CAN DATA PROCESSING

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Objective:

- Perform simultaneous calculations on a large dataset obtained from a 2012 Chevrolet Malibu's CAN bus.
- Target signals include engine speed, vehicle speed, engine coolant temperature, fuel tank level, and trip distance

General Data Analysis:

- Minimum, Maximum, and Average for every signal.

In-Depth Calculation and Data Analysis

- Acceleration using vehicle speed and timestamp. Driving flags raised for hard acceleration and hard braking.

Histogram Generation:

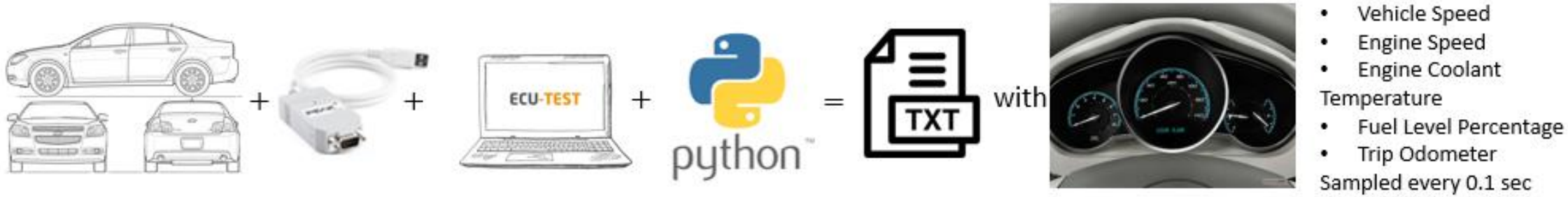
- Created a histogram for engine speed, vehicle speed, and acceleration where intervals were established over a specified range, showcasing the distribution of engine speed, vehicle speed, and acceleration data.

Parallel Computation with TBB:

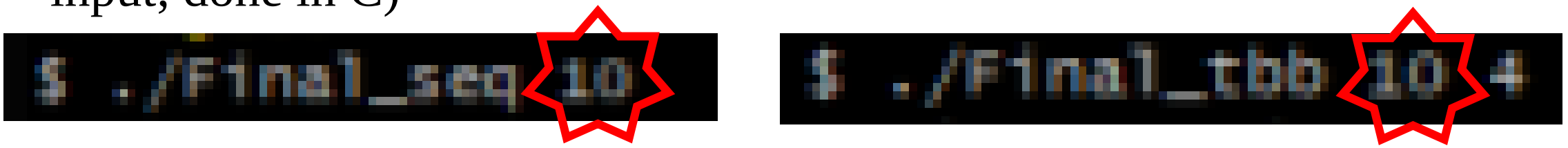
- Applied TBB's parallel for and parallel reduce techniques to enhance the efficiency of data processing tasks

Overall Diagram

- Stage 1 (Obtain 305,000 data points from vehicle)



- Stage 2 (Read in text file & expand data set with a multiplier based on user input; done in C)



[1,2,3,4] with "N Multiplier" = 2 --------> [1,2,3,4,1,2,3,4]

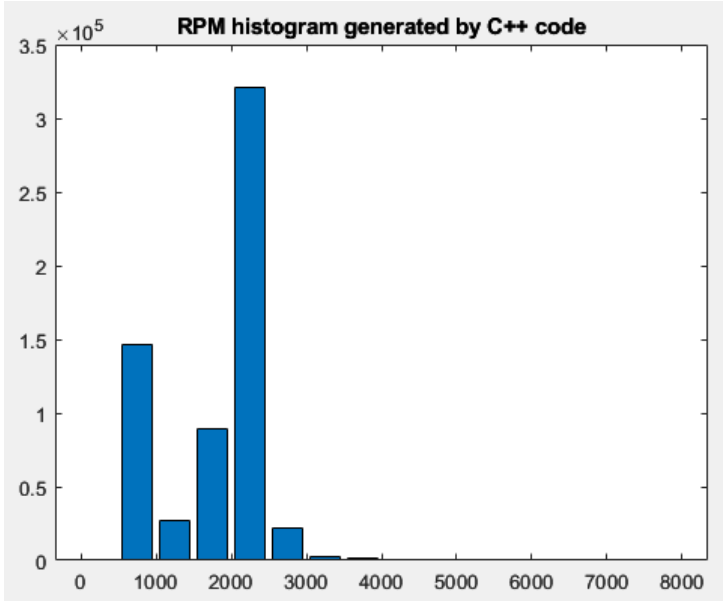
Overall Diagram Continued…

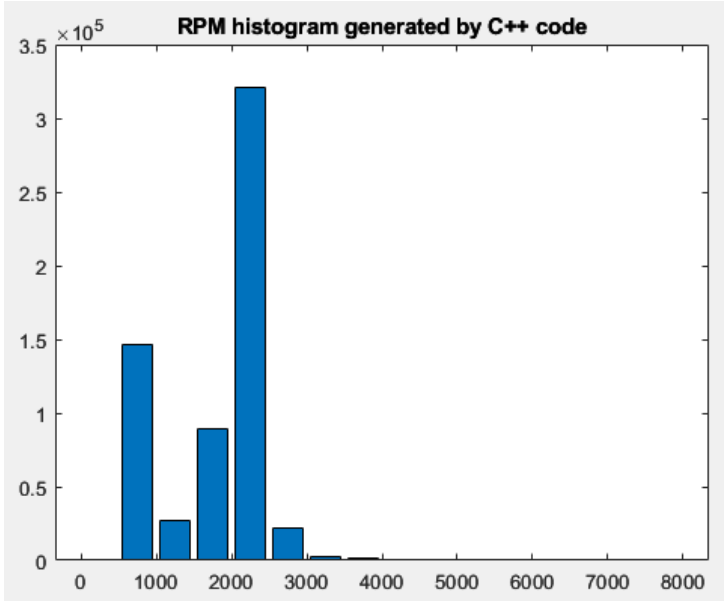
- Stage 3 (Computations in C; print to terminal; write .bof for histograms)

```
----------------------Max Values-------------------------------
Max Engine Speed: 4590.5rpm at 7997.23s
Max Vehicle Speed: 135kph at 8248.04s
Max Fuel Percentage: 42.3529% at 133.822s
Max ECT: 85 Degrees Celsius at 5446.32s
Max Distance Travelled: 169km at 8590.41s
---------------------------------------------------------------
```

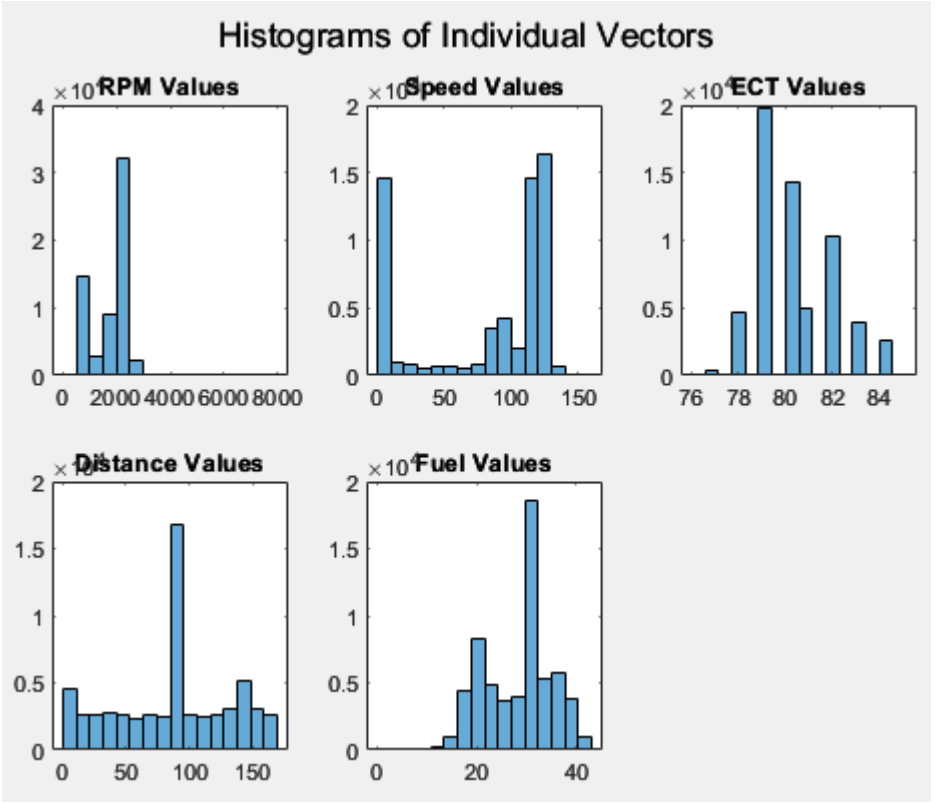
```
Hard Acceleration  =  360
Hard Braking  =  80
Cruising  =  11840
```

- Stage 4 (Graphing in MATLAB)





- Stage 5 (Verification of computational accuracy in MATLAB)



Algorithm – Sequential Computations

Step 1

- Use findMax function to get maximum for every signal
- Use findMin function to get minimum for every signal
- Use findAvg function to get average for every signal

Step 2

- Use for loop to get acceleration for every vehicle speed data point

```
acceleration[i] = ((Vehicle_Speed.Data[i+1] -  Vehicle_Speed.Data[i]) / ((Vehicle_Speed.timestamp[i+1] - Vehicle_Speed.timestamp[i])*3.6))
```

- Divide acceleration data into 10 second chunks (100 points per chunk)
  - Find min and max within each chunk
  - Categorize as hard braking if min < -5.4 m/s
  - Categorize as hard acceleration if max > 2.7 m/s (0-60 mph in 10 sec)

Algorithm – Sequential Computations

Step 3

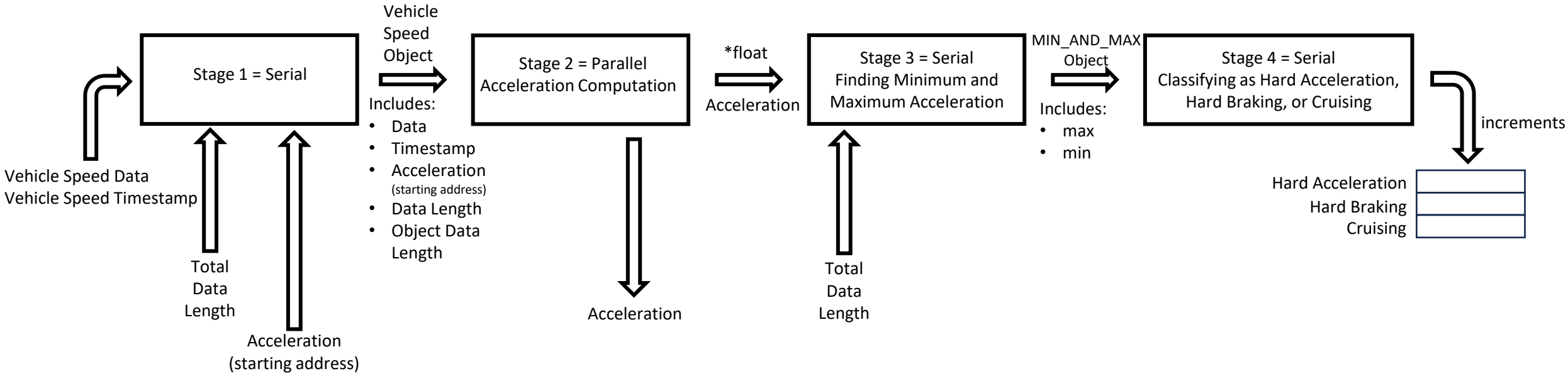
- Use CreateHistogram function to create histogram for engine speed, vehicle speed, and acceleration
  - Engine Speed Range = 0 – 8000 rpms w/ bins every 500 rpms
  - Vehicle Speed Range = 0 – 160 km/hr w/ bins every 10 km/hr
  - Acceleration Range = -10 – 10 m/(s^2) w/ bins every 1 m/(s^2)

Step 4

- Display results to terminal

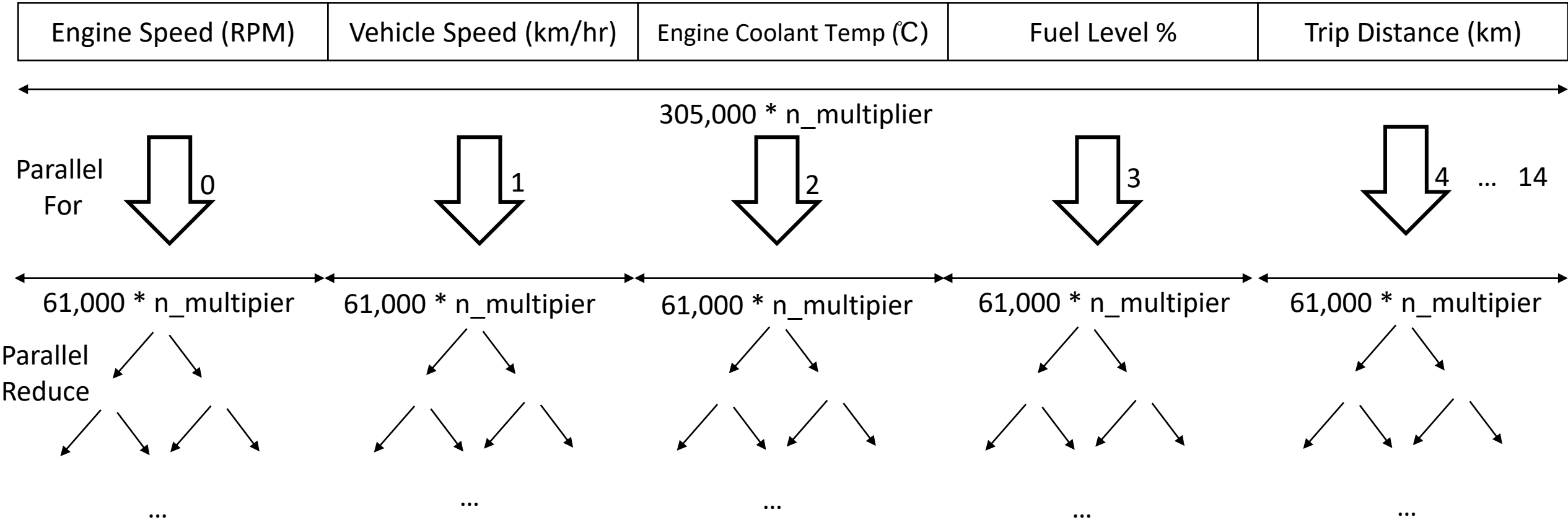
Parallelization Strategy – Part 1 – Pipeline

- Parallel Pipeline used for the acceleration computations and driving analysis.
  - Acceleration calculation stays the same as before
    - However, it is done in a parallel pipeline state to increase computation time
  - The length of the input vectors will be 61000 * n_multiplier.
  - Each Vehicle Speed Object will be packed with 100 data points.
  - Acceleration saved for other computations to use.



Parallelization Strategy – Part 2 – Main Parallel_for Loop

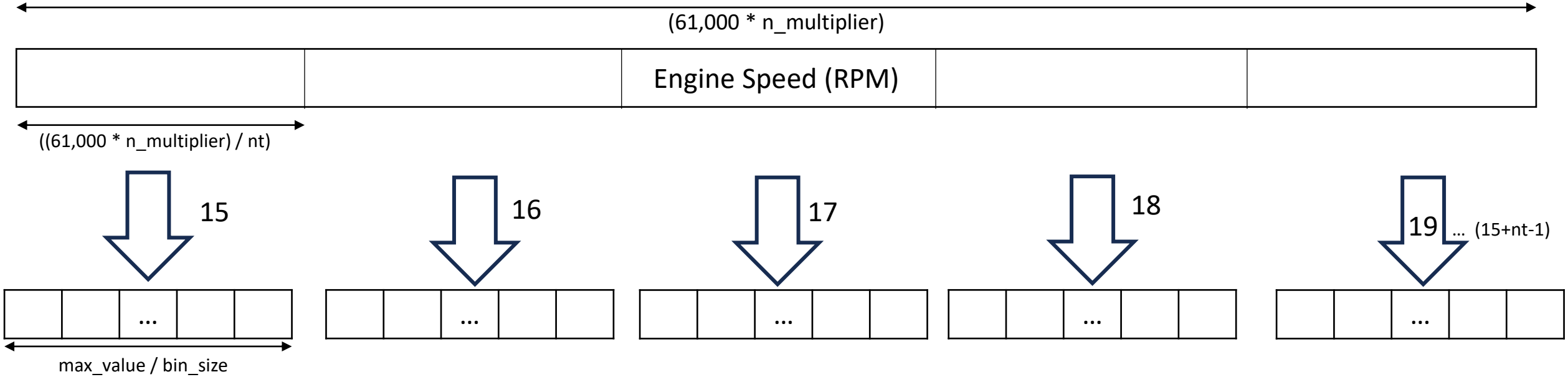
- Calculates maximum, minimums, averages, and partial histograms concurrently



To get a min, max, and average for each value

Parallelization Strategy – Part 2 – Main Parallel_for Loop

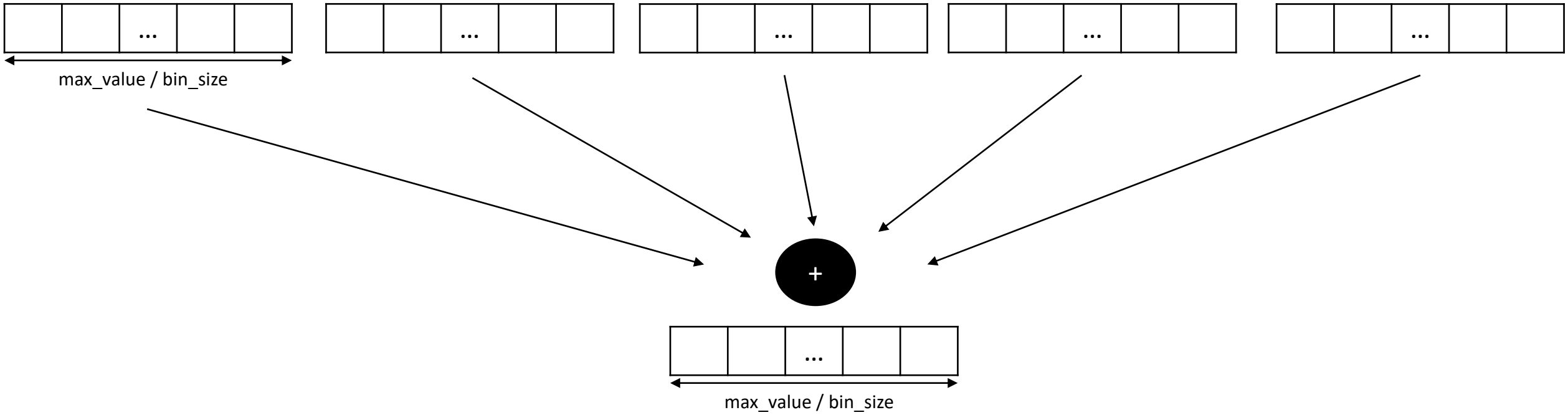
- Calculates maximum, minimums, averages, and partial histograms concurrently



- This part was repeated for Vehicle Speed and Acceleration
  - Engine Speed (15):(15+nt-1)
  - Vehicle Speed (15+nt):(15+(2*nt)-1)
  - Acceleration (15+(2*nt)):(15+(3*nt)-1)

Parallelization Strategy – Part 3 – Histogram Generation

- Reduction was implemented to reduce all the partial histograms of Vehicle Speed, Engine Speed, and Acceleration into 3 final histograms
  - An example of one is shown below going from nt partial histograms to one final histogram
  - The three reduction processes were implemented sequential
    - Potential improvement: parallel_for to do three reductions at once



Results Computational Accuracy

Sequential

```
Hard Acceleration  =  18
Hard Braking  =  4
Cruising  =  592
----------------------Max Values-----------------------------
Max Engine Speed: 4590.5rpm at 7997.23s
Max Vehicle Speed: 135kph at 8243.65s
Max Fuel Percentage: 42.3529% at 40.4935s
Max ECT: 85 Degrees Celsius at 5180.43s
Max Distance Travelled: 169km at 8552.07s
-------------------------------------------------------------
----------------------Min Values-----------------------------
Min Engine Speed: 687rpm at 5484.05s
Min Vehicle Speed: 0kph at 0.040112s
Min Fuel Percentage: 1.96078% at 7976.77s
Min ECT: 76 Degrees Celsius at 38.3815s
Min Distance Travelled: 0km at 0.076763s
-------------------------------------------------------------
----------------------Avg Values-----------------------------
Avg Engine Speed: 1751.57rpm
Avg Vehicle Speed: 80.7815kph
Avg Fuel Percentage: 28.5279%
Avg ECT: 80.2756 Degrees Celsius
Avg Distance Travelled: 85.616km
-------------------------------------------------------------
```

TBB

```
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Hard Braking  =  4
Cruising  =  592
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```

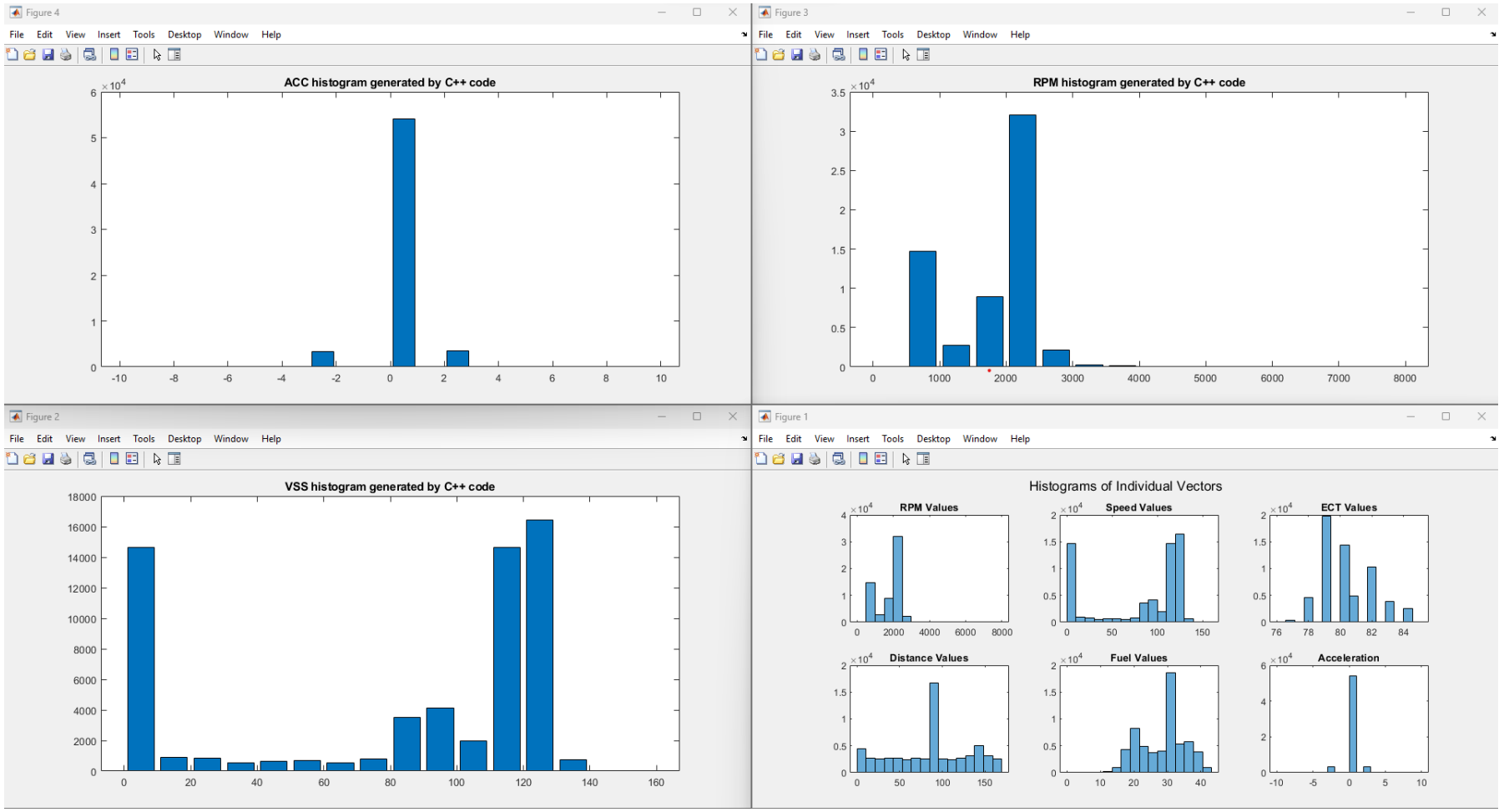
MATLAB

```
Average rpm 1751.5629
Average Vehicle Speed 80.7815
Average ECT 80.2756
Max rpm: 4590.5
Max Vehicle Speed: 135
Max Engine Coolant Temperature: 85
Max Vehicle Distance: 169
Max Fuel Level Percentage: 42.3529
Min rpm: 687
Min Vehicle Speed: 0
Min Engine Coolant Temperature: 76
Min Vehicle Distance: 0
Min Fuel Level Percentage: 1.9608
Min Acceleration below -5.4:
     4

Max Acceleration above 2.7:
    18
```

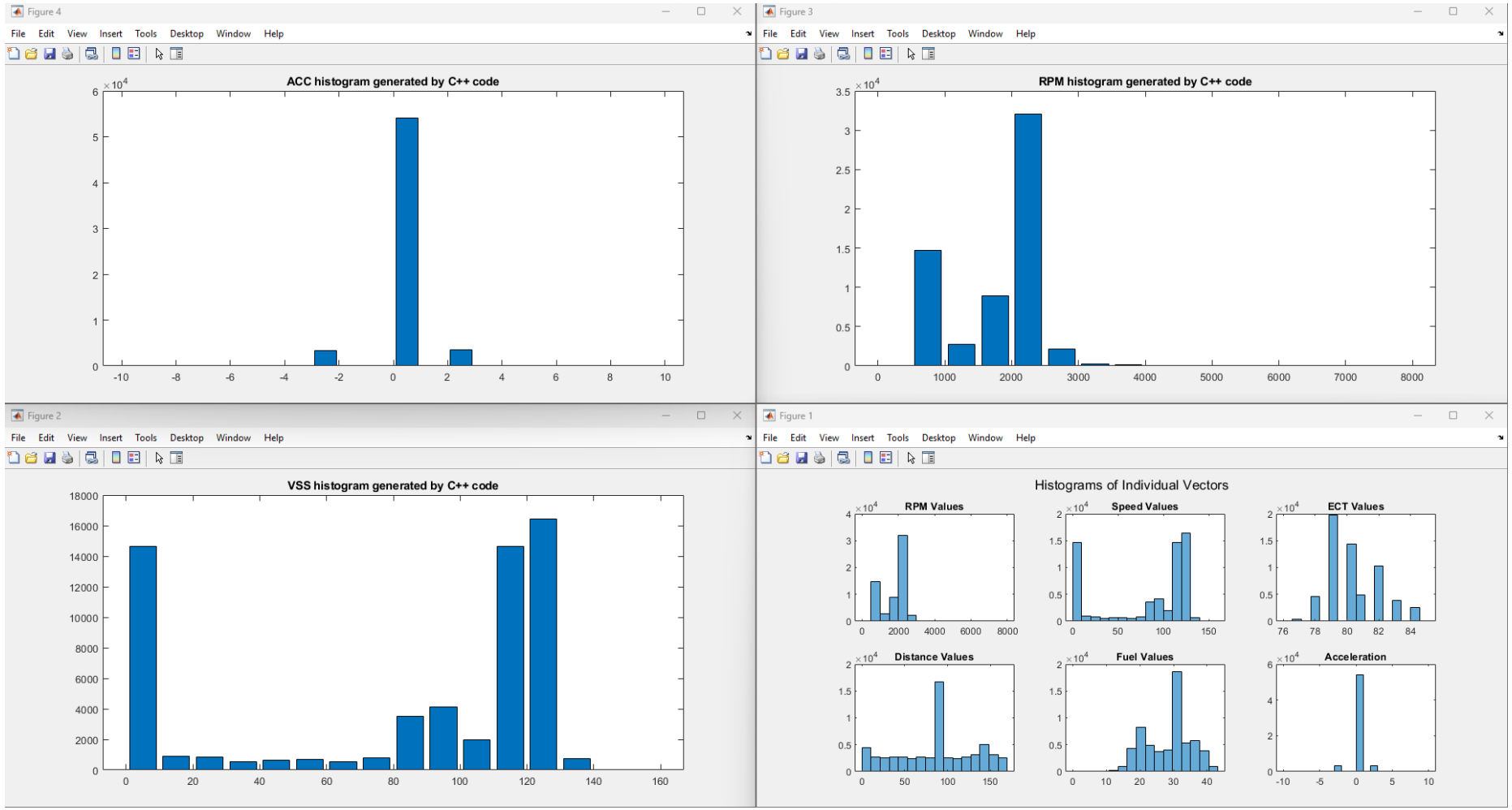
Results Computational Accuracy

Sequential



Results Computational Accuracy

TBB



Results – Intel i7-9750H

TBB						
Partial Histograms	Time (us)					
n_multiplier	1	2	3	5	10	20
1	2676	5654	7220	11972	19940	41966
2	2760	3782	6231	10856	20901	35039
3	2883	4760	6011	11248	17781	37393
4	2519	4213	7247	9817	17770	35012
5	2407	3658	5884	10051	27005	33910
6	2398	3969	6029	9141	18525	35762
7	2670	3902	5813	9036	17473	34254
8	2474	3851	6012	9517	17920	34106
9	2584	3575	5667	9758	18406	34375
10	2369	4501	5478	11677	19067	34794
Sequential	3865	7639	11746	19428	38947	99799

Results – Intel Atom N2600

TBB						
Partial Histograms	Time (us)					
n_multiplier	1	2	3	5	10	20
1	52255	79130	124571	196808	393620	700837
2	43241	74653	114854	178859	364176	700975
3	38822	75983	111964	179158	374134	674151
4	41780	73932	110953	181367	354300	661860
5	38122	75849	112523	175732	321321	666547
6	43029	73381	104755	167970	333460	707556
7	39735	73439	105001	174309	349233	667655
8	40941	74566	106476	172085	349536	698942
9	39208	71427	106097	170767	325624	667857
10	40492	68626	110670	174775	334168	664871
Sequential	67451	111742	137725	229263	458284	916667

Results – TBB vs Sequential Computation Times

*Intel i7-9750H
*4 Partial Histograms

DEMO