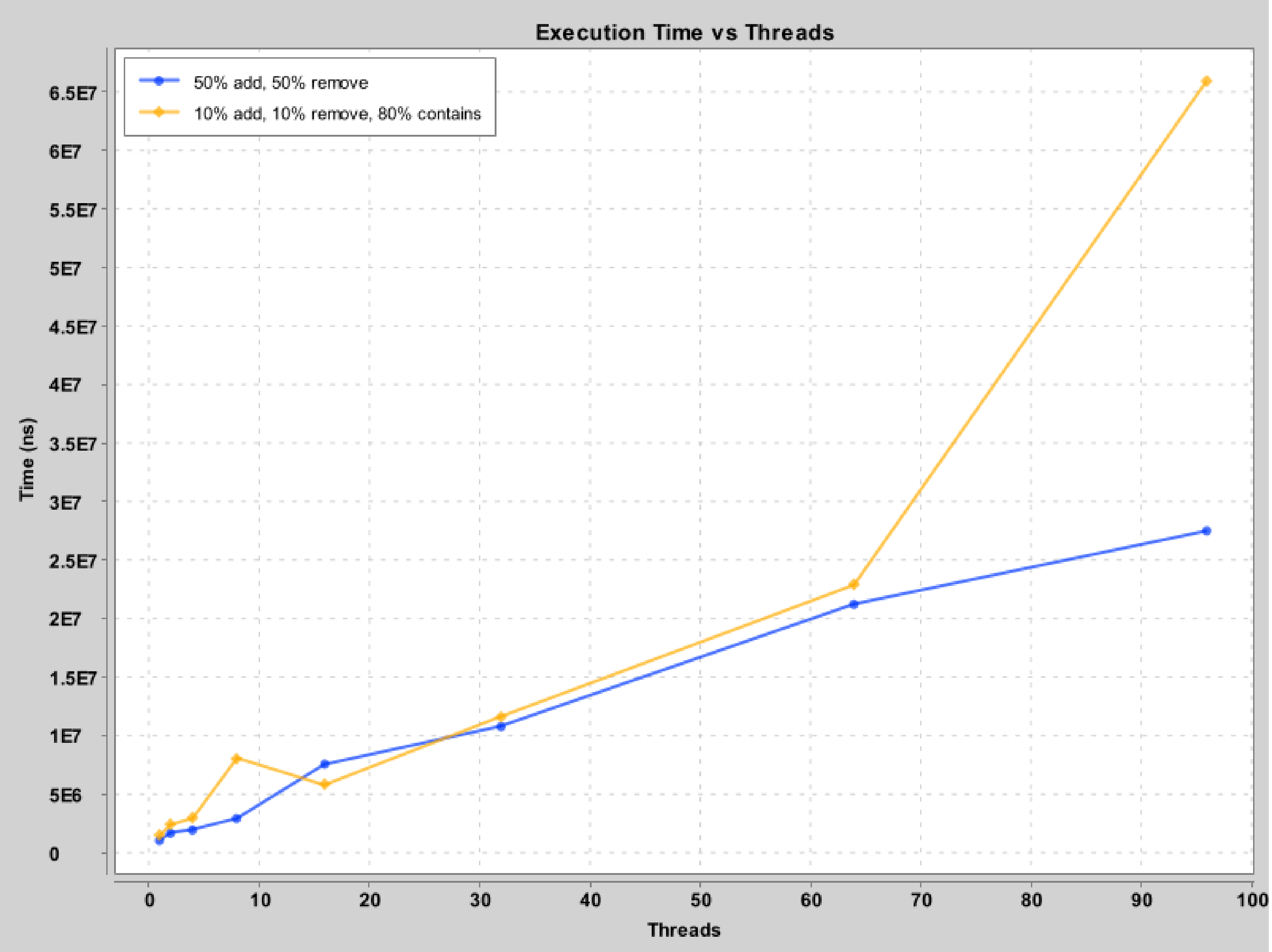
- `plots/PDCPlot1.java` (Run on PDC)
- `plots/PDCPlot2.java` (Run on PDC)

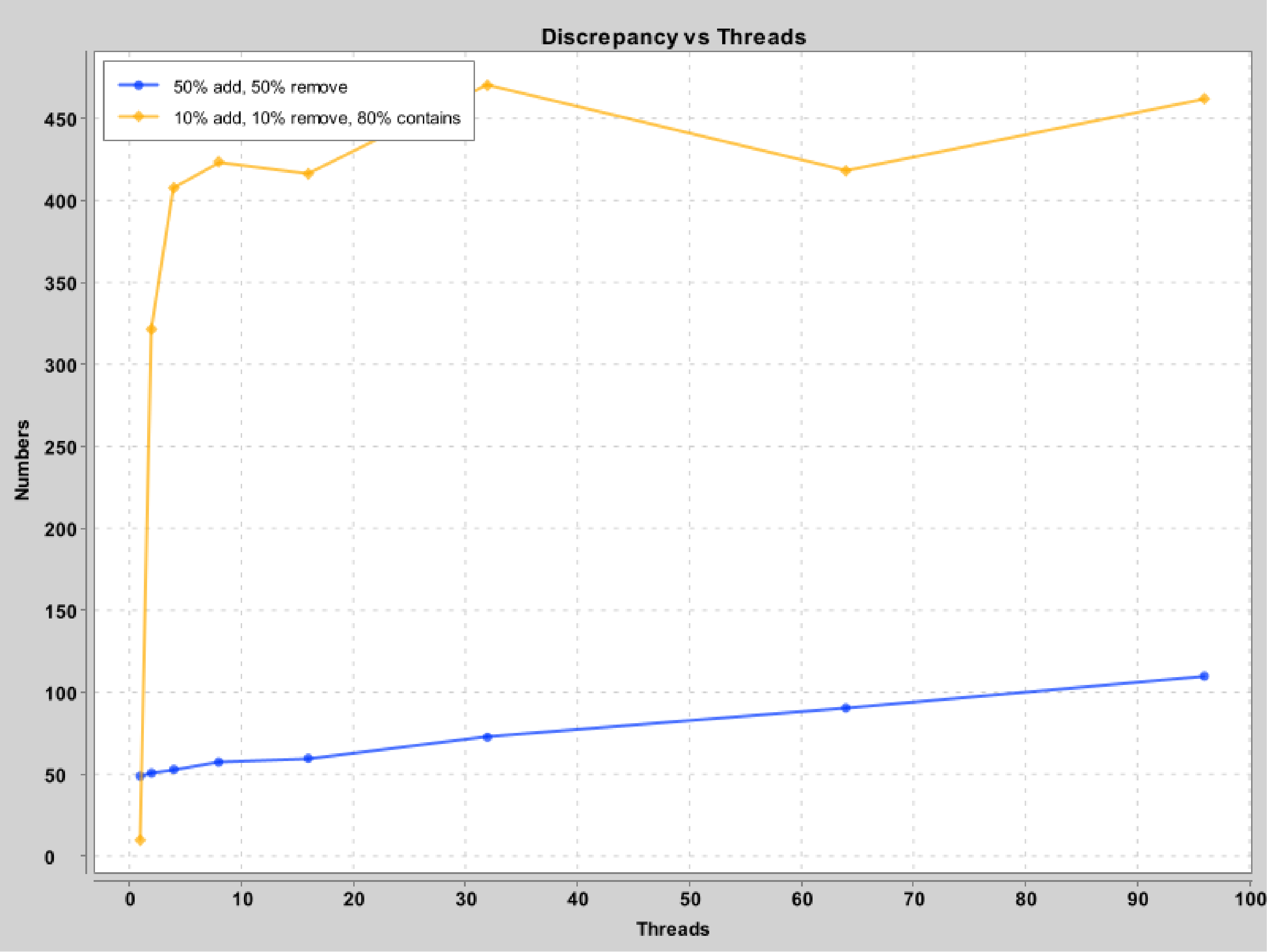

Execution Time vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Time (ns)
3.2E7
3E7
2.8E7
2.6E7
2.4E7
2.2E7
2E7
1.8E7
1.6E7
1.4E7
1.2E7
1E7
8E6
6E6
4E6
2E6
0
Threads
0
10
20
30
40
50
60
70
80
90
100

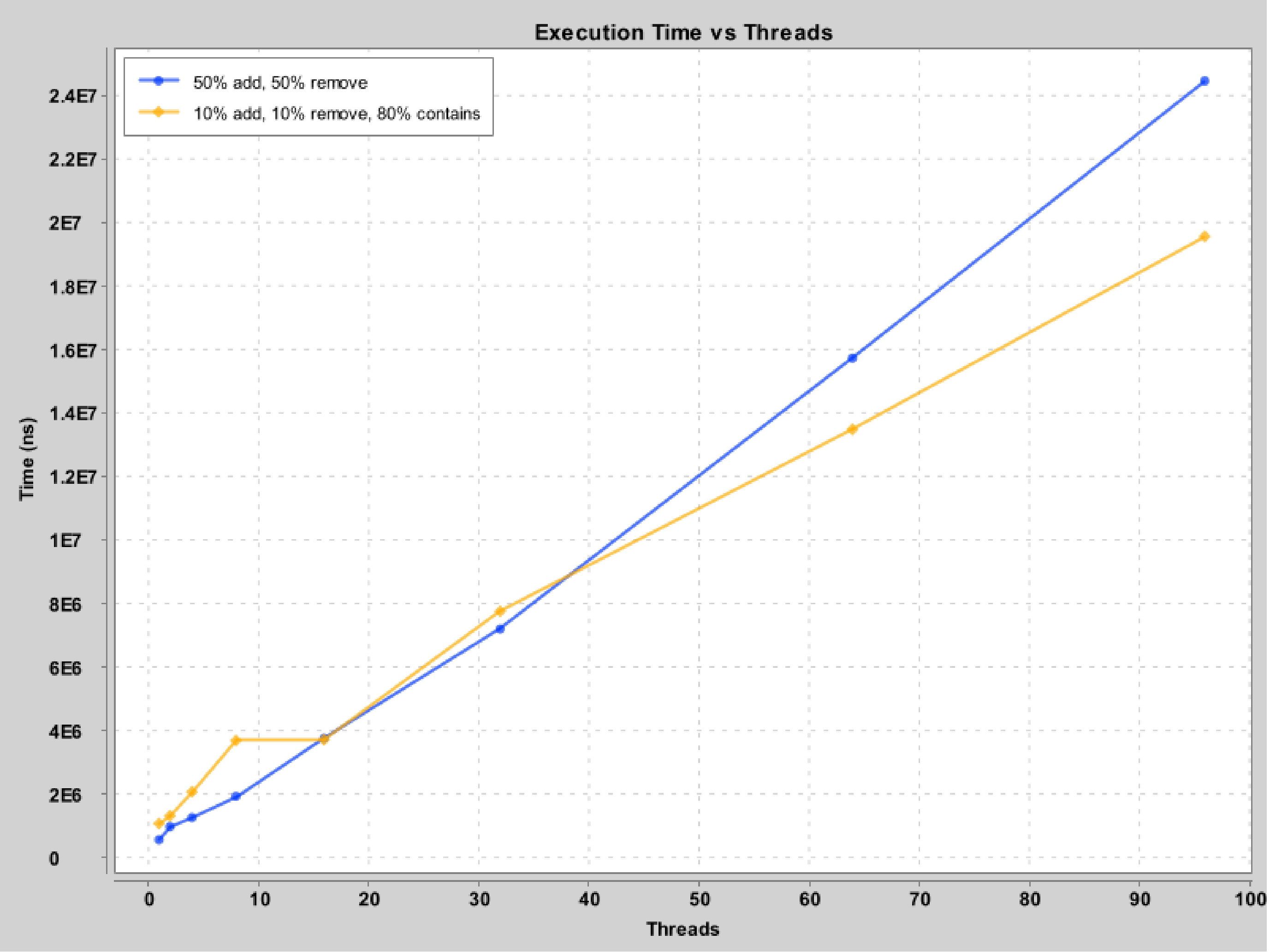

Discrepancy vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Numbers
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
10
20
30
40
50
60
70
80
90
100
Threads

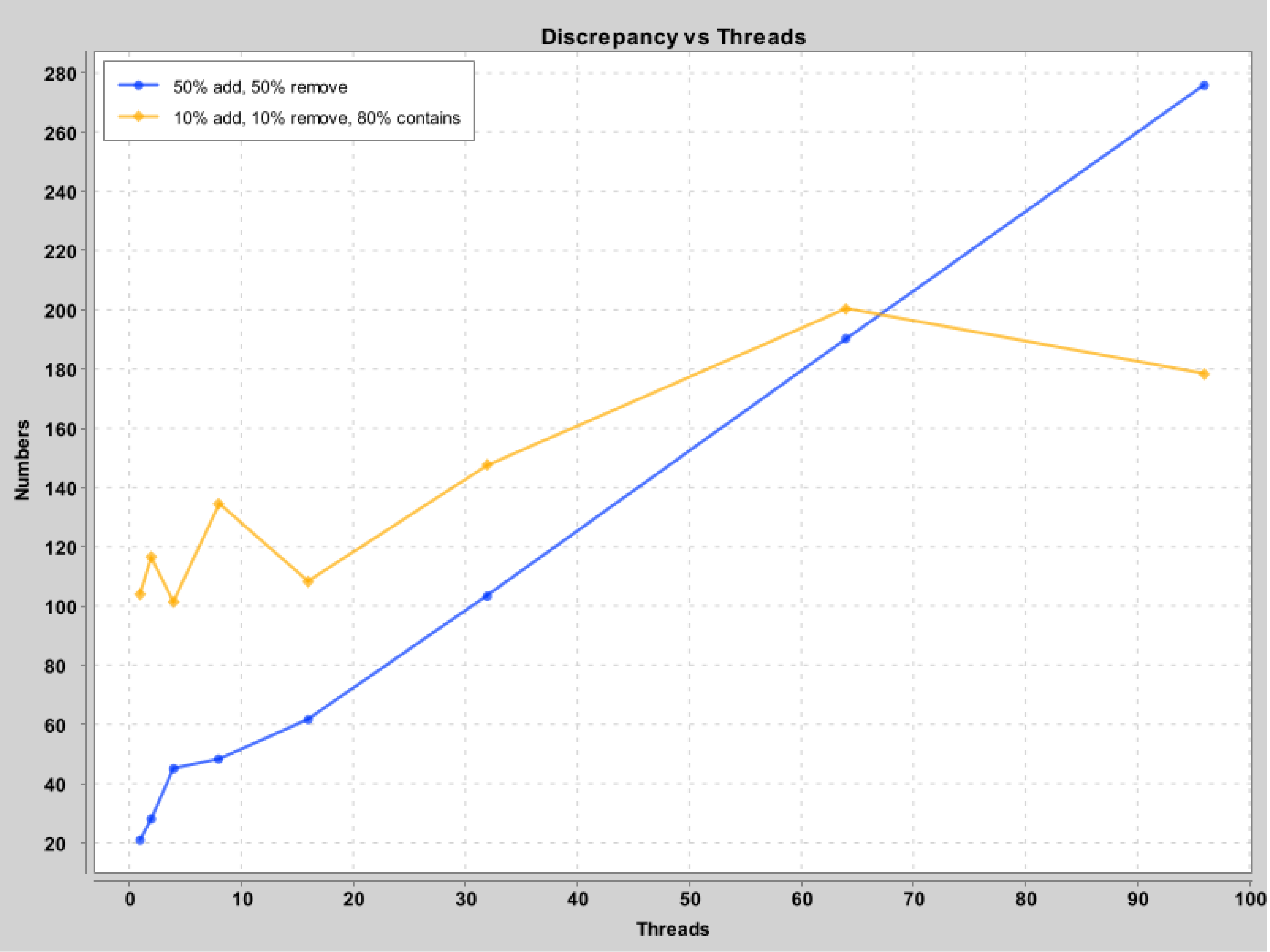

Execution Time vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Time (ns)
3.8E7
3.6E7
3.4E7
3.2E7
3E7
2.8E7
2.6E7
2.4E7
2.2E7
2E7
1.8E7
1.6E7
1.4E7
1.2E7
1E7
8E6
6E6
4E6
2E6
0
0
10
20
30
40
50
60
70
80
90
100
Threads


Discrepancy vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Numbers
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Threads


Execution Time vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Time (ns)
6.5E7
6E7
5.5E7
5E7
4.5E7
4E7
3.5E7
3E7
2.5E7
2E7
1.5E7
1E7
5E6
0
0
10
20
30
40
50
60
70
80
90
100
Threads


Discrepancy vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Numbers
0
50
100
150
200
250
300
350
400
450
Threads
0
10
20
30
40
50
60
70
80
90
100


Execution Time vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Time (ns)
2.4E7
2.2E7
2E7
1.8E7
1.6E7
1.4E7
1.2E7
1E7
8E6
6E6
4E6
2E6
0
Threads
0
10
20
30
40
50
60
70
80
90
100


Discrepancy vs Threads
50% add, 50% remove
10% add, 10% remove, 80% contains
Numbers
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
Threads