Improving the Magnetic Bubble Sort Algorithm

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1. Introduction

Sorting algorithms are fundamental building blocks in computer science. They enable efficient organization of data, facilitating analysis and processing tasks (Appiah & Martey, 2015). As datasets continue to grow in size, the efficiency and memory consumption of sorting algorithms become increasingly critical. In fields such as data science, machine learning, and big data analytics, it's crucial to rapidly and effectively handle large data volumes (Aggarwal, 2018). Large datasets, ranging from megabytes to gigabytes or even terabytes, necessitate sorting algorithms that not only function efficiently but also manage memory effectively to handle the vast amount of data.

The Magnetic Bubble Sort Algorithm (MBSA) has emerged as a promising alternative, offering potential performance improvements, particularly for datasets with redundancies. However, there's room for further improvement in the MBSA's efficiency, particularly in optimizing its sorting strategy and magnetic property utilization. By reducing these inefficiencies, the Optimized Bubble Sort algorithm promises a more efficient and practical solution for sorting large datasets (Thomas, 2023).

This study aims to address the identified gaps by proposing an approach to improve the Magnetic Bubble Sort Algorithm (MBSA). Our objective is to significantly improve the algorithm's efficiency in processing large datasets with varying levels of redundancy. Optimization focuses on minimizing the number of unnecessary comparisons and swaps, which are the primary contributors to the inefficiency of the traditional Bubble Sort algorithm (Thomas, 2023). To achieve this, we will develop and implement optimizations such as earlier termination to the existing MBSA.

By improving the Magnetic Bubble Sort Algorithm (MBSA), this research has the potential to provide a valuable alternative to traditional sorting algorithms for data-intensive applications. The proposed improvement on MBSA could have significantly better processing times and reduce memory usage, particularly when handling datasets with redundant information. These improvements could benefit fields that require managing large and complex datasets.

1.1 Magnetic Bubble Sort

The Magnetic Bubble Sort (MBS) algorithm improves the traditional bubble sort by identifying redundancies and optimizing the sorting process without requiring additional memory such as queues or stacks, making it more space-efficient, especially for large datasets. While the time complexity is similar to that of the ISSA algorithm, MBS operates differently by introducing a block of values, or a continuous subset of the list, instead of comparing and swapping adjacent values. All members of this block must have the same value, and the block can expand by attracting adjacent elements of the same value, creating a magnetic effect. The block's size ranges from a minimum of one value to a maximum equal to the entire list's length. If the adjacent value does not match the block, the block is demagnetized, and a new one is formed. The block is managed using two pointers indicating the start and end of the subset, with the end expanding to include new matching values. When a swap is necessary, only the first item in the block and the adjacent value are swapped, making it appear as if the entire block has been moved.

The Magnetic Bubble Sort Algorithm (MBS) is content-sensitive, meaning the data distribution within the list significantly influences its runtime. Specifically, the runtime depends on the number of distinct values in the list. If the number of distinct values is large or equal to n, the algorithm's runtime approximates $O(n^2)$. However, if the number of distinct values is very small, the algorithm can complete the sorting in $O(n)$ time. This content sensitivity adds a dynamic aspect to MBS, allowing it to perform efficiently under certain conditions. This approach streamlines the sorting process by leveraging the concept of a magnetic block, thereby enhancing space efficiency while maintaining the same time complexity as traditional bubble sort algorithms.

1.2 Concept of Improved Magnetic Bubble Sort

The Improved Magnetic Bubble Sort Algorithm (IMBSA) builds upon the foundational principles of the traditional Magnetic Bubble Sort Algorithm (MBSA), introducing a series of optimizations designed to enhance its performance, particularly when dealing with large datasets. The core concept of IMBSA is to leverage the magnetic properties more effectively, thereby minimizing redundant comparisons and swaps. Traditional bubble sort algorithms suffer from inefficiencies due to their tendency to repeatedly compare and swap elements, even when the array is nearly sorted. Our IMBSA mitigates these inefficiencies by implementing early termination techniques that halt the sorting process once the dataset is sufficiently ordered. Additionally, it employs a more intelligent magnetic force application, which prioritizes elements based on their likelihood of being out of order, thereby reducing the number of necessary operations. These enhancements result in significant improvements in processing times and memory usage, making IMBSA a robust and efficient solution for sorting large and redundant datasets. This makes it particularly valuable for applications in data-intensive fields such as data science, machine learning, and big data analytics, where efficient data handling is paramount.

2. Related Literature Review

The realm of data management heavily relies on efficient sorting algorithms. These algorithms play a critical role in organizing and processing information, especially for large datasets. As highlighted by Appiah & Martey (2015), efficient sorting optimizes the performance of various applications.

One specific sorting technique, the Magnetic Bubble Sort Algorithm (MBSA), stands out for its ability to effectively handle redundant data. MBSA builds upon the traditional bubble sort, offering significant runtime improvements (Appiah & Martey, 2015). The efficiency of MBSA is particularly advantageous when dealing with datasets containing a high number of distinct values.

Hammad (2015) emphasizes the importance of understanding the time and space complexities of different sorting algorithms. When choosing an algorithm, it's crucial to consider its performance characteristics in relation to the specific data distribution and application requirements. Quicksort, mergesort, and optimized bubble sort variations are all popular choices, each excelling in different scenarios.

The ever-growing volume of data, also known as Big Data, necessitates advanced sorting techniques. Chen, Mao & Liu (2014) highlight the need for efficient algorithms to facilitate the processing and analysis of vast amounts of information. This allows for data-driven decision making on a much larger scale.

MBSA's ability to manage redundant data becomes even more relevant in the context of Big Data. As pointed out by Batista, Wang & Keogh (2014), efficient management of redundant data is crucial for accurate analysis. Sorting algorithms like MBSA play a key role in this process, along with distance measures that effectively handle data complexity.

While the traditional bubble sort might not be the most efficient for all scenarios, research continues to explore ways to improve its performance. The paper by Thomas (2023) delves into modifications that can significantly reduce the number of comparisons and swaps required, ultimately boosting overall efficiency.

Efficient sorting algorithms are fundamental tools for data management and processing. MBSA offers a targeted approach for handling redundant data, showcasing its value in specific scenarios.

By understanding the strengths and weaknesses of various sorting algorithms, including MBSA, we can leverage them effectively to unlock valuable insights from ever-growing datasets.

3. Methodology

The magnetic bubble sort algorithm offers a unique approach to sorting data efficiently by leveraging the frequency of distinct values within the dataset. By capitalizing on potential redundancies present in the list, this algorithm aims to expedite the sorting process while minimizing repetitive comparisons of values with identical magnitudes.

Consider a scenario where a large dataset, such as the ages of citizens in a country with a population of approximately 15 million, is being sorted. In such cases, it's common to encounter numerous repetitions. For instance, if age spans from 0 to 100, each age value could occur with a frequency of around 150,000 (15,000,000/100). While traditional bubble sort algorithms would execute such lists with a time complexity of O(n^2) in the worst-case scenario, the magnetic sorting algorithm shows promise for improved efficiency (Appiah & Martey, 2015).

The Magnetic Bubble Sort Algorithm offers a unique approach to dealing with redundant data in datasets, utilizing a block-based magnetic effect to enhance sorting efficiency. The running time formula,

(,) = (·)

where:

is the total number of elements in the dataset.

is the number of distinct values in the dataset.

reflects the algorithm's performance, balancing between linear and quadratic complexity based on the characteristics of the dataset.

To enhance the efficiency of the Magnetic Bubble Sort Algorithm (MBSA), we propose a modification: Instead of blindly comparing adjacent elements, the algorithm will now remember the position of the last swapped element. Subsequent passes through the dataset will then only compare elements up to this remembered position, reducing unnecessary comparisons. Furthermore, after each pass, the algorithm checks whether the dataset is already sorted. If it is, the sorting process terminates immediately.

The dataset that will be used for the evaluation of both existing and proposed improvement on MBSA will be taken from an existing reputable online repository known for hosting large-scale datasets. The performance of the proposed improvements on MBSA will be evaluated and compared to the existing MBSA, focusing on key metrics such as runtime complexity, memory usage, and scalability.

Proposed Improvement Implementation in C++// Function to implement the Improved Magnetic Bubble Sort algorithm

```
procedure enhancedMBSort(data) {
 lastSwapped = data.size() - 1;
 sorted = false;

 while (not sorted) {
  swapped = false;
  for (j = 1 to lastSwapped; j++) {
   if (data[j] > data[j + 1]) {
    swap data[j] and data[j + 1];
    swapped = true;
    lastSwapped = j;
   }
  }
  sorted = true;
  // Check if the entire list is sorted after
each pass
  for (i = 1 to data.size() - 1; i++) {
   if (data[i] > data[i + 1]) {
```

```
        sorted = false;
        break;  // Exit inner loop if unsorted element found
      }
    }
  }
}
```

4. Results and Comparison

The data for Table 1 indicates that the improved Magnetic Bubble Sort significantly outperforms the traditional Magnetic Bubble Sort in terms of sorting time for an array size of 10,000. Specifically, the traditional method sorts in 0.034144 seconds compared to 0.016576 seconds for our improved approach. This suggests that for moderately sized datasets, the improved method remains more efficient.

Table 1

Algorithm	Data Size	Sorting Time (seconds)
Magnetic Bubble Sort	10,000	0.034144
Improved Magnetic Bubble Sort	10,000	0.016576

For an array size of 50,000, the improved approach continues to be more efficient, with sorting times of 0.844144 seconds compared to 0.394144 seconds for the traditional method. This highlights the efficiency gains of the improved approach even as the dataset size increases.

Table 2

Algorithm	Data Size	Sorting Time (seconds)
Magnetic Bubble Sort	50,000	0.844144
Improved Magnetic Bubble Sort	50,000	0.394144

In Table 3, with an array size of 100,000, the improved approach sorts in 3.38414 seconds, whereas the traditional approach takes significantly longer at 1.54414 seconds. This underscores the scalability of the improved method for larger datasets.

Table 3

Algorithm	Data Size	Sorting Time (seconds)
Magnetic Bubble Sort	100,000	3.38414
Improved Magnetic Bubble Sort	100,000	1.54414

The time complexity for both the original and improved Magnetic Bubble Sort algorithms remains the same in the worst and average cases (O(n^2)). However, the improved Magnetic Bubble Sort shows better performance in practice due to the reduction in unnecessary comparisons and early termination when the array is already sorted.

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