International Conference on Advancements in Computing Technologies - ICACT 2018 ISSN: 2454-4248
Volume: 4 Issue: 2 25 – 27

Time and Energy Efficiency: A Comparative Study of Sorting Algorithms Implemented in C

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Abstract— In this era of digital revolution where the usage of computing devices has increased drastically, there is renewed focus on energy efficiency. Energy consumed depends on both the hardware and software used. The algorithm used to implement the software has a major impact. This paper studies how different sorting algorithms have an impact on energy consumption.

Keywords— *Time efficiency, Algorithms, Energy efficiency, Energy consumption, Joulemeter.*

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I. INTRODUCTION

Computing devices are increasingly used in all walks of life. Due to this, the energy consumed for computing has grown exponentially in recent years. This coupled with the depletion of natural resources and deteriorating environment has made energy efficiency the need of the hour. Recent advances in hardware technology have improved the situation to some extent. Virtualization of hardware has also resulted in efficient sharing of computing resources. Recent hardware and operating systems provide better support for tools that measure efficiency.

Lower energy utilization reduces heat dissipation and increases the reliability and life of electronic components used in computer hardware. It also directly reduces energy bills. Reduced energy usage also contributes to a cleaner environment. This is the key motivation for this work.

Software components can also play a significant role in the reduction of energy usage. For example, a careless implementation of sleep can become a huge bottleneck in a computer, by doing unproductive work. Sorting is the most commonly used algorithms as this algorithm helps reduce the time complexity of search algorithms. For example, a binary search can only be done if the records are in sorted order. There are several hardware and software tools to measure the power consumed by an algorithm. In this experiment, a tool named Joulemeter (Energy profiling tool) is used which estimates the power usage of running applications on a computer by evaluating how much hardware resources are being used. It measures the resources like CPU, memory, disk, monitor and translating the resource usage to real power usage based on the power models. [1]

The next section of the paper is structured as follows: Section II introduces the literature review, Section III describes the proposed method, Section IV presents experimental analysis and Section V provides conclusions.

II. LITERATURE REVIEW

Jain et al, Proposed algorithm model to measure the energy consumption based on switching complexity and randomness generation. Switching complexity is evaluated by using the bubble sort algorithm and for randomness generation quick sort algorithm is used. The results state that the model they proposed is not the right model as it doesn't show much difference in energy consumption. A study towards joint cache, timing and randomness would also be a further direction. [2]

Bunse et al, conducted experiments to measure energy consumption of various sorting algorithms. Here two different experiments are conducted first experiment measured the energy consumption of various sorting algorithms for integer values and the second experiment deals with the same algorithms but with varying data sizes and float values. Finally, the result state that the Insertion sort is energy efficient and for the floating values requires more energy than integer values. In future they plan to experiment with more complex hardware platforms. [3]

Johann et al proposed metric and measurement method for different sorting algorithms. This method enables software developers to continuously measure and monitor the energy consumption of the software during the development process. Basically metric is defined as:

Energy efficiency= Productive work / Energy consumed

The source code instrumentation is mostly used for software profiling (the usage of specific instructions).The algorithm with the superior asymptotic run time seems to also have the greater energy efficiency. [4]

Kor et al, identify the energy consumption on windows and iOS devices by running the web-based and standalone application. Three sets of experiment are carried out and Joulemeter is used, to record the energy consumption values. Internet explorer found to more efficient than other browsers in windows and puffin web browser in iOS. In case of running the media player vcl player is more energy efficient

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than a window media player. In future external device is used to measure the energy for iOS device and media player [5]

Rashid et al, proposed that algorithmic design must be considered for the energy consumption. Various experiments for monitoring the energy impact of algorithm execution using different programming languages. The experiment is performed using Raspberry Pi and the flow of the experiment is carried out through the Goal Question Metric approach. The experimental result states that both algorithm and the language significantly affect the total energy consumption. Future direction is to investigate the hardware factors that affect energy consumption and how they are related to specific languages. [6]

III. Proposed Method

In this paper, we have chosen the following sorting algorithm implemented in c: selection sort, insertion sort, bubble sort, merge sort, quick sort and shell sort for profiling the energy consumption. For this purpose, we have selected 10,000 random integer values. Joulemeter tool is calibrated. In the power usage tab the process name of the implemented c algorithm is specified in a text box "Enter the program name". To record the power usage details create empty csv files and click Browse button to add that file.

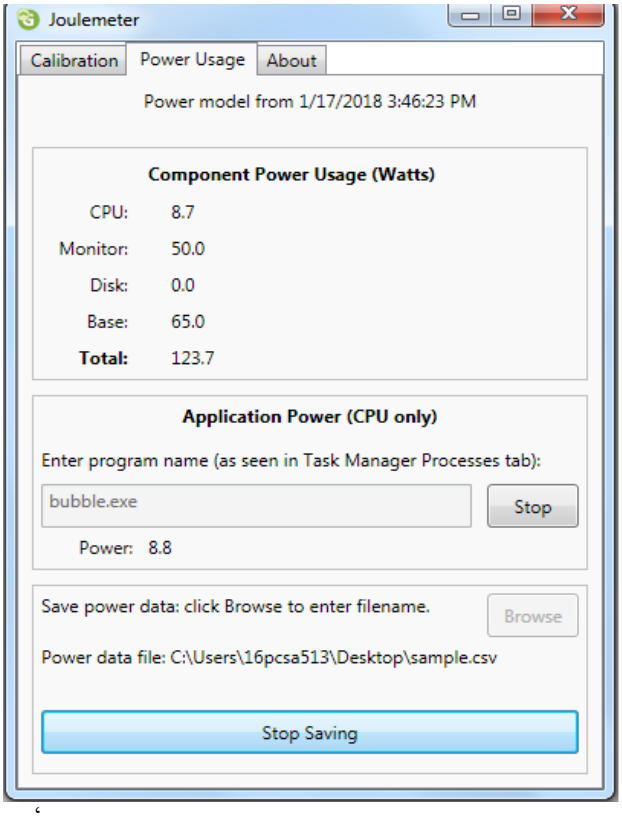

Figure 1: Joulemeter (Power monitor)

Start the recording in Joulemeter tool and execute the specified c algorithm. The recorded csv file gives details about Time stamp, Total power, CPU, Disk, Monitor and Application power in watts (W). We calculate the energy using the formula:

Energy (J) = Power (W) *Time (s)

IV. Experimental Analysis

The proposed method is executed in C-Free 5.0. The result obtained from the proposed method is analyzed for energy consumption of the algorithms and to know about the power usage and the time factor for each algorithms. The below result have been tested on Intel® core™ i5 processor, 64 bit windows 7 operating system.

Algorithm	Execution Time(ms)	Energy (J)
Quick Sort	1.028	0.0053432
Merge Sort	1.005	0.0055319
Shell Sort	1.064	0.00577075
Selection Sort	60.853	0.5320723
Insertion Sort	63.882	0.56276645
Bubble Sort	354.902	3.11557735

Table 1: Execution Time (ms) and Energy (J)

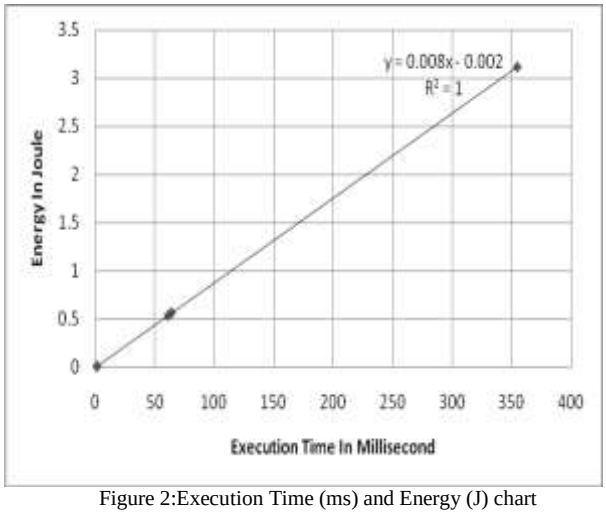

Figure 2:Execution Time (ms) and Energy (J) chart

From this result, it's clear that if the execution time of the program increase and there is a chance of more energy consumption. The correlation between the time and energy were found to be 0.999. Both the time and energy have an impact on the efficiency of the algorithm.

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Algorithm	Peak Power (W)
Quick Sort	5.7
Merge Sort	7.3
Shell Sort	8.8
Insertion Sort	8.8
Selection Sort	8.8
Bubble Sort	8.9

Table 2: Peak Power of Algorithm (W)

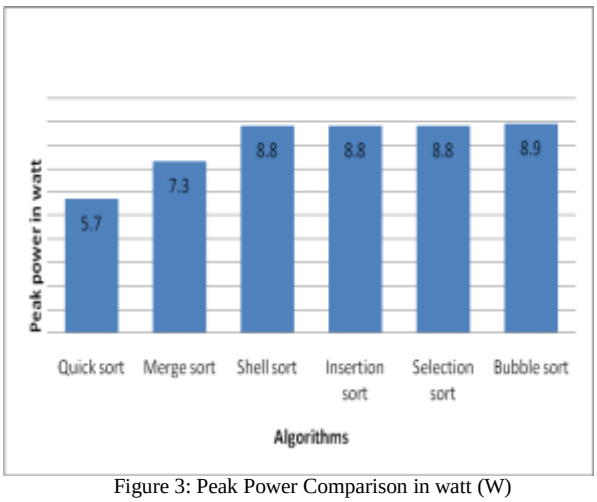

Figure 3: Peak Power Comparison in watt (W)

Peak power consumption of sort algorithm is observed. Among the various algorithms highest peak power is consumed in bubble sort and value is found to be 8.9 W.

V. CONCLUSION

The proposed method measures the energy consumption of various sorting algorithms implemented in C using the tool and to study how those algorithms have an impact on reducing the energy consumption. Hence, from the experimental analysis time and energy consumption for quick sort, merge sort and shell sort found to be in the same range, which is comparatively less than any other algorithms. Followed by insertion sort and selection sort which is far better than bubble sort. Therefore, these results provide choice for developers to trade off between time and energy efficiency based on their requirements.

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