

# Characterizing Execution Times on Realistic Programs

Young-Kyoon Suh,  
Data & Knowledge Engineering Laboratory,  
School of Computer Science and Engineering,  
Kyungpook National University

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## 1 Description

This document characterizes execution times measured on several real-world programs with different input sizes. To achieve this characterization, we discuss various histograms of execution times, measured in program time (PT), of the programs throughout this document. In this work we wish to achieve several goals as follows. The first goal is to unravel any structure behind the histograms and present insights into how such structure is formed. Another goal is to build a statistical distribution (or model) fitting in the histograms. From that distribution, we may reach predicting a concrete execution time considering system noise via the model on an arbitrary algorithm with a given input on a real execution environment. As a note, the execution times were measured along with the EMPv5 [1] protocol.

## 2 Histograms of the Execution Times on Real-World Programs

This section shows histograms for runs on different real-world programs with varying input sizes. In addition to the insertion sort program, we use another kind of program—*matrix multiplication*. For these programs, we varied their input sizes by  $2\times$  while trying some intermediate sizes increased by  $\sqrt{2}$  and measured execution times of the programs over each input size. We then exhibit different kinds of histograms in the subsequent sections.

**Experimental Notes:** In the experiments we also used four nodes (`sodb8`, `sodb9`, `sodb10`, and `sodb12`) in the same cluster. A short summary of the experiments is shown in Table 1.

Machine	Task Length	Description	Time Length
<code>sodb9</code> (plugged into <i>the upper left</i> power strip)	SORT100, SORT200, SORT400, SORT800	Runs of 300 samples	2018-04-09 ~2018-04-12
<code>sodb10</code> (plugged into <i>the upper left</i> power strip)	MATC1K, MATC2K, MATC4K, MATC8K	Runs of 300 samples	2018-03-02 ~2018-03-12
<code>sodb12</code> (plugged into <i>the upper right</i> power strip)	MATR1K, MATR2K, MATR4K, MATR8K	Runs of 300 samples	2018-03-02 ~2018-03-12

Table 1: Detailed description of INC data used for histograms

## 2.1 Insertion Sort on sodb9

This section shows a series of histograms of an insertion sorting program that sorts the elements of a given array in non-decreasing order. The program repeatedly runs 300 times for a given input size. Note that each sort program over a specific input size is termed SORT $x$ : for instance, SORT100 indicates the insertion sort program over 100K elements. This experiment was performed on sodb9 plugged into *the upper left* power strip.

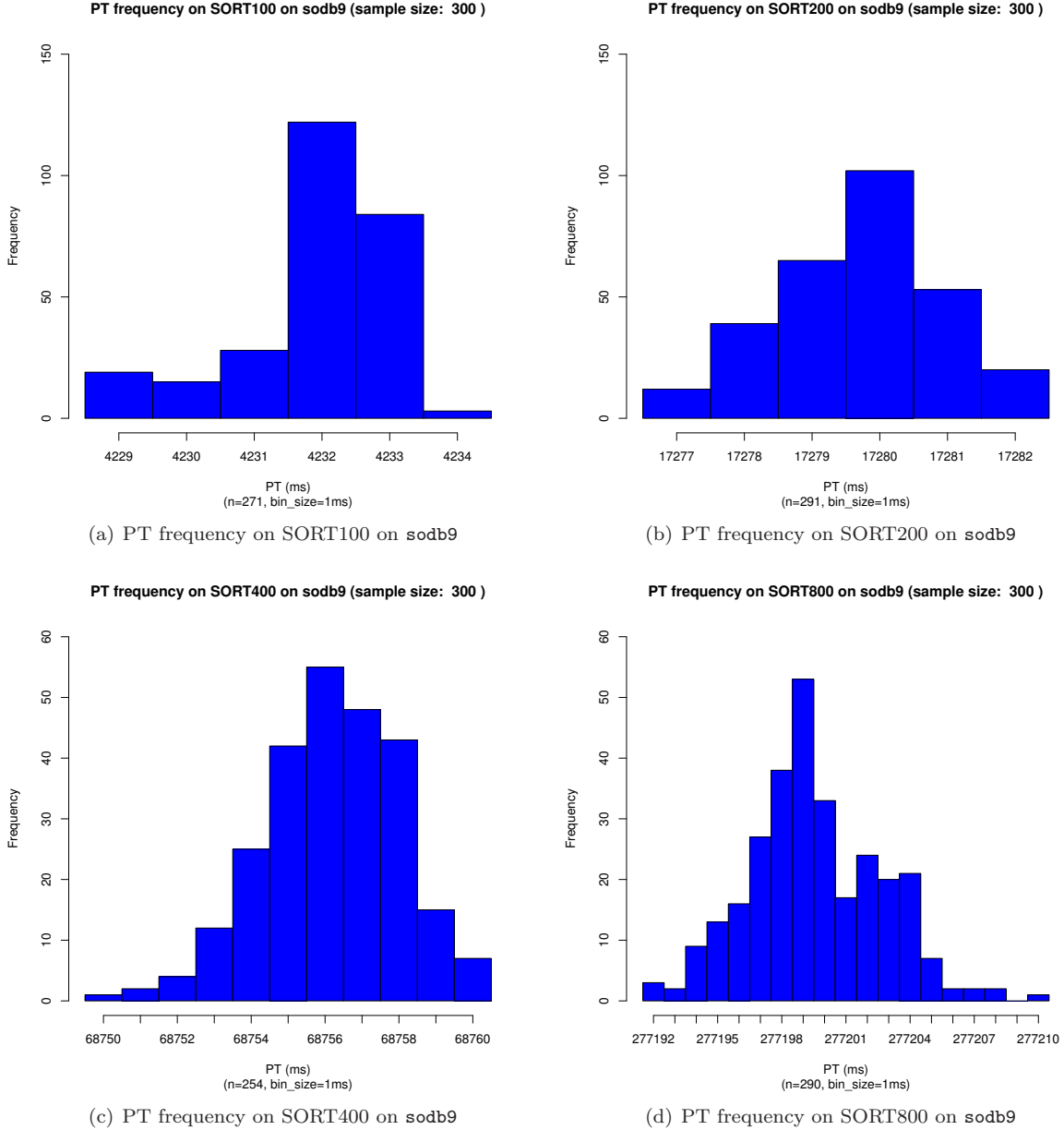


Figure 1: PT Histograms of SORT100 ... SORT800 on sodb9

## 2.2 Matrix Multiplication

This section shows a series of histograms of the execution times of an matrix multiplication program. We used the same sample size for each input size of this program: i.e., 40 iterations. For simplicity, we used two square matrices for performing their multiplication in the program. We also varied the input sizes of each of the two matrices: from 1K×1K to 8K×8K integer elements that are also randomly generated. Note that each matrix multiplication program for a specific size is called MAT $xyyyy$ , where  $x$  indicates which major, specifically *column* vs. *row*, is used, and  $yyyy$ , how large a given matrix is. For instance, MATC1000 represents a matrix multiplication program in column major over two square matrices having 1,000 integer (random) elements in a row (and a column).

### 2.2.1 Column Major

Figure 2 shows a series of histograms of the execution times measured on the same matrix multiplication program in column major as the input sizes grows. The program was run on *sodb10* plugged into *the upper left* power strip.

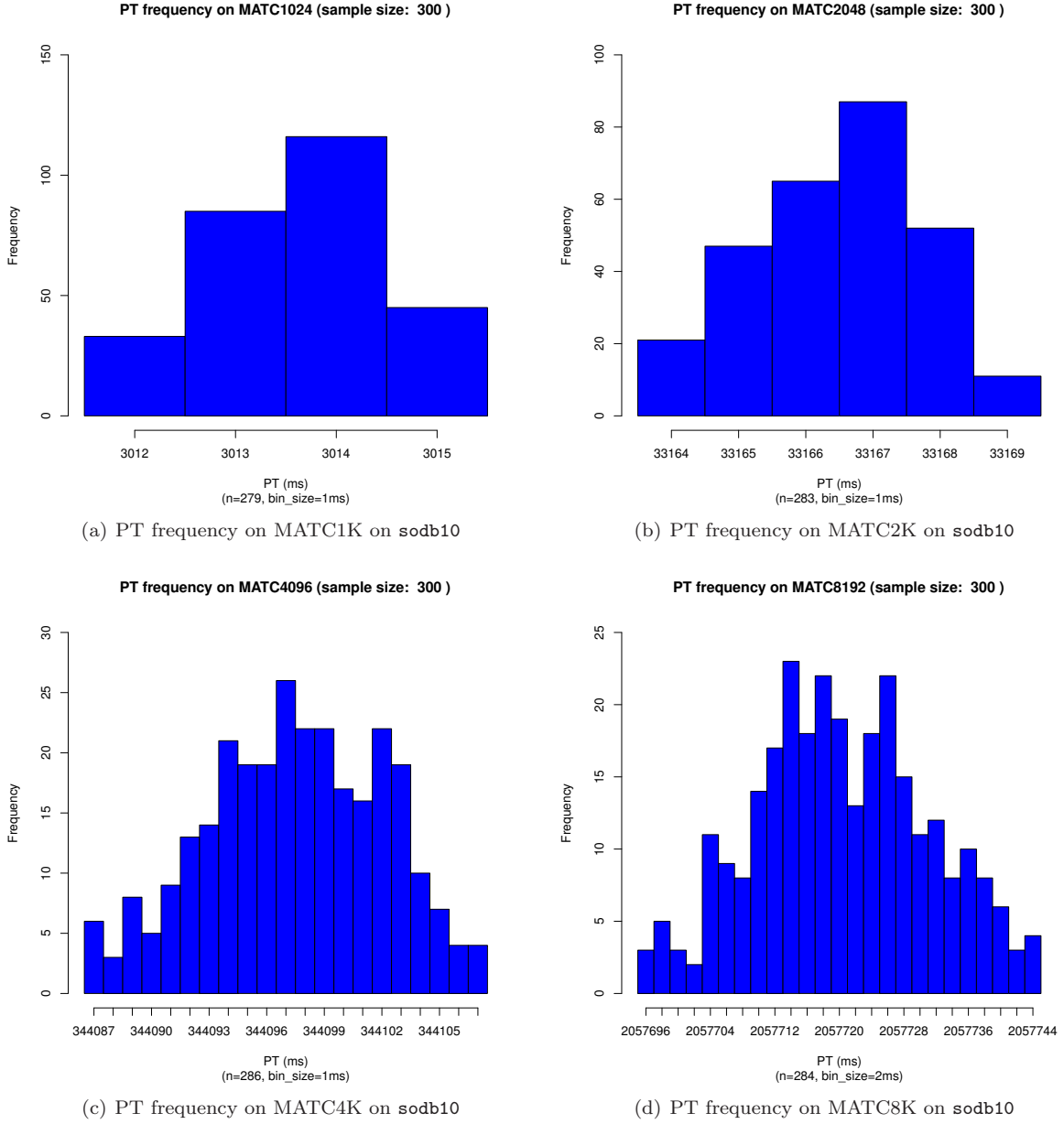


Figure 2: PT Histograms of MATC1024 ... MATC8192

## 2.2.2 Row Major

Figure 2 shows a series of histograms of the execution times measured on the same matrix multiplication program in row major as the input sizes grows. The program was run on `sodb12` plugged into *the upper right* power strip.

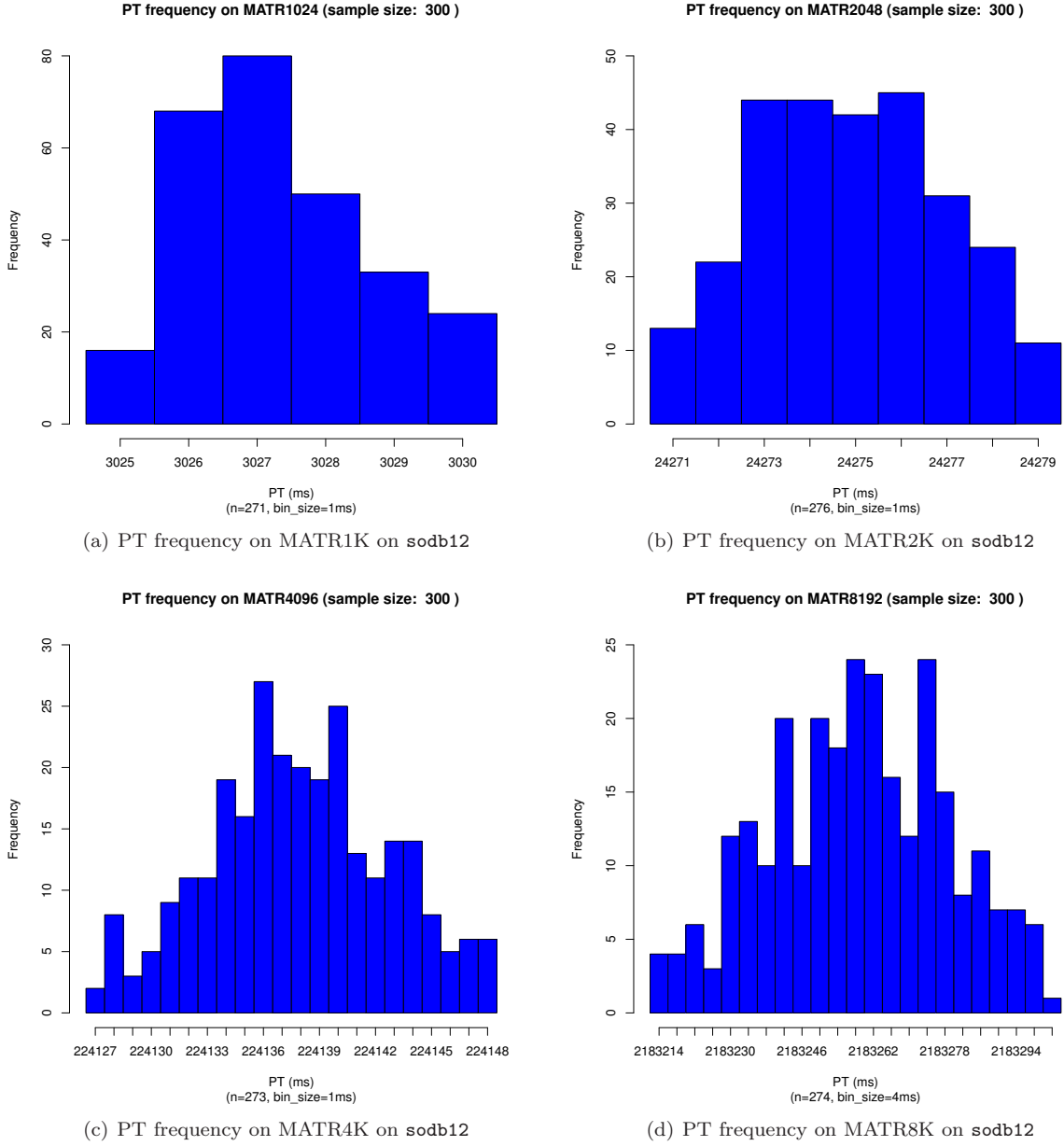


Figure 3: PT Histograms of MATR1K ... MATR8K

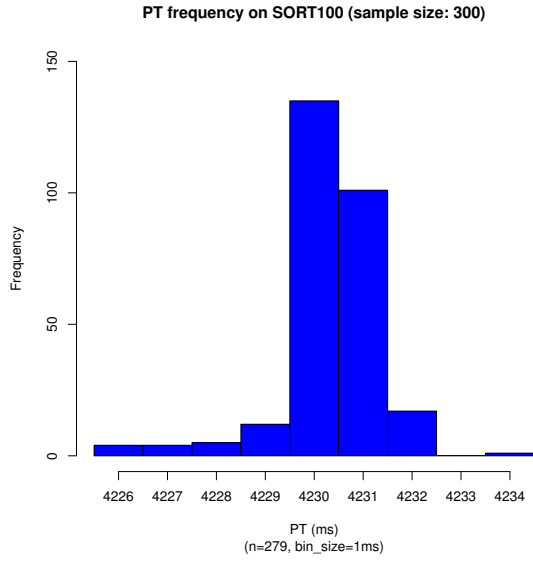
### 3 Appendix

#### 3.1 Insertion Sort on sodb8

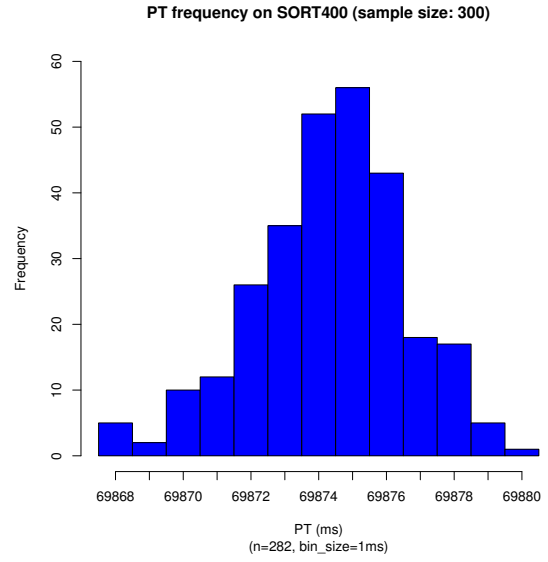
This section shows a series of histograms of an insertion sorting program that sorts the elements of a given array in non-decreasing order. The program repeatedly runs 300 times for a given input size. The input size for the program varies from 100,000 to 1,160,000 integer elements, which are randomly generated. Note that each sort program over a specific input size is termed SORT $x$ : for instance, SORT100 indicates the insertion sort program over 100K elements.

Machine	Task Length	Description	Time Length
sodb8 (plugged into the <i>bottom left</i> power strip)	SORT100      ... SORT2320	Runs of 300 samples	2018-03-02 ~2018-03-10

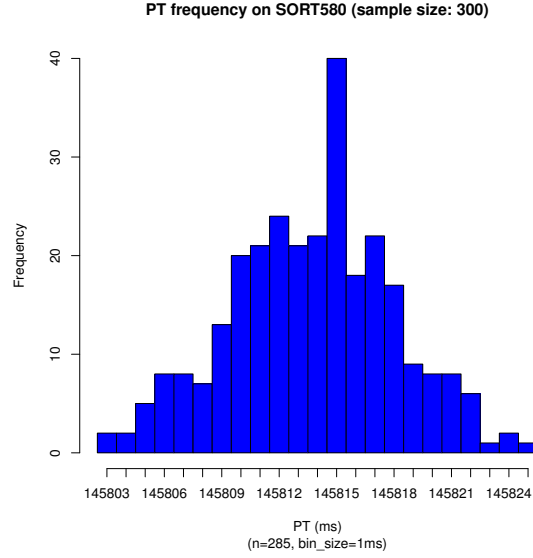
Table 2: Detailed description of INC data used for the subsequent histograms



(a) PT frequency on SORT100 on `sodb8`

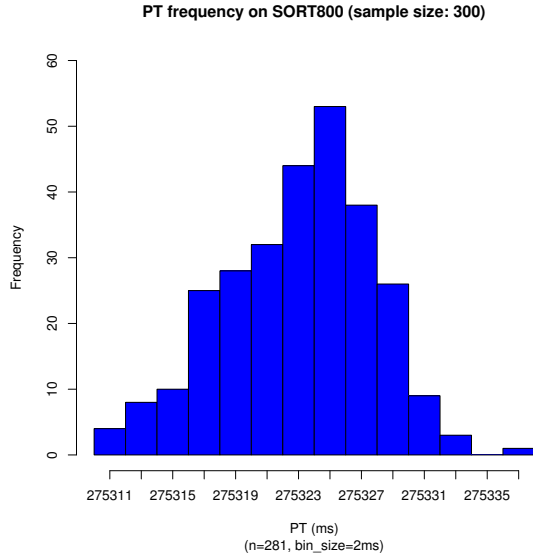


(b) PT frequency on SORT400 on `sodb8`

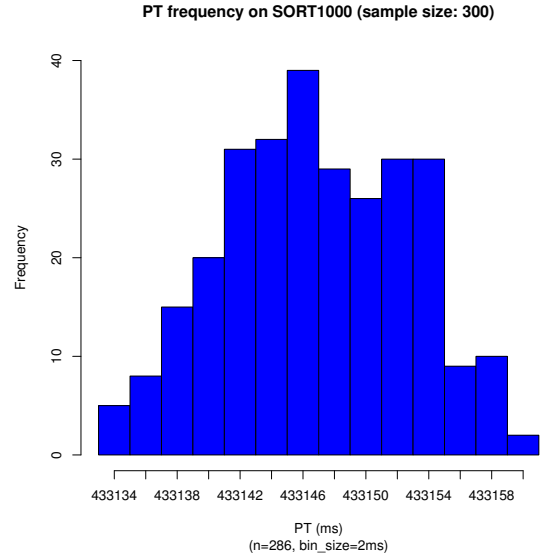


(c) PT frequency on SORT580 on `sodb8`

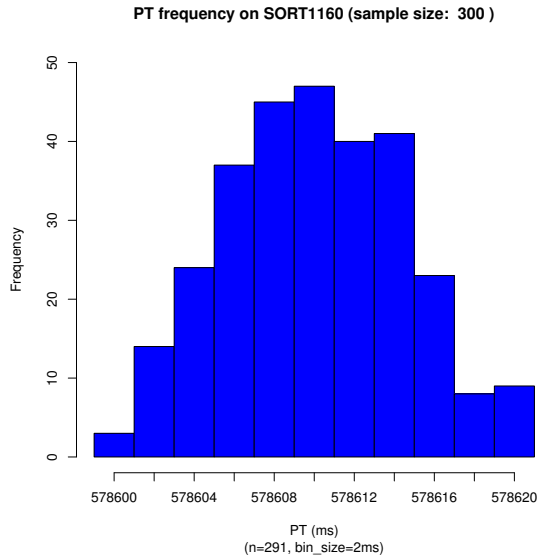
Figure 4: PT Histograms of SORT100 ... SORT580



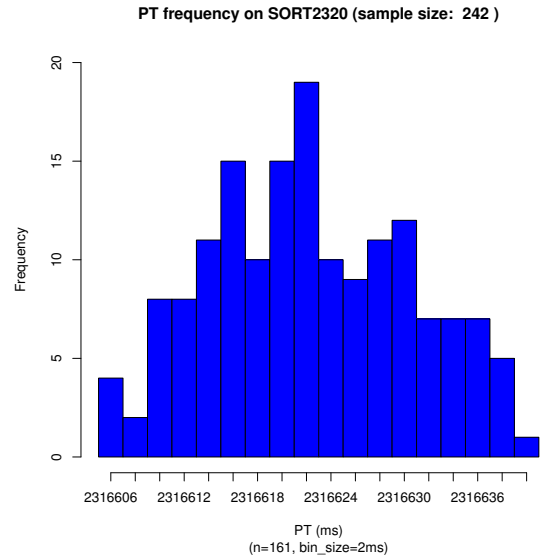
(a) PT frequency on SORT800 on sodb8



(b) PT frequency on SORT1000 on sodb8



(c) PT frequency on SORT1160 on sodb8



(d) PT frequency on SORT2320 on sodb8

Figure 5: PT Histograms of SORT800 ... SORT2320

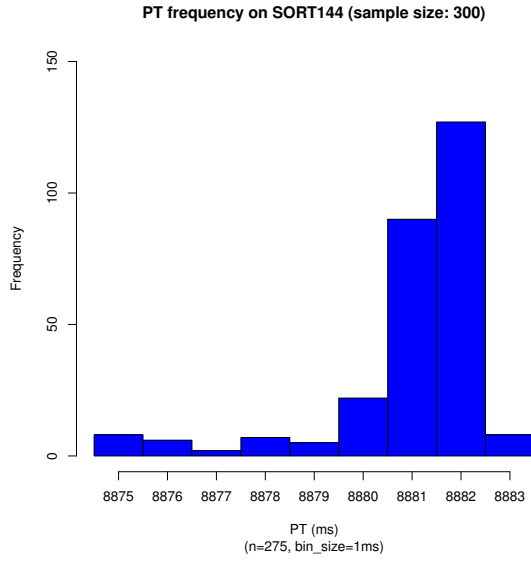


### 3.2 One-to-One Comparison between An Insertion Sort & A Corresponding INC Programs

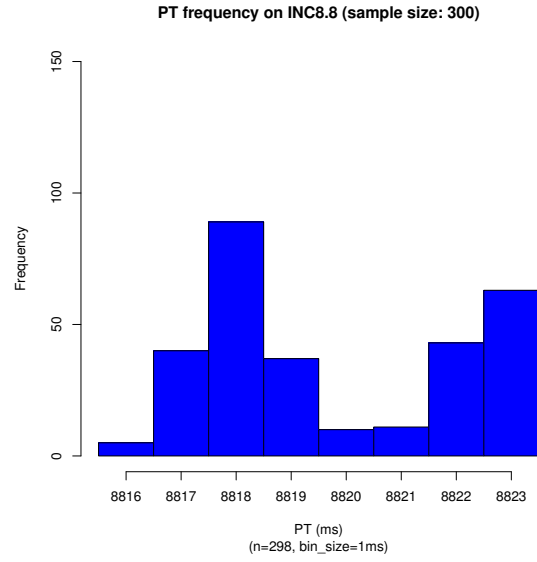
This section compares program time histograms of an insertion sort and a nested-for-loop programs (termed INC) with different input sizes. The insertion sort program sorts the elements of a given array in non-decreasing order. The program repeatedly runs 300 times for a given input size. The input size for the program varies from 144K to 344K integer elements, which are randomly generated. Note that each sort program over a specific input size is termed *SORT $x$* : for instance, *SORT100* indicates the insertion sort program over 100K elements. An INC program’s task length is correspondingly determined by the program time of an *SORT* program. In Figures 6, 7, and 8 we perform a match on an *SORT* program and its corresponding INC program.

Machine	Task Length	Description	Time Length
sodb8 (plugged into the <i>bottom left</i> power strip)	SORT144 ... SORT344	Runs of 300 samples	2018-03-09 ~2018-03-17
sodb10 (plugged into the <i>upper left</i> power strip)	INC8.8 ... INC51.5	Runs of 300 samples	2018-03-18 ~2018-03-18

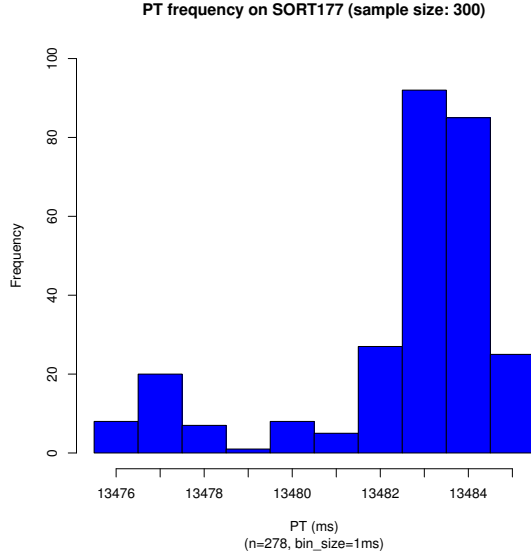
Table 3: Detailed description of INC data used for the subsequent histograms



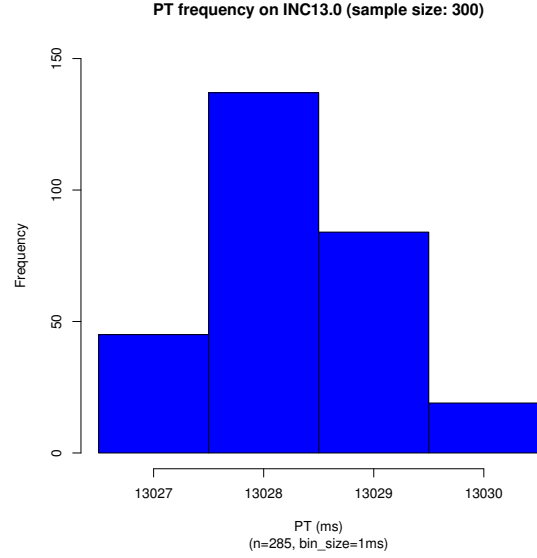
(a) PT frequency on SORT144 on *sodb8*



(b) PT frequency on INC8.8 on *sodb10*

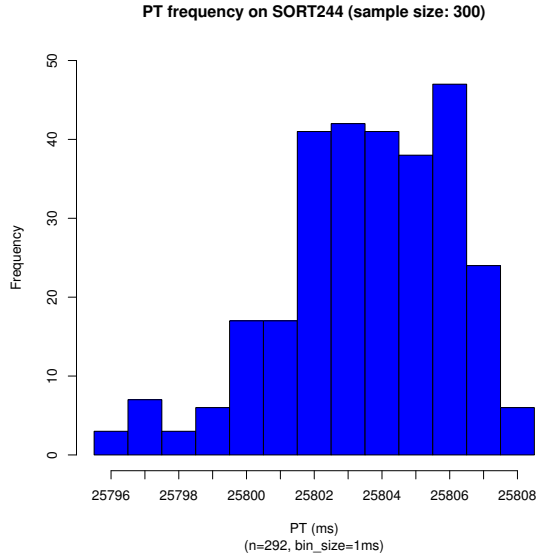


(c) PT frequency on SORT177 on *sodb8*

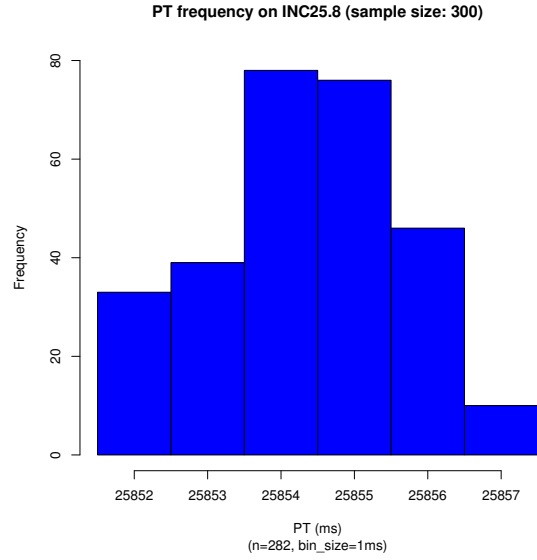


(d) PT frequency on INC13 on *sodb10*

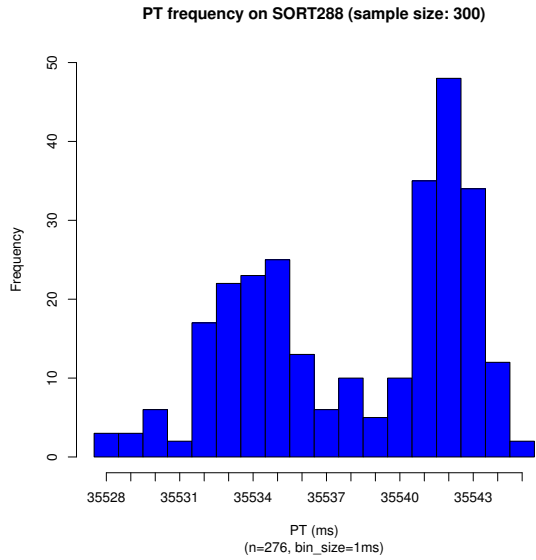
Figure 6: PT Histograms I



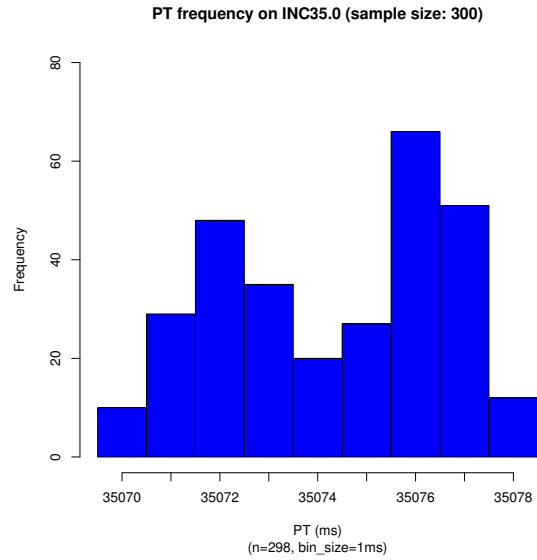
(a) PT frequency on SORT244 on sodb8



(b) PT frequency on INC25.8 on sodb10

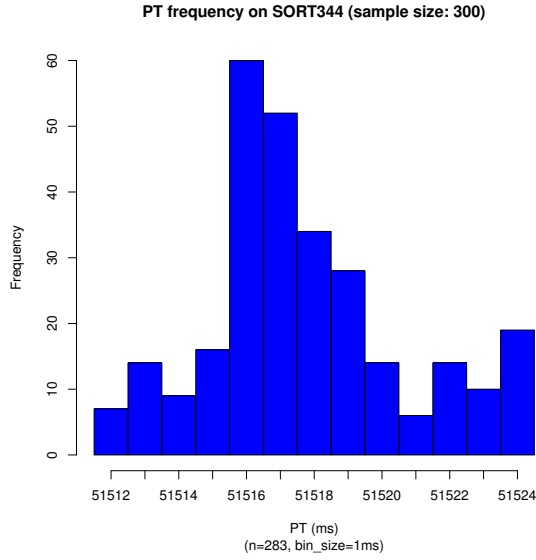


(c) PT frequency on SORT288 on sodb8

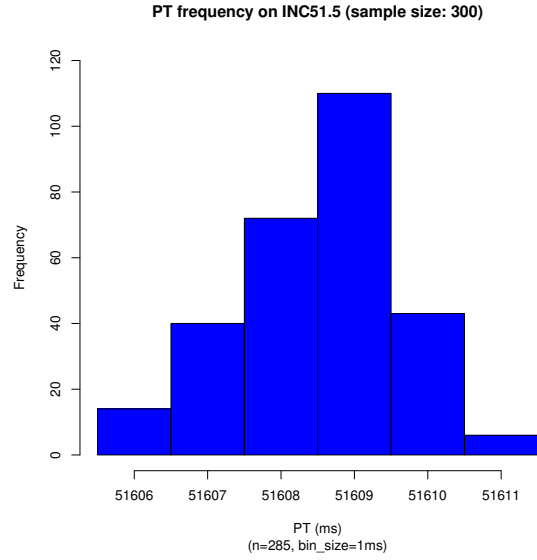


(d) PT frequency on INC35 on sodb10

Figure 7: PT Histogram Comparison II



(a) PT frequency on SORT344 on `sodb8`



(b) PT frequency on INC51.5 on `sodb10`

Figure 8: PT Histogram Comparison III

## References

- [1] Young-Kyoon Suh, Richard T. Snodgrass, John Kececiloglu, Peter J. Downey, Rob S. Maier, and Cheng Yi, “EMP: Execution Time Measurement Protocol for Compute-Bound Programs”, in *Software: Practice and Experience*, 47(4):559–597, 2017.
- [2] Sabah Currim, Richard T. Snodgrass, Young-Kyoon Suh, and Rui Zhang, “DBMS Metrology: Measuring Query Time”, in *ACM Transactions on Database Systems*, 42(1):3:1–42(+8), 2017.