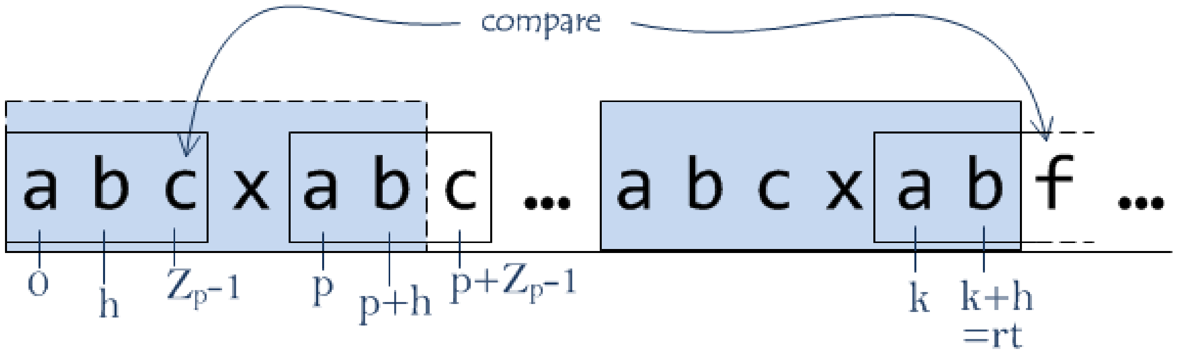
Assignment 1

Parallel String Searching Algorithm on Shared Memory

Introduction

For this assignment, I used Z-algorithms for string searching. Z-algorithms is a linear time pattern searching algorithm that has a fast enough searching speed that will not affect lots in a string searching system.



For this assignment, I used 3 books that I got from https://www.gutenberg.org/ebooks/100 which is given in the Ed forum. The 3 books are **Dracula** (words: 164442), **Romeo and Juliet** (words: 28982), and **The Odyssey** (words: 132519). I get the word count of the books by using the inbuilt Linux function e.g., *wc -w Dracula.txt*. Besides I created a serial program to make the book into a list of words to use in the assignment.

Serial Code

The main function will loop through the books.

And for the read files function we will open the file, read it, and put it in an array. Then we will run the check unique function after we create the array.

Pseudocode

```
Main {
For (all books) {
        run Read_files function.
        }
}
/Function/
Read_files (file name, file length) {
        For (file length) {
```

```
        Write it into an array.
    }

    For(file length){
    Change all the alphabet into lowercase.
    Run check unique function if it is unique write to the unique array.
    }
}
checkUnique (word, the unique array, length of the array) {
    for (length of the array){
        Combine the word with the word in the unique array.
        Run z_algo to see if it is inside the unique array already.
    }
}
Z_algo(combined string, z_array, lengthof the string){
    Initiate left and right pointer to zero and the first index of the array be the length of the string,
        For (the length of the string) {
            If (I > right pointer) {
                Left = right =I;
                While (check character) r++;
                Update the z_box;
                Let the right pointer 1 index forward
            }
            Else{
            Int k = i-l;
            If (check k pointer in z_box or not) {
                Update z_box
            } else{
                L=I;
                While( check character) r++;
```

```
                    Update z_box
                    Let the right pointer 1 index forward
                    }
                }
            }
}
```

So, from the pseudocode, we can separate the for loops into the main loop, read the file loop, check the unique loop, and pattern-matching loop.

The main loop: I1 = 0, O1= readfile(filename (0), filelength (0))

I2=1, O2 =readfile(filename (1), filelength (1))

$I1 \cap O2$ = ∅ (Anti dependency)

$I2 \cap O1$ = ∅ (Flow dependency)

$O1 \cap O2$ = ∅ (Output dependency)

Therefore, it satisfies Bernstein's condition.

Read the file loop: I1 = 0, O1 = W [0]=word0

I2 = 1, O2 = W [1] = word1

$I1 \cap O2$ = ∅ (Anti dependency)

$I2 \cap O1$ = ∅ (Flow dependency)

$O1 \cap O2$ = ∅ (Output dependency)

Therefore, it satisfies Bernstein's condition.

Check unique loop: I1= 0, O1=check Unique(word0, the unique array, length of the array)

I2 = 1, O2=check Unique(word1, the unique array, length of the array)

$O1 \cap O2$ = uses same unique array

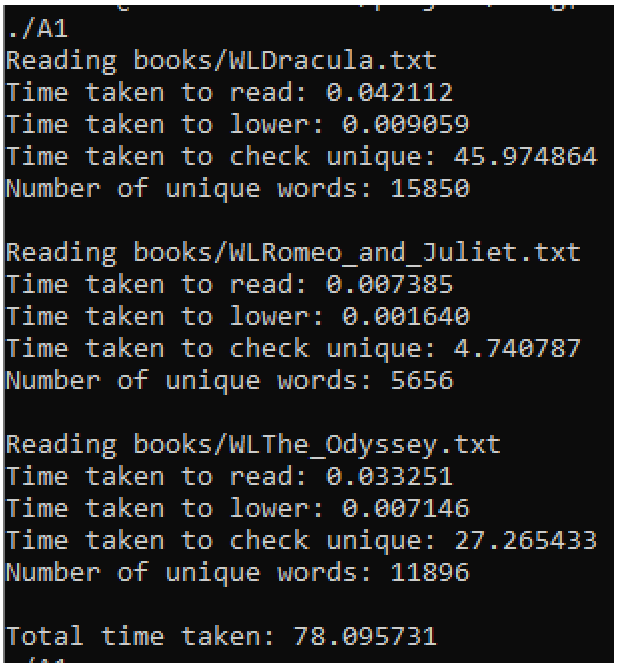
Therefore, it doesn't satisfy Bernstein's condition. It can be parallelized but will occur in race conditions.

Pattern matching loop: I1 = length of the array0, O1= return value

I2 = length of the array1, O2=return value

$O1 \cap O2$ = return value.

It doesn't satisfy Bernstein's condition.



```
./A1
Reading books/WLDracula.txt
Time taken to read: 0.042112
Time taken to lower: 0.009059
Time taken to check unique: 45.974864
Number of unique words: 15850

Reading books/WLRomeo_and_Juliet.txt
Time taken to read: 0.007385
Time taken to lower: 0.001640
Time taken to check unique: 4.740787
Number of unique words: 5656

Reading books/WLThe_Odyssey.txt
Time taken to read: 0.033251
Time taken to lower: 0.007146
Time taken to check unique: 27.265433
Number of unique words: 11896

Total time taken: 78.095731
```

Theoretical Speed Up:

1/ (Rs + Rp/p) = 1/ (all read time/total time + (all check unique/total time)/number of threads)

= 1/ (1.288*10^-3 +0.9985/4)

=3.985

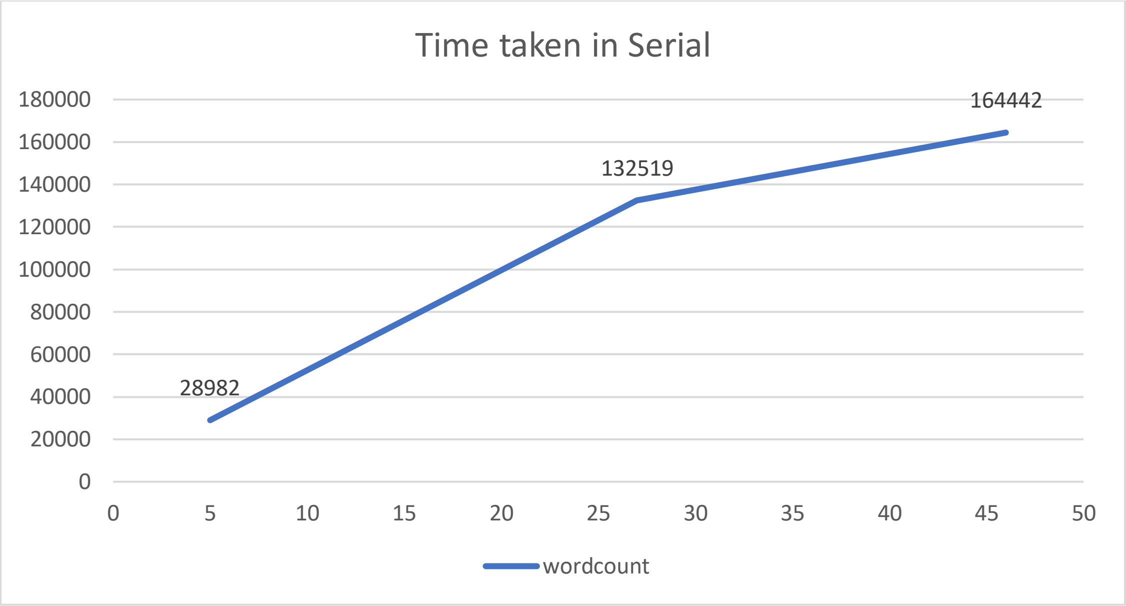
1/ (Rs + Rp/p) = 1/ (all read time/total time + (all check unique/total time)/number of threads)

= 1/ (4.7061*10^-3 +0.9985/8)

=7.930

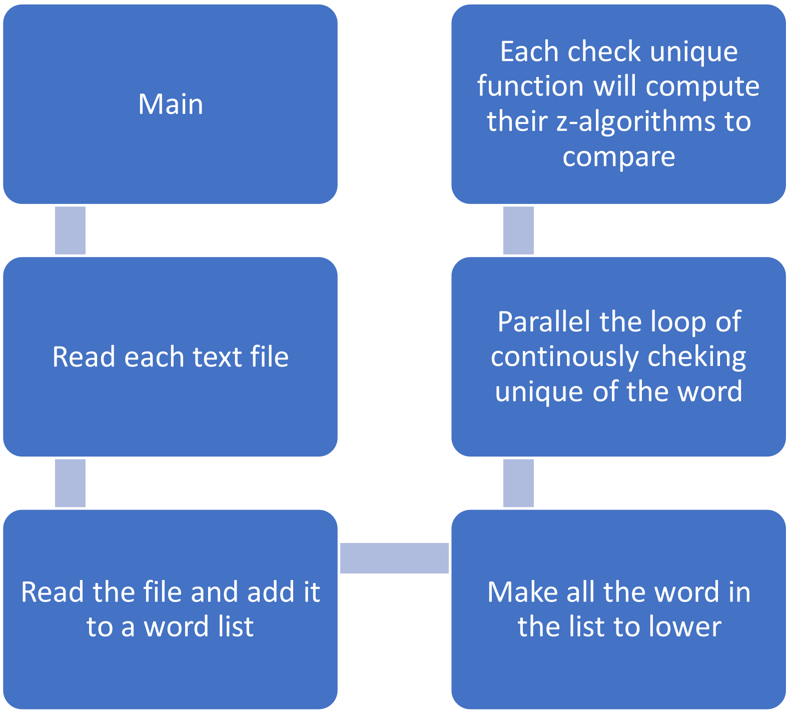
Word vs. Run time.

	Total words	Run time
Dracula	164442	Approximate 46s
Romeo and Juliet	28982	Approximate 5s
The Odyssey	132519	Approximate 27s



Based on the graph above we can see that the higher the word count the longer the time taken in serial code.

Parallel code


Main
Read each text file
Read the file and add it to a word list
Make all the word in the list to lower
Parallel the loop of continously cheking unique of the word
Each check unique function will compute their z-algorithms to compare

I selected to parallel the check unique loop to parallelize as it will have the most speedup from the serial code. I used 4 and 8 threads to parallelize the serial code and used reduction to get the unique word count. As we know this parallelized code will occur in race conditions while updating the unique word list since there will be different threads that find the same unique word that is not in the list and update at the same time so that there will be some words that consist in the list multiple times.

Results

Threads (4)	Serial Time	Serial Word Count	Parallel Time	Parallel Word Count
Dracula	45.974864	15850	7.411373	26509
Romeo & Juliet	4.740787	5656	0.832161	8945
The Odyssey	27.265433	11896	6.676119	20373
Total	77.981084	33402	13.722481	55827

Actual total speed up: 77.981084/13.722481= 5.682724866

Actual each book speed up: Dracula 45.974864/7.411373=6.20328568

Romeo & Juliet 4.740787/0.832161=5.696958882

The Odyssey 27.265433/6.676119=4.084024416

Threads (8)	**Serial Time**	**Serial Word Count**	**Parallel Time**	**Parallel Word Count**
Dracula	45.974864	15850	3.274175	33758
Romeo & Juliet	4.740787	5656	0.323620	10941
The Odyssey	27.265433	11896	2.858759	26438
Total	77.981084	33402	6.456554	71131

Actual total speed up: 77.981084/6.456554=12.07781798

Actual each book speed up: Dracula 45.974864/3.274175= 14.0416636

Romeo & Juliet 4.740787/0.323620= 14.64923985

The Odyssey 27.265433/2.858759= 9.537506659

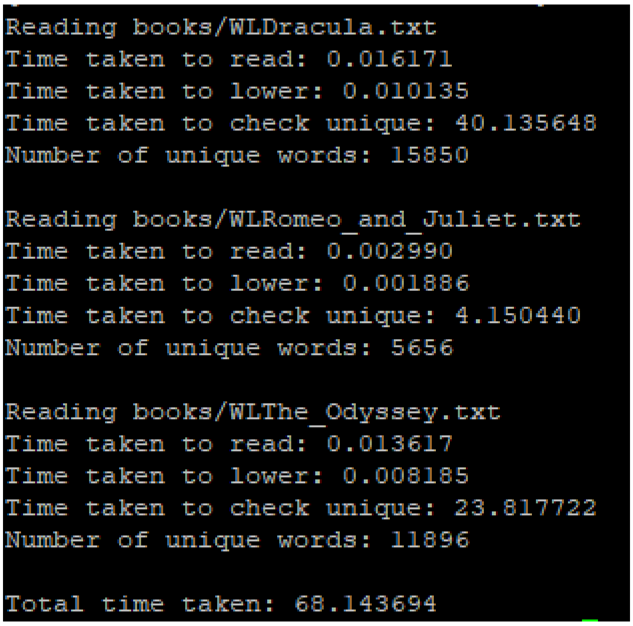
Based on these two tables above we can see that the more threads we used the more speed up we got but it sped up more than the theoretical speed up because we selected to parallel the check unique loop which will occur in race conditions so we can also observe that the word count from serial to parallel increased since the thread might upload the same unique word to the list at the same time. Furthermore, we can also observe from serial code the percentage of the unique word in the word list will also affect the word count after parallel. For, Dracula has 15850 unique words out of 164442. Percentage: 15850/164442=0.096 =9.6%, Romeo and Juliet 5656 unique words out of 28982. Percentage: 5656/28982=0.1859=19.52%, and The Odyssey 11896 unique words out of 132519. Percentage: 11896/132519=0.0852=8.97%

Threads (4)	**Percentage of Unique words**	**Speed up**	**False unique word count**	**Percentage of Wrong count**
Dracula	9.6%	6.20328568	10659	67.25%
Romeo & Juliet	19.52%	5.696958882	3289	58.15%
The Odyssey	8.97%	4.084024416	8477	71.26&

Threads (8)	**Percentage of Unique words**	**Speed up**	**False unique word**	**Percentage of Wrong count**
Dracula	9.6%	13.225	17908	112.98%
Romeo & Juliet	19.52%	14.736	5285	93.44%
The Odyssey	8.97%	9.7127	14542	122.24%

Based on the table above, we can see that the percentage of unique words in the books will affect the speed up when we have more unique words in a book then the speed up will be faster. And we can also observe that when we increase the threads the false percentage of reading the same unique words will increase by approximately 40% for each book. Also, with a higher percentage of wrong word count, we will get a lower speed up. We can assume that the threads have been waiting to update the unique words while other threads are still updating the array.

CAAS

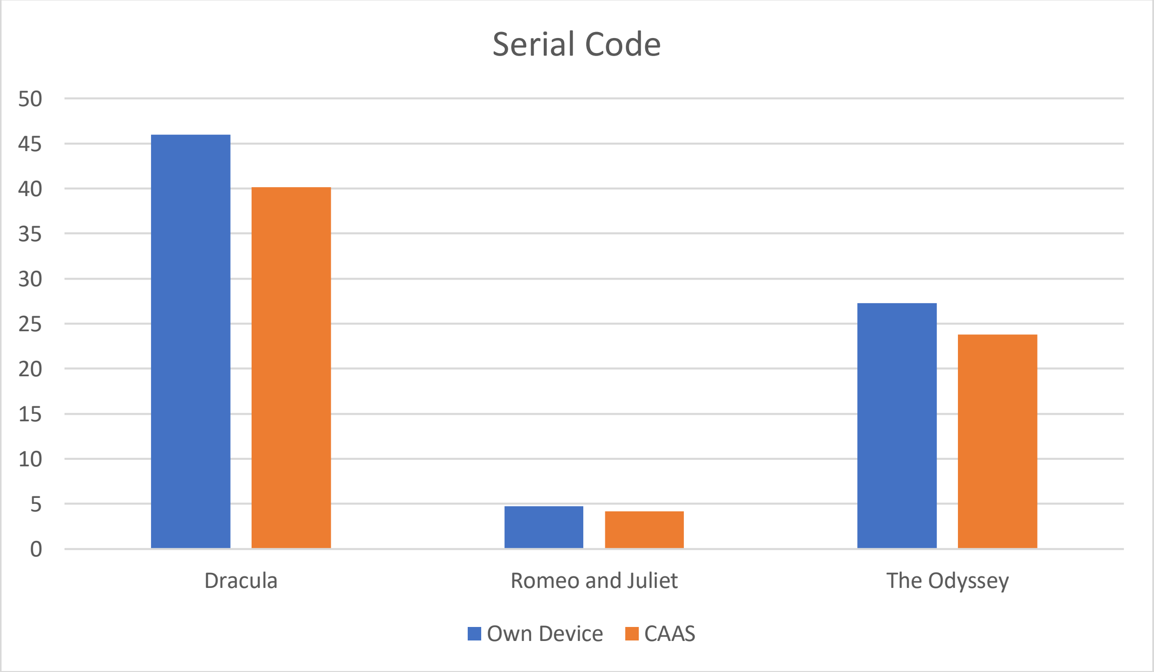


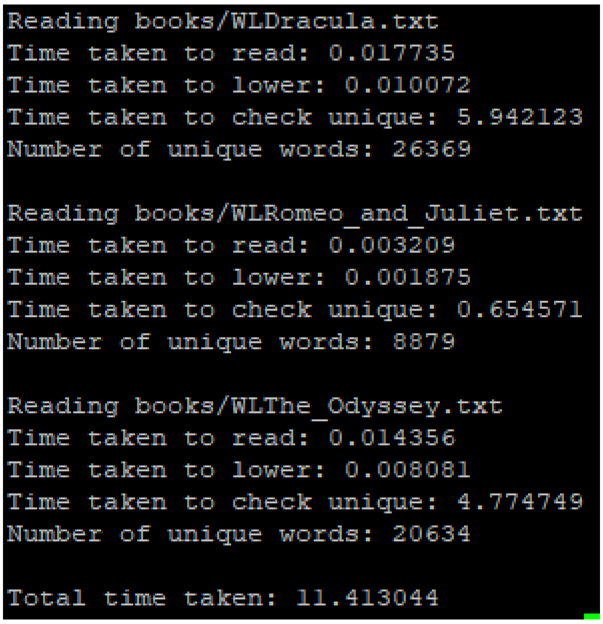
```
Reading books/WLDracula.txt
Time taken to read: 0.016171
Time taken to lower: 0.010135
Time taken to check unique: 40.135648
Number of unique words: 15850

Reading books/WLRomeo_and_Juliet.txt
Time taken to read: 0.002990
Time taken to lower: 0.001886
Time taken to check unique: 4.150440
Number of unique words: 5656

Reading books/WLThe_Odyssey.txt
Time taken to read: 0.013617
Time taken to lower: 0.008185
Time taken to check unique: 23.817722
Number of unique words: 11896

Total time taken: 68.143694
```

Serial run in CAAS.

	Time taken
Dracula	40.135648
Romeo and Juliet	4.150440
The Odyssey	23.817722
Total time	67.463308

We can compare the time on CAAS and our own local device.

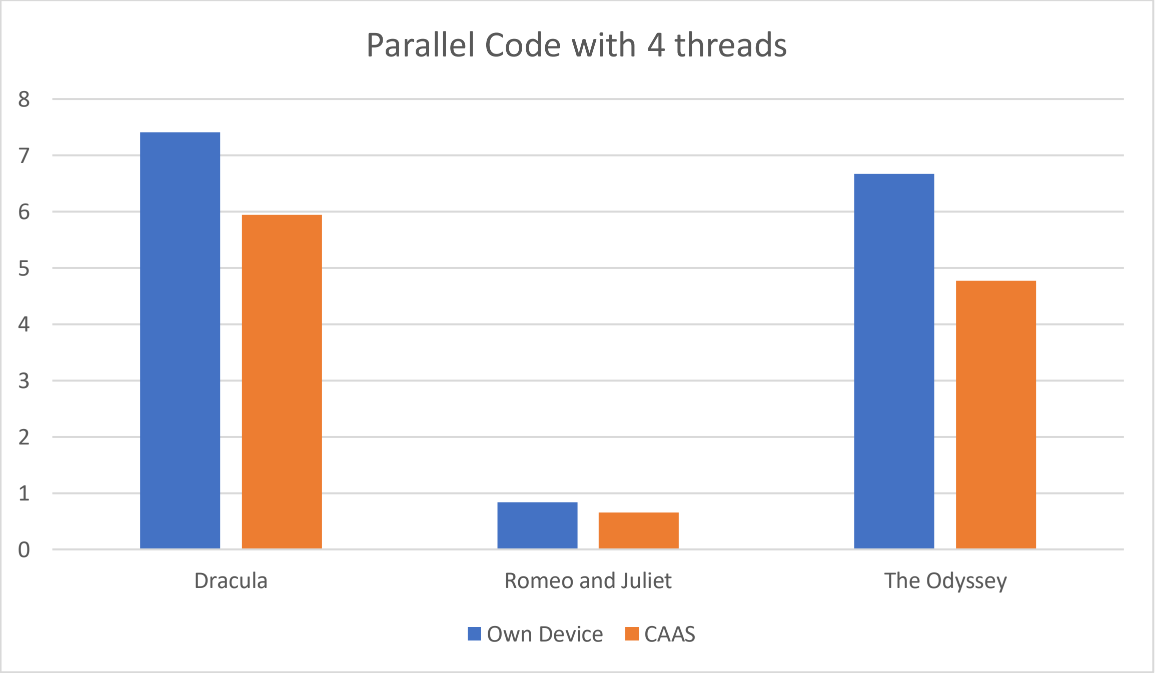


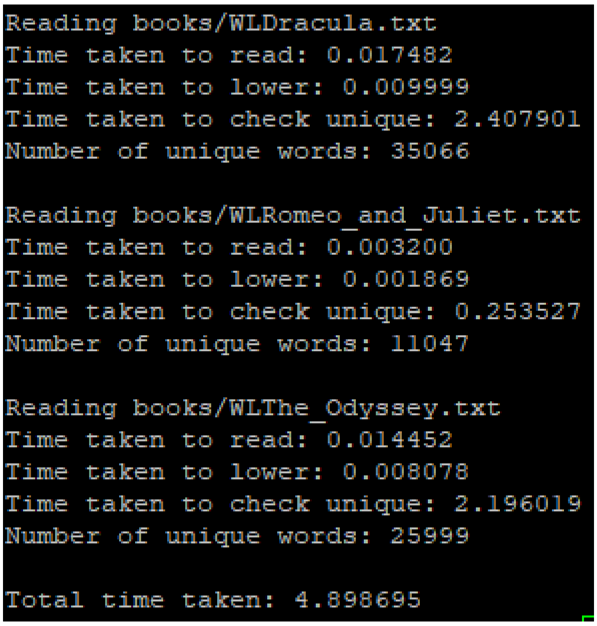


```
Reading books/WLDracula.txt
Time taken to read: 0.017735
Time taken to lower: 0.010072
Time taken to check unique: 5.942123
Number of unique words: 26369

Reading books/WLRomeo_and_Juliet.txt
Time taken to read: 0.003209
Time taken to lower: 0.001875
Time taken to check unique: 0.654571
Number of unique words: 8879

Reading books/WLThe_Odyssey.txt
Time taken to read: 0.014356
Time taken to lower: 0.008081
Time taken to check unique: 4.774749
Number of unique words: 20634

Total time taken: 11.413044
```

Parallel in CAAS

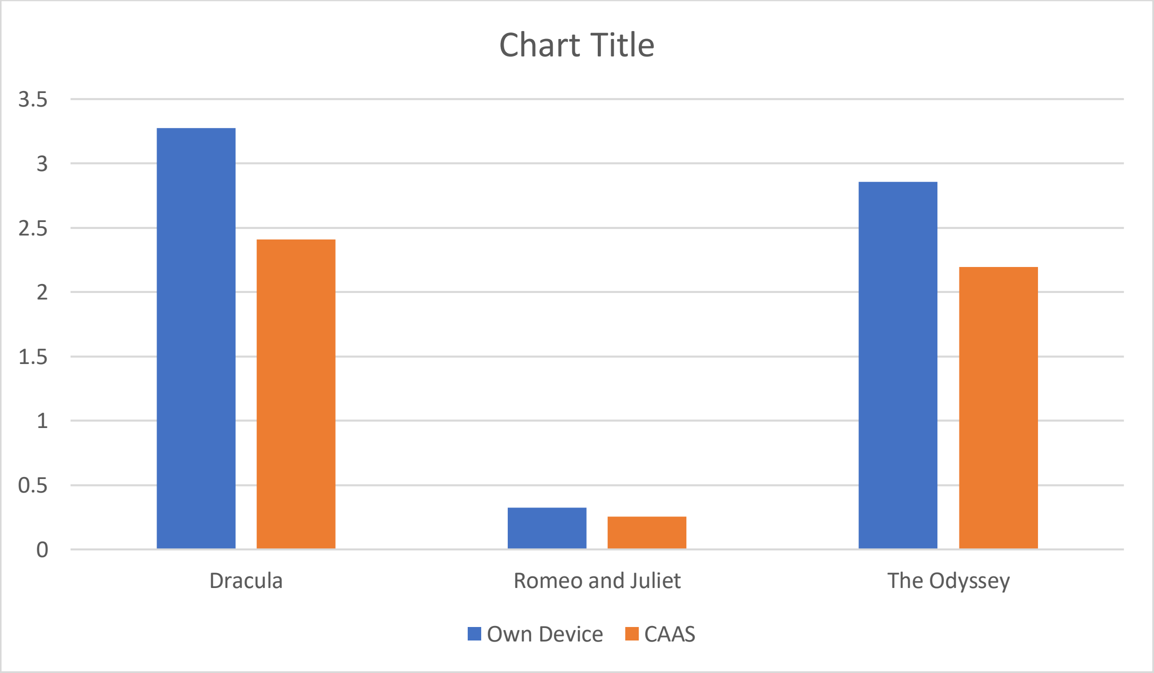
Thread (4)	Serial time taken	Serial word count	Time taken	Parallel word count
Dracula	40.135648	15850	5.942123	26369
Romeo and Juliet	4.150440	5656	0.654571	8879
The Odyssey	23.817722	11896	4.774749	20634
Total time	67.463308	33402	11.471443	55882





```
Reading books/WLDracula.txt
Time taken to read: 0.017482
Time taken to lower: 0.009999
Time taken to check unique: 2.407901
Number of unique words: 35066

Reading books/WLRomeo_and_Juliet.txt
Time taken to read: 0.003200
Time taken to lower: 0.001869
Time taken to check unique: 0.253527
Number of unique words: 11047

Reading books/WLThe_Odyssey.txt
Time taken to read: 0.014452
Time taken to lower: 0.008078
Time taken to check unique: 2.196019
Number of unique words: 25999

Total time taken: 4.898695
```

Thread (8)	Serial time taken	Serial word count	Time taken	Parallel word count
Dracula	40.135648	15850	2.407901	35066
Romeo and Juliet	4.150440	5656	0.253527	11047
The Odyssey	23.817722	11896	2.196019	25999
Total time	67.463308	33402	4.857447	72112



Based on the serial code and parallel code runs in a single computer and CAAS platform. We can observe that CAAS runs faster than a single device, which is normal as CAAS has a higher computing power compared to our own single computer.

Actual Speed up of CAAS

Threads 4

Actual total speed up: 67.463308/11.471443=5.88097836

Actual each book speed up: Dracula 40.135648/5.942123= 6.75442901

Romeo & Juliet 4.150440/0.654571= 6.34070254

The Odyssey 23.817722/4.774749= 4.98826682

Threads 8

Actual total speed up: 67.463308/4.857447=13.8886349146

Actual each book speed up: Dracula 40.135648/2.407901= 16.6683131906

Romeo & Juliet 4.150440/0.253527= 16.3708007431

The Odyssey 23.817722/2.196019= 10.8458633555

	Own Device (T4)	CAAS (T4)	Own Device (T8)	CAAS (T8)
Dracula	6.20328568	6.75442901	13.225	16.6683131906
Romeo and Juliet	5.696958882	6.34070254	14.736	16.3708007431
The Odyssey	4.084024416	4.98826682	9.7127	10.8458633555
Total time	5.682724866	5.88097836	12.07781798	13.8886349146

From the above, we can observe that CAAS has a higher speedup compared to our own device. Since we choose to increase the speed up of the algorithms it means we sacrifice the accuracy of determining whether the word is the only word in the unique list or not which means that the unique word array will have multiple same words in it.