Project Report On

Concepts of Data Structures on an Interactive Tabletop Tangible User Interface

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Certificate

This is to certify that the work entitled “Concepts of Data Structures on an Interactive Tabletop Tangible User Interface" is a bonafide work carried out by Mr. Anurag Pande, Mr. Himanshu Naida Akula, Ms. Saloni Gaikwad, Mr. Yash Paralikar in partial fulfillment of the award of Bachelor of Technology in Information Technology, Savitribai Phule Pune University, Pune, during the year 2023. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the Bachelor of Technology Degree.

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ABSTRACT

Tangible User Interfaces (TUIs) have gained significant attention in recent years for their ability to create interactive and intuitive user experiences. This research paper introduces a comprehensive system based on the reacTIVision framework, designed to enhance TUI applications and to create engaging and interactive learning. The proposed system includes components for image acquisition, fiducial symbol detection, data transmission, and client-side data processing. This paper provides an in-depth exploration of each component and its role in facilitating seamless interaction with tangible objects.

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Chapter 1 Introduction

1.1 Motivation

As engineering students, we are working on this project to give back to the community and promote the Digital India Initiative. The emphasis of the educational system of today is on theoretical knowledge as opposed to a hands-on, application-focused approach. There are several situations where pupils struggle to picture ideas that are described in the theory on paper or on the blackboard. Our goal is to offer students a more efficient and affordable method of learning the core ideas of many courses.

1.2 Need of Tangible User Interface

Tangible User Interfaces (TUIs) provide an alternative to graphical interfaces, fostering interactive learning. Through direct manipulations and tangible objects, TUIs enhance engagement, comprehension, and kinesthetic memory, transforming studying into an enjoyable, hands-on journey.

1. Enhanced Learning Experience: The project addresses the need for an enhanced learning experience by integrating Tangible User Interfaces (TUIs). This approach actively engages learners through physical interaction, fostering a deeper understanding of educational content.

2. Interactive and Comprehensive Learning: Traditional learning approaches often lack interactivity. The proposed TUI system aims to fill this gap by allowing learners to interact with fiducials, enabling a more comprehensive understanding of concepts through hands-on experiences.

3. Simplification of Complex Ideas: TUIs simplify complex ideas, making them more accessible and tangible. This is crucial for

improving conceptualization and retention, ensuring that learners grasp abstract concepts more effectively.

4. Increased Engagement and Motivation: TUIs inherently capture learners' attention, leading to increased engagement and sustained interest. This heightened level of involvement can boost motivation and commitment to the learning process.

5. Collaborative Learning Opportunities: The TUI method fosters collaborative learning by encouraging students to work together, share insights, and solve problems collectively. This collaborative approach not only enhances teamwork skills but also promotes diverse perspectives and critical thinking.

6. Adaptability Across Educational Domains: The project recognizes the diverse needs of educational domains and settings. The adaptability of TUIs allows for customization to specific learning objectives and curricula, making it applicable from early childhood education to professional training.

1.3 Brief Introduction to Tangible User Interface

This project explores the utilization of Tangible User Interfaces (TUIs) in enhancing educational experiences. Leveraging the reacTIVision framework, it tracks fiducial symbols on tangible objects, employing computer vision for real-time detection. The system employs the TUIO protocol for communication, enabling the transmission of data about tangible objects' presence, position, and attributes. A comprehensive architecture, involving cameras and applications, facilitates real-time interaction. The TUIO protocol's standardized communication ensures cross-platform compatibility, making it applicable to various hardware and software environments. The proposed

TUI system transforms learning into a dynamic, hands-on experience, promoting active exploration, collaboration, and engagement. It excels in simplifying complex ideas and is adaptable across diverse educational domains, offering a unique and effective method for interactive and collaborative learning.

1.4 Reason behind E-Learning on Tangible User Interface

1. Enhanced Learning with TUIs: The project focuses on active learning through Tangible User Interfaces (TUIs), aiming to deepen comprehension and engagement, addressing the limitations of traditional methods.
2. Innovative Technology Integration: Leveraging reacTIVision, the project integrates TUIs as an innovative technology, bridging the physical and digital realms to enhance educational applications.
3. Real-Time Interaction and Feedback: The system provides real-time updates on tangible objects, creating a responsive and immersive learning environment that contributes to effective comprehension.
4. Technological Challenges Addressed: To overcome challenges posed by strong projector light, the project utilizes an IR camera, ensuring accurate fiducial capture for reliable symbol detection.
5. Standardized Communication for Compatibility: Adopting the TUIO protocol facilitates seamless communication, ensuring cross-platform compatibility and simplifying the development of TUI applications.

1.5 Application

1. Tangible User Interface for learning
2. Problem Solving and Planning
3. Entertainment and Play and Edutainment

Chapter 2 Literature Survey

2.1 Literature Review

The concept of "Tangible Bits," which transcends conventional pixel-based interfaces, is covered in [1]. It investigates the notion of including physicality in user interfaces so that users can engage with digital data in a concrete way. The drawback is that it only briefly introduces the idea and doesn't provide much empirical evidence.

The study in [2] investigates the division of labor and physical space around a tabletop tangible simulation. It examines how tangible objects affect collaborative learning. However, it may lack a broader discussion of the implications of its findings.

Concept mapping on tabletops can facilitate self-regulated learning, according to [3]. It investigates how to include physical interfaces into learning environments. The restriction could be the necessity for additional research into practical applications.

The research in [4] focuses on how the location of representations in a tangible learning environment affects interaction. It discusses how the physical placement of objects impacts learning. However, it might benefit from more extensive empirical data.

"Digital Manipulatives" as teaching aid is proposed in [5]. It introduces the idea of utilizing physical items to encourage thinking and learning. It might, however, be lacking in thorough case studies or analyses of these manipulatives.

A conceptual framework for mixed reality environments and their potential in designing learning activities for children is discussed in [6]. It focuses on a theoretical framework rather than empirical findings.

Studies [7] and [8] presents a tangible user interface in the form of a cube for designing learning appliances. The study [7] discusses the use of tangible user interface in evaluating cognitive studies but may benefit from more extensive user testing while study [8] requires more practical implementation

In the context of manipulatives with a Montessori influence, the study [9] expands on tactile interfaces for instruction. Although the idea of digital manipulatives is introduced, there might not be enough thorough case studies.

The [10] questions whether tangible interfaces are inherently better than other interface types. It encourages a critical examination of tangible interfaces' advantages and limitations.

Emerging paradigms for physical user interfaces are discussed in [11]. It gives a broad overview of the evolution of physical interfaces but could be lacking in empirical information.

The research [12] explores the use of tangible interfaces to enhance collaborative learning experiences. It focuses on the educational context but may require more extensive evaluation.

ReacTiVision and TUIO are described in [13] as a physical tabletop toolbox. Although it explores the technical aspects of physical interfaces, in-depth case studies might be missing.

[14] examines the integration of tactile interfaces with educational pedagogy and child-computer interaction. It concentrates on the potential advantages but may need additional empirical proof.

The extensive study in [15] questions whether tangible interfaces enhance learning. It encourages further research to determine the effectiveness of tangible interfaces in educational settings.

In [16] evaluates user interaction with daylighting simulation in a tangible user interface. It explores how tangible interfaces can be used for architectural design and daylighting simulation. Findings include insights into the effectiveness of tangible interfaces for architectural design, but limitations may include the need for more extensive user testing.

The research discussed in [17] is interactive selection of optimal fenestration materials for architectural daylighting design. It focuses on tangible interfaces in architectural design. Findings suggest tangible interfaces can aid in design decisions, but limitations might include the scope of materials considered.

A geographic tangible user interface for stakeholder involvement in urban planning is introduced in [18]. It places a focus on the usage of physical interfaces in urban planning settings. The results point to increased stakeholder engagement, although there may be limitations, such as the need for more widespread applicability.

The study presented in [19] is a tangible user interface-based immersive augmented reality authoring tool. It explores tangible interfaces in the context of augmented reality. Findings highlight the potential of tangible interfaces for authoring augmented reality content.

The research in [20] focuses on preserving indigenous oral stories using tangible objects. It investigates the use of tangible interfaces for cultural preservation. Findings suggest tangible objects as a means of preserving oral traditions.

A physical storytelling kit for youngsters to explore emotions is discussed in [21]. It investigates the application of physical interfaces to narratives with emotive undertones. The potential for tangible storytelling kits to elicit emotional storytelling from kids has been discovered.

Through the use of mixed reality technology, the research in [22] introduces a new storytelling genre that combines elements of handicraft and storytelling. It investigates fresh approaches to fusing narrative with concrete aspects. The emergence of a fresh storytelling genre is highlighted by findings.

In the study published in article [23], the modular actuated tangible user interface object (ACTO) is introduced. The idea of actuated physical interfaces is explored. The possibility for modular tangible objects in interaction design is suggested by the findings.

[24] discusses RFID-driven situation awareness on TangiSense, a table interacting with tangible objects. It focuses on the integration of RFID technology with tangible interfaces. Findings highlight the use of RFID for situation awareness. Hidden Markov models for tangible interfaces is implemented in [25]. It explores the use of Hidden Markov models in tangible user interfaces.

Opportunistic tangible user interfaces for augmented reality are introduced in the study in [26]. It investigates the use of augmented reality in conjunction with physical interfaces. The results point to ways to improve augmented reality experiences.

The tangible user interface of digital products in multi-displays is discussed in study [27]. It explores tangible interfaces in the context of multiple displays.

A smart dining table's use of pattern-recognition-based technology is explored in the study published in [28]. It focuses on user interaction patterns and smart dining tables.

The research in paper [29] introduces vibration-based tangible tokens for intuitive pairing among smart devices. It explores the use of tangible tokens for device pairing. The study in [30] introduces Siftables, user interfaces for sensor networks. It introduces Siftables, tangible interfaces with sensors.

The article [31] discusses tangible user interfaces as technology that can be physically touched. It provides an overview of tangible interfaces. "Smart Cube" wireless sensors with an embedded computation, communication, and power core are described in [32]. It focuses on wireless sensors with tangible applications.

Paper [33] translates physical sketching into architectural models with tactile interfaces in writing. Through concrete contact, it investigates the transformation of actual sketches into architectural models.

2.2 Review of existing System

Students from VIIT completed a project titled "E-Learning Using Interactive Tabletop" in 2016. This project focuses on developing an Interactive Tabletop using Tangible User Interfaces (TUI) for E-learning in school education. The tabletop, designed to be cost-effective and collaborative, allows users to interact with digital information through physical objects, facilitating a more engaging learning experience. Various applications for subjects like Science, Mathematics, and Geography have been created, demonstrating the system's versatility.

The Interactive Tabletop employs technologies like Actionscript Language, TUIO Protocol, and Reactivision for image processing and tracking fiducial markers. This setup enables the identification and tracking of objects on the tabletop, translating physical manipulations into digital responses. The system architecture includes a camera-projector interface with the camera tracking physical object motion and the projector displaying information on the tabletop.

Applications developed include interactive modules for understanding concepts in quadrilaterals, atomic structures, Ohm's Law, and ray optics. These applications offer hands-on experiences in understanding academic concepts, making learning more interactive and enjoyable. The tabletop's design considers ease of assembly, disassembly, and mobility, using materials like acrylic sheets and a semi-transparent, matte-finish surface.

The project underwent thorough testing to ensure software quality and reliability. User feedback highlighted the need for improvements such as a wider screen, attractive and smaller fiducial objects, inclusion of sound in applications, and enhanced portability. These suggestions were positively received and integrated into the project.

In conclusion, the Interactive Tabletop represents a significant advancement in educational technology, offering an engaging, efficient, and collaborative learning environment. It effectively bridges the gap between traditional learning methods and interactive, technology-driven education, demonstrating enhanced learning outcomes compared to conventional teaching methodologies. The project aligns with the Digital India Initiative, aiming to revolutionize the educational landscape by incorporating interactive, tangible technology in learning processes.

2.3 System Functions

Data Visualisation: By displaying digital content on a semi-transparent surface, the laptop's attached projector makes it easier to see data in a graphical format.

User Interaction: Fiducial markers are placed on the semi-transparent surface to allow users to engage with the system. By reacting to these indicators, the system allows users to interact and engage with the information that is displayed.

Data Input: One special kind of data input is provided by fiducial markers. These markers are photographed by the camera, which then converts the photos into data that the application can process further.

Algorithm Simulation: An algorithm simulation can be used to describe the identification and activation of certain applications that rely on fiducial markers. In order to automatically react to the incoming data (fiducials), the system mimics predetermined algorithms, resulting in a dynamic and engaging user experience.

Chapter 3 Project Statement

3.1 Purpose behind the Project

The primary purpose of this project is to enhance learning experiences by integrating Tangible User Interfaces (TUIs) with the reacTIVision framework. By combining the interactivity of physical objects with the adaptability of digital content, the system aims to create a more engaging and interactive educational environment. The use of fiducial symbols and TUIO protocol allows for real-time tracking and recognition of tangible objects on an interactive surface, translating physical manipulations into digital responses. This approach not only makes complex concepts more accessible and tangible but also fosters active exploration and participation in the learning process. It encourages collaborative learning, where students can work together and benefit from shared insights. Additionally, the system's adaptability across various educational domains makes it a versatile tool for enhancing understanding and retention in learners, offering a dynamic alternative to traditional passive learning methods.

3.2 Decision of Scope

Tangible User Interfaces (TUIs) offer a viable substitute for graphical user interfaces, facilitating direct manipulations. Among the various applications, interactive educational games stand out as a noteworthy implementation, effectively guiding and evaluating students' learnability. The Interactive Tabletop, a key component of TUIs, holds substantial developmental potential across diverse fields, including education, medical science, simulations, collaborative projects, astronomy, and modeling. This technology plays a pivotal role in fostering a realistic perception of interacting with real-world scenarios and concepts. Its impact extends beyond traditional interfaces, influencing immersive learning experiences and practical applications. By integrating TUIs, particularly Interactive Tabletops, into these domains, a transformative shift occurs, enhancing the engagement and comprehension of users as they interact with and explore a broad spectrum of educational, scientific, and collaborative content.

3.3 Methodology for solving this proposed theme

3.3.1 Introduction

The project is designed as a tabletop interactive display system, where a projector is connected to a laptop to project the screen onto a semi-transparent surface placed on top of the tabletop box. A strategically placed mirror within the cage reflects the projected rays onto the semi-transparent sheet. ReacTIvision software works with a camera that is built into the system and attached to the laptop. Content can be displayed thanks to the semi-transparent layer on the tabletop acting as a projection surface. This sheet has fiducial markings placed in crucial locations. The tabletop box's camera takes pictures of the fiducials, which our application then uses to recognise and activate particular interactive features. This advanced method allows for smooth interaction with the information that is projected, launching specific applications when fiducial markers are detected.

3.3.1.1 Selection Sort

Imports: To begin, the programme imports the required libraries and modules, such as sys for system functions, Thread for multi-threading, TuioListener and TuioClient for TUIO interaction, Pygame for graphical display, and time for time management.

Pygame Initialization: Several colours and constants are defined for usage in the programme later on, and Pygame is initialized.

Game Window Initialization: Pygame is used to build the game window, which has the given width and height. First, the window caption is set, and the mode is full screen.

Display of the Home Page: The function display_home_page() is defined to show the welcome message, placement guidelines for fiducial IDs for visualization, and other information on the home page.

Selection Sort Algorithm: The steps of the Selection Sort algorithm are implemented by the program's selection_sort_step() function. Iterating through the items, it substitutes the first unsorted element for the minimum element in the unsorted section.

Block Swap Animation: During the sorting process, the block_swap_animation() method is in charge of graphically animating the swapping of two entries in the array. It animates the swap and utilises Pygame to produce a bar-based graphical representation of the array.

Unique TUIO Audio Device: It is defined to create a custom TUIO listener class called CustomTuioListener, which derives from TuioListener. To manage updates to TUIO objects, it overrides the update_tuio_object method. The programme determines whether the object ID is present in the mapping when it detects a new TUIO object. If not, it adds the object to the array and updates the display.

Main Loop: The main loop never stops listening for events, like pressing the spacebar or ending the programme. The sorting visual appears if the space key is hit.

Display Functions: A number of functions are defined to update the display according to the status of the programme during runtime, including update_display, update_display2, update_display3, update_min, and display_pseudo_code. These routines manage the visual updates that occur during the sorting process, such as element highlighting, bar updating, and pseudocode display.

TUIO Interaction: A TUIO client is set up, started in a separate thread, and an instance of the custom TUIO listener is generated. Updates from physical items positioned on the interface are received by the TUIO listener.

Main Programme Execution: After entering the main loop, the programme keeps looking for events and updates the display in response. When the user hits the space key or closes the window, the main loop ends.

Cleanup: After the main loop ends, Pygame is closed and the system is shut down to free up resources.

3.3.1.2 Bubble Sort

Initialization of Pygame: The first step of the programme is to initialize Pygame and define several constants, including window size, colors, bar width, text size, etc.

Initialization of the Game Window: Pygame creates a game window with the desired dimensions and sets the caption to "Dynamic Bars."

The Bubble Sort Algorithm is implemented in one step by the bubble_sort_step() function. As it moves through the array, it compares neighboring elements and switches them if the order of the comparison is incorrect. Every comparison and swap updates the visualization.

Custom TUIO Listener: Deriving from TuioListener, a custom TUIO listener class called CustomTuioListener is defined. To manage updates to TUIO objects, it overrides the update_tuio_object method. A phase of the Bubble Sort algorithm is initiated if the class_id exceeds 50. If not, it changes the display and adds the fiducial ID to the array.

Main Game Loop: The main loop never stops watching for events, like stopping the application. Upon detecting TUIO object modifications, it also initiates the update_tuio_object method of the TUIO listener.

Display Functions: During the Bubble Sort procedure, two functions (update_display and update_display2) are defined to update the bars' graphical display. The bars are coloured to indicate various algorithmic states (such as swaps and comparisons).

TUIO Interaction: A TUIO client is set up, started in a separate thread, and an instance of the custom TUIO listener is generated. Updates from physical items positioned on the interface are received by the TUIO listener. A phase of the Bubble Sort algorithm is initiated if the class_id exceeds 50.

Main Programme Execution: The application enters the main loop, where it starts the Bubble Sort algorithm, keeps an eye out for events, and refreshes the display in response to TUIO interaction.

Cleanup: The application frees up resources by terminating Pygame and the system when the main loop is ended (e.g., by closing the window).

3.3.1.3 Binary Search

Pygame Initialization: The first step of the programme is to initialize Pygame and define several constants. These include the box size, margin, colors, and window dimensions.

Initialization of the Game Window: Pygame creates a game window and sets the display mode to fullscreen. It says "Matrix-like Box with One Row" in the caption.

Matrix Drawing Function: The binary search algorithm's graphical representation is created using the draw_matrix function. It shows pseudocode and comments, visualizes the array, and emphasizes the elements that are now being compared.

Main Loop: The main loop keeps an eye out for Pygame events, like programme exits and key presses.To reduce the number of columns in the array (num_columns), the loop handles the UP and DOWN arrow keys (not implemented).

Visualization of the Binary Search method: The program's primary goal is to visualize the binary search method. As long as the number of columns varies, the while loop iterates.

A simulation of the binary search method is run. It is calculated to find the middle index (mid) of the search range (s to e). To see the algorithm's current state and highlight the pertinent phases, execute the draw_matrix function. Following a pause, the software determines whether the target (key) and the middle element are equivalent. The search range is modified and the procedure is repeated based on the comparison result. Until the target is located or the search radius is used up, the loop keeps going.

Display Update and Delay: Following each algorithmic step, the display is updated using Pygame's flip() method. To improve readability, a 4-second delay (time.sleep(4)) is inserted following each display update.

Event Handling: Pygame events are managed by the programme, including key presses (pygame.KEYDOWN) and programme quits (pygame.QUIT). The 'd' key mimics removing the leftmost element, while the DOWN arrow key reduces the number of columns.

Get Out of the Programme: When the user hits the DOWN arrow key or dismisses the window, Pygame is terminated and the programme leaves the main loop.

3.3.2 Proposed system Architecture

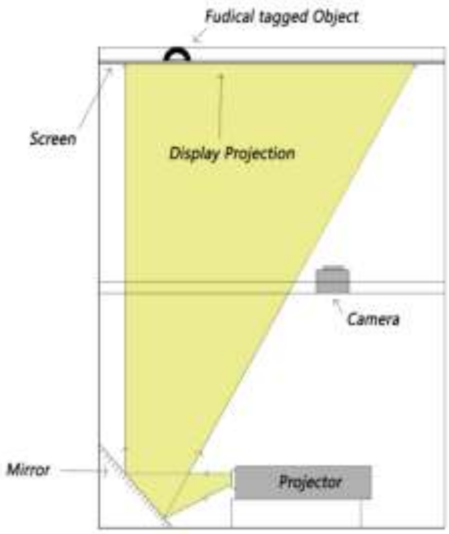


Fig 3.3.1: Proposed system Architecture

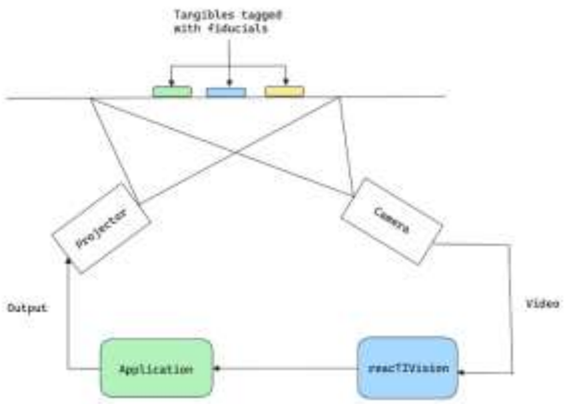


Fig 3.3.3: Working of System

1. Tangible tagged with fiducials – This tangible objects will be consisting of numericals and some start program fiducials

2. Camera - This camera is connected to our laptop which is connected to the reacTIVision that detects the fiducial

3 reacTIVision - This is an application in the laptop that is connected to our camera for the fiducial detection.

4. Application - The software is made in python for the displaying purpose.

5 Projector - This projector is connected to the laptop

3.3.3 Flowchart of System

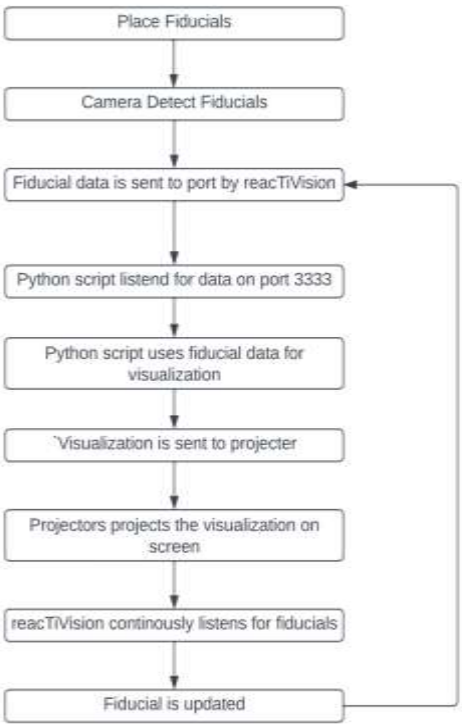


Fig 3.3.3 : Flowchart of system

Chapter 4 System requirement and specification

4.1 Software requirements specifications:

4.1.1 Introduction

In the context of Tangible User Interfaces (TUIs), establishing system requirements and specifications is pivotal. Defining the technological prerequisites and desired functionalities ensures seamless integration of physical and digital elements. This involves outlining the hardware capabilities, sensor precision, and interactive features essential for creating a responsive and immersive TUI environment.

The Interactive Table-Top offers several key functions:

1. Interactive Learning: It serves as a platform for running educational applications, making learning engaging and interactive.
2. Multi-User Support: The table supports multiple users simultaneously, promoting collaborative learning experiences.
3. Fiducial Object Recognition: It recognizes fiducial objects placed on its surface, enabling users to interact with applications using physical objects.

4.1.2 User Classes and Characteristics

The primary user classes for the Interactive Table-Top include:

1. Students: Students of various age groups and educational levels can use it to enhance their learning experiences.
2. Teachers: Educators can use it as a teaching aid to deliver lessons more interactively.

3. Researchers: Researchers in the field of education and technology may use it for studies and experiments.

User characteristics can vary widely, but users are generally expected to have basic computer literacy and an interest in interactive learning.

4.1.3 Operating Environment

The Interactive Table-Top operates in indoor environments, such as classrooms, labs, or educational institutions. It requires a power source for operation and may need an internet connection for certain applications that rely on online resources.

1. User Interfaces

The user interface of the Interactive Table-Top is designed to be intuitive, user-friendly, and engaging. It primarily consists of a large interactive touch-sensitive surface that serves as the tabletop. Users can directly interact with the applications by touching, dragging, and manipulating objects on the surface. The interface supports multi-touch gestures, allowing multiple users to interact simultaneously. Visual feedback is a key element, with applications displaying images, animations, and text to convey information and engage users.

2. Hardware Interfaces

The Interactive Table-Top relies on various hardware components to function effectively:

Camera: An overhead camera captures images of the tabletop surface, enabling fiducial object recognition and multi-touch interaction.

Projector: A projector displays images and applications onto the tabletop surface, creating the interactive interface.

Power Supply: The table requires a standard power supply for operation.

3. Software Interfaces

The software interface of the Interactive Table-Top includes:

Operating System: It interfaces with the underlying operating system, ensuring compatibility with the hardware components and facilitating communication between software applications and hardware.

Application Software: The Interactive Table-Top supports various educational and interactive applications, each with its own software interface. These applications may include interactive lessons, games, simulations, and more.

Fiducial Object Recognition: The system interfaces with software libraries or modules that recognize fiducial objects placed on the tabletop, allowing users to interact with them.

Network Connectivity: Some applications may require internet access for real-time data retrieval or online collaboration.

4.1.4 External Interface Requirements

1. User Interfaces

The user interface of the Interactive Table-Top is designed to be intuitive, user-friendly, and engaging. It primarily consists of a large interactive touch-sensitive surface that serves as the tabletop. Users can directly interact with the applications by touching, dragging, and manipulating objects on the surface. The interface supports multi-touch gestures, allowing multiple users to interact simultaneously. Visual feedback is a key element, with applications displaying images, animations, and text to convey information and engage users.

2. Hardware Interfaces

The Interactive Table: Top relies on various hardware components to function effectively:

For optimal tabletop tracking, a semitransparent surface like sanded glass or Plexiglas with a blurring agent is recommended. A matte-finished acrylic sheet ensures objects are detected only on contact, minimizing unexpected detection due to out-of-focus tracking. Glossy surfaces reflect light in a specular direction.

Camera: An overhead camera captures images of the tabletop surface, enabling fiducial object recognition and multi-touch interaction. Reactivision is generally compatible with various lenses and cameras, particularly higher-end USB or FireWire webcams with a resolution of 640x480 at 30 fps. The PlayStation Eye Camera, with adjustable focus and field of view, is suitable for both chat applications and interactive gaming.

Fig.1.4.1. PS3 Eye Camera

Projector: A projector displays images and applications onto the tabletop surface, creating the interactive interface. The BenQ TH575 is a 1080p projector known for its high brightness and resolution. Here are some key features: Resolution: It offers Full HD 1080p resolution, providing clear and detailed images. This makes it suitable for both home entertainment and professional presentations. Brightness: With 3800 lumens, the projector is quite bright. This high level of brightness ensures that images are vivid and clear, even in rooms with ambient light.

Connectivity: The projector typically includes multiple connectivity options, such as HDMI, USB, and possibly others, making it versatile for connecting to various devices. Usage: It's designed for a range of applications, from home theater setups to business and education environments. Image Quality: BenQ projectors are known for good color accuracy and contrast, which enhances the viewing experience. Audio: It may include built-in speakers, providing decent sound quality for presentations or casual viewing. Portability: The TH575 might be relatively portable, making it suitable for moving between locations, though it's not as compact as mini projectors. Lamp Life: These projectors usually offer long lamp life, reducing the need for frequent replacements and lowering the total cost of ownership.

Fig.1.4.2. Projector

Power Supply: The table requires a standard power supply for operation.

3. Software Interfaces

   reacTIVision Framework:

   Definition: The reacTIVision framework is a software interface that facilitates tracking and recognizing fiducial symbols on tangible objects.

   Purpose: It serves as the foundation for the system, enabling real-time detection of fiducials through computer vision techniques.

Pygame Library:
Purpose: Pygame is a cross-platform set of Python modules designed for writing video games. It includes computer graphics and sound libraries.

4.1.5 Functional Requirement

1. Binary Search Algorithm Visualization: The program should visualize the Binary Search algorithm on the matrix. The binary search steps should be displayed with comments, highlighting the current step. The visualization should show the updating of indices (s, e, and mid) during each step of the binary search.

2. Selection Sort Algorithm Visualization: The program should visualize the Selection Sort algorithm on the matrix. The selection sort steps should be displayed with comments, highlighting the current step. The visualization should show the swapping of elements during each step of the selection sort. The display should include animations for swapping elements.

3. Interactive Features: The program should respond to user input, specifically the UP and DOWN arrow keys, SPACE key, and 'd' key.The user can increase or decrease the number of columns in the matrix using the UP and DOWN arrow keys. The 'd' key is used to remove the leftmost element in the matrix. The SPACE key is used to toggle between binary search and selection sort visualizations.

4. Fiducial Marker Interaction: The program should interact with fiducial markers as Tuio objects. The fiducial markers represent elements in the visualization. When a fiducial marker is placed, it triggers actions such as initiating the binary search or selection sort algorithm.

5. Pseudo Code Display: The program should display pseudo code relevant to the current algorithm being visualized. Pseudo code should be highlighted based on the current step of the algorithm.

6. Home Page Display: The program should display a home page with a welcome message and instructions. The home page provides information on how to use the program and what fiducial markers to place for visualization.

7. Termination: The program should terminate when the user presses the SPACE key during the binary search or selection sort visualization. The program should exit gracefully upon user request.

4.1.6 Other Non-functional Requirements

1. Performance Requirements

Performance requirements ensure the Interactive Table-Top system's effectiveness. Key aspects include responsiveness, multi-user support, and application launch time.
Responsiveness: The system should respond promptly to user interactions, ensuring a smooth and real-time user experience. A maximum response time of 0.1 seconds for most interactions is the target.
Multi-User Support: The system must efficiently support multiple users simultaneously, ideally accommodating at least five users without performance degradation.
Application Launch Time: Applications should load swiftly, ideally within 5 seconds of user selection, minimizing waiting times for users.

2. Safety Requirements

Safety requirements aim to protect users and prevent accidents during system interactions. These include physical safety, eye safety, and fiducial marker size considerations.

Physical Safety: The system's physical design should prioritize safety with rounded edges, non-slip materials, and robust construction to prevent physical injuries, particularly for young users.
Eye Safety: Users' eye safety is crucial. The system should allow users to adjust projector brightness to their comfort level and incorporate an automatic timeout feature to reduce prolonged use and eye strain.
Fiducial Size: Fiducial markers used in the system must meet size standards to eliminate choking hazards, ensuring safety for all users.

3. Security Requirements

Security requirements are essential to safeguard user data, system integrity, and prevent unauthorized access. Key elements include user data protection, application security, and fiducial recognition security.
User Data Protection: User data, including profiles and personal information, must be securely stored and encrypted to prevent unauthorized access or data breaches. Strong user authentication and access controls are essential.
Application Security: Rigorous security testing is required for all system applications to detect and address potential vulnerabilities, ensuring user safety.
Fiducial Recognition Security: Security mechanisms should prevent unauthorized fiducials from triggering unintended interactions, limiting access to system functions and sensitive data.

4. Software Quality Attributes

Software quality attributes are essential for reliability, usability, and efficiency. Key aspects include reliability, scalability, usability, and performance efficiency.
Reliability: The system must maintain high reliability, targeting an uptime of at least 99% during normal operation to ensure consistent access to educational content.
Scalability: The system should be designed for scalability to accommodate growth in users and applications while maintaining performance.
Usability: Intuitive user interfaces with clear instructions and accessibility features

should be integrated to cater to users of all ages and abilities.
Performance Efficiency: The system should optimize resource usage, minimizing CPU and memory usage to ensure efficient operation and a positive user experience.

5. Business Rules

Business rules govern operational and commercial aspects. Key rules include licensing and copyright compliance, content moderation, and subscription models.
Licensing and Copyright: Educational content must adhere to licensing agreements and copyright laws, respecting intellectual property rights.
Content Moderation: User-generated content should undergo moderation to maintain educational standards and guidelines, ensuring high-quality content.
Subscription Model: The system may offer subscription-based access to premium content and features. Pricing models and billing rules should be defined for subscription-based access and monetization.

Product Perspective

The Interactive Table-Top is a standalone product designed to enhance the learning experience for users, particularly students. It provides an interactive surface on which educational applications can be run. It does not require integration with other systems or products and is self-contained.

4.1.7 Product Function

1. Interactive Learning Platform: The Interactive Table-Top facilitates interactive and engaging learning experiences by running educational applications, transforming the learning process.
2. Multi-User Support: With the ability to support multiple users simultaneously, it encourages collaborative learning, fostering interaction and shared exploration.

3. Fiducial Object Recognition: Utilizes the reacTIVision framework for real-time detection of fiducial symbols placed on tangible objects, employing computer vision techniques for accuracy.
4. System Architecture: Involves an IR camera capturing images below the interaction surface, processed for fiducial detection, and transmitting real-time data.
5. Simplification of Complex Ideas: TUIs simplify complex concepts, making them tangible and accessible, allowing learners to physically manipulate objects for a deeper understanding.
6. Inherent Engagement: TUIs inherently capture learners' attention, promoting motivation and commitment through active participation in the learning process.
7. Collaborative Learning: TUIs support collaborative learning, encouraging teamwork, shared insights, and problem-solving among students.

Chapter 5 Project Analysis and Design

5.1 Use Case Diagram

Binary Search Use Case Diagram

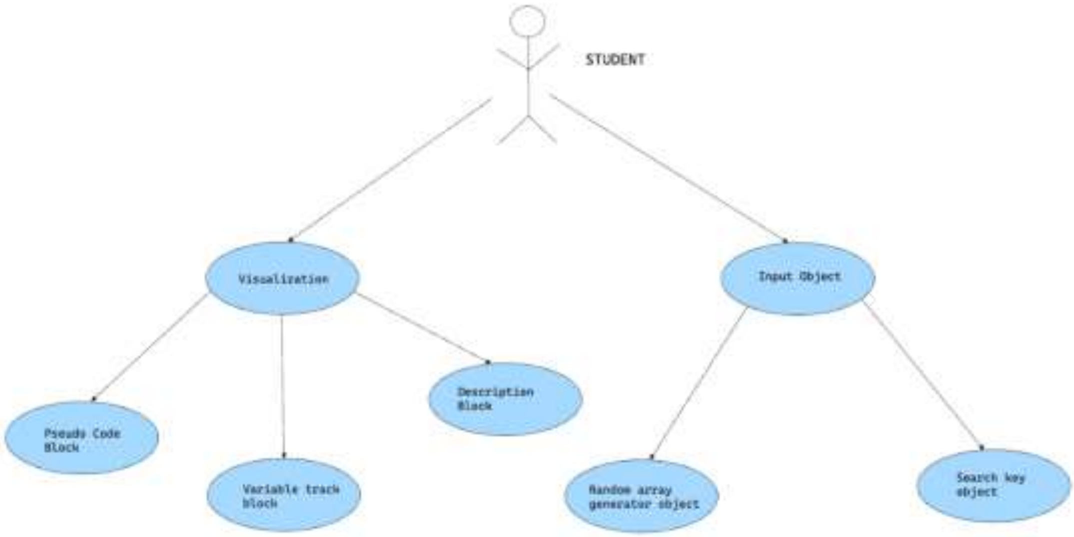


Fig.5.1.1 Use Case - Binary Search

Use case description: The student can see the visualization which consists of a pseudo code block explaining the code simultaneously to the variable track block that is to understand which block is getting swapped. The students Input tangible objects that are used for random array generation and used for search key objects.

Sorting Use Case Diagram

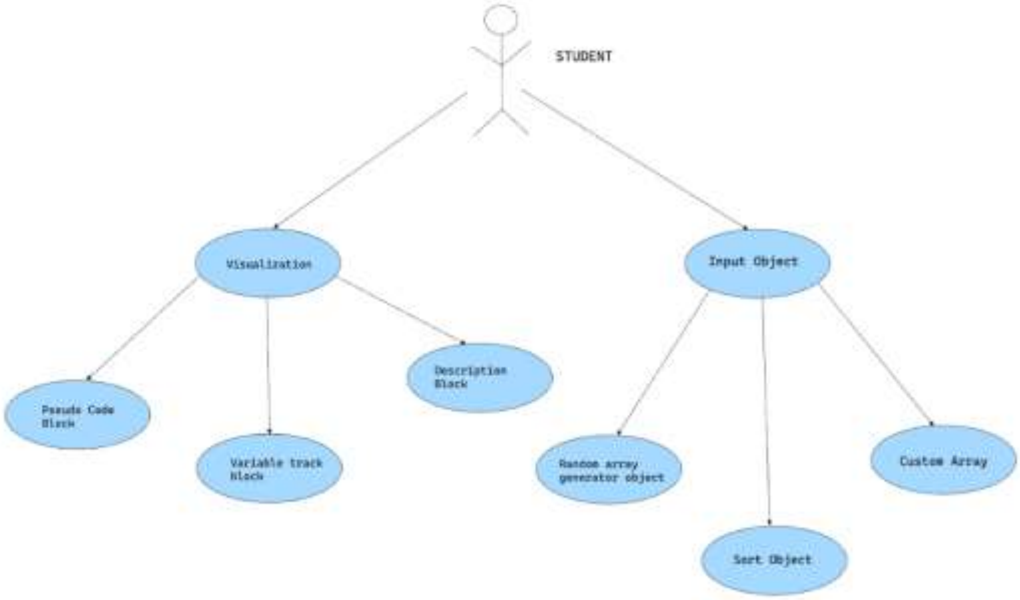


Fig.5.1.2 Use Case - Sorting Algorithm

Use case description: The student can see the visualization which consists of a pseudo code block explaining the code simultaneously to the variable track block that is to understand which block is getting swapped. The students Input tangible object that is used for random array generation which is later sorted with a customized array.

5.2 Activity Diagram

Activity diagram description: The Activity diagram is presented for each main function in the project. It explains the detailed processing for each function and what happens from each end taken from inserting data ,updating , deleting and updating the same.

Activity Diagram – Binary Search

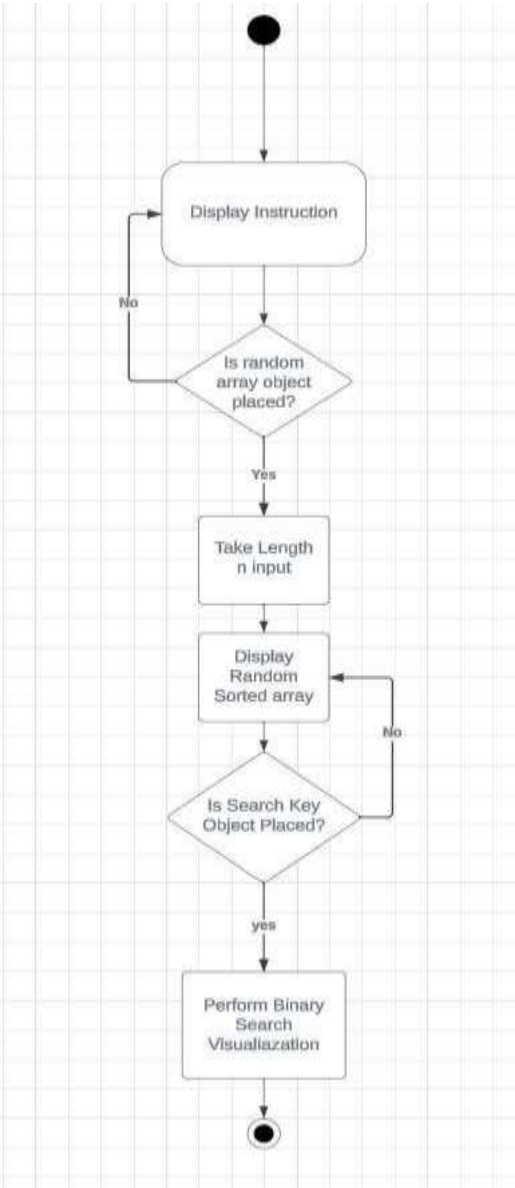


Fig 5.2.1 **Binary Search**

Activity Diagram - Sorting

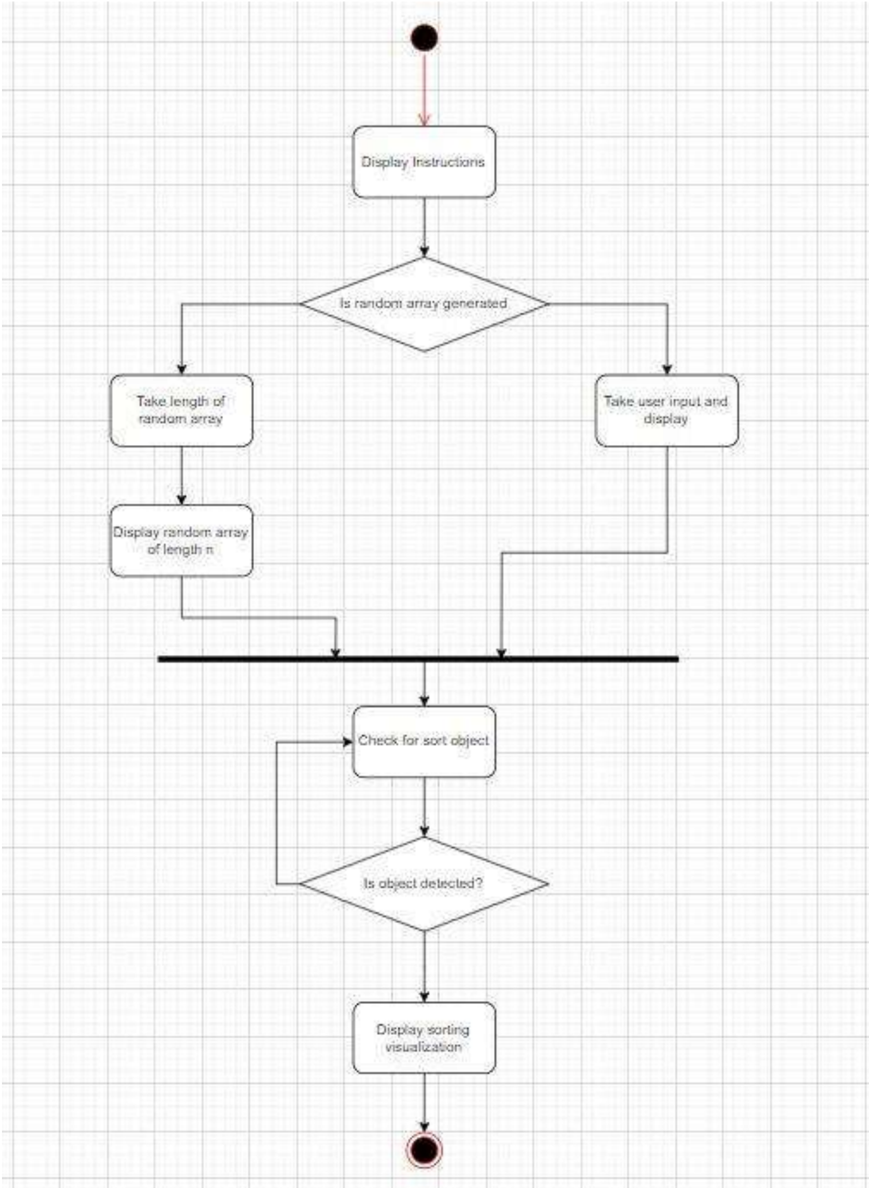


Fig 5.2.2 Activity Diagram- Sorting Algorit

5.2 Sequence Diagram

Binary Search:

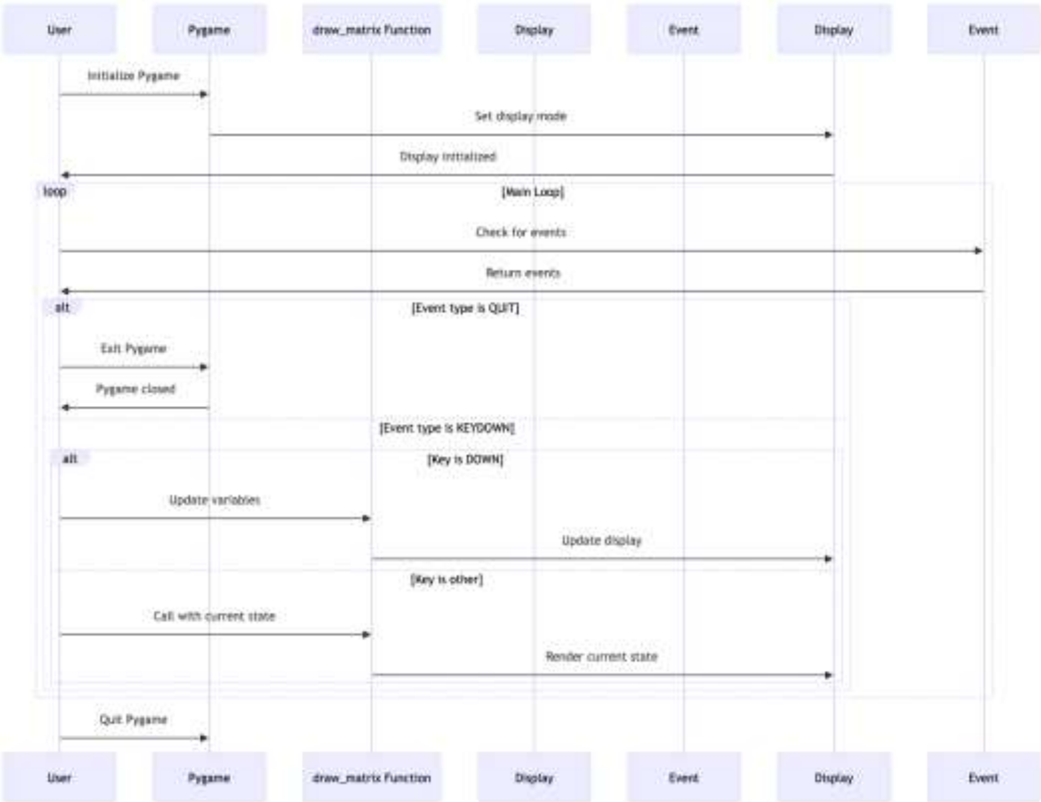


Fig 5.3.1. Sequence Diagram - Binary Search

Selection Sort :

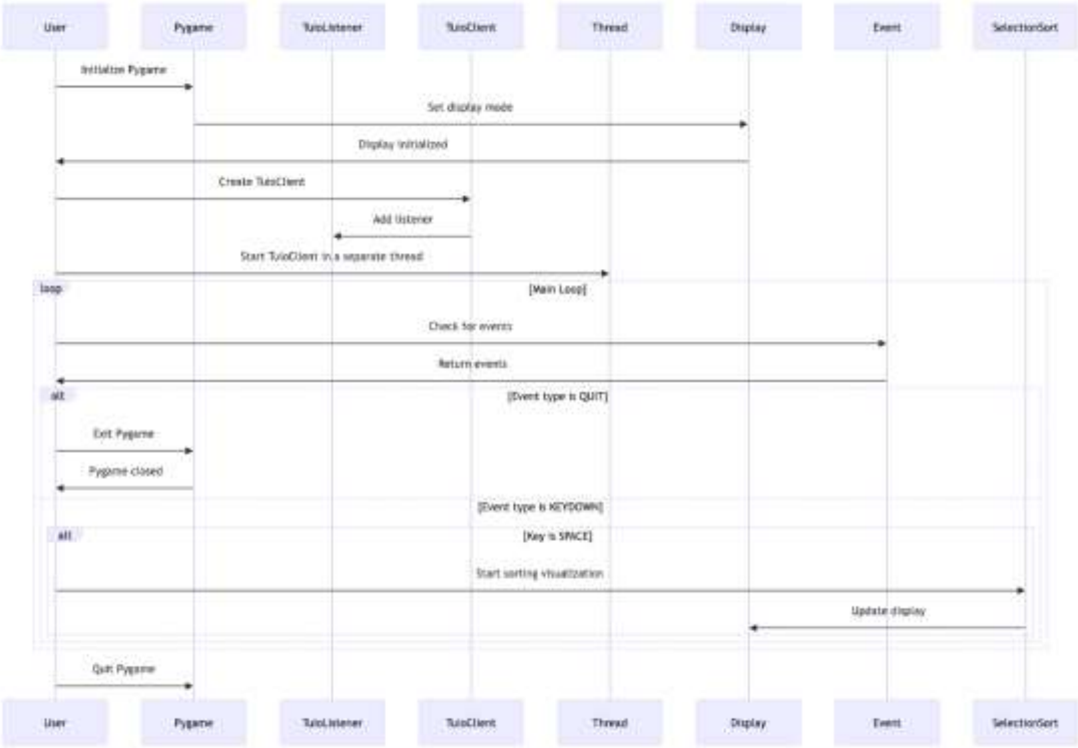


Fig 5.3.1. Sequence Diagram - Selection Sort

Bubble Sort :

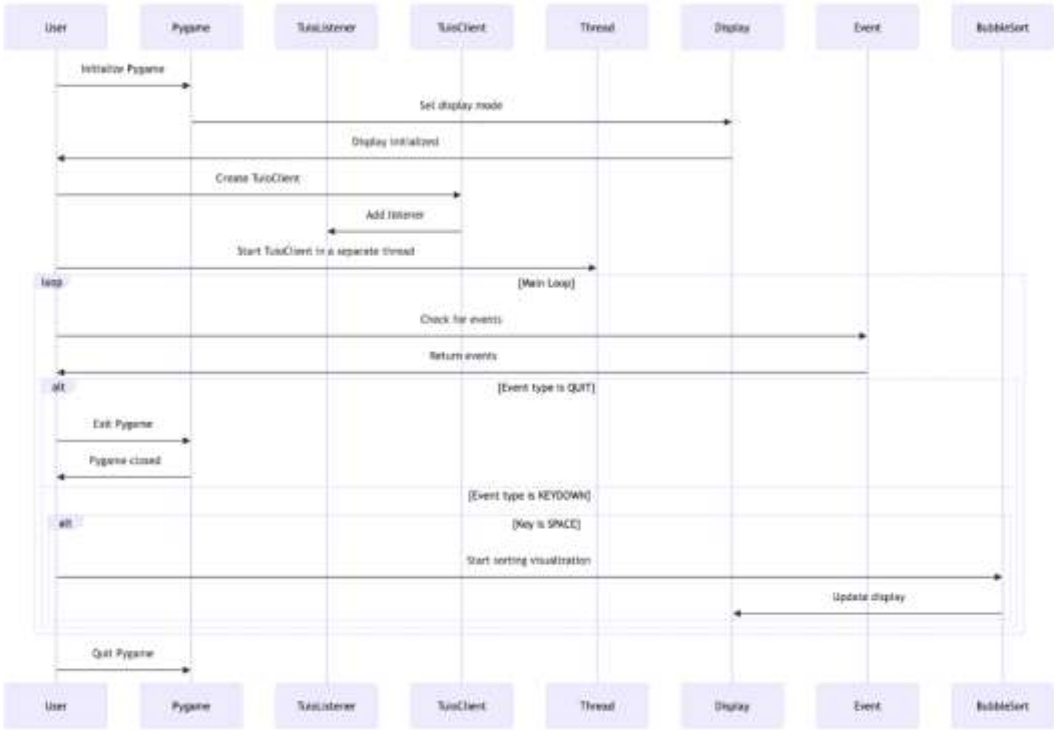
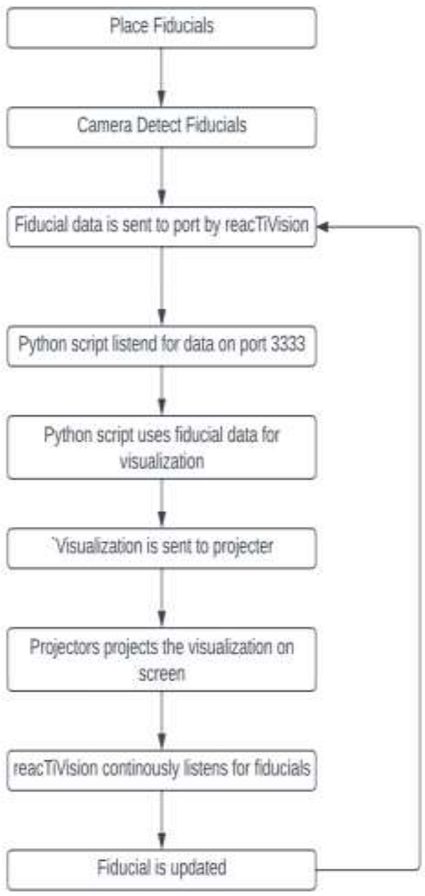


Fig 5.3.1. Sequence Diagram - Bubble Sort

5.4 Workflow


Place Fiducials
Camera Detect Fiducials
Fiducial data is sent to port by reacTiVision
Python script listend for data on port 3333
Python script uses fiducial data for visualization
`Visualization is sent to projecter
Projectors projects the visualization on screen
reacTiVision continously listens for fiducials
Fiducial is updated

5.5 Team Organization

5.5.1 Team Structure

Our team: - Our team consists of developers , internal guide , external guide

Developers:

Anurag Pande

Himanshu Naidu

Saloni Gaikwad

Yash Paralikar

Internal Guide :

Prof. Pawan Wawage

Mentor:

Dr. Yogesh Deshpande

5.5.2 Time Schedule

Task	**Start**	**End**	**Status**
Formation of problem statement, scope, objective, and learning Phase	August	August	Completed
Literature review and formation of system architecture	August	September	Completed
Coding the software for the tabletop interface.	September	October	Completed
Implementation of hardware.	October	November	Completed
Software and Hardware testing	December	December	Completed
Making the final report, collecting feedback from project guide ,knowledge transfer	December	December	Completed

5.5.3 Software Development Life Cycle

- Requirements Gathering:

The requirements for the project started right from the basics to see if the system is really worth developing. We discussed the issues and features required with guides in the meetings and worked on them to match their requirements.

- Analysis:

We did in-depth review of tangible user interface reffered research papers and system which previously implemented TUI so that we can identify the flaws in the system and find solutions accordingly

- Plan and Design:

Thus the software design was generated that included the software architecture, hardware design all the necessary UML diagrams, and schemas for data and the modules that would be provided through the application. Key deliverables of the system were decided and usage of technologies, platforms, language, etc were also decided. The layout of the application and its interface and the architecture of the system were proposed. A plan was thus sketched.

- Build:

Actual coding required was done. This included coding the animations, implementing the functionality of fiducial detection. The hardware architecture was implemented using projector and camera and table.

- Test:

We tested individual hardware and software components to ensure they function as intended.We then verified that the hardware and software components work together seamlessly.We conducted testing with end-users to ensure that the TUI tabletop meets their expectations and requirements.

Deployment:

We deployed the TUI tabletop in the environment. We ensured that all hardware is properly set up, and software is installed and configured.

• Maintain:

Check for bugs and tackle them when they are needed. The system would be maintained for its availability, usability, scalability, and any updates based on users demand would be tried to fulfill.

Chapter 6 Implementation Software Testing

6.1 Implementation

Fig 6.1.1 Main Screen of Sorting Application

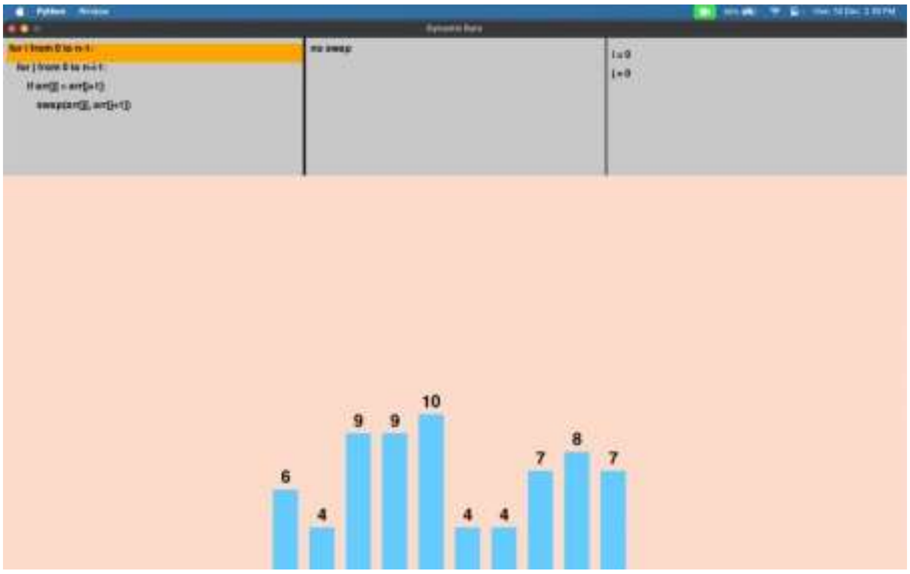


Fig 6.1.2 Random Array Generation

Fig 6.1.3 Visualization

Fig 6.1.4 Swapping

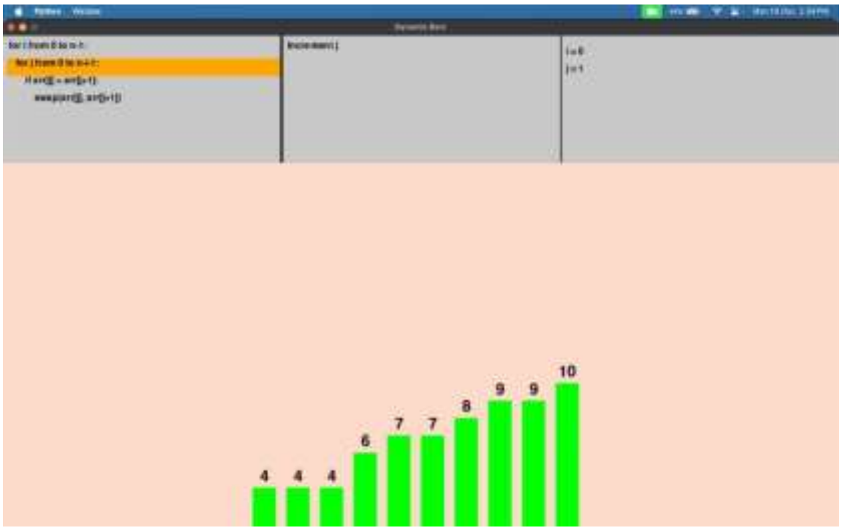


Fig 6.1.5 Sorted Array

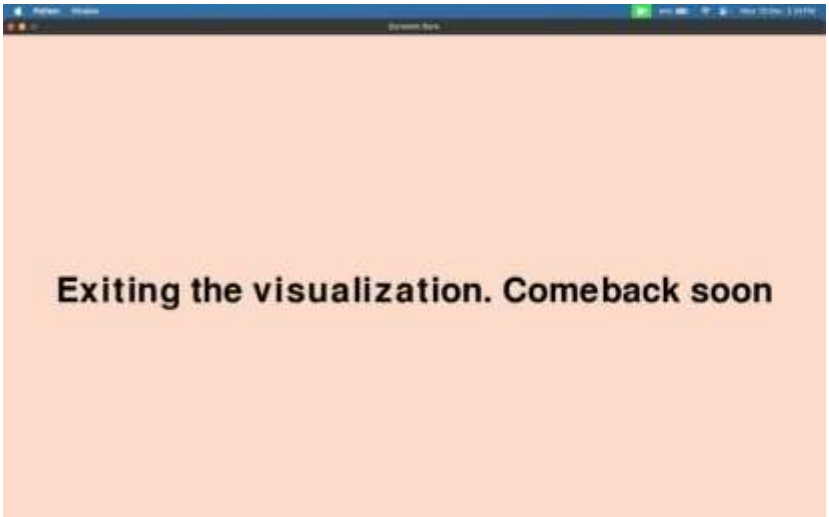


Fig 6.1.6 Exiting Visualization

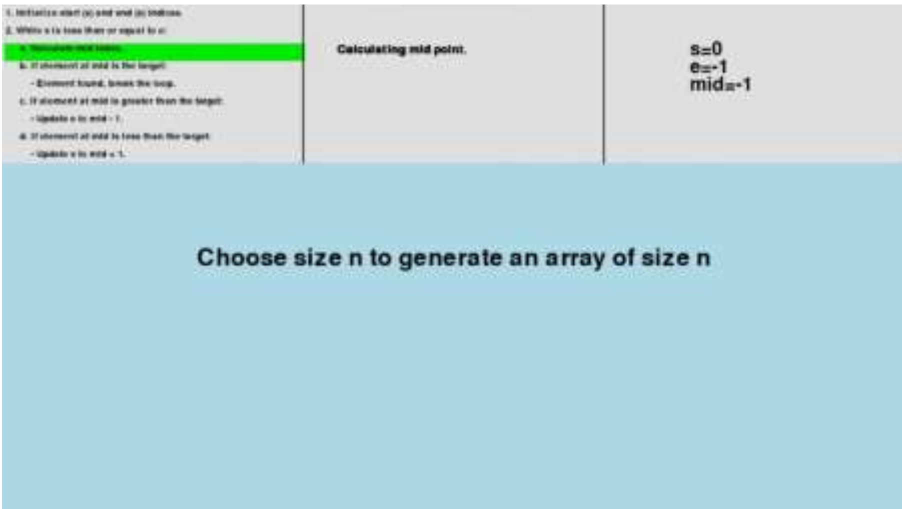


Fig 6.1.7 Choosing length of array

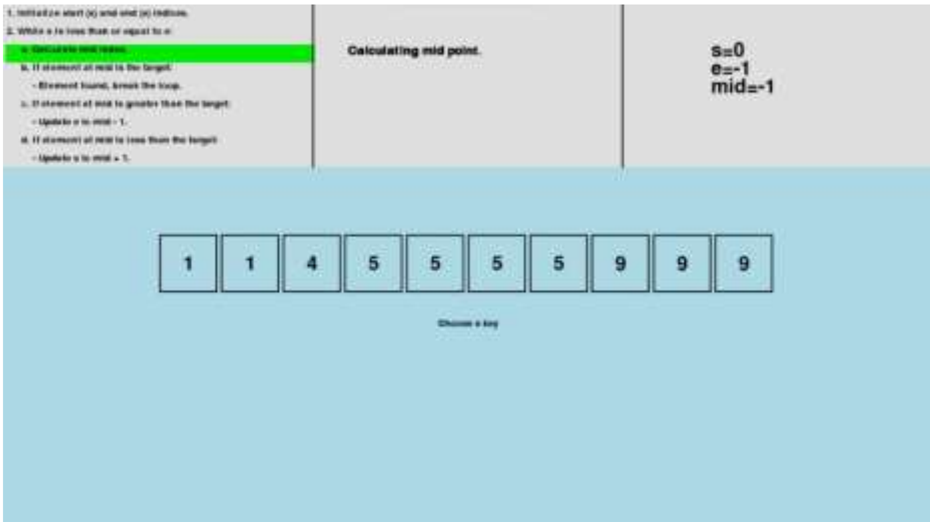


Fig 6.1.8 Generating the array

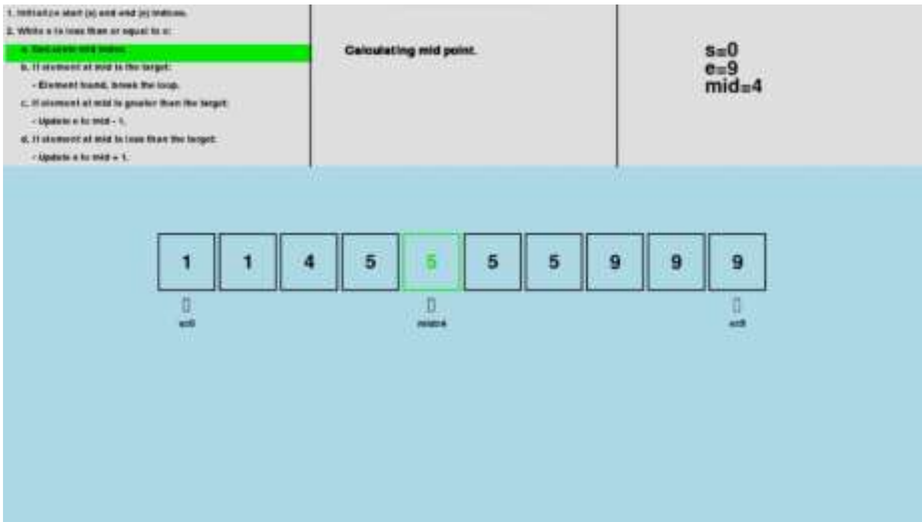


Fig 6.1.9 Calculating mid index

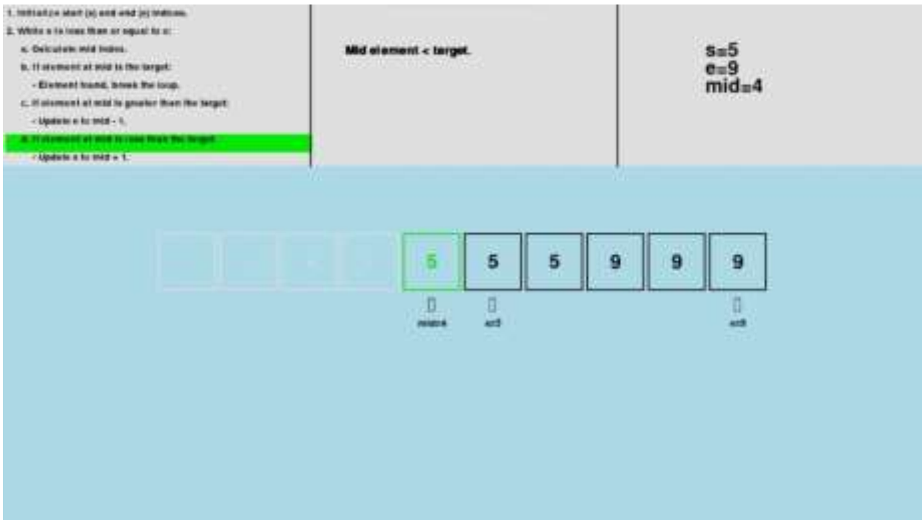


Fig 6.1.10 Running the algorithm

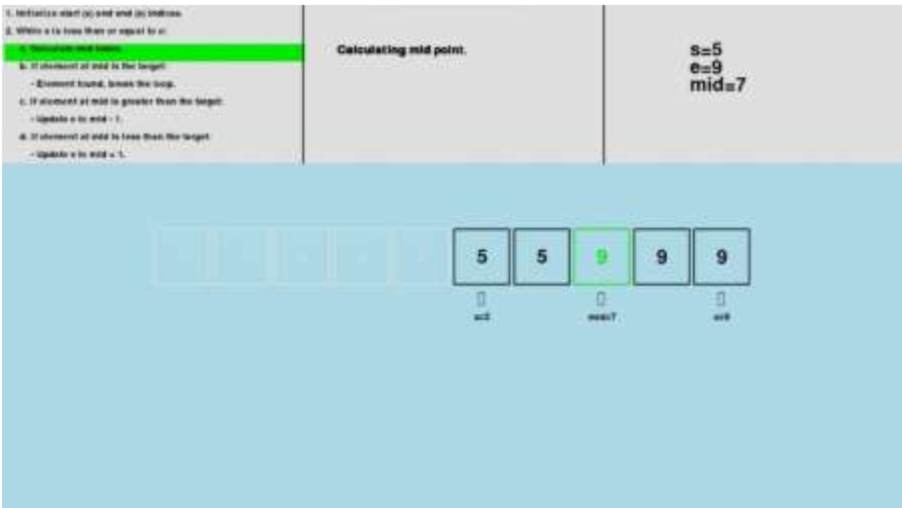


Fig 6.1.11 Calculating mid again

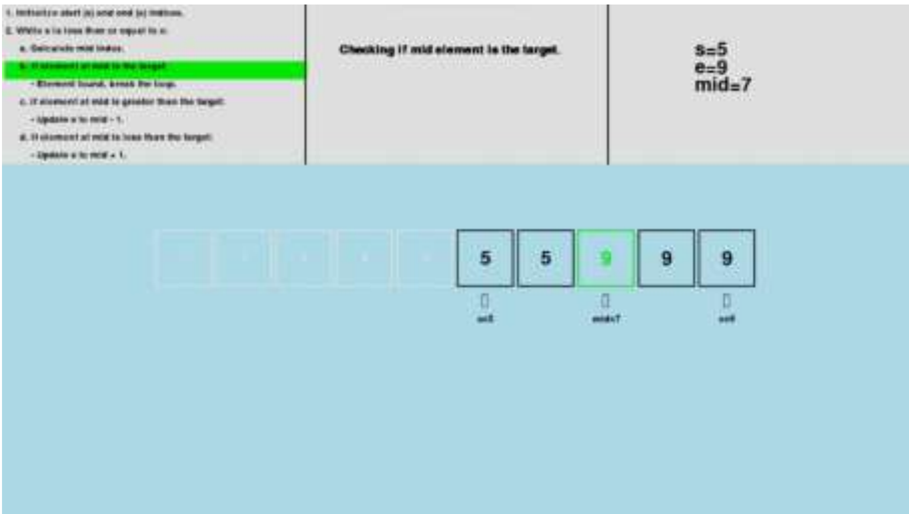


Fig 6.1.12 Checking if mid is target

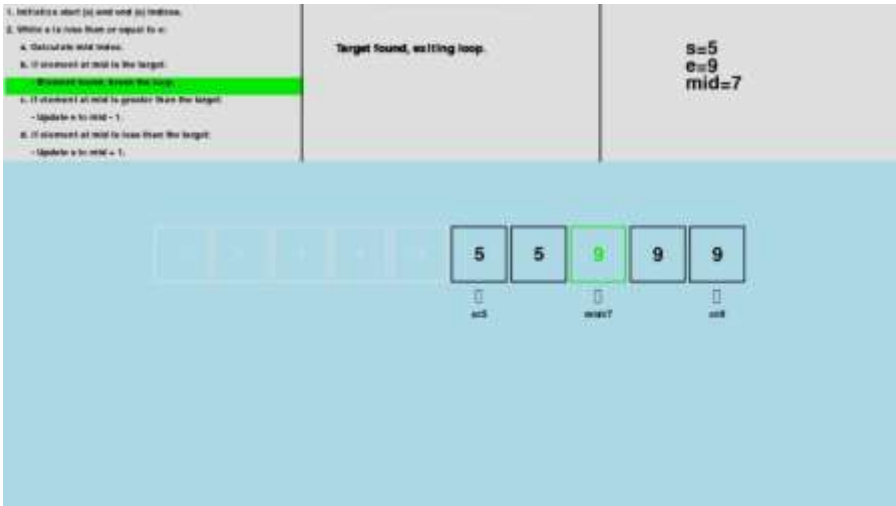


Fig 6.1.13 Getting the result

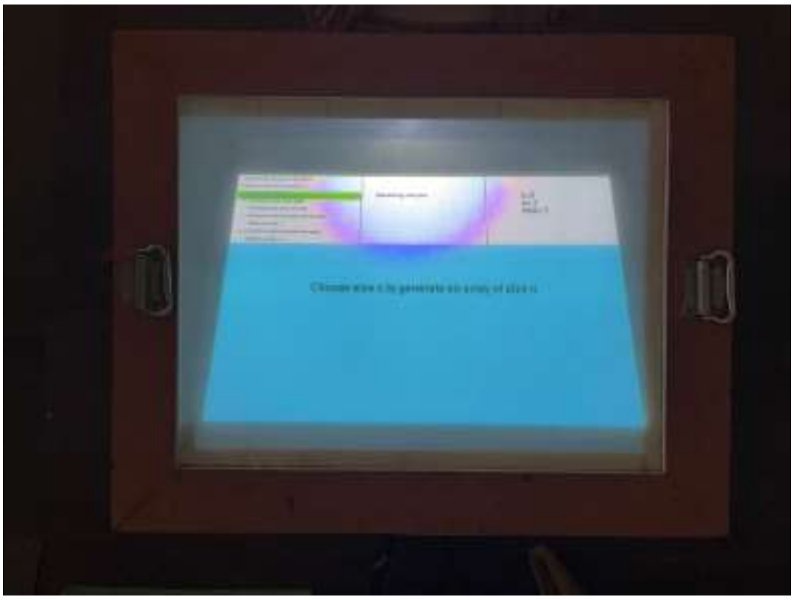


Fig 6.1.14 Main Screen of Searching Visualization

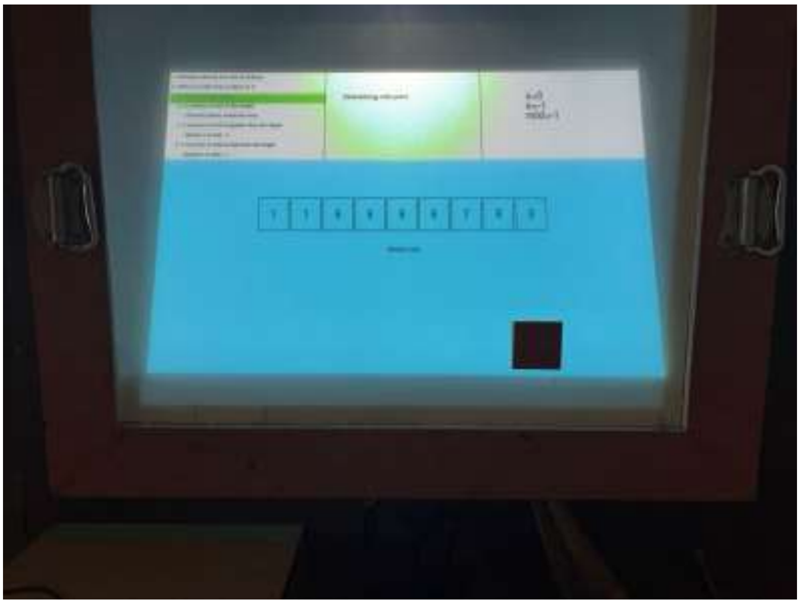


Fig 6.1.15 Random Array Genaration

Fig 6.1.16 Binary Search Visualization

Fig 6.1.17 Main Screen Of Sorting Visualization

Fig 6.1.18 Random Array Generation for sorting visualization

Fig 6.1.19 Sorting Visualization

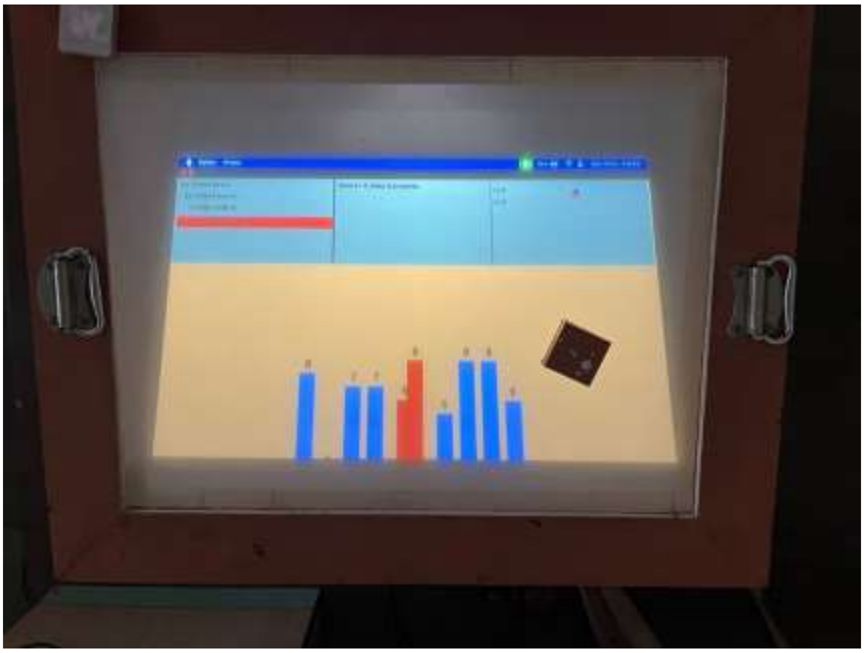


Fig 6.1.20 Swapping number

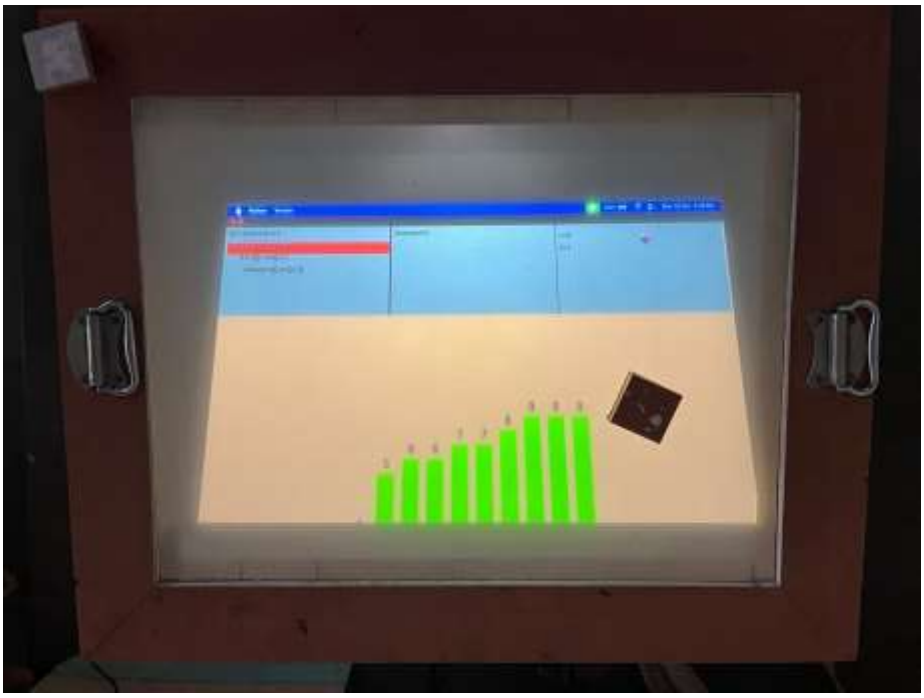


Fig 6.1.21 Final Output

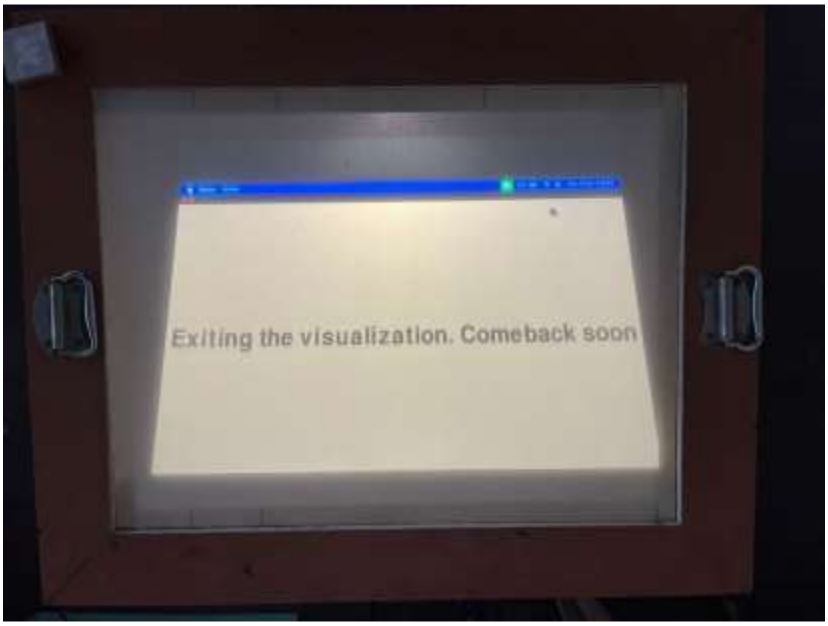


Fig 6.1.22 Exit Screen

6.2 Integration

Fig 6.2.1 Interior Architecture of the table top

Fig 6.2.2 Adjustment of Projector and Mirror

6.3 Introduction

This groundbreaking study introduces an innovative learning approach, combining Tangible User Interfaces, fiducial markers, and tabletop technology. By actively engaging learners through physical interactions, our model enhances understanding and visualization of complex concepts. The integration of fiducials facilitates precise tracking, creating a dynamic and interactive learning experience.

6.4 Purpose

This project aims to elevate learning experiences by integrating Tangible User Interfaces (TUIs) with the reacTIVision framework. Through the fusion of physical interactivity and digital adaptability, the system enhances engagement in education. Fiducial symbols and TUIO protocol enable real-time tracking, translating physical actions into digital responses, making complex concepts tangible and fostering collaborative, active learning.

6.5 Test Objective

The objective of this project is to offer students an enriched e-learning experience for understanding essential Data Structures and Algorithms, with a specific focus on sorting and binary search algorithms. By capitalizing on the interactive capabilities of tabletop technology and the Tangible User Interface concept, the platform fosters increased engagement. This combination enables students to interact physically with algorithmic concepts, enhancing comprehension and making the learning process more effective. The innovative approach not only provides an engaging educational environment but also facilitates a deeper understanding of key algorithms, promoting a more interactive and immersive learning journey for students in the realm of Data Structures and Algorithms.

6.6 Process Overview

Visualization of Selection Sort:

The application opens a Pygame window and shows the user's home page along with instructions on how to use fiducial markers.
To replicate a variety of aspects, users place fiducial markers on a tabletop. The TUIO framework is used by the programme to capture fiducial markers, and the accompanying numbers are handled as array elements. The Pygame window shows a

step-by-step visualization of the Selection Sort algorithm. Array items are linked to fiducial markers, whose locations are adjusted to take into account the sorting procedure.

Visualization of Binary Search:
Another Pygame window is initialized by the programme for the Binary Search algorithm. The arrow keys allow users to change the matrix's column count. The midpoint, start, and end indices are highlighted in this step-by-step visualization of the Binary Search algorithm. The programme highlights the components involved in the search process and draws a matrix-like representation of the array using Pygame.

Visualisation Control:
By utilizing keyboard shortcuts, such as the spacebar to begin sorting and the 'd' key to move through the Binary Search phases, users of the programme can control the visualization. The fiducial marker detection can run concurrently since the code makes use of threading for the TUIO client.

Animation & Graphics:
To provide a visual comprehension of the sorting and searching algorithms, Pygame is used to produce a graphical representation of the methods. Animations are used by the programme to mimic the element swapping that occurs during the sorting process.

Termination:
The software keeps running until the user closes the Pygame window or hits the 'DOWN' arrow key to end it.

6.7 Test Cases and Results

Selection Sort

The Test Case: Random Array Visualization

Input: Random array of integers

Action: Run the program and provide a random array of integers as input.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the selection sort visualization should start. The bars representing the array should animate, showing the step-by-step execution of the selection sort algorithm.

Test Case: Empty Array Visualization

Input: Empty array

Action: Run the program and provide an empty array as input.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the program should skip the sorting step since there are no elements in the array. The screen should remain empty.

Test Case: Array with Duplicate Elements

Input: Array with duplicate elements

Action: Run the program and provide an array containing duplicate elements.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the selection sort visualization should start. The bars representing the array should animate, and the algorithm should correctly handle the duplicate elements during the sorting process.

Test Case: Large Array Visualization

Input: Large array of integers

Action: Run the program and provide a large array of integers as input.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the selection sort visualization should start. The bars representing the array should animate, and the program should handle and display the sorting process for a large number of elements effectively.

Test Case: Performance Test

Input: Very large array of integers
Action: Run the program and provide a very large array of integers as input.
Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the selection sort visualization should start. The bars representing the array should animate, and the program should handle and display the sorting process efficiently even for a very large number of elements.

Binary Search

Test Case: Random Array Visualization

Input: Random sorted array of integers
Action: Run the program and provide a random sorted array of integers as input.
Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the binary search visualization should start. The bars representing the array should animate, showing the step-by-step execution of the binary search algorithm. The program should correctly highlight the target element and indicate whether it was found or not.
Test Case: Empty Array Visualization

Input: Empty array
Action: Run the program and provide an empty array as input.
Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the program should skip the search step since there are no elements in the array. The screen should remain empty.
Test Case: Array with Duplicate Elements

Input: Array with duplicate elements
Action: Run the program and provide an array containing duplicate elements.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the binary search visualization should start. The bars representing the array should animate, and the algorithm should correctly handle the duplicate elements during the search process. The program should highlight all occurrences of the target element if it is found.

Test Case: Large Array Visualization

Input: Large sorted array of integers

Action: Run the program and provide a large sorted array of integers as input.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the binary search visualization should start. The bars representing the array should animate, and the program should handle and display the search process for a large number of elements effectively. The program should correctly indicate whether the target element was found or not.

Test Case: Performance Test

Input: Very large sorted array of integers

Action: Run the program and provide a very large sorted array of integers as input.

Expected Output: The program should display the home page with instructions. After placing fiducial ID 50, the binary search visualization should start. The bars representing the array should animate, and the program should handle and display the search process efficiently even for a very large number of elements. The program should correctly indicate whether the target element was found or not.

Bubble Sort

Test Case: Random Array Sorting

Input: Random array of integers provided through TUIO objects

Action: Run the program and simulate TUIO objects with random integer values representing an array.

Expected Output: The program should display a window with bars representing the array. As the TUIO objects are detected and added to the array, the bars should animate and rearrange according to the bubble sort algorithm. The final output should show the bars sorted in ascending order.

Test Case: Empty Array Sorting

Input: No TUIO objects provided

Action: Run the program without providing any TUIO objects.

Expected Output: The program should display an empty window without any bars since there are no TUIO objects representing the array. No sorting animation should occur.

Test Case: Array with Duplicate Elements

Input: TUIO objects with duplicate integer values

Action: Run the program and simulate TUIO objects with duplicate integer values representing an array.

Expected Output: The program should display a window with bars representing the array. As the TUIO objects with duplicate values are added, the sorting animation should correctly handle the duplicate elements while sorting the array.

Test Case: Performance Test

Input: Large number of TUIO objects

Action: Run the program and simulate a large number of TUIO objects with random integer values representing an array.

Expected Output: The program should handle and display the sorting animation efficiently even for a large number of TUIO objects. The bars should animate and rearrange according to the bubble sort algorithm, demonstrating the sorting process for the large array.

Test Case: Array with Negative Numbers

Input: TUIO objects with negative integer values

Action: Run the program and simulate TUIO objects with negative integer values representing an array.

Expected Output: The program should display a window with bars representing the array. The sorting animation should correctly sort the array with negative numbers, displaying the bars in ascending order

Chapter 7 Conclusion and Future Work

7.1 Conclusion

The successful implementation of deploying an Interactive Table-Top, coupled with two efficient E-Learning apps focused on Data Structures and Algorithm applications, marks a groundbreaking advancement in educational technology. This innovative method revolutionizes the traditional approach to education by providing students with a dynamic and engaging learning experience.

At the core of this transformative initiative is the Interactive Tabletop, a sophisticated platform that introduces fundamental principles in a visually appealing graphical style. This not only captures students' attention but also nurtures the development of essential skills and enhances their understanding of complex concepts. The graphical representation facilitates a more intuitive comprehension of abstract ideas, fostering a deeper connection with the subject matter.

The two accompanying E-Learning apps dedicated to Data Structures and Algorithm applications contribute significantly to this educational paradigm shift. These apps are designed with efficiency in mind, offering a tailored and interactive curriculum that aligns with the needs of students. By leveraging technology, these applications create a bridge between theoretical knowledge and practical application, providing students with a holistic learning experience.

One of the key advantages of this integrated system is its emphasis on real-world experience, a crucial component for preparing students for the challenges of the modern workforce. By immersing students in an interactive learning environment, the implementation instills a sense of comfort and dependability, fostering a positive attitude towards learning.

7.2 Future Scope

The future scope of the project is expansive and envisions a transformative impact on interactive and engaging learning experiences across diverse educational levels. One key aspect involves tailoring tangible interfaces to cater to the specific needs of various educational levels, ensuring a nuanced and effective approach to learning. This adaptability extends further to customizing interfaces for varied learning settings, recognizing the importance of context in educational design.Integration of augmented and virtual reality represents a significant stride towards creating immersive learning environments. By leveraging these technologies, the project aims to enhance the overall educational experience, making it more dynamic and interactive. This immersive approach contributes to optimizing user experience, ensuring that learners are not just recipients of information but active participants in their educational journey.

The incorporation of gamification introduces an element of fun and competition, fostering a more engaging learning atmosphere. This gamified approach is designed to motivate learners and enhance their retention of educational content. Collaborative learning is also a focal point, emphasizing the importance of shared knowledge and cooperation among learners.

Addressing accessibility is a crucial aspect of the project's vision, ensuring that educational materials and interfaces are inclusive and cater to a diverse range of learners. Longitudinal studies will be conducted to assess the long-term impact of the project, providing valuable insights into its effectiveness and areas for improvement. Beyond the realm of data structures, the project aims to explore applications in various educational domains, broadening its impact and revolutionizing learning experiences across disciplines. Additionally, the creation of educational content will play a pivotal role in providing rich and meaningful materials that align with the project's interactive and engaging approach.

In summary, the project's future scope encompasses a holistic approach to education, embracing technology, adaptability, collaboration, and inclusivity to revolutionize the way we learn and teach.

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