Assignment 1

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1) A concise pdf file listing the time and space computational complexity of: linear search, binary search, hashing, Bloom filter, Cuckoo filter. Use appropriate parameters to describe the complexity, e.g., Bloom filter uses n (estimated number of elements/logins), m (bit array of m bits), and k (number of hash functions). You do not need to justify the complexity; only to explain each parameters used and provide the formula with appropriate references.

Time and Space Complexity Analysis

Algorithm	**Time Complexity (Search)**	**Space Complexity**	**Parameters**
Linear Search	O(n)	O(n)	n = number of elements
Binary Search	O(log n)	O(n)	n = number of elements
Hashing	O(1) (average), O(n) (worst)	O(n)	n = number of elements
Bloom Filter	O(k)	O(m)	n = estimated number of elements m = size of bit array k = number of hash functions
Cuckoo Filter	O(1)	O(n)	n = number of elements

References:

- Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2009). *Introduction to algorithms*. MIT press.
- "Bloom Filters - Introduction and Implementation." GeeksforGeeks, 28 Nov. 2023, www.geeksforgeeks.org/bloom-filters-introduction-and-implementation/.
- "Cuckoo Filter: Practically Better Than Bloom." Cse.wustl.edu, https://www.cse.wustl.edu/~jain/cse573-14/ftp/mdfg.pdf.

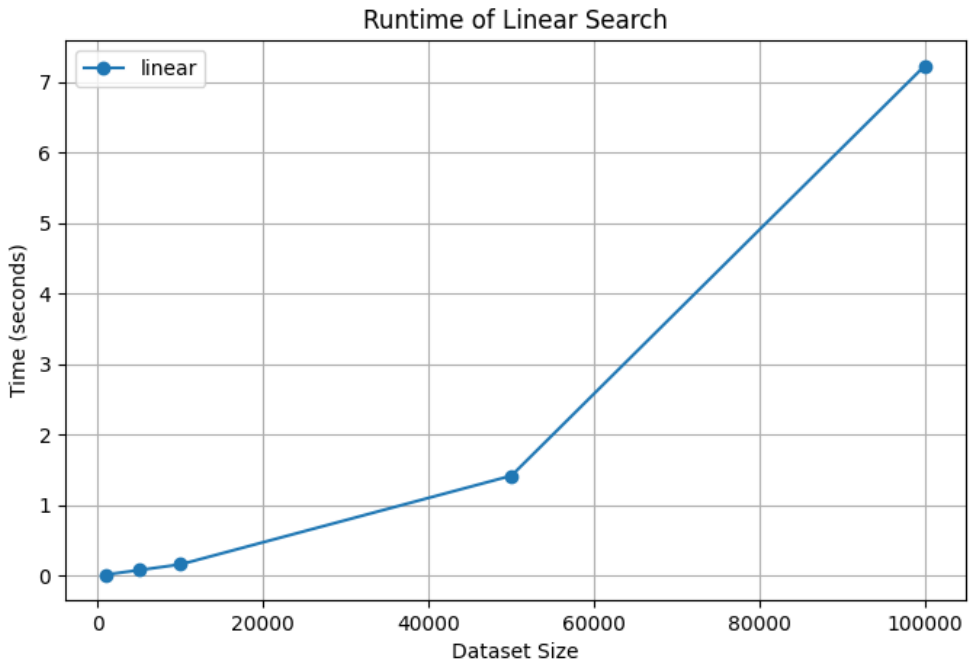
Parameter Explanations:

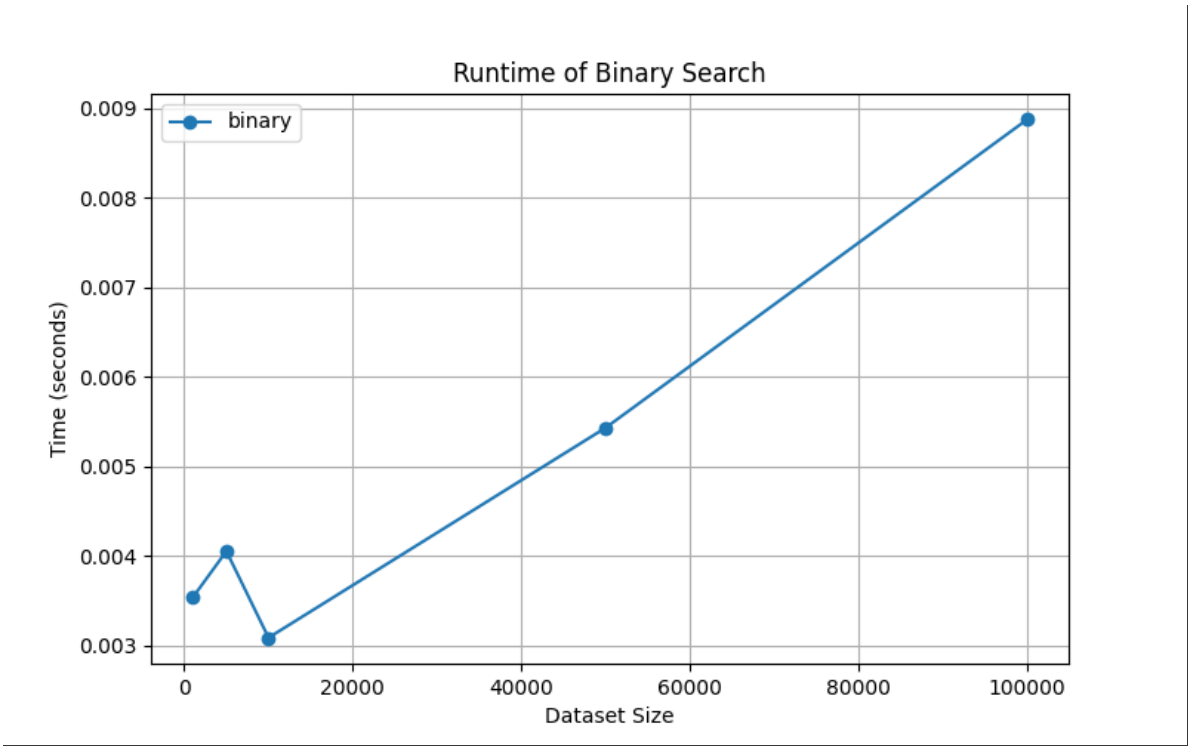
- **n:** The number of elements (logins) stored in the data structure.
- **m:** The size of the bit array in a Bloom filter.
- **k:** The number of hash functions used in a Bloom filter.

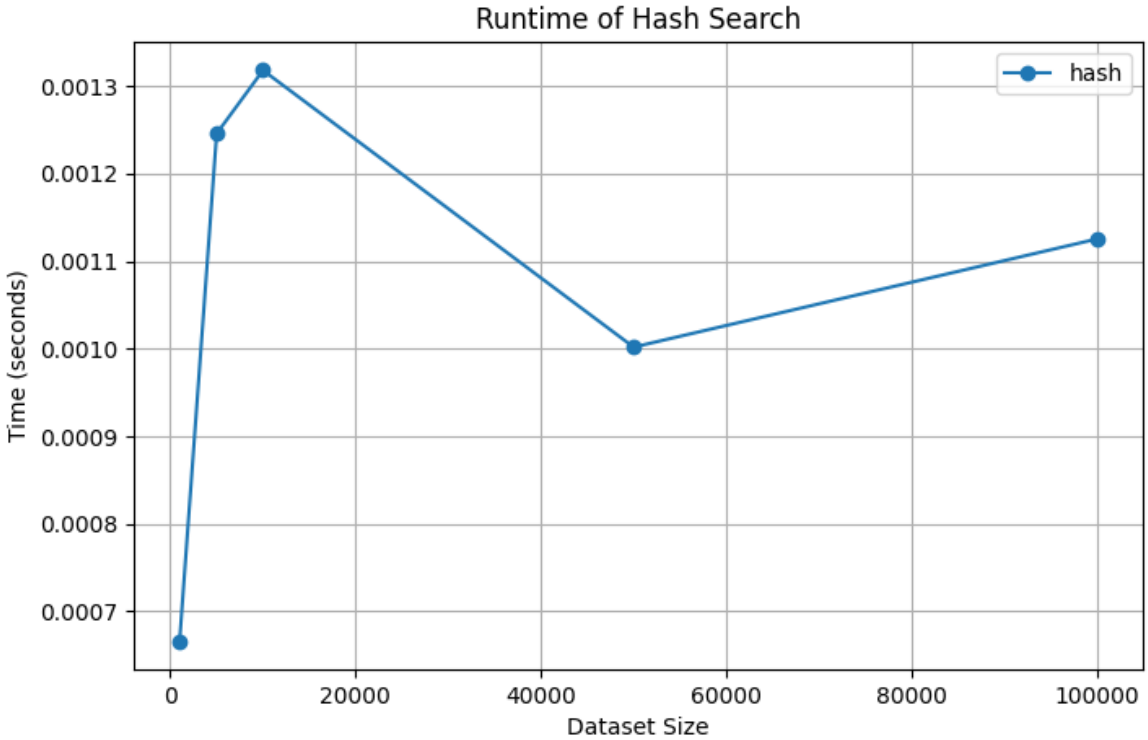
2) Plots showing the run time complexity for large enough data. You can generate strings dataset using synthesized functions. Aim for at least one million data. Then, run your program with different implementations using linear search, binary search, hashing, Bloom filter, Cuckoo filter, and compare their run time in a plot. Include this analysis in your pdf file and explain if it supports your analysis. Remember to upload your dataset on the web and include a link to the dataset in the pdf file.

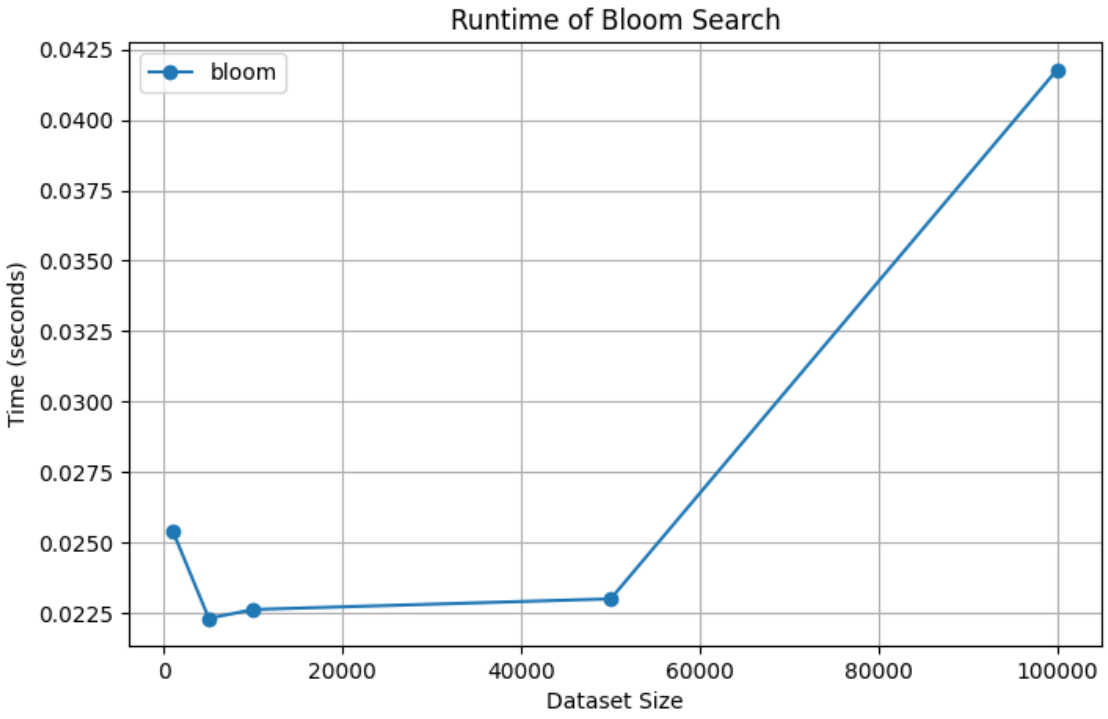
```
Running linear search with dataset size: 1000
run_experiment took 0.0157 seconds
Running linear search with dataset size: 5000
run_experiment took 0.0792 seconds
Running linear search with dataset size: 10000
run_experiment took 0.1602 seconds
Running linear search with dataset size: 50000
run_experiment took 1.4172 seconds
Running linear search with dataset size: 100000
run_experiment took 7.2301 seconds
Running binary search with dataset size: 1000
run_experiment took 0.0035 seconds
Running binary search with dataset size: 5000
run_experiment took 0.0041 seconds
Running binary search with dataset size: 10000
run_experiment took 0.0031 seconds
Running binary search with dataset size: 50000
run_experiment took 0.0054 seconds
Running binary search with dataset size: 100000
run_experiment took 0.0089 seconds
Running hash search with dataset size: 1000
run_experiment took 0.0007 seconds
Running hash search with dataset size: 5000
run_experiment took 0.0012 seconds
Running hash search with dataset size: 10000
run_experiment took 0.0013 seconds
Running hash search with dataset size: 50000
run_experiment took 0.0010 seconds
```

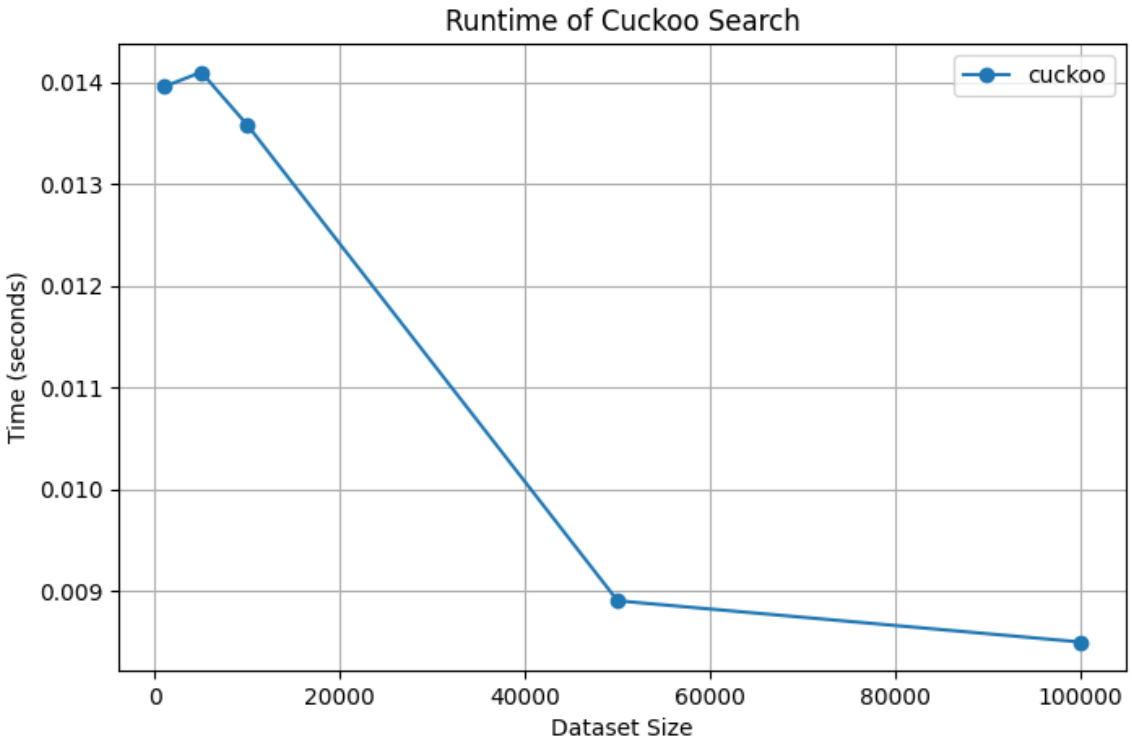
```
Running hash search with dataset size: 100000
run_experiment took 0.0011 seconds
Running bloom search with dataset size: 1000
run_experiment took 0.0254 seconds
Running bloom search with dataset size: 5000
run_experiment took 0.0223 seconds
Running bloom search with dataset size: 10000
run_experiment took 0.0226 seconds
Running bloom search with dataset size: 50000
run_experiment took 0.0230 seconds
Running bloom search with dataset size: 100000
run_experiment took 0.0418 seconds
Running cuckoo search with dataset size: 1000
run_experiment took 0.0140 seconds
Running cuckoo search with dataset size: 5000
run_experiment took 0.0141 seconds
Running cuckoo search with dataset size: 10000
run_experiment took 0.0136 seconds
Running cuckoo search with dataset size: 50000
run_experiment took 0.0089 seconds
Running cuckoo search with dataset size: 100000
run_experiment took 0.0085 seconds
```

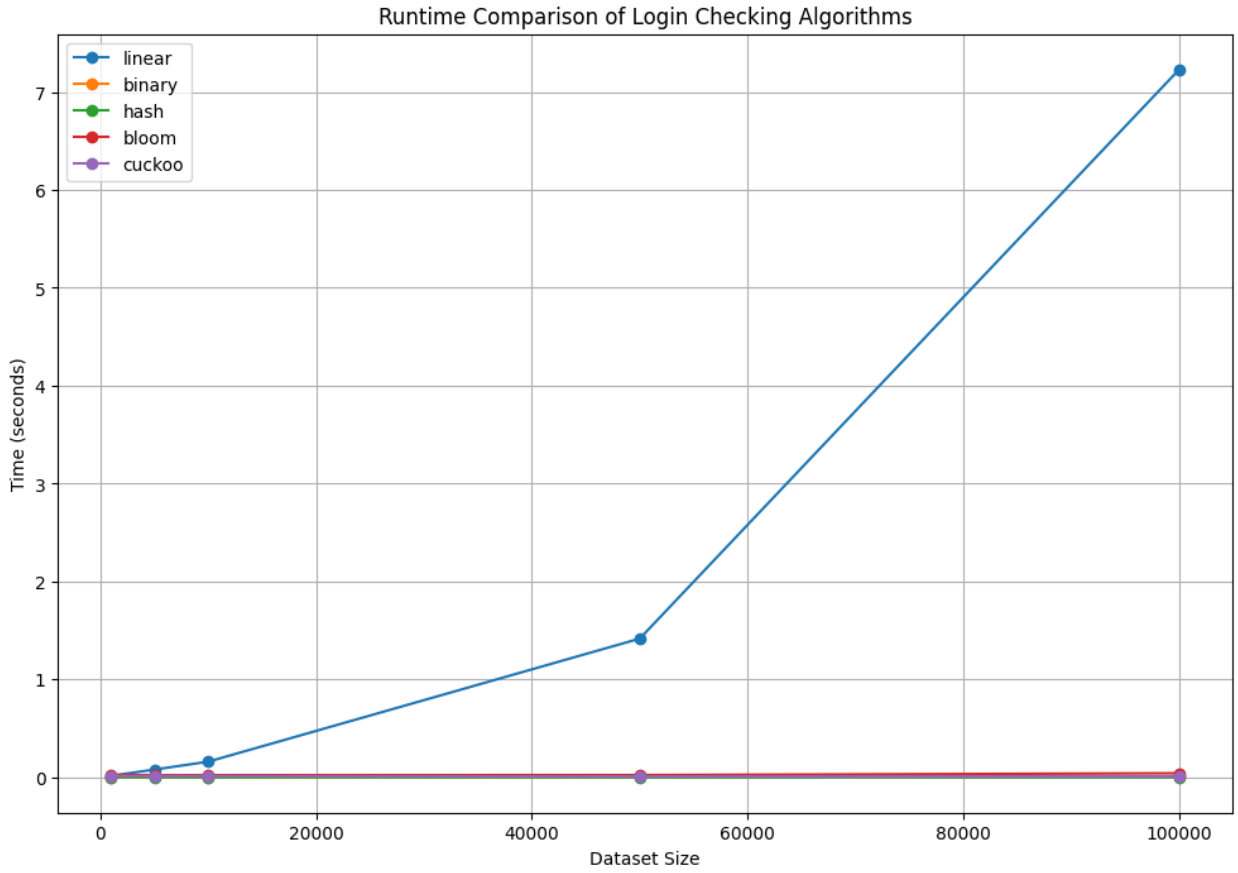



Runtime of Binary Search
binary
Time (seconds)
Dataset Size
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0
20000
40000
60000
80000
100000


Runtime of Hash Search
hash
Time (seconds)
Dataset Size
0.0013
0.0012
0.0011
0.0010
0.0009
0.0008
0.0007
0
20000
40000
60000
80000
100000


Runtime of Bloom Search
bloom
Time (seconds)
0.0425
0.0400
0.0375
0.0350
0.0325
0.0300
0.0275
0.0250
0.0225
0
20000
40000
60000
80000
100000
Dataset Size


Runtime of Cuckoo Search
cuckoo
Time (seconds)
0.014
0.013
0.012
0.011
0.010
0.009
0
20000
40000
60000
80000
100000
Dataset Size



3) Python code comparing the hashing, Bloom filter, and Cuckoo filter. Add the link of your GitHub repository for this assignment to the pdf file.

Github link: https://github.com/MahmoudOsama97/TheLoginCheckerProblem

Pdf link:
https://github.com/MahmoudOsama97/TheLoginCheckerProblem/blob/main/Assignment1.pdf

Folder structure:

```
login-checker/
├── README.md           # Instructions and project description
├── Assignment1.pdf    # Project dependencies
├── Assignment1.ipynb    # colab notebook
├── src/                # Source code
│   ├── dataset.py      # Dataset generation
│   ├── login_checker.py # Implementations of all algorithms
│   ├── main.py         # Main script for running experiments and plotting
│   └── utils.py        # Utility functions
├── workspace/                # Source code
│   ├── username_dataset.txt         # dataset
│   └── .png        # plots for all algorithms
└── tests/              # Unit tests
    └── test.py
```

General Steps to Use the project:

Option1:

1. **Clone the Repository: git clone https://github.com/MahmoudOsama97/TheLoginCheckerProblem.git**
2. **Run the Code: python3 src/main.py**

Option2:

Use colab notebook directly by uploading it to google colab or by running it in VS Code

Note: code is a combination from:

1) **Being manually written**
2) **browsed from github repos and geeksforgeeks site**
3) **used Gemini in some parts to understand the algorithms and have example code.**