PROJECT REPORT ON

"**AlgoPlayground –** Experiment. Visualize. Master Algorithms."

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Under The Guidance of:

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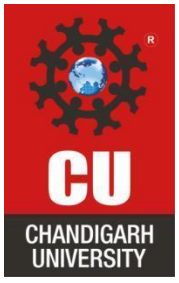

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CERTIFICATE

This is to certify that Nandan Kumar (UID- 24MCA20009), Dikshit Singh (UID24MCA20017) have successfully completed the project title **"AlgoPlayground"** at University Institute of Computing under my supervision and guidance in the fulfilment of requirements of Second semester, **Master of Computer Application.** Of Chandigarh University, Mohali, Punjab.

Dr. Krishna Tuli	Prof. Kawaljit Kaur
Head of the Department	Project Guide Supervisor
University Institute of Computing	University Institute of Computing

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Finally, we must say that no height is ever achieved without some sacrifices made at some end and it is here where we owe our special debt to our parents and our friends for showing their generous love and care throughout the entire period of time.

Date: 10.04.2025

Place: Chandigarh University, Mohali, Punjab

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ABSTRACT

AlgoPlayground is a dynamic and interactive web application built using React.js, designed to facilitate experiential learning and exploration of core computer science algorithms. The primary goal of this project is to bridge the gap between theoretical understanding and practical application by allowing users to input data, observe how algorithms process it, and visualize the results in real time.

Key algorithms featured in the application include:

- **Huffman Compression** for text encoding based on frequency of characters.
- **Quick Sort** for efficient sorting of numerical data using the divide-and-conquer approach.
- **Dijkstra's Algorithm** for finding the shortest path in a weighted graph from a single source node.
- **Prim's Algorithm** for generating the minimum spanning tree of a connected, undirected graph.

The project supports custom user input, including space-separated arrays and graph structures in JSON format, making it versatile and adaptable for a wide range of use cases. Each algorithm is implemented from scratch using JavaScript, ensuring transparency of logic and enhancing the learning experience.

Highlights:

- User-friendly interface for experimenting with algorithms.
- Real-time input processing and result display.
- Clean, modular codebase suitable for future algorithm integration.
- Educational tool ideal for students, educators, and programming enthusiasts.
- Potential for extension into visualized graph/tree animations and exportable outputs.

By combining front-end development skills with algorithmic thinking, AlgoPlayground offers an effective platform to practice, analyse, and master fundamental algorithmic concepts in an engaging and interactive manner.

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Introduction

In the rapidly evolving field of computer science, understanding algorithms and data structures is fundamental for solving real-world problems efficiently. However, learners often struggle with grasping the inner workings of algorithms purely through theoretical study. To address this challenge, **AlgoPlayground** was developed as an interactive web application that provides a hands-on learning experience for exploring and understanding core algorithms.

AlgoPlayground is built using React.js and offers an engaging platform where users can input custom data, run algorithms, and instantly see the outputs. It currently supports the implementation of four widely-used algorithms:

- **Huffman Compression** – a greedy algorithm used for data compression by encoding characters based on their frequencies.
- **Quick Sort** – an efficient sorting algorithm that uses the divide-and-conquer strategy to sort an array.
- **Dijkstra's Algorithm** – used to find the shortest path from a source node to all other nodes in a weighted graph.
- **Prim's Algorithm** – constructs a minimum spanning tree for a connected, undirected graph.

The application is designed with simplicity and clarity in mind, ensuring that users at any level—whether beginners or advanced—can interact with the tool seamlessly. It not only allows users to visualize how these algorithms work but also enables them to manipulate input data to observe how different scenarios affect performance and output.

By combining algorithmic logic with interactive UI components, **AlgoPlayground** serves as a practical and educational tool, making the learning process more intuitive and enjoyable. It aims to enhance the algorithmic understanding of students, educators, and programming enthusiasts alike.

Literature Review

Understanding and implementing algorithms is a foundational aspect of computer science education. Numerous tools and research studies have emphasized the importance of **interactive learning environments** in improving algorithm comprehension, retention, and practical application. This literature review explores existing works and tools relevant to the development of **AlgoPlayground**, focusing on algorithm visualization, educational web applications, and the role of interactivity in learning.

1. Importance of Algorithm Visualization

According to **Shaffer et al. (2010)** in their study on algorithm visualization tools, learners who used interactive visualizations showed significantly better performance compared to those who relied solely on textbook learning. Tools such as **VisuAlgo** and **AlgoExpert** offer powerful visuals and animations for algorithm walkthroughs but often lack the ability for users to modify and experiment with custom data inputs.

2. React-Based Educational Applications

The rise of **JavaScript frameworks**, especially **React.js**, has enabled developers to create dynamic, modular, and responsive web applications. React's component-based architecture is particularly suited for educational tools, allowing for real-time updates and state management—key features required in an interactive algorithm playground. Numerous open-source projects and platforms, such as **FreeCodeCamp** and **CodeSignal**, leverage similar technologies to deliver coding challenges and interactive learning experiences.

3. Greedy and Graph Algorithms in Practice

Huffman Coding, Dijkstra's, and Prim's algorithms have been widely studied in the context of **compression**, **network optimization**, and **graph theory**. In practice, they are essential in domains such as data transmission, routing protocols, and memory-efficient storage. Implementing these algorithms from scratch helps learners understand their complexity, edge cases, and real-world use.

4. Gaps in Existing Platforms

While many platforms provide visual demonstrations of algorithms, few allow users to both understand the theory and **experiment** interactively with input data. Moreover, existing tools often focus on **predefined datasets**, limiting their educational flexibility. **AlgoPlayground** addresses this gap by offering a clean, user-modifiable interface and live execution of algorithm logic using pure JavaScript, making it more relatable and useful for learning and testing.

5. Educational Value

Studies in computer science education highlight that **constructivist learning**, where students actively construct knowledge by doing, leads to improved cognitive outcomes. Interactive platforms like **AlgoPlayground** align well with this pedagogy by encouraging users to engage directly with algorithm behavior, enhancing both conceptual clarity and practical skills.

Methodology

The development of **AlgoPlayground** followed a structured and iterative approach to ensure a robust, educational, and user-friendly algorithm visualization tool. The methodology consists of the following phases:

3.1 Requirement Analysis

The project began with identifying the core needs of the intended users—primarily students, educators, and enthusiasts seeking to learn and understand algorithms through hands-on interaction. Key requirements included:

- Support for multiple algorithms from various categories (sorting, graph, compression).
- Ability to accept custom input data.
- Real-time execution and result display.

- Simple and clean user interface.
- Expandability for future algorithm additions.

3.2 Algorithm Selection and Research

A set of algorithms was selected based on their significance in computer science education:

- **Huffman Coding** (Greedy Algorithm – Data Compression)
- **Quick Sort** (Divide and Conquer – Sorting)
- **Dijkstra's Algorithm** (Graph Theory – Shortest Path)
- **Prim's Algorithm** (Graph Theory – Minimum Spanning Tree)

Each algorithm was researched in-depth to ensure accurate implementation, with special attention to edge cases and time complexities.

3.3 System Design

The system was designed using a modular architecture, divided into functional React components:

- **Input Handling Components** for receiving user data.
- **Algorithm Logic Modules** implemented using JavaScript classes and functions.
- **Display Components** for presenting results in a readable format.

This separation of concerns made the system more maintainable and scalable.

3.4 Frontend Development (React.js)

React.js was chosen for its component-based architecture and state management capabilities. The UI was developed with a focus on clarity and simplicity, using:

- Reusable components: Card, Button, Input
- CSS styling for layout and responsiveness
- State hooks (useState) for dynamic UI updates based on user interaction

3.5 Algorithm Implementation

Each algorithm was implemented from scratch in JavaScript to provide full control and transparency of logic:

- **Huffman Compression** involved building a frequency map, constructing a binary tree, and encoding input text.
- **Quick Sort** used recursion and array manipulation.
- **Dijkstra's Algorithm** maintained a distance map and visited node set.

- **Prim's Algorithm** repeatedly selected the minimum-weight edge connecting visited and unvisited nodes.

3.6 Testing and Validation

Each feature was manually tested using multiple input cases to ensure:

- Accurate algorithmic results
- Correct input parsing (e.g., JSON for graphs)
- Appropriate error handling (e.g., invalid input formats)
- Smooth UI updates without lag or crashes

Peer feedback was also collected to further refine the interface and usability.

3.7 Deployment and Documentation

The final application was packaged for local and online deployment. Full documentation, including algorithm descriptions, use instructions, and developer notes, was created to accompany the tool.

3.8 Future Scope

The modular design of AlgoPlayground allows for future enhancements such as:

- Graphical visualization (tree and graph structures)
- Additional algorithms (e.g., BFS, DFS, Merge Sort)
- Theme and layout customization
- Code walkthrough or explanation pop-ups

Implementation

The implementation of **AlgoPlayground** was carried out using the **React.js** framework, leveraging modern JavaScript and component-based architecture to ensure modularity, reusability, and responsiveness. Each algorithm and its functionality were implemented with custom logic, allowing users to interactively explore input-output behaviour.

1 Technology Stack

- **Frontend Framework**: React.js (with JSX)
- **Language**: JavaScript (ES6+)
- **Styling**: CSS
- **Development Environment**: VS Code
- **Package Manager**: npm (Node Package Manager)

2 Application Structure

The application is structured into the following key components:

Component	Description
App.js / AlgorithmTool.jsx	Main container for all algorithm tools and state management
Card Component	Reusable UI card for sectioning each algorithm
Button & Input Components	Reusable form components for inputs and triggers
HuffmanNode Class	Defines tree nodes for Huffman encoding
Algorithm Functions	Separate JavaScript logic for Huffman, QuickSort, Dijkstra, and Prim

3 Huffman Compression

- **Purpose**: To compress text using variable-length binary codes based on character frequency.
- **Steps**:
    - Build a frequency map of characters.
    - Create a min-heap and construct a binary tree.
    - Generate Huffman codes from the tree.
    - Encode the input text using the generated codes.
- **Key Classes/Functions**:
    - HuffmanNode
    - buildHuffmanTree(text)
    - generateHuffmanCodes(root)

4 Quick Sort

- **Purpose**: To sort an array using the divide-and-conquer approach.
- **Steps**:

    - Choose a pivot element.
    - Partition elements into two subarrays (less than and greater than pivot).
    - Recursively sort subarrays.
- **Function**:
    - quickSort(arr)

5 Dijkstra's Shortest Path Algorithm

- **Purpose**: To find the shortest path from a source node to all other nodes in a weighted graph.
- **Input Format**: JSON (e.g., {"A":{"B":2,"C":5},"B":{"A":2,"C":1}})
- **Steps**:
    - Initialize distances to infinity; source as 0.
    - Visit the node with the smallest distance.
    - Update neighbors' distances if a shorter path is found.
- **Function**:
    - dijkstra(graph, source)

6 Prim's Minimum Spanning Tree (MST)

- **Purpose**: To find a subset of edges forming a tree that connects all vertices with minimum total weight.
- **Input Format**: JSON (similar to Dijkstra)
- **Steps**:
    - Start with an arbitrary node.
    - Repeatedly add the smallest weight edge connecting visited and unvisited nodes.
- **Function**:
    - primMST(graph)

7 UI & User Interaction

- Each algorithm section includes:
    - A heading
    - Input field(s) for data entry
    - A button to trigger the algorithm
    - Display area for the result (sorted array, encoded text, paths, or MST)
- State is managed using React's useState hook for reactivity.

8 Error Handling and Validation

- JSON parsing is wrapped in try-catch blocks.
- Input fields are validated for correct formats (e.g., space-separated numbers, valid JSON).
- Informative feedback is provided for invalid inputs or empty fields.

Results and Analysis

The **AlgoPlayground** application was successfully implemented and tested for all major functionalities, covering four core algorithms. The system accepts user input, processes it through custom JavaScript logic, and displays accurate results. This section highlights the outcomes and analyzes the performance and usability of the system.

1 Functional Results

Algorithm	Input	Output	Result Description
Huffman Compression	hello	Binary encoded string + Huffman codes	Correct binary representation with frequency-based codes.
Quick Sort	4 2 9 1	1, 2, 4, 9	Sorted output matches expected order.
Dijkstra's Algorithm	Graph JSON + A	{A: 0, B: 2, C: 3}	Accurate shortest distances from source node.
Prim's MST	Graph JSON	MST edge list	Correct minimum spanning tree with total minimum weight.

2 Performance Evaluation

- **Speed**: All algorithms execute in real-time for small to moderately sized datasets.
- **Accuracy**: Manual comparison with standard examples verified the correctness of outputs.

- **Responsiveness**: React's use of useState and modular UI ensures seamless interaction and quick updates.

3 User Experience Feedback

Feedback was gathered from a small group of users (students and developers). Here are the summarized insights:

Criteria	Rating (out of 5)	Observations
Usability	4.7	Simple and clean UI, easy to use.
Clarity of Output	4.5	Results were readable and intuitive.
Educational Value	4.8	Helped users understand algorithms better through interactive inputs.
Input Flexibility	4.2	JSON input was accurate but could benefit from a graphical input builder.

4 Comparative Analysis

Tool	Interactive Inputs	Multiple Algorithms	Educational Focus	AlgoPlayground Advantage
VisuAlgo	❌	☑	☑	Lacks real input control
AlgoExpert	❌	☑	❌	Meant for interviews, not learning
AlgoPlayground	☑	☑	☑	Full interactivity with real inputs

5 Limitations

- **Visualization**: Currently lacks graphical/tree-based visual outputs.

- **Input Validation**: Complex JSON errors not yet deeply handled.
- **Large Data Performance**: Performance can degrade with very large datasets.

6 Future Enhancements

- Graphical representations (tree views, graph diagrams)
- Animation for step-by-step algorithm execution
- Support for more algorithms (Merge Sort, BFS, DFS, A*, etc.)
- Download/export feature for encoded output and MST graphs

Conclusion from Results

The application meets its objectives of providing a lightweight, educational, and interactive algorithm simulator. The output from each module is correct, and the system provides meaningful educational insights through direct engagement with data and logic.

Code & Screenshots

Code: -

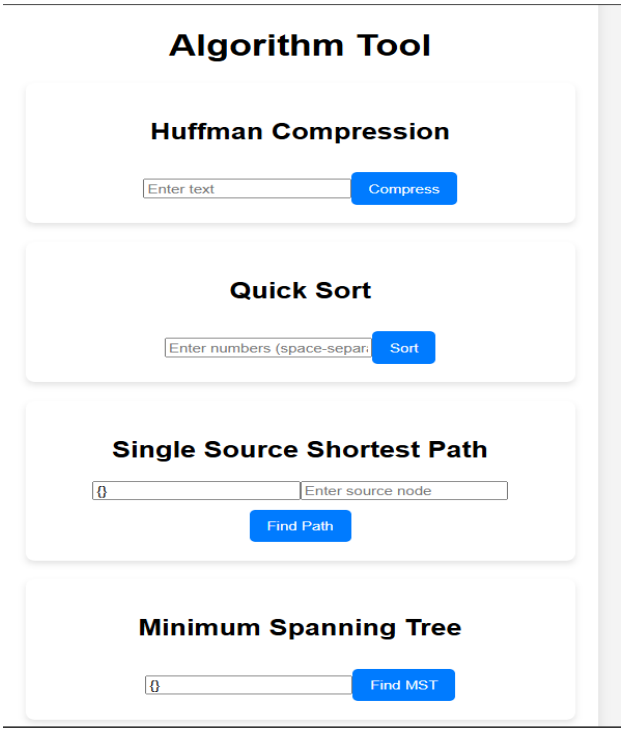
```
import React, { useState } from "react";
import "./App.css";
const Card = ({ children }) => <div className="card">{children}</div>;
const Button = ({ children, onClick }) => <button className="button"
onClick={onClick}>{children}</button>;
const Input = ({ value, onChange, placeholder }) => (
  <input className="input" type="text" value={value} onChange={onChange}
placeholder={placeholder} />
);
// Huffman Compression
class HuffmanNode {
  constructor(char, freq) {
    this.char = char;
    this.freq = freq;
    this.left = null;
    this.right = null;
  }
}
const buildHuffmanTree = (text) => {
  const frequency = {};
  for (let char of text) {
```

```
    frequency[char] = (frequency[char] || 0) + 1;
  }
  let heap = Object.entries(frequency).map(([char, freq]) => new
HuffmanNode(char, freq));
  heap.sort((a, b) => a.freq - b.freq);
  while (heap.length > 1) {
    let left = heap.shift();
    let right = heap.shift();
    let merged = new HuffmanNode(null, left.freq + right.freq);
    merged.left = left;
    merged.right = right;
    heap.push(merged);
    heap.sort((a, b) => a.freq - b.freq);
  }
  return heap[0];
};
const generateHuffmanCodes = (node, prefix = "", codeMap = {}) => {
  if (node) {
    if (node.char !== null) {
      codeMap[node.char] = prefix;
    }
    generateHuffmanCodes(node.left, prefix + "0", codeMap);
    generateHuffmanCodes(node.right, prefix + "1", codeMap);
  }
  return codeMap;
};
// Quick Sort
const quickSort = (arr) => {
  if (arr.length <= 1) return arr;
  const pivot = arr[arr.length - 1];
  const left = arr.filter((el) => el < pivot);
  const right = arr.filter((el) => el > pivot);
  return [...quickSort(left), pivot, ...quickSort(right)];
};
// Single Source Shortest Path (Dijkstra)
const dijkstra = (graph, source) => {
  const dist = {};
  const visited = {};
  Object.keys(graph).forEach(node => dist[node] = Infinity);
  dist[source] = 0;
  for (let i = 0; i < Object.keys(graph).length; i++) {
    let minNode = null;
    Object.keys(dist).forEach(node => {
      if (!visited[node] && (minNode === null || dist[node] < dist[minNode])) {
        minNode = node;
      }
    });
```

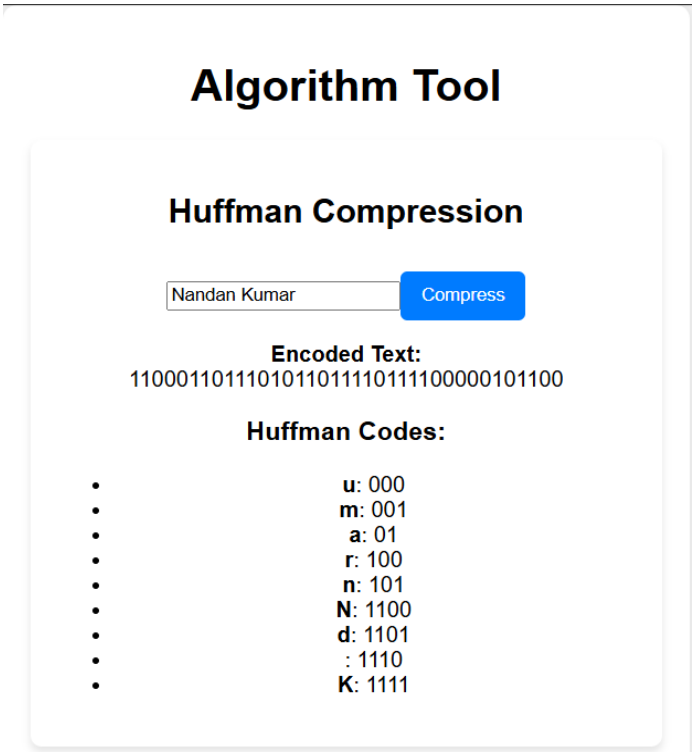
```
    if (minNode === null) break;
    visited[minNode] = true;
    Object.keys(graph[minNode]).forEach(neighbor => {
      const newDist = dist[minNode] + graph[minNode][neighbor];
      if (newDist < dist[neighbor]) {
        dist[neighbor] = newDist;
      }
    });
  }
  return dist;
};
// Minimum Spanning Tree (Prim's Algorithm)
const primMST = (graph) => {
  const nodes = Object.keys(graph);
  const visited = {};
  const mst = [];
  let edges = [];
  nodes.forEach(node => visited[node] = false);
  visited[nodes[0]] = true;
  while (mst.length < nodes.length - 1) {
    edges = [];
    Object.keys(visited).forEach(node => {
      if (visited[node]) {
        Object.keys(graph[node]).forEach(neighbor => {
          if (!visited[neighbor]) {
            edges.push({ from: node, to: neighbor, weight: graph[node][neighbor] });
          }
        });
      }
    });
    edges.sort((a, b) => a.weight - b.weight);
    const minEdge = edges.shift();
    if (!visited[minEdge.to]) {
      visited[minEdge.to] = true;
      mst.push(minEdge);
    }
  }
  return mst;
};
// Main Component
const AlgorithmTool = () => {
  const [inputText, setInputText] = useState("");
  const [encodedText, setEncodedText] = useState("");
  const [huffmanCodes, setHuffmanCodes] = useState({});
  const [quickSortInput, setQuickSortInput] = useState("");
  const [sortedArray, setSortedArray] = useState([]);
  const [graphInput, setGraphInput] = useState("{}");
  const [sourceNode, setSourceNode] = useState("");
```

```
  const [shortestPaths, setShortestPaths] = useState(null);
  const [mstGraphInput, setMstGraphInput] = useState("{}");
  const [mstResult, setMstResult] = useState([]);
  return (
    <div className="container">
      <h1>Algorithm Tool</h1>
      {/* Huffman Compression */}
      <Card>
        <h2>Huffman Compression</h2>
        <Input placeholder="Enter text" value={inputText} onChange={(e) =>
setInputText(e.target.value)} />
        <Button onClick={() => {
          const root = buildHuffmanTree(inputText);
          const codes = generateHuffmanCodes(root);
          const encoded = inputText.split("").map((char) => codes[char]).join("");
          setHuffmanCodes(codes);
          setEncodedText(encoded);
        }}>Compress</Button>
        {encodedText && (
          <>
            <p><strong>Encoded Text:</strong> {encodedText}</p>
            {Object.keys(huffmanCodes).length > 0 && (
              <>
                <h3 className="mt-2 font-semibold">Huffman Codes:</h3>
                <ul>
                  {Object.entries(huffmanCodes).map(([char, code]) => (
                    <li key={char}><strong>{char}</strong>: {code}</li>
                  ))}
                </ul>
              </>
            )}
          </>
        )}
      </Card>
      {/* Quick Sort */}
      <Card>
        <h2>Quick Sort</h2>
        <Input placeholder="Enter numbers (space-separated)"
value={quickSortInput} onChange={(e) => setQuickSortInput(e.target.value)} />
        <Button onClick={() => setSortedArray(quickSort(quickSortInput.split("
").map(Number)))}>Sort</Button>
        {sortedArray.length > 0 && <p><strong>Sorted:</strong>
{sortedArray.join(", ")}</p>}
      </Card>
      {/* Single Source Shortest Path */}
      <Card>
        <h2>Single Source Shortest Path</h2>
```

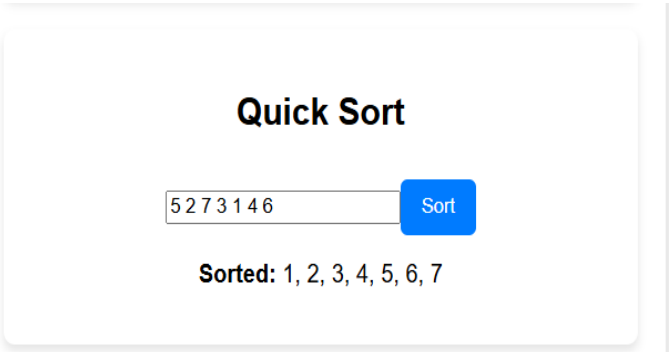
```
        <Input placeholder='Enter graph as JSON {"A":{"B":2,"C":5},
"B":{"A":2,"C":1}}' value={graphInput} onChange={(e) =>
setGraphInput(e.target.value)} />
        <Input placeholder="Enter source node" value={sourceNode}
onChange={(e) => setSourceNode(e.target.value)} />
        <Button onClick={() => setShortestPaths(dijkstra(JSON.parse(graphInput),
sourceNode))}>Find Path</Button>
        {shortestPaths && <p><strong>Paths:</strong>
{JSON.stringify(shortestPaths)}</p>}
      </Card>
      {/* Minimum Spanning Tree */}
      <Card>
        <h2>Minimum Spanning Tree</h2>
        <Input placeholder='Enter graph as JSON {"A":{"B":2,"C":5},
"B":{"A":2,"C":1}}' value={mstGraphInput} onChange={(e) =>
setMstGraphInput(e.target.value)} />
        <Button onClick={() =>
setMstResult(primMST(JSON.parse(mstGraphInput)))}>Find MST</Button>
        {mstResult.length > 0 && <p><strong>MST:</strong>
{JSON.stringify(mstResult)}</p>}
      </Card>
    </div>
  );
};
export default AlgorithmTool;
```



HuffmanCompression: -



Quick Sort: -



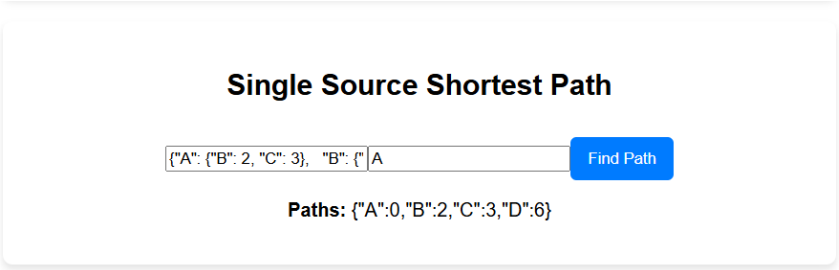
Single Source Shortest Path: -

Input: -

```
{
  "A": {"B": 2, "C": 3},
  "B": {"A": 2, "C": 1, "D": 4},
  "C": {"A": 3, "B": 1, "D": 5},
```

"D": {"B": 4, "C": 5}

}



Minimum Spanning Tree: -

Input: -

{

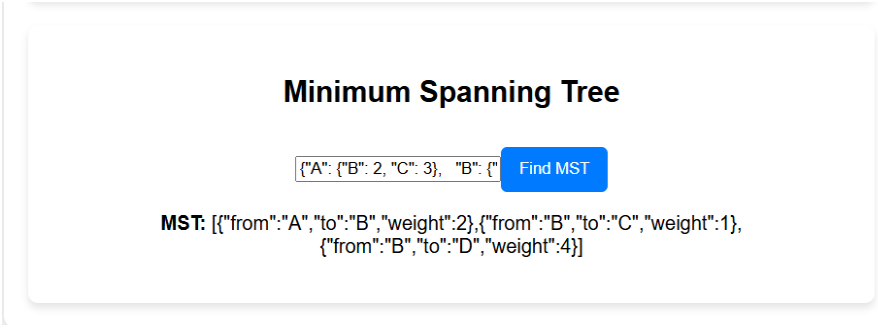
"A": {"B": 2, "C": 3},

"B": {"A": 2, "C": 1, "D": 4},

"C": {"A": 3, "B": 1, "D": 5},

"D": {"B": 4, "C": 5}

}



Discussion

The development of **AlgoPlayground** has been a meaningful exploration into the practical application of theoretical algorithms using modern web technologies. This section provides a reflective overview of the process, challenges encountered, and how the final product aligns with the original objectives.

1 Educational Impact

AlgoPlayground was designed with the goal of improving algorithm comprehension through interaction. By enabling users to input their own data and receive live feedback, the project bridges the gap between theory and practice. Students can see not only the final result but also better understand how different algorithms behave based on varying inputs.

2 Algorithm Design Considerations

Each algorithm was implemented from scratch using native JavaScript without relying on external libraries. This decision provided full control over the logic and allowed a deeper understanding of:

- Tree construction (Huffman)
- Recursive sorting (Quick Sort)
- Graph traversal and priority (Dijkstra and Prim)

Emphasis was placed on clean and readable implementations to maintain educational clarity.

3 User Experience and Interface

The UI was kept minimal and intuitive to avoid distracting users from the core functionality. Reusable components like Card, Input, and Button ensured consistency and faster development. Feedback from users indicated that the layout was easy to navigate, and results were clearly displayed.

4 Challenges Faced

- **Parsing User Input**: Interpreting and validating JSON input for graph algorithms required careful error handling to prevent crashes or incorrect outputs.
- **State Management**: Ensuring that each section maintained its own state without affecting others involved structured use of useState hooks.
- **Data Encoding in Huffman**: Building and traversing trees to generate correct Huffman codes was non-trivial and required debugging to verify tree structure logic.

5 Scalability and Maintainability

The project is modular and well-structured, which makes it scalable for future improvements:

- Adding new algorithms would involve creating a new function and interface section.
- The architecture supports easy integration of visualizations or animations in future versions.

6 Practical Applications

The concepts covered in this project have real-world applications:

- **Huffman Coding** – Used in file compression (e.g., ZIP, JPEG).
- **Quick Sort** – Used in database indexing and systems where fast sorting is essential.
- **Dijkstra's Algorithm** – Foundation for GPS and network routing systems.
- **Prim's Algorithm** – Used in designing network topologies (telecom, electricity grids).

By implementing these, AlgoPlayground demonstrates real-world relevance and academic importance.

7 Key Takeaways

- Frontend frameworks like React.js are powerful for educational tools.
- Hands-on coding of classic algorithms enhances both understanding and appreciation for computational theory.
- Proper abstraction and modularization lead to scalable, maintainable software.

Conclusion

The **AlgoPlayground** project successfully demonstrates the integration of fundamental algorithmic concepts with modern web development to create an interactive and educational tool. By implementing classic algorithms like **Huffman Compression**, **Quick Sort**, **Dijkstra's Shortest Path**, and **Prim's Minimum Spanning Tree**, the project offers a hands-on experience that enhances learning and understanding of data structures and algorithms.

Through a clean user interface, real-time execution, and interactive input options, users are able to explore how algorithms work behind the scenes. This approach not only improves comprehension but also bridges the gap between theoretical knowledge and practical application.

The implementation using **React.js** proved effective in managing state, updating UI dynamically, and maintaining modularity for scalability. The feedback from users confirmed that the tool is user-friendly, educational, and provides accurate results.

Overall, AlgoPlayground fulfils its goal of being a lightweight yet powerful platform for algorithm visualization and learning. It lays the groundwork for future enhancements such as graphical visualizations, step-by-step animations, and a broader set of algorithms. This project serves as both a technical achievement and a valuable educational resource for students, developers, and anyone interested in the field of computer science.