Algo Analyzer: A Detailed Approach to Analyzing and Visualizing Algorithmic Complexity

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Abstract— **The Algo Analyzer is an innovative platform designed to simplify the learning and application of algorithms through interactive visualizations, real-time execution, and performance analysis. Catering to students, educators, and professionals, it provides step-by-step breakdowns, dynamic animations, multilingual code, pseudocode generation, and a variety of algorithms, such as sorting, searching, and graph traversal. Users can simulate inputs, compare algorithm efficiency, and customize execution to deepen their understanding and enhance decision-making. By bridging the gap between theoretical concepts and practical implementation, the Algo Analyzer empowers users to master algorithmic problem-solving while addressing challenges like performance optimization, user experience, and security. This comprehensive tool aims to revolutionize algorithm education and foster innovation across academia and industry. By bridging the gap between theoretical concepts and practical implementation, the Algo Analyzer serves as a versatile tool for education and professional development. Educators can integrate the platform into their teaching to provide students with a hands-on, visual approach to learning, while professionals can leverage its features to analyze and optimize algorithms for real-world applications. The platform also encourages experimentation and innovation by allowing users to customize algorithm execution and test edge cases, fostering critical thinking and problem-solving skills. Despite challenges such as performance optimization for large datasets, ensuring a user-friendly interface, and maintaining accurate and up-to-date content, the Algo Analyzer has the potential to become a cornerstone in algorithm education and application. By addressing these challenges and continuously evolving to meet user needs, the project aims to provide a robust, scalable, and impactful solution that empowers users to master algorithms and apply them effectively across various domains, from software development to artificial intelligence and data science**

Keywords— Algorithm Analysis, Time Complexity, Space Complexity, Performance Profiling, Code Optimization, Algorithm Visualization, Computational Efficiency, Sorting Algorithms, Searching Algorithms, Dynamic Programming, Benchmarking, Input Scaling, Algorithm Comparison, Execution Time Measurement, Resource Consumption, Algorithmic Paradigms, , Data Structures.

I. INTRODUCTION

The excerpt discusses the challenges of teaching abstract concepts like algorithms in computer science education and highlights the effectiveness of visualization techniques (AVs) in overcoming these challenges. By representing algorithms graphically,AVs can make difficult, intangible ideas more concrete and understandable.

These visualizations engage both teachers and students, offering an appealing and interactive way to present algorithms and data structures. AVs enhance communication, promote active learning, and allow students to explore ideas at their own pace. The paper aims to review existing work in the field of algorithm visualization, assess its progress, and propose areas for further research to improve computer science education through better algorithm recognition. [1].

The importance of algorithm visualization tools in helping students and teachers understand and teach algorithms and data structures. It highlights the historical significance of Baecker's video-tape visualization of sorting algorithms and introduces the Brown Algorithm Simulator and Animator (BALSA) as an example of such tools. The text points out the difficulties students face in understanding theoretical concepts, especially in distance education, and

emphasizes the challenges of traditional teaching methods.
As a result, many tools for visualizing algorithms have been created, ranging from basic systems to interactive computer-based tutors. However, these tools still struggle to fully engage students and ensure satisfaction, particularly in online learning environments. [2].

The passage discusses the challenges of teaching algorithms in computer science and introduces an algorithm visualizer as a solution. With the help of interactive visualizations, students can see sorting and graph pathfinding algorithms in action thanks to the visualizer, which was developed with React.js. Because of its programmable features, which include speed and complexity adjustments, it may be used by students with varying ability levels. The visualizer aims to enhance understanding by offering a user-friendly interface where students can step through algorithms and observe their progression. It provides an engaging and effective way to learn algorithms and has received positive feedback from users.[3].

This introduction provides a broad overview of these points, highlighting the importance of the study and setting the stage for the detailed discussion that follows..

II. LITERATURE REVIEW

The literature review explores the analysis of algorithms has long been a critical aspect of computer science, as it allows for the evaluation of an algorithm's efficiency, scalability, and overall performance. With the growing complexity of computational problems, the need for effective tools to analyze algorithms has become more pronounced. These advancements have not only facilitated better performance analysis but have also become valuable in educational settings, helping students grasp complex algorithmic concepts more intuitively.

ALSA: A system created in the 1980s that lets studen ts see, manipulate, and engage with algorithm animat ions to aid in their understanding of algorithms.
It featured dynamic image displays, the ability to restart algorithms, and save settings. Tango: An animation system that supports real-time, smooth, 2D graphics for algorithms. It uses a transformation paradigm and is designed for ease of use, allowing users to work with embedded data structures or text files. GAIGS: A system that provides users with summaries of algorithm data structures and events. It allows users to view and interact with the data at their own pace, but doesn't allow for detecting the effect of code on system performance. DynaLab: A system designed for interactive learning in a lab setting, where students can experiment with algorithms, visualize time complexity, and undo steps in animations. t is compatible with a variety of operating systems, including Microsoft Windows and X Windows. SWAN: A C/C++ tool for visualizing data structures. It is appropriate for investigating diverse data structures since it lets users create graph views and interact with the animation using different components. JAWAA: A Java-based tool that uses a simple command language to create animations of data structures. It is platform-independent and allows users to control animation speed and interact with objects like stacks, trees, and other data structures .FLAIR: A repository for Artificial Intelligence courses, allowing students to experiment with search algorithms and visualize their performance. It includes features for comparing different algorithms by opening multiple windows at the same time.[1]

Recent interest in algorithm visualizer tools has grown, especially with the rise of web-based learning environments. While these tools effectively demonstrate algorithms, evaluations show that passive visualizations with low engagement have minimal impact on learning. A meta-study by Hundhausen emphasized that the effectiveness of these tools relies more on active learner engagement than on the visualizations themselves. Research on algorithm visualizer tools highlights several key features for effective learning, such as navigation through animations, textual explanations, and feedback for both learners and teachers. Studies have also focused on improving tool usability by including runtime analysis, step-by-step visualizations, and time complexity comparisons for better understanding. Additionally, guidelines for pedagogical success recommend adapting tools to learners' knowledge levels, providing performance data, and allowing customization to enhance the learning experience for students and educators. With the rise of web-based learning environments, algorithm visualization (AV) tools have gained significant attention in computer science education. These tools provide students with a dynamic and interactive way to understand complex algorithms by offering visual representations of their execution. However, research has shown that the effectiveness of AV tools largely depends on learner engagement rather than the visualizations themselves. Hundhausen's meta-study emphasizes that passive learning methods have minimal impact, whereas interactive and adaptive learning environments significantly enhance students' comprehension and retention.This section explores recent advancements in algorithm visualization tools, the pedagogical principles guiding their development, key usability features, and future directions for improving their effectiveness.Algorithm visualization tools have evolved from simple animations to highly interactive learning environments. While early AV tools functioned as passive animations, modern research suggests that engagement-driven interactivity plays a far greater role in learning outcomes.Algorithm visualization tools have evolved significantly, with modern systems prioritizing interactivity, usability, and adaptability. Research highlights that passive visualizations alone do not significantly improve learning—active engagement is crucial. The most effective AV tools incorporate step-by-step navigation, real-time feedback, performance tracking, and personalized learning paths.Future advancements in AV technology should focus on mobile compatibility, AI-driven personalization, and enhanced collaboration to create more engaging and effective learning environments. [2]

Algorithm visualization has been widely explored as an educational tool to improve comprehension of complex algorithmic concepts. Various studies and tools have aimed to enhance students' learning experience through interactive visual representations of algorithms.Clement and Tausky (2015) discussed an algorithm animation contest, highlighting the importance of visualization in engaging students and improving their understanding. Similarly, Thomas and Chen (2017) conducted a survey on interactive algorithm visualizations, emphasizing their impact on learning outcomes in computer science education.Bhaduri and Swamy (2019) proposed an interactive algorithm visualization framework to aid students in understanding fundamental computing concepts. Their work demonstrated that visual tools significantly enhance engagement and retention. Alharbi et al. (2019) compared different algorithm visualization tools and concluded that effective visualizations should offer user interactivity and customization.Li et al. (2017) explored the use of JavaScript and SVG for visualizing algorithms, providing an efficient and flexible approach to real-time algorithm visualization. Meanwhile, Patil and Gaikwad (2019) conducted a survey on various algorithm visualization techniques, reinforcing their role in simplifying complex concepts for learners.Liu et al. (2019) studied the impact of sorting algorithm visualizations on comprehension and perception, indicating that visual aids help students grasp intricate sorting mechanisms. Ovcinnikovs and Grave (2017) analyzed different algorithm visualization toolkits and their effectiveness in educational environments. Lehnert and Huesken (2020) focused on interactive visualization in sorting algorithms and highlighted its positive effect on students' ability to understand and recall sorting mechanisms. Lastly, Lee et al. (2019) examined the role of algorithm visualization in introductory programming courses, noting its influence on student perceptions and retention rates.These studies collectively underscore the significance of algorithm visualization tools in computer science education. The research highlights that interactive and customizable visualizers, such as the one presented in this paper, can bridge the gap between theoretical knowledge and practical understanding, making algorithm learning more accessible and effective.[3]

The field of algorithm visualization has been extensively studied as a means to enhance students' comprehension of algorithmic processes. The need for interactive learning tools arises from the challenges faced by students in grasping complex algorithmic concepts, often due to the abstract nature of programming.Several studies emphasize the significance of visualization in learning. Research has demonstrated that visualization tools improve engagement, comprehension, and retention of information among students. Traditional learning methods, which rely heavily on memorization and static textbook explanations, often fail to provide an intuitive understanding of algorithms.The use of web-based visualization tools has gained traction due to their accessibility and ease of use. The implementation of visualization techniques using technologies such as HTML5, JavaScript, and CSS allows for an interactive and engaging learning experience. Studies indicate that real-time interaction with algorithms fosters deeper conceptual understanding, as students can observe how data structures transform step-by-step.

Algorithm visualizers commonly focus on key computational concepts such as sorting, searching, and pathfinding algorithms. Existing research highlights the importance of algorithm visualization tools in fostering computational thinking and problem-solving skills.A comparative analysis of different visualization tools suggests that students who engage with interactive visualizers demonstrate better problem-solving abilities than those who rely solely on traditional teaching methods. Studies also highlight that visualization aids reduce cognitive overload by presenting algorithmic processes in an easily digestible manner.Additionally, research on sorting and pathfinding visualizations has shown that students retain information better when exposed to animations rather than static explanations. By incorporating step-by-step execution, animations, and real-time feedback, modern algorithm visualizers make learning more efficient and engaging.Several previous works have explored the impact of interactive tools in algorithm education. Websites such as GeeksforGeeks, Pathfinding Visualizer, and Algorithm-Visualizer.org have contributed to the growing body of algorithm visualization resources. These tools have proven effective in providing students with hands-on learning experiences, allowing them to test different algorithms dynamically.The existing research supports the development of interactive visualization tools as a means to enhance programming education, reduce learning barriers, and improve algorithm comprehension. The study presented in this paper builds upon these findings by proposing a web-based Algorithm Visualizer, which integrates sorting and pathfinding algorithms with an intuitive user interface.[4]

This paper outlines a conceptual framework for animating algorithms and provides examples of algorithms visualized through the system.Tango: A Framework & System for Algorithm Animation: This paper introduces a framework and system designed to effectively convey the meaning, methodology, and purpose of algorithms through animation. The impact of algorithm animation on teaching algorithms and data structures is examined in this research, which also provides a brief overview of algorithm animation systems' historical development. Using the JSAV to Create Interesting Online Learning Resources The JavaScript Algorithm Visualization Library is the subject of this paper. It makes it easier to create interactive algorithm visualizations and provides learners with different levels of participation. Algorithm Animation Techniques: The research focuses on an integrated environment that lets users interact with graphical representations of algorithms that change dynamically. Using Algorithm Visualizations in Computer Science Education: This work introduces a platform that allows for dynamic pseudo code modifications and provides instructional algorithm visualizations. Algorithm Visualization: A Report on the State of the Field: This document provides an overview of the state of algorithm visualization, covering topics such as content distribution, visualization quality, and creative techniques. Design and Assessment of a Web-based Dynamic Algorithm Visualization Environment for Novices: This work introduces a web-based environment that uses dynamic visualizations to educate novices fundamental algorithmic principles. Critical Analysis of Algorithm Visualization Study: In order to assist students in better understanding data structures and algorithms, this article presents a hybrid mobile application for interactive algorithm visualization. Learning Spatial Data Algorithms using an Algorithm Visualization System This study describes a web-based system that uses visualization to teach spatial data algorithms. [7].

Algorithm visualization (AV) has emerged as an essential tool in teaching data structures and algorithms (DSA). The complex and abstract nature of DSA makes it difficult for students to grasp concepts through traditional teaching methods such as textbooks and static images. AV aims to enhance comprehension by presenting algorithmic processes dynamically through animations and interactive interfaces.AV systems have been developed to facilitate learning by enabling students to interact with visual representations of algorithms. According to previous studies, interactivity plays a crucial role in student engagement and knowledge retention. Studies highlight that passive visualization, such as animation videos, has limited impact on learning outcomes compared to active, interactive approaches.Studies indicate that students face multiple challenges in learning DSA. To address these challenges, interactive AV systems are recommended, where students can manipulate algorithmic steps, predict outcomes, and engage in problem-solving exercises.Several AV models and guidelines have been proposed to improve learning effectiveness.Pedagogical Guidelines: Early AV guidelines emphasize aspects like accessibility to large audiences, gneral-purpose usability, interactivity, step-wise replay options, and quiz-based assessments.Constructivist Learning Theory-Based Models: Some models incorporate real-world analogies, direct manipulation, and auditory feedback to enhance comprehension.The Data Structure Learning (DSL) Model: This model integrates aural instruction with visual components to reduce cognitive load and improve learning efficiency.VizAlgo-Based AV System: This system uses multiple views, color coding, and screen design techniques to improve cognitive processing.Mobile AV Systems: AV research on mobile platforms remains limited[8].

III. RESEARCH METHODOLOGY

This project focuses on developing an effective algorithm visualizer tool to enhance student engagement and learning outcomes. The design process integrates pedagogical, usability, and accessibility principles to create intuitive user interactions and visualizations. It follows three key phases: establishing requirements, designing alternatives and prototyping, and evaluation. The requirements were identified through a comprehensive literature review, determining essential goals and features. In the prototyping phase, user interactions and visual elements were designed based on Schneiderman’s Eight Golden Rules of UI Design. While the evaluation phase is still in progress, it will be conducted using a Likert scale survey to assess usability and effectiveness. This work primarily highlights the requirements and prototyping phases, with evaluation to follow.

The existing application already includes basic algorithm visualization for path-finding, sorting algorithms, mazes, patterns, and time complexity analysis. To enhance its realism and comprehensibility, additional features are being integrated. One key addition is CPU scheduling algorithm visualization, which will help students understand how the CPU manages multiple parallel processes while ensuring maximum resource utilization, minimal response time, fair allocation, and high throughput. The visualization will cover popular scheduling algorithms such as First-Come, First-Served (FCFS), Shortest Job Next (SJN), Priority Scheduling, Shortest Remaining Time, Round Robin (RR), and Multiple-Level Queues Scheduling. Another enhancement is tree-based visualization of algorithms, aligning with the way algorithms are traditionally taught in textbooks. This feature aims to facilitate a smooth transition from classroom learning to e-learning by initially presenting algorithms through tree structures and later introducing more advanced visual representations. These improvements will broaden the application's knowledge base and provide students with a more interactive and effective learning experience.

The application will introduce a Pause and Play feature, allowing users to temporarily stop and resume visualizations without restarting, ensuring an uninterrupted learning experience. Additionally, real-world application simulations will demonstrate the practical use of algorithms, such as geo-location and navigation systems for shortest-route finding and delivery and logistics management for optimizing e-commerce operations. These improvements aim to enhance engagement, connect theory with real-world applications, and extend usability beyond students to industries. [6]

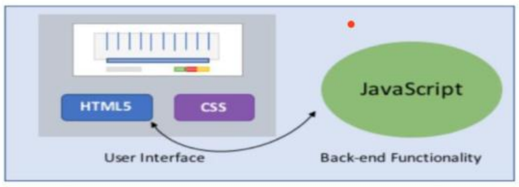

Fig 1: System architecture 1

The Algorithm Visualization System's structure is depicted in Fig. 1's System Architecture Diagram, which also emphasizes the connection between the back-end functionality and the user interface (UI). The structure and styling of the visualization platform are defined by HTML5 and CSS, which are used in the User Interface's construction to give users an easy-to-use and aesthetically pleasing experience. JavaScript, which manages the main logic, user interactions, and dynamic rendering of algorithm visualizations, powers the back-end functionality. Real-time graphical representations are produced by JavaScript after it processes user inputs and runs the chosen algorithms. Users can effectively interact with the system thanks to this architecture, which guarantees a smooth and engaging visualization experience. The combination of HTML5, CSS, and JavaScript provides a robust, web-based solution for algorithm visualization, making complex computational processes more accessible and easier to understand.

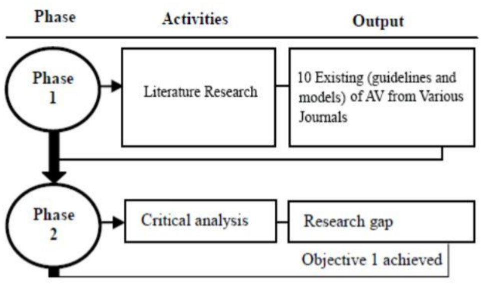

Fig 2: Summary of Activities

The Summary of Activities diagram outlines a two-phase research approach to analyzing algorithm visualization (AV) tools.Phase 1 focuses on Literature Research, where existing guidelines and models of AV from 10 different journal sources are reviewed. This phase helps in understanding the current state of AV tools, their methodologies, and best practices for effective learning and user engagement. The key output of this phase is a collection of existing models and guidelines that serve as a foundation for further research.Phase 2 involves Critical Analysis, where the gathered literature is examined in-depth to identify gaps in existing research. This analysis highlights unexplored areas, limitations, or shortcomings in current AV models, leading to the identification of a research gap. Addressing this gap is crucial for innovation and improvement in AV tools. The successful completion of this phase results in achieving Objective 1, which likely pertains to defining a research problem or laying the groundwork for further development in AV methodologies.This structured approach ensures a comprehensive evaluation of existing AV tools and sets the stage for meaningful advancements in algorithm visualization. In the first phase, existing AV study guidelines and models are gathered. A thorough literature search was done during this phase. Ten prior models and recommendations were collected. In order to achieve the primary goal of this ongoing study, these collected studies were then critically examined and assessed in the second phase.

Data Movement An external entity (an external system that transmits or receives data) is represented by a rectangle in this diagram, while a process (a process that modifies data and produces an output) is shown by a circle. While the arrows pointing away from the process indicate output, the arrows pointing towards the process indicate input.

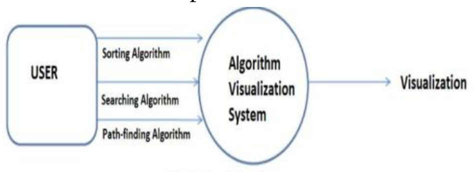

Fig 3: Data Flow Diagram

The Data Flow Diagram (DFD) in Fig 3 illustrates the process of how users interact with the Algorithm Visualization System to receive graphical representations of algorithm executions. The diagram begins with the User, who inputs a request to visualize a specific algorithm. The system supports various types of algorithms, including Sorting Algorithms, Searching Algorithms, and Path-finding Algorithms. Once the user selects an algorithm, it is processed by the Algorithm Visualization System, which dynamically generates visual representations of the algorithm's execution. Finally, the system outputs the Visualization, providing an interactive and comprehensible way for users to understand how the chosen algorithm functions. This visualization aids in better conceptual learning, making abstract algorithmic concepts more tangible and accessible for learners. The DFD effectively represents the user-system interaction, ensuring a clear and structured flow of data within the system. Upon receiving the user's selection, the Algorithm Visualization System processes the input, executes the chosen algorithm, and dynamically generates a step-by-step visual representation of its execution. This visualization provides a graphical depiction of how data structures and elements change over time as the algorithm progresses. The system effectively translates complex logical operations into an interactive, real-time simulation, enabling users to observe and analyze how different algorithms function under varying conditions. The primary objective of this visualization-based learning approach is to enhance users' comprehension of algorithmic concepts by making abstract computations more tangible and intuitive. Instead of merely studying pseudocode or textual explanations, users can actively engage with the visual output, which helps in identifying patterns, understanding efficiency, and improving problem-solving skills.

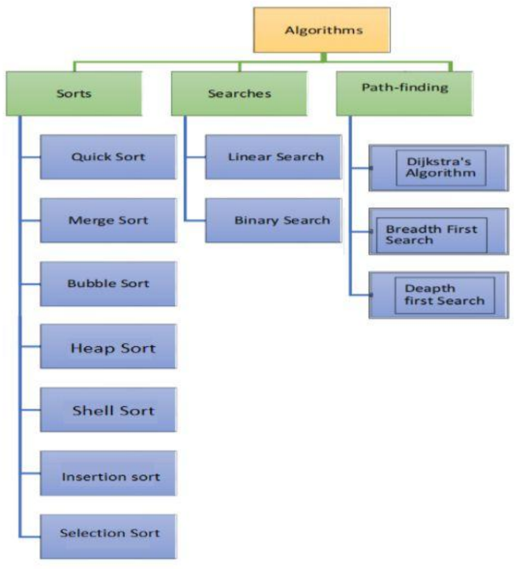

Figure 4. Algorithms in proposed solution

The next phase, depicted in Figure 4, describes the procedure of the There are three different kinds of algorithms in the suggested system.

1. The algorithm for sorting
2. Algorithm for Searching
3. Algorithms that find paths

Algorithms for Sorting:
The array or list of numbers is rearranged using a sorting algorithm based on a comparison operator applied to the members. Depending on the comparison operator, a list of components can be ordered either in ascending or descending order.

Looking for Algorithms:
To verify or retrieve an element from a data structure where it is stored, searching algorithms are created.
Depending on the kind of search operation, these algorithms are divided into two primary categories.
Linear search This algorithm iteratively goes through the array list, checking each entry.
An algorithm specifically designed to search through a sorted list of elements is called interval search. Since it does not examine every element, it is more effective.
Example: Binary search
Path-finding Algorithm: To solve a lot of computer science problems, users must determine the shortest path between two points. Algorithms for finding paths are created.

IV. RESULTS

Through a comprehensive survey conducted by our team, we found that 60% of students responded better to understanding concepts through visualization rather than relying on their imagination or traditional teaching methods. This reinforces the widely accepted principle that visual aids such as images, videos, and animations significantly enhance memory retention and comprehension. Numerous studies and experiments have consistently demonstrated that humans tend to remember visual information more effectively compared to text-based or oral explanations. By leveraging this advantage, our project aims to make learning algorithms more engaging, intuitive, and accessible.

One of the key strengths of our visualization tool is its ability to present algorithmic processes in a way that students can relate to real-life scenarios. The inclusion of mazes and patterns in our application provides students with a practical perspective, as they can associate obstacles in the form of walls with real-world obstructions, thereby enhancing their conceptual clarity. Furthermore, teachers often struggle to explain complex algorithms in a way that captures students' interest without making the lessons monotonous. Our interactive and user-friendly interface serves as an effective teaching aid, reducing the likelihood of students losing focus or getting distracted. By making learning dynamic and engaging, our tool enhances students' ability to grasp complex concepts with ease.Additionally, our project can seamlessly integrate with the existing education system, promoting alternative learning methods beyond the conventional blackboard approach. The web-based nature of our application ensures that it is easily accessible to students and teachers without requiring additional software installations, making it a convenient supplement to classroom education. In uncertain times, where remote learning has become a necessity, relying solely on traditional one-to-one, offline teaching is no longer practical. E-learning is the future of education, and our project contributes to this evolving landscape by reinforcing a self-paced, interactive, and visually driven learning experience. By integrating visualization with education, we bridge the gap between traditional and modern learning techniques, ensuring a more efficient, effective, and engaging approach to understanding algorithms.

A survey was conducted to assess the impact of the proposed features on users’ willingness to adopt the Algorithm Visualizer application, and the results showed a 10% increase in preference, rising from 60% to 70%. This improvement highlights the growing acceptance of visualization-based learning. Research suggests that people retain information better when it is presented as a storyline or linked to real-life experiences, making the enhanced features highly effective in helping students grasp and retain algorithmic concepts for a longer period. Additionally, integrating real-world applications of algorithms fosters a research-oriented mindset, encouraging students to analyze and understand the functioning of concepts beyond textbooks. The updated application will also assist teachers in simplifying complex topics, reducing their workload, and providing them with an opportunity to innovate new visualization techniques to further enhance the learning experience.

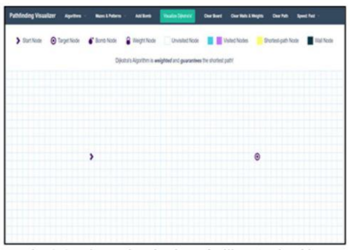
Fig. 4. Starting and End points of Dijkstra's algorithm

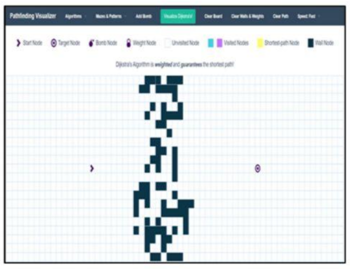
Fig. 5. Obstacles in the grid

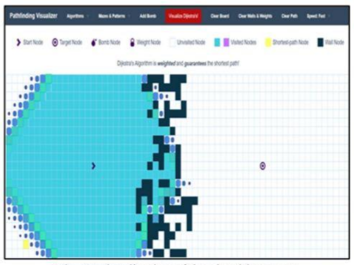
Fig. 6. Visualization of the algorithm starts

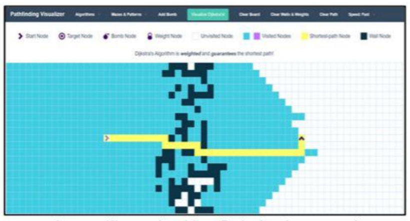
Fig. 7. Dijkstra algorithm finds the shortest path

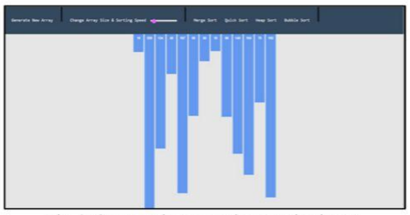
Fig. 8. Generate the unsorted array using button

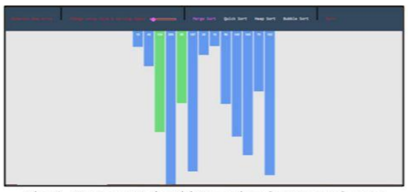
Fig. 9. Merge sort algorithm sorting the unsorted array

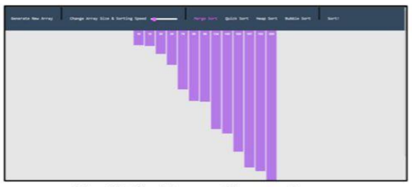
Fig. 10. Final image of the sorted array

V. CONCLUSION

Algorithm recognition serves as a valuable educational tool alongside traditional teaching methods in computer science, offering an engaging way to enhance understanding. Unlike simple data visualization, algorithm visualization follows structured behavioral rules, making it a less common yet essential approach for better comprehension. Designers continually explore innovative methods to improve its effectiveness. Beyond aiding pattern recognition, visualization enhances cognitive abilities, enabling individuals to grasp complex, invisible processes and apply this knowledge across various domains. This reinforces the idea that visualization is not just a tool but a means to improve intelligence and problem-solving skills.

The literature review highlights a gap in algorithm visualization research, as most existing models and guidelines focus on desktop platforms and websites rather than mobile applications. Even the few mobile-focused studies lack comprehensive interaction and user interface principles. n order to provide organized principles for interactive algorithm visualization on a hybrid mobile application (INAVOHMA), this work uses comparative analysis to identify these research gaps. The hybrid approach ensures compatibility across multiple operating systems, such as Android and iOS. Future research will focus on refining interactivity strategies, exploring design frameworks, and enhancing user interface elements to improve the effectiveness of algorithm visualization.

REFERENCES

[1] Sweeta Bansal , Karan Kohli , Krishna Kumar Vishwakarma , Kush Gupta Computer Science and Engineering, Inderprastha Engineering College, Uttar Pradesh, India

[2] Rohit L. Ugile, Ritesh B. Barure, Gajanan S. Sawant, Prof. Laxmikant Malphedwar ,Student, Computer Engineering, Dr. D.Y. Patil College Of Engineering AndInnovation, Varale, Talegaon, Pune, India. Guide, Computer Engineering, Dr. D.Y. Patil College Of Engineering And Innovation, Varale, Talegaon, Pune, India.

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[9] Ahmad Affandi Supli, Norshuhada Shiratuddin and Syamsul Bahrin Zaibon, “Critical Analysis on Algorithm Visualization Study”, International Journal of Computer Applications (0975 – 8887), Volume 150 – No.11, Sep 2016.

[10]] C. Shaffer. A Practical Introduction to Data Structures and Algorithm Analysis. Prentice Hall, second edition, 2001.

[11] P. Saraiya. Effective features of algorithm visualizations. Master’s thesis, Department of Computer Science, Virginia Tech, July 2002.

[12] K. Becker and M. Beacham, "A tool for teaching advanced data structures to computer science students: an overview of the BDP system," Journal of Computing Sciences, vol. 16, no. 2, pp., 2001

[13] E.Vrachnos and A. Jimoyiannis, "Design and evaluation of a web-based dynamic algorithm visualization environment for novices," Procedia Computer Science, vol. 27, pp. 2014.

[14] A. Dix, J. Finlay, G. D. Abowd and R. Beale, Human-Computer Interaction, 3. Edition, Ed., Harlow: Pearson Education, 2004.

[15] G. Robling and T. L. Naps, "A testbed for pedagogical requirements in algorithm visualizations," in Conference on Innovation and Technology in Computer Science Education, New York, USA, 2002.

[16] Liu, J., Lu, Y., & Tian, Y. (2019). Visualizing Sorting Algorithms: An Empirical Study on Comprehension and Perception. Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing.

[17] Ovcinnikovs, A., & Grave, I. (2017). Analysis of Algorithm Visualization Toolkits. Proceedings of the 13th International Conference on Web Information Systems and Technologies,

[18] Lehnert, W., & Huesken, A. (2020). Interactive Visualization of Algorithms: A Case Study on Sorting. Journal of Educational Computing Research, 58(6), 1608-1630.

[19] Alharbi, S., Al-Mutairi, S., & Alajmi, B. (2019). A Comparative Study of Algorithm Visualization Tools. International Journal of Emerging Technologies in Learning.