School of Engineering and Informatics

UNIVERSITY OF SUSSEX

947G5: Advanced Software Engineering

Title	Technical Documentation by Group 6
Candidate Numbers	276187, 276267, 276280, 276293, 276375, 277822, 284318, 284946
Module Leader	Prof. Hsi-Ming Ho
Course Title	MSc Advanced Computer Science
Date Submitted	12/15/2023

Abstract

This report presents the study, design and analysis of a software project targeted at creating a web-based game application that consists of N-Queens problem, Polysphere Problem in 2 Dimension and Polysphere Problem in 3 Dimension. This project is developed as a part of the course module Advanced Software Engineering as a tool to learn software development in large scale IT industries and to understand distinct methodologies involved for the development. The project has been created by the collaborative and determined efforts of the team members of Group-6

Acknowledgement

The team members of Group – 6 express sincere gratitude to our teacher and module convenor Prof. Hsi-Ming Ho for his constant support and invaluable insights throughout the course of this project. His expertise and guidance have been crucial in achieving success through the journey of the project development. Furthermore, a heartfelt thank you to all the members of Project Group 6. The dedicated hard work, sheer determination, and collective effort of all the team members have played an important role in achieving the goals of developing this project. The commitment to excellence and working together has made this journey fulfilling and has provided a rewarding experience to all. Thank you all for your valuable contributions.

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1 INTRODUCTION

1.1 Overview

This comprehensive report unfolds an in-depth study and analysis, delving into a purposeful software initiative aimed at the development of web-based game application. The primary objective of this application is to engage users in the interactive exploration and resolution of puzzles, specifically focusing on the N-Queens puzzle, the Polysphere Puzzle in a 2-dimensional grid, and the Polysphere Puzzle in a 3-dimensional pyramid. The central emphasis of this web application development project is to empower users to independently engage with and solve these intricate puzzles.

This web application is developed to offer users the capability to actively participate in the puzzle-solving process. It is designed to let users navigate through the N-Queens puzzle, strategically placing queens on a chessboard, and tackling the Polysphere Puzzles in both 2D and 3D environments by placing different shapes on the grids. Furthermore, the application is equipped to present solutions to these puzzles upon user request, to help users understand, compare and revaluate their solutions.

The primary recipients of this report encompass the esteemed professor, referred to as the client, and the dedicated members constituting Project Group 6. The journey of the development of this project serves as an educational tool for an immersive and hands-on learning experience in software development procedures. To replicate the authentic experience of an enduring software development project, the development approach involved the adoption of the agile methodology. This strategic choice allowed all parties to proactively respond to the evolving needs and preferences of the client by delivering requested features and valuable feedback in a timely manner.

1.2 Project Tasks

The project consisted of the systematic implementation of the three widely recognized puzzles - N-Queens Problem, the Polysphere Puzzle in a 2D grid, and the Polysphere Puzzle in a 3D pyramid - undertaken in distinct stages. The following sections provide a detailed briefing on each of the puzzles incorporated into the project.

1.2.1 N-Queens Problem

The N-Queens problem requires the strategic placement of N number of Queen chess pieces on an N×N chessboard so that no two Queens attack each other. This means that the user must place the Queen pieces in such a way that no two Queens can be placed facing each other in a straight line or diagonally. This classic puzzle is implemented in the project for Chessboard sizes 4×4 to 10×10 for 4 Queens and 10 Queens respectively.

1.2.2 Polysphere Problem - 2 Dimension

In the 2D Polysphere Problem, the user will be presented with a white grid board and a selection of puzzle pieces, each uniquely fashioned with a specific arrangement of spheres and distinct colours. The challenge lies in the user's ability to strategically place each puzzle piece on the board, ensuring that every shape effectively covers all the white spaces while also preventing any overlap between two puzzle pieces.

1.2.3 Polysphere Problem - 3 Dimension

Like the 2D Polysphere Problem, the user 3D Polysphere Problem in will be presented with a selection of puzzle pieces, each uniquely fashioned with a specific arrangement of spheres and distinct colours. However, unlike the 2D Polysphere Problem, here the user will be given a 3 dimensional pyramid board. Here the challenge is that the user must strategically position each puzzle piece on the pyramid without distorting its shape, effectively covering all the white spaces without overlap between two puzzle pieces.

2 DEVELOPMENT

2.1 Development Methodology

To replicate the authentic experience of a rigorous software development project, the development approach involved the adoption of the Agile methodology. This strategic choice allowed all parties to proactively respond to the evolving needs and preferences of the client by delivering requested features and valuable feedback in a timely manner. GitHub will be the platform for all aspects of development tracking in collaboration with the client. GitHub provides an efficient environment that can be used to maintain communication, version control, and project management throughout the development process. By using GitHub, it is possible to maintain transparency and collaboration, and also the client has the access to be actively involved in monitoring and providing feedback on the project's progress.

2.2 Software Tools

The project utilized following set of tools to support various aspects of development:

- **PyCharm IDE**: This integrated development environment (IDE) served as the primary platform for coding and overall development.
- **Python:** The project was implemented using the Python programming language, which was employed for coding and algorithmic development.
- **HTML, CSS, and JavaScript:** These web technologies were utilized for frontend development and the creation of the puzzle board animation.
- **Three.js and Orbit Controls:** These libraries played a crucial role in implementing the 3D pyramid animation within the project.
- **MySQL:** The MySQL database management system was chosen to store and manage puzzle solutions efficiently.
- **Ubuntu Minimal Linux OS:** The project was hosted on the Ubuntu Minimal Linux operating system, providing a robust and secure environment for the application.

The project used the following Python libraries:

- **Django:** Chosen as the framework of choice, Django provided a robust foundation for building and structuring the application.
- **pip:** This package installer was used in managing and installing the required Python packages.
- **mysql-connector and mysqlclient:** These libraries provided the connection to the database server for efficient interaction with MySQL.

- **OCI and OCI-cli:** Utilized for accessing the bucket storage in the Oracle Cloud, these libraries played a pivotal role in integrating cloud-based resources into the project.
- **Pillow:** Employed for image processing related to the polysphere puzzle, Pillow enhanced the project's capabilities in handling graphical elements with efficiency and versatility.

2.3 Implementation

The project's implementation unfolded through a series of structured tasks, each contributing to the overall development and refinement of the application. Here's an elaboration on each task:

2.3.1 Task 1: Create GitHub account and repository

In this phase, the project plan was devised to create a primary structure of the project.

2.3.2 Task 2: Develop N-Queens Puzzle Solver

Within this phase, we employed the Backtracking algorithm to tackle the NQueens Puzzle. To manage computation time complexity and resourceintensive operations, we set a constraint of 10 queens. Recognizing the potential for further enhancement, a roadmap was established for future optimization, proposing an extension of the N-Queens puzzle to 15 queens using the DLX algorithm. This forward-looking initiative was identified as a feature request, paving the way for continued improvements.

2.3.3 Task 3: Develop Polysphere Puzzle Solver

The task focused on addressing the Polysphere puzzle with a strategic shift towards Donald Knuth's Algorithm X, opting for its expedited solution generation—80,445 in total. This approach, which excluded rotation and reflection images for heightened computation efficiency, significantly outpaced the traditional backtracking method. Notably, our DLX approach yielded all solutions within a mere 39 minutes, a stark contrast to the 7 hours required by the backtracking method on medium-graded microprocessors. Furthermore, a comprehensive plan was devised to print and store solutions in object storage in the cloud. This initiative aimed to accelerate user access to solutions during gameplay and content creation, minimizing unnecessary computations and enhancing user experience.

2.3.4 Task 4: Develop Polysphere Pyramid Puzzle Solver

Building on the success of the DLX algorithm, Task 4 refined the process further. By incorporating optimizations into the cover and uncover functions of the algorithm's logic, we achieved a notable improvement. The DLX algorithm, applied to this task, yielded a total of 26,720 solutions within an impressive 34-minute timeframe—demonstrating a considerable acceleration compared to previous implementations.

2.3.5 Task 5: Additional Features and Free Exploration

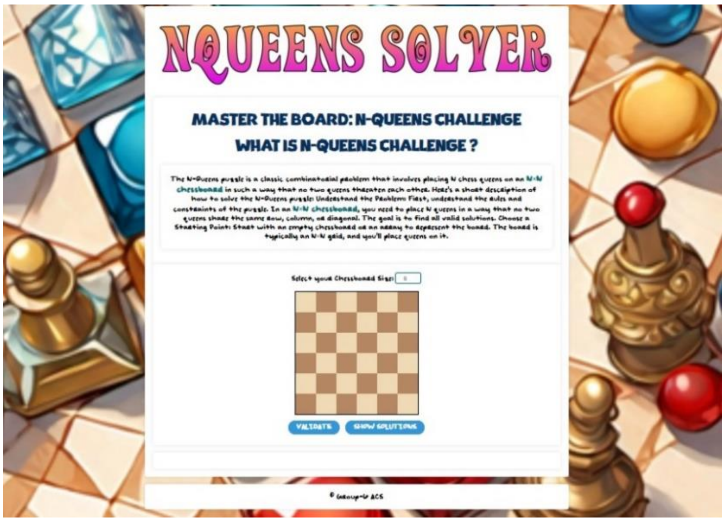
In the final phase, the project underwent consolidation and refinement. Adopting a portal-hub design approach, we integrated all project components seamlessly. User authentication pages were implemented, and game levels were introduced to accommodate players of various ages. The inclusion of team descriptions, along with direct links to the project's source code and technical documentation, not only added transparency but positioned the project as an inspirational resource for those seeking reference and insight. This holistic approach not only ensured a userfriendly and engaging experience but also solidified the project's accessibility and relevance.

3 TESTING

Following sections lists the test cases and results for each game to evaluate the software functionality is as expected and meets the specified functional requirements. The goal of this phase is to ensure the functionality and reliability of the implemented code and algorithm fulfilling its intended purpose.

3.1 N-Queens Problem

S.No.	Test Case	Expected Result	Results
1	To test the successful launch of N-Queens Server	Successful Launch of Server	Server launched successfully.[Fig-1]
2	To test the display of chess board is in accordance with the size selected.	The Chessboard is displayed when range is between 4-10 size. In case of 'out of range' input by the user, the server displays a pop up indicating incorrect range input. Display of chessboard should be accurate.	The results are as expected.[Fig-1][Fig-2]



NQUEENS SOLVER

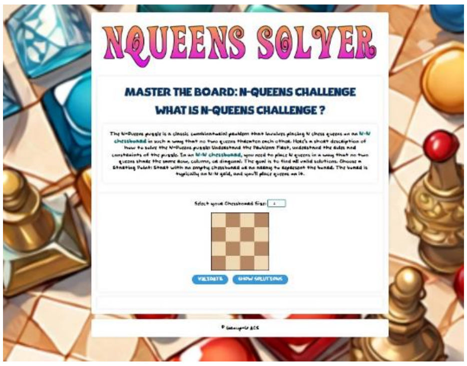
MASTER THE BOARD: N-QUEENS CHALLENGE

WHAT IS N-QUEENS CHALLENGE ?

The N-Queens puzzle is a classic combinatorial problem that involves placing N chess queens on an N×N chessboard in such a way that no two queens threaten each other. Here's a short description of how to solve the N-Queens puzzle: Understand the Problem: First, understand the rules and constraints of the puzzle. In an N×N chessboard, you need to place N queens in a way that no two queens share the same row, column, or diagonal. The goal is to find all valid solutions. Choose a Starting Point: Start with an empty chessboard or an array to represent the board. The board is typically an N×N grid, and you'll place queens on it.

Select your Chessboard Size: 6

Figure 1



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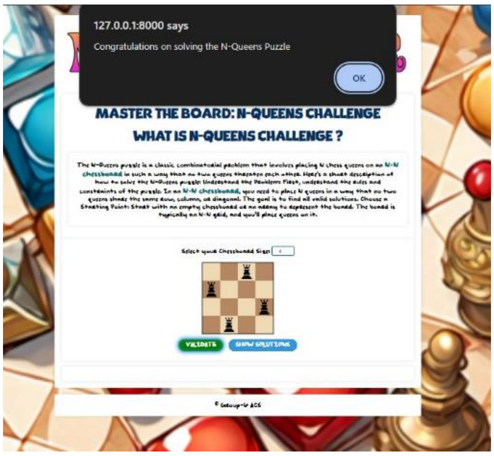
Select your Chessboard Size: 4

© Group-IV ACS

Figure 2

S.No.	Test Case	Expected Result	Results
3	To test the validation of solution presented to user	**Case 1**: Display pop up to the user if the validation of their solution is correct.	Results are presented in [Fig-3]
		Case 2: Display pop up to the user if the validation of their solution is incorrect.	Results are presented in [Fig-4]



127.0.0.1:8000 says

Congratulations on solving the N-Queens Puzzle

MASTER THE BOARD: N-QUEENS CHALLENGE

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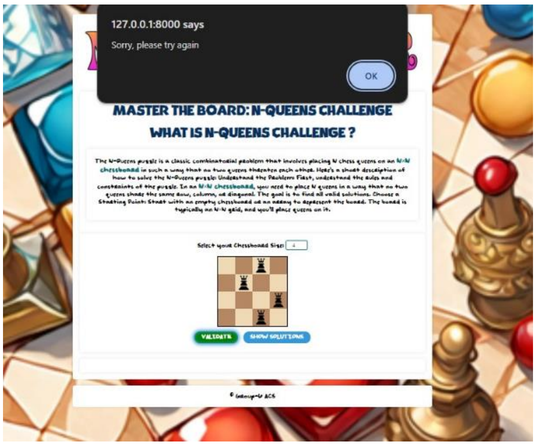
Figure 3



127.0.0.1:8000 says

Sorry, please try again

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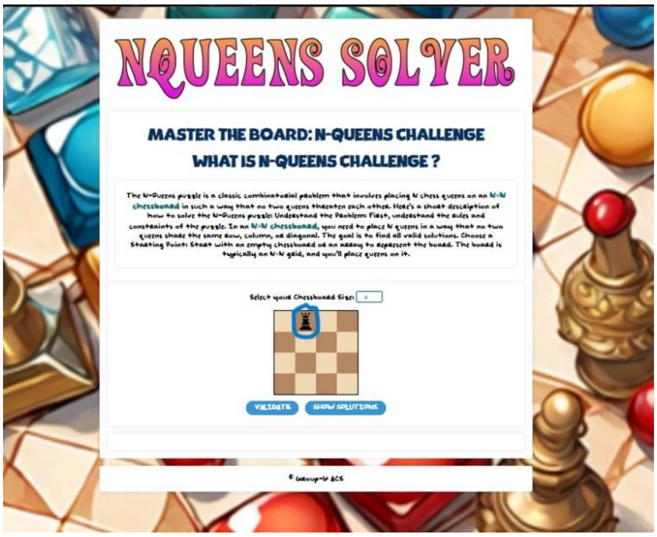
© Group-IV ACS

Figure 4

S.No.	Test Case	Expected Result	Results
4	To test placement and removal of Queen Pieces by clicking.	First click on chessboard should place the Queen piece on that position and Second Click on the Queen piece should remove the said piece.	Each expected action is performed successfully. [Fig-5][Fig-6]



NQUEENS SOLVER

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Select your Chessboard Size: 4

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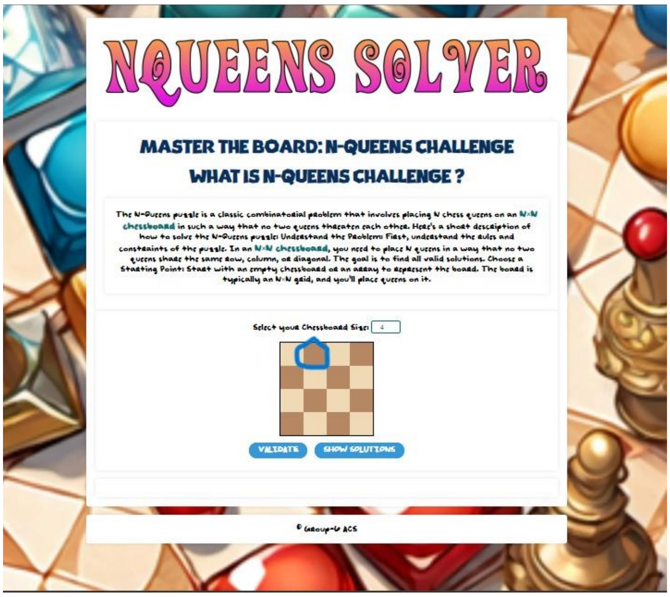
Figure 5



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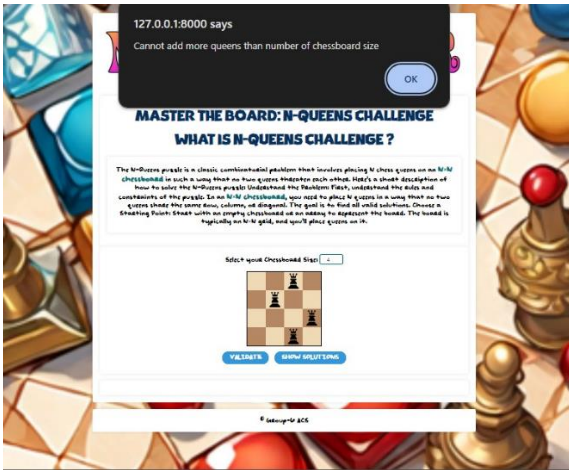
Select your Chessboard Size: 4

© Group-6 ACS

Figure 6

S.No.	Test Case	Expected Result	Results
5	To test the number of Queen pieces placed is not more than the corresponding size of the Chessboard.	To ensure if user attempts placing Queens more than the size of the Chessboard, an error pop up is displayed to the user.	The user is displayed the error pop up message as expected.[Fig-7]



127.0.0.1:8000 says

Cannot add more queens than number of chessboard size

MASTER THE BOARD: N-QUEENS CHALLENGE

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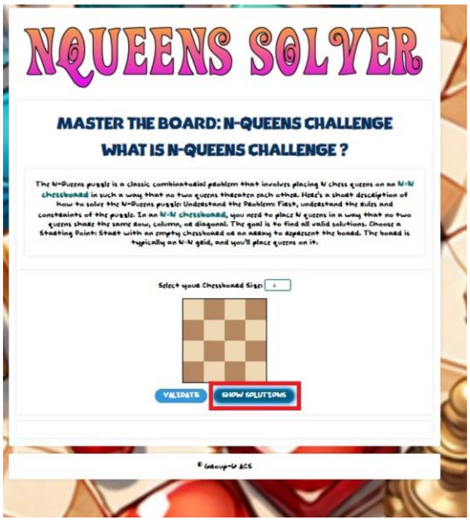
Select your Chessboard Size: 4

Figure 7

S.No.	Test Case	Expected Result	Results
6	To verify the accuracy of the presented solutions	Accurate solutions are displayed after clicking “Show Solution” button according to the partially filled or empty chessboard and solutions are hidden after clicking “Hide Solution” button.	The presented solutions are accurate as per the rules of the game.[Fig-8][Fig-9]



NQUEENS SOLVER

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Figure 8

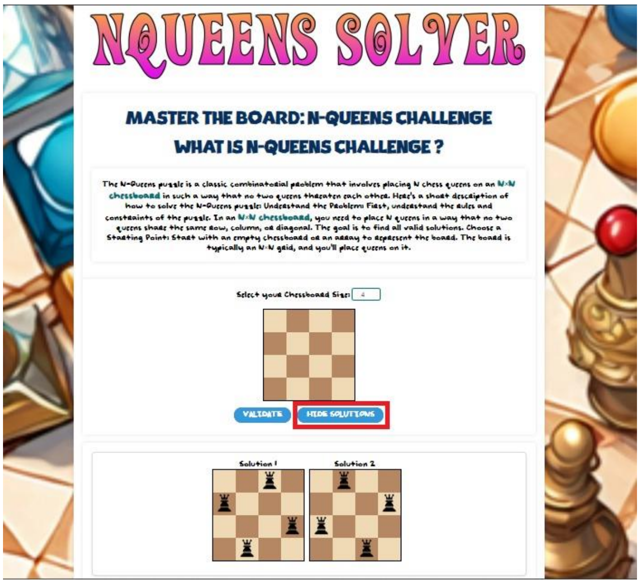

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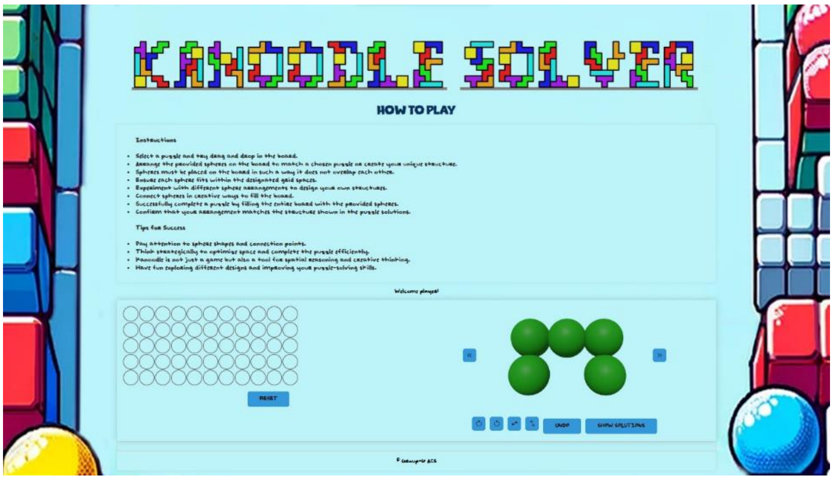
Figure 9

3.2 Polysphere Puzzle-2D

S.No.	Test Case	Expected Result	Results
1	To test the successful launch of Polyshpere Puzzle -2D Server	Successful Launch of Server	Server launched successfully.[Fig-10]



Instructions

- Select a puzzle and try drag and drop in the board.
- Arrange the provided spheres on the board to match a chosen puzzle or create your unique structure.
- Spheres must be placed on the board in such a way it does not overlap each other.
- Ensure each sphere fits within the designated grid spaces.
- Experiment with different sphere arrangements to design your own structures.
- Connect spheres in creative ways to fill the board.
- Successfully complete a puzzle by filling the entire board with the provided spheres.
- Confirm that your arrangement matches the structure shown in the puzzle solutions.

Tips for Success

- Pay attention to sphere shapes and connection points.
- Think strategically to optimise space and complete the puzzle efficiently.
- Kanoodle is not just a game but also a tool for spatial reasoning and creative thinking.
- Have fun exploring different designs and improving your puzzle-solving skills.

Welcome player!

Figure 10

S.No.	Test Case	Expected Result	Results
2	To test the placement of polysphere pieces into the board.	Accurate placement of the pieces by dragging and dropping polysphere pieces onto the board as per user's expectation and removal of the last placed piece by clicking "undo" button.	Dragging and dropping action is as expected [Fig-11][Fig-12] as well as "undo" action. [Fig-13][Fig-14]

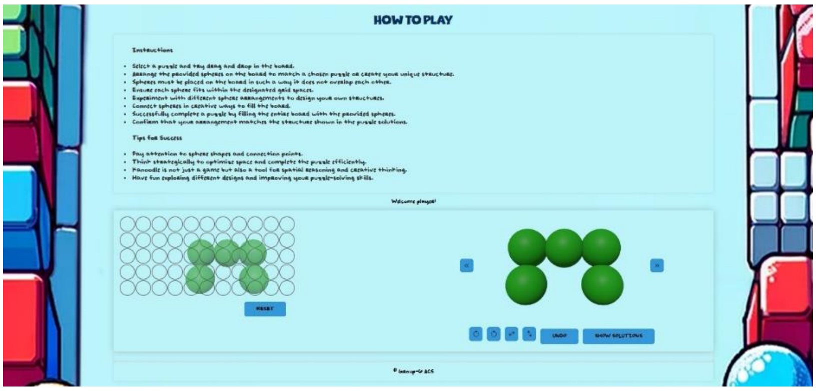


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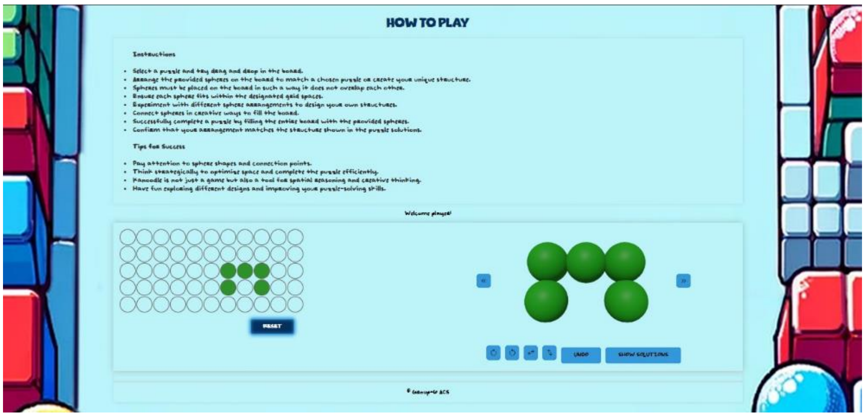
Figure 11



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Welcome player!

Figure 12

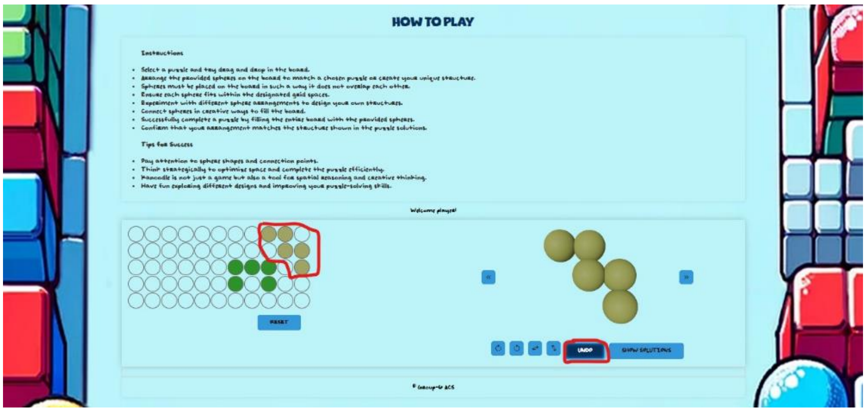

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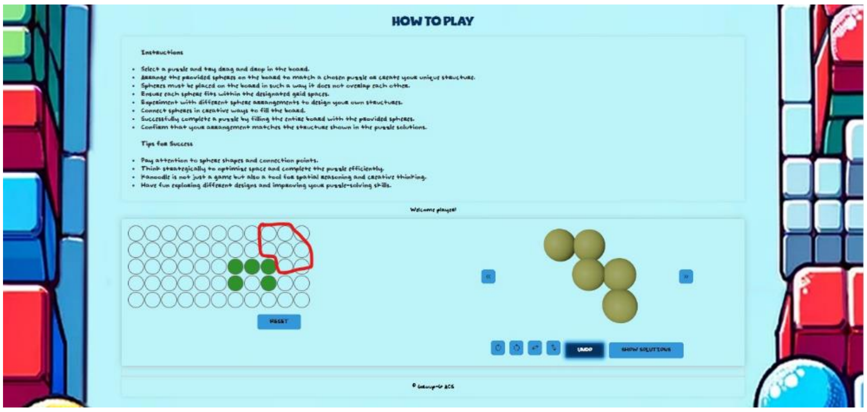
Figure 13



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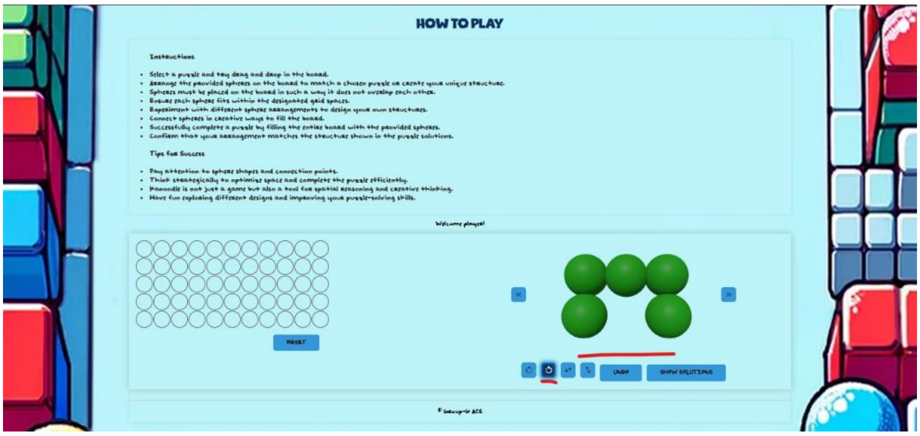
Welcome player!

Figure 14

S.No.	Test Case	Expected Result	Results

3	To test the accuracy of rotation and restructuring of the polysphere pieces using the provided buttons.	**Case 1**: Verification of left and right rotate symbol buttons. 90 degrees left or right Rotation of the polysphere pieces by click of each respective left or right rotate symbol button.	Button functions are as expected. [Fig-15][Fig-16] [Fig-17]
		Case 2: Verification up-down and side-to-side flip symbol buttons. 180 degrees' flip of the polysphere pieces by click of up-down or side-to-side flip symbol buttons.	Button functions are as expected. [Fig-18][Fig-19] [Fig-20]



HOW TO PLAY

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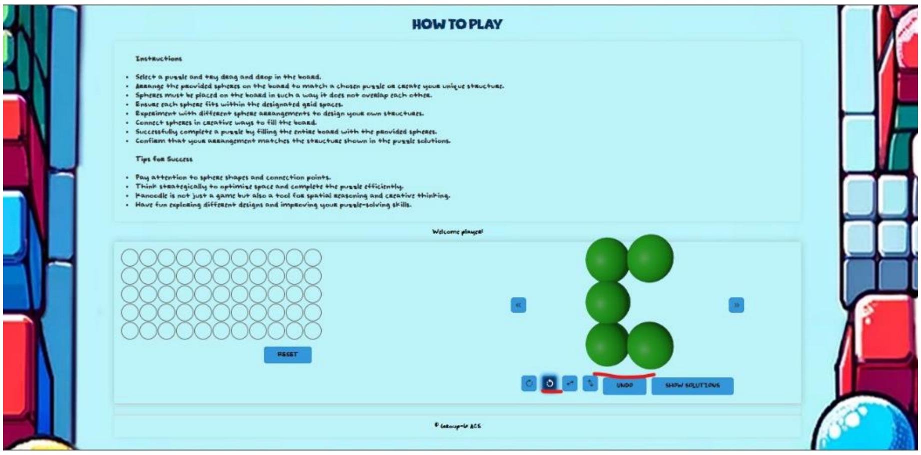
Welcome player!

Figure 15



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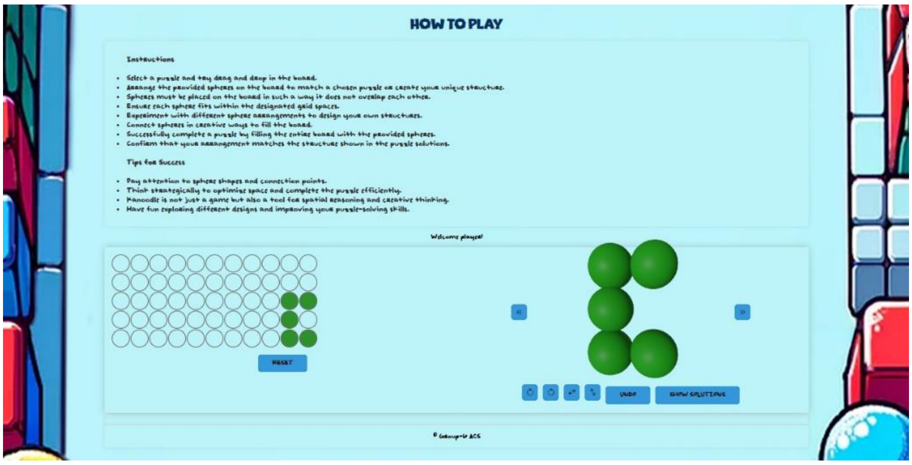
Welcome player!

Figure 16



HOW TO PLAY

Instructions

- Select a puzzle and try drag and drop in the board.
- Arrange the provided spheres on the board to match a chosen puzzle or create your unique structure.
- Spheres must be placed on the board in such a way it does not overlap each other.
- Ensure each sphere fits within the designated grid spaces.
- Experiment with different sphere arrangements to design your own structures.
- Connect spheres in creative ways to fill the board.
- Successfully complete a puzzle by filling the entire board with the provided spheres.
- Confirm that your arrangement matches the structure shown in the puzzle solutions.

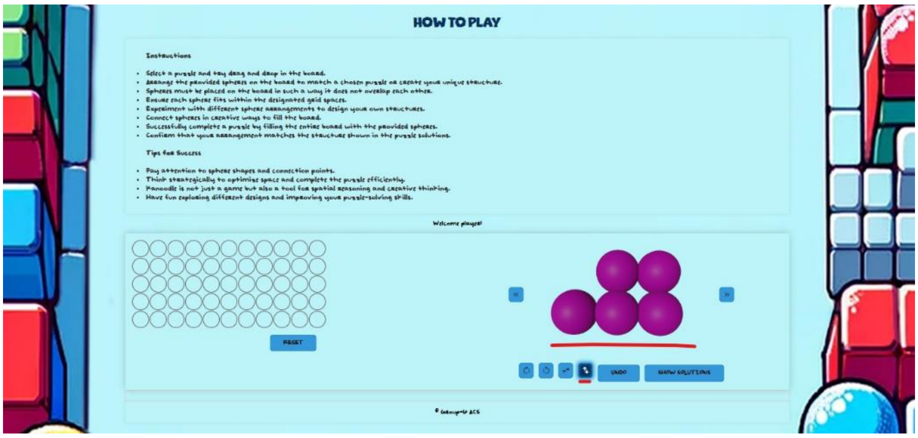
Tips for Success

- Pay attention to sphere shapes and connection points.
- Think strategically to optimize space and complete the puzzle efficiently.
- Kanoodle is not just a game but also a tool for spatial reasoning and creative thinking.
- Have fun exploring different designs and improving your puzzle-solving skills.

Welcome player!

© Group-16 ACS

Figure 17



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Welcome player!

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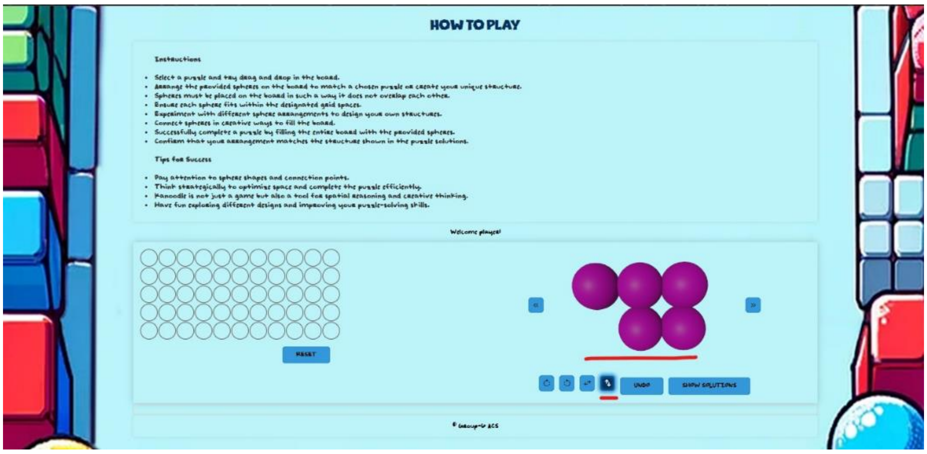
Figure 18



HOW TO PLAY

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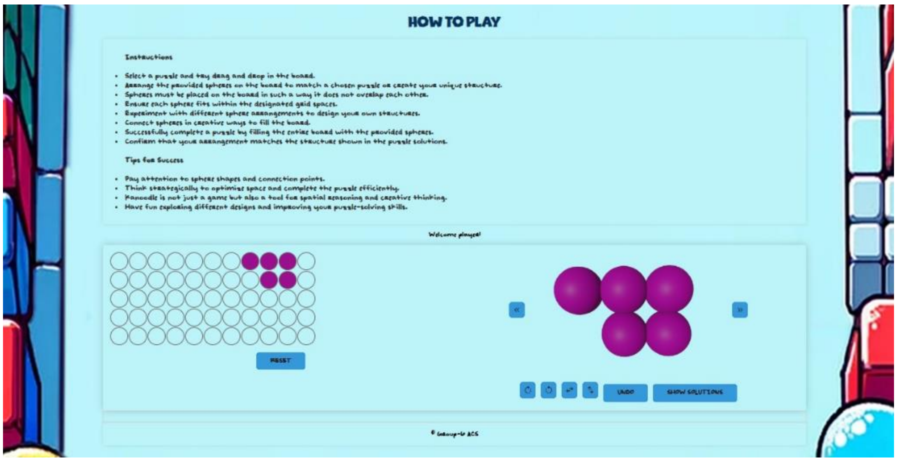
Welcome player!

© Group-16 ACS

Figure 19



HOW TO PLAY

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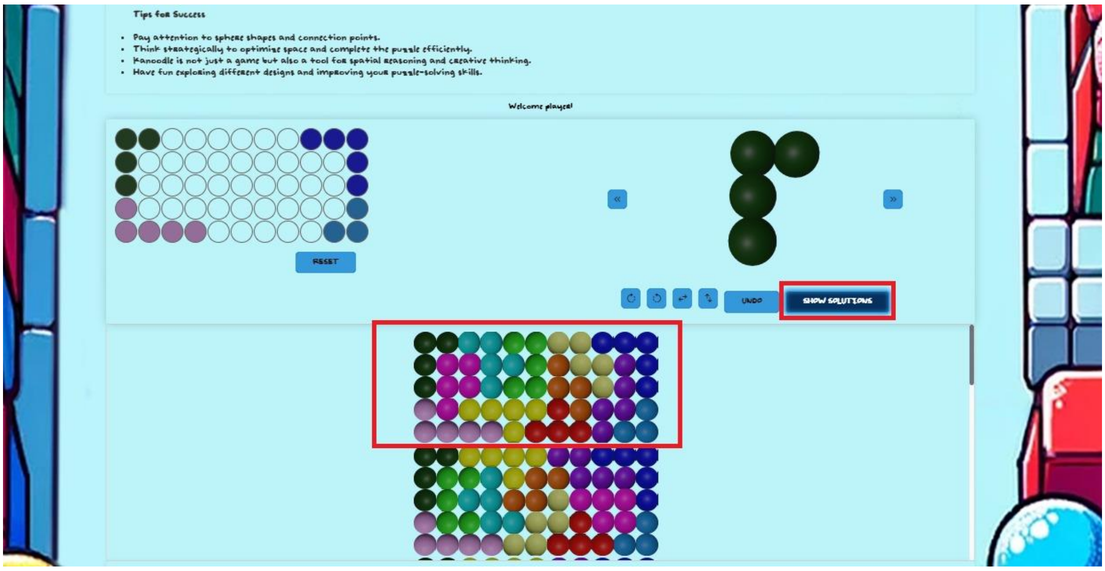
Welcome player!

Figure 20

S.No.	Test Case	Expected Result	Results
4	To test the accuracy of the presented solutions.	**Case 1**: To verify functionality of "Show Solution" Button Solutions are displayed after clicking "Show Solution" button and in case of no possible solutions for user's piece arrangement on board, a message is displayed	Button function is as expected. [Fig-21]
		Case 2: To verify the accurate solution is presented.	Accurate solution is presented.[Fig-22]



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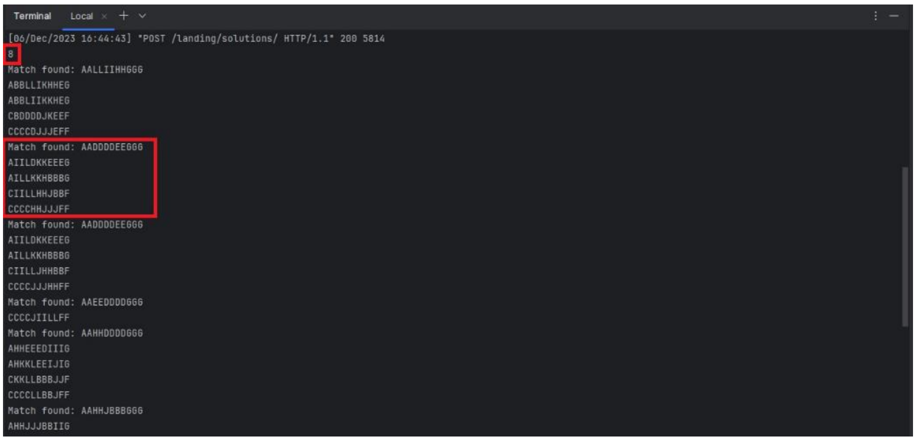
Welcome player!

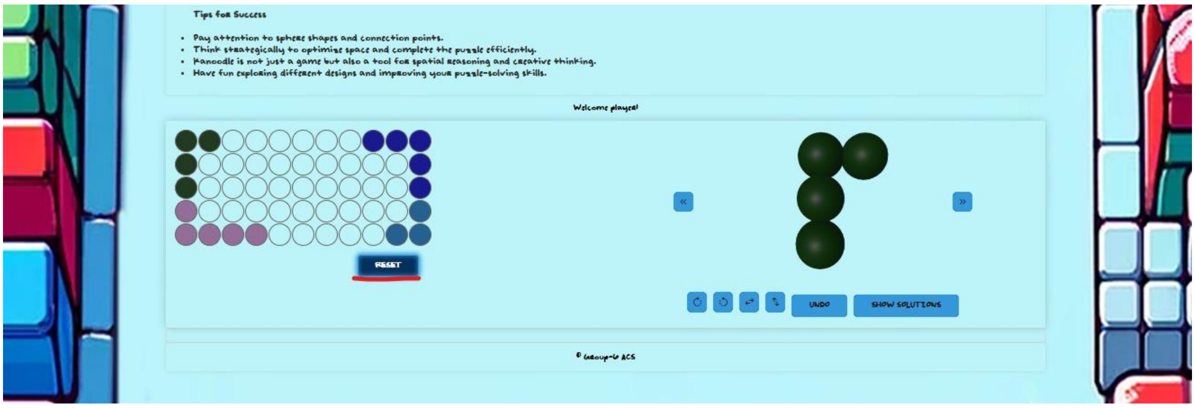
Figure 21



```
[06/Dec/2023 16:44:43] "POST /landing/solutions/ HTTP/1.1" 200 5814
8
Match found: AALLIIHHGGG
ABBLLIKHHEG
ABBLIIKKHEG
CBDDDDJKEEF
CCCCDJJJEFF
Match found: AADDDDEEGGG
AIILDKKEEEG
AILLKKHBBBG
CIILLHHJBBF
CCCCHHJJJFF
Match found: AADDDDEEGGG
AIILDKKEEEG
AILLKKHBBBG
CIILLJHHBBF
CCCCJJJHHFF
Match found: AAEEDDDDGGG
CCCCJIILLFF
Match found: AAHHDDDDGGG
AHHEEEDIIIG
AHKKLEEIJIG
CKKLLBBBJJF
CCCCLLBBJFF
Match found: AAHHJBBBGGG
AHHJJJBBIIG
```

Figure 22

S.No.	Test Case	Expected Result	Results
5	To test the Reset button	The “Reset” button should clear all the pieces from the board.	Button function is as expected. [Fig-23][Fig-24]



Tips for Success

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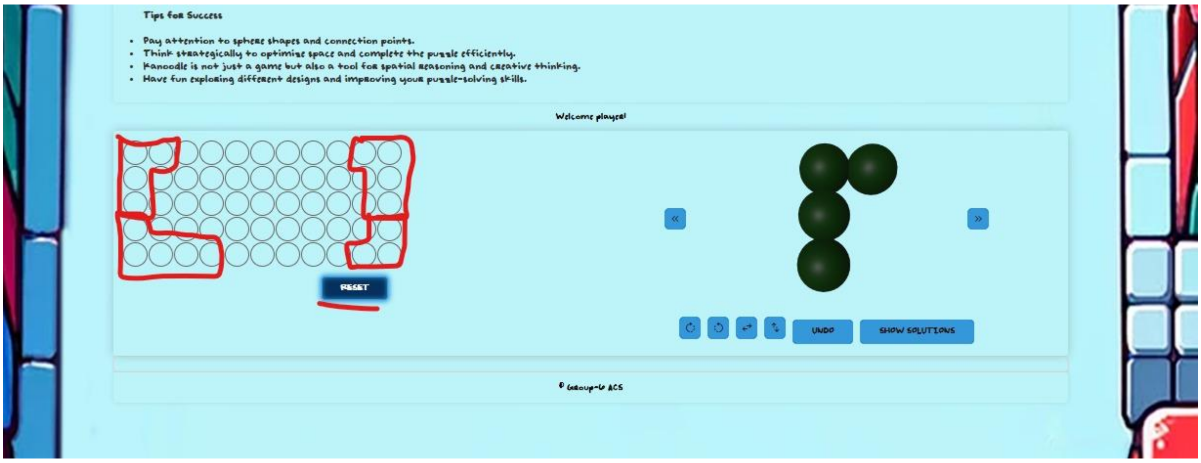
Figure 23



Tips for Success

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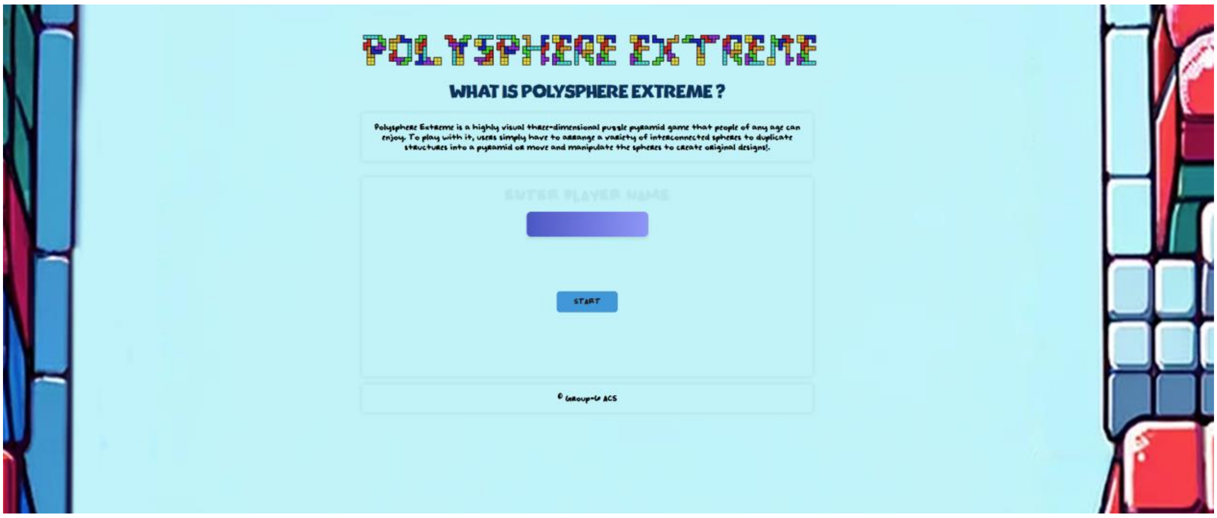
Figure 24

3.3 Polysphere Extreme

S.No.	Test Case	Expected Result	Results
1	To test the successful launch of Polyshpere Puzzle -3D Server	Successful Launch of Server	Server launched successfully. [Fig 25 & 26]

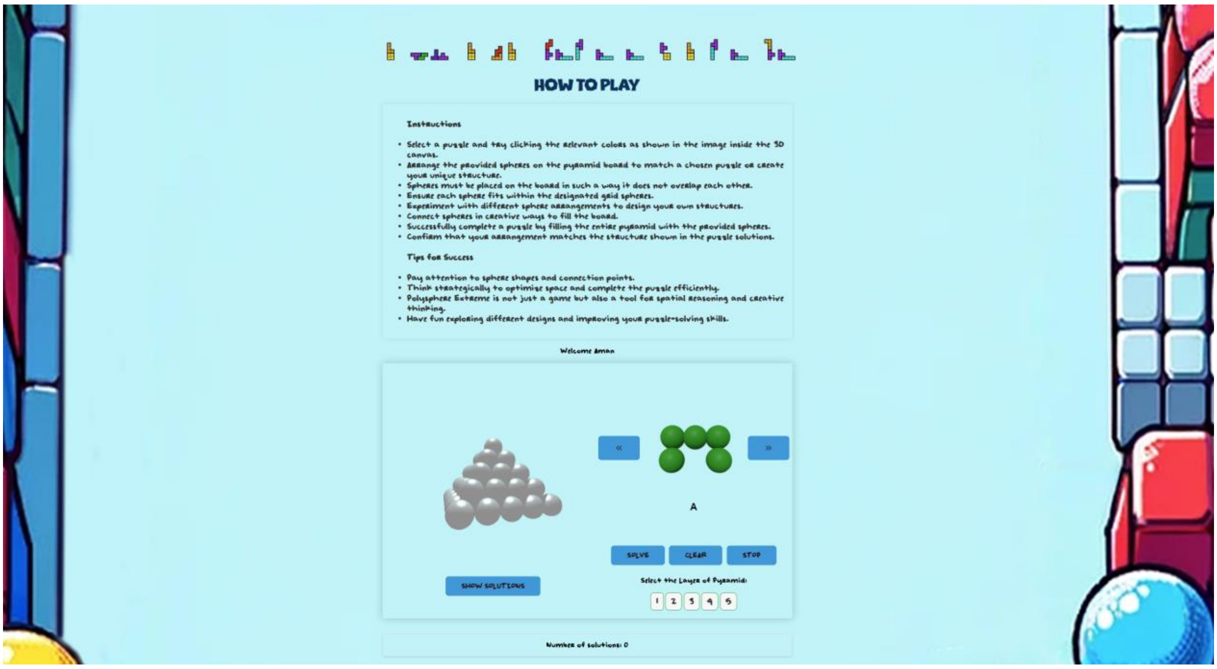


POLYSPHERE EXTREME

WHAT IS POLYSPHERE EXTREME ?

Polysphere Extreme is a highly visual three-dimensional puzzle pyramid game that people of any age can enjoy. To play with it, users simply have to arrange a variety of interconnected spheres to duplicate structures into a pyramid or move and manipulate the spheres to create original designs!.

Figure 25



HOW TO PLAY

Instructions

- Select a puzzle and try clicking the relevant colors as shown in the image inside the 3D canvas.
- Arrange the provided spheres on the pyramid board to match a chosen puzzle or create your unique structure.
- Spheres must be placed on the board in such a way it does not overlap each other.
- Ensure each sphere fits within the designated grid spheres.
- Experiment with different sphere arrangements to design your own structures.
- Connect spheres in creative ways to fill the board.
- Successfully complete a puzzle by filling the entire pyramid with the provided spheres.
- Confirm that your arrangement matches the structure shown in the puzzle solutions.

Tips for Success

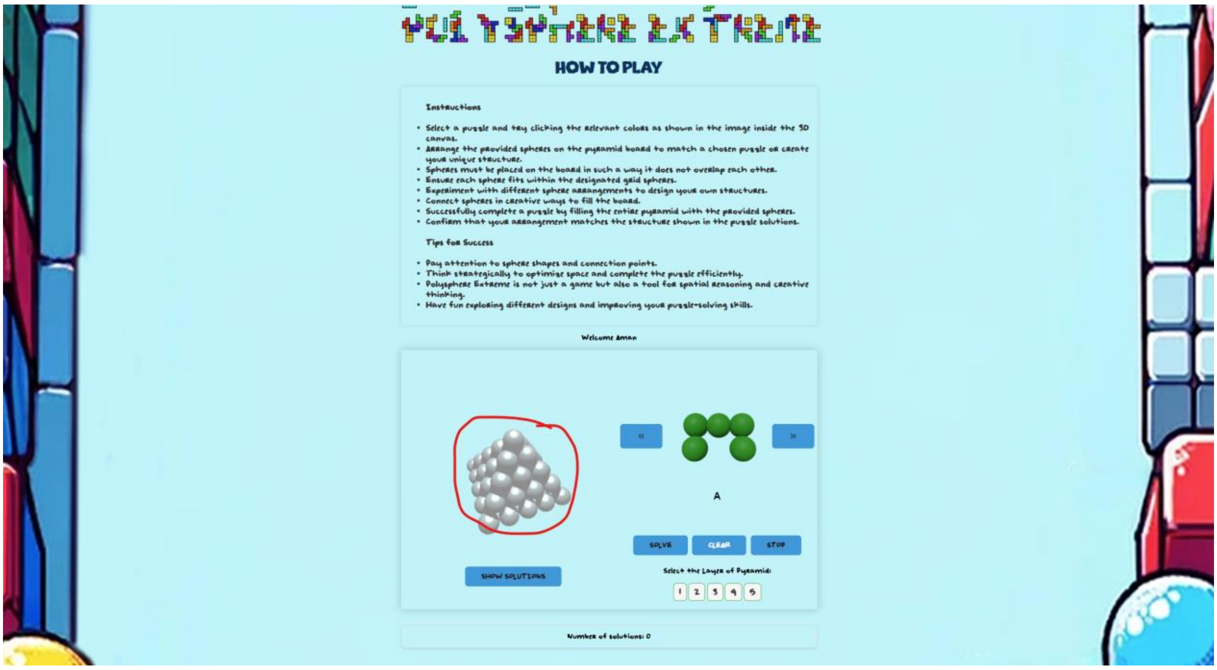
- Pay attention to sphere shapes and connection points.
- Think strategically to optimize space and complete the puzzle efficiently.
- Polysphere Extreme is not just a game but also a tool for spatial reasoning and creative thinking.
- Have fun exploring different designs and improving your puzzle-solving skills.

Welcome Aman

Number of solutions: 0

Figure 26

S.No.	Test Case	Expected Result	Results
2	to test the 3D rotation of the polyshpere pyramid.	Dragging of the mouse should display the view of the pyramid from 3-dimensional perspective.	Successful implementation of functionality. [Fig 27]



Instructions

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- Have fun exploring different designs and improving your puzzle-solving skills.

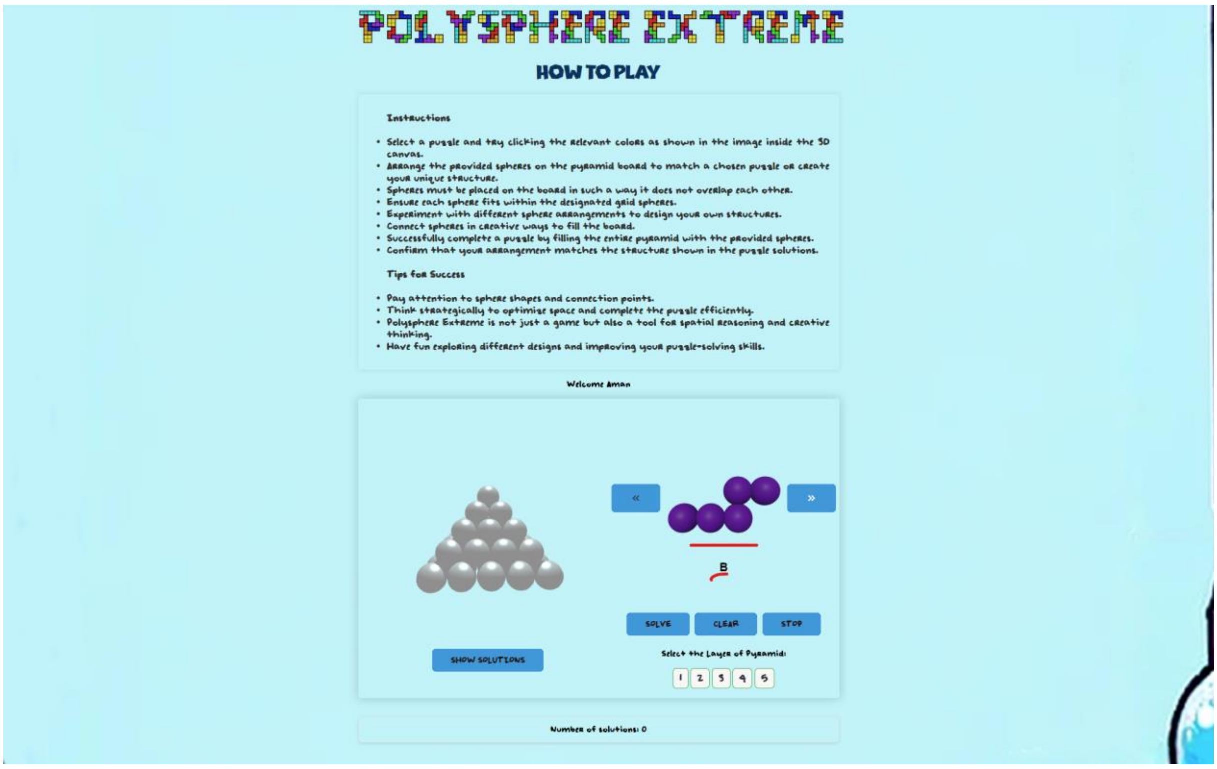
Welcome Aman

Select the Layer of Pyramid:

Number of solutions: 0

Figure 27

S.No.	Test Case	Expected Result	Results
3	To verify selection of the shapes	Display of the choices of the shapes by selecting right or left swipe buttons.	Successful implementation of selection functions. [Fig 28 & 29]



POLYSPHERE EXTREME

HOW TO PLAY

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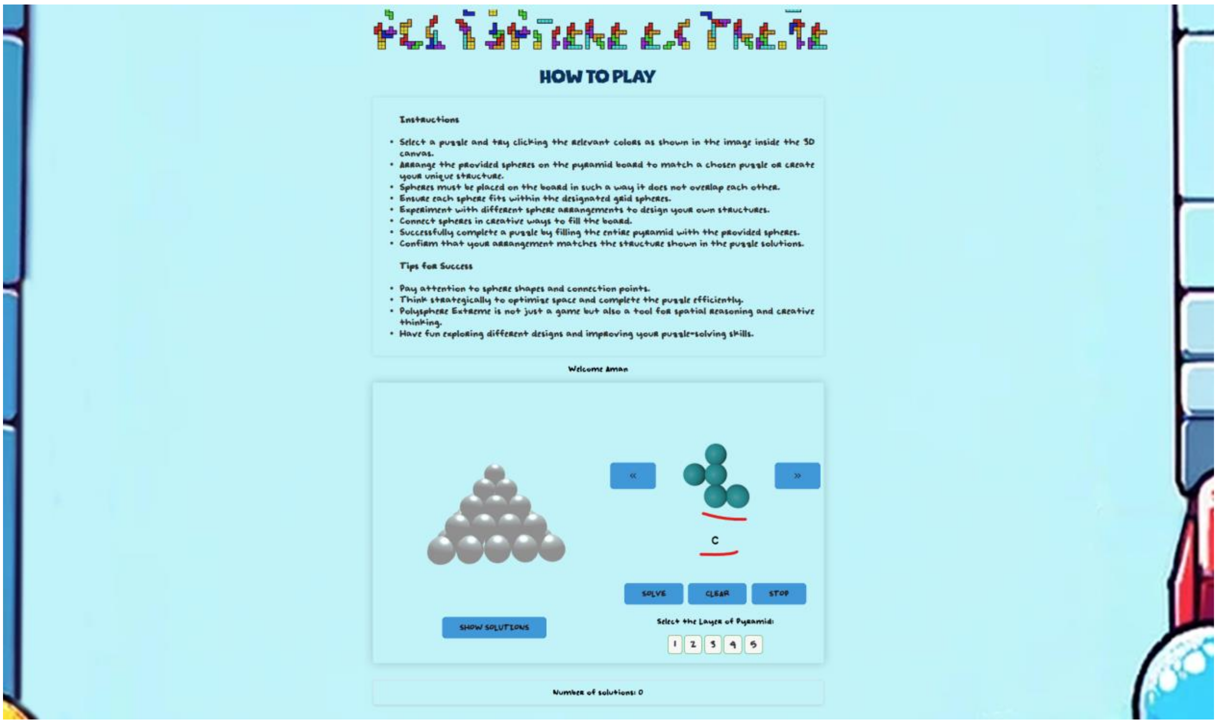
Welcome Aman

Select the Layer of Pyramid:

Number of solutions: 0

Figure 28



HOW TO PLAY

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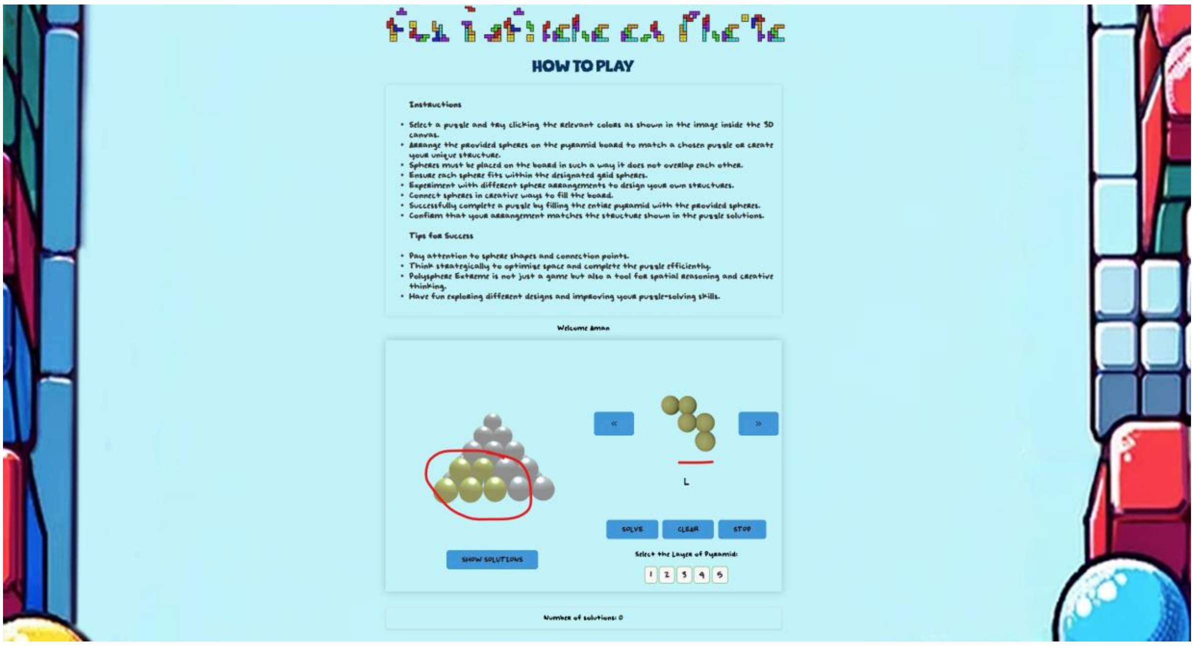
Welcome Aman

Select the Layer of Pyramid:

Number of solutions: 0

Figure 29

S.No.	Test Case	Expected Result	Results
4	To test the colouring of the spheres in the pyramid according to shape selected by the user.	**Case 1:** Clicking on the spheres should colour it in the shade of the shape selected by the user	Successful colour functionality. [Fig 30]



HOW TO PLAY

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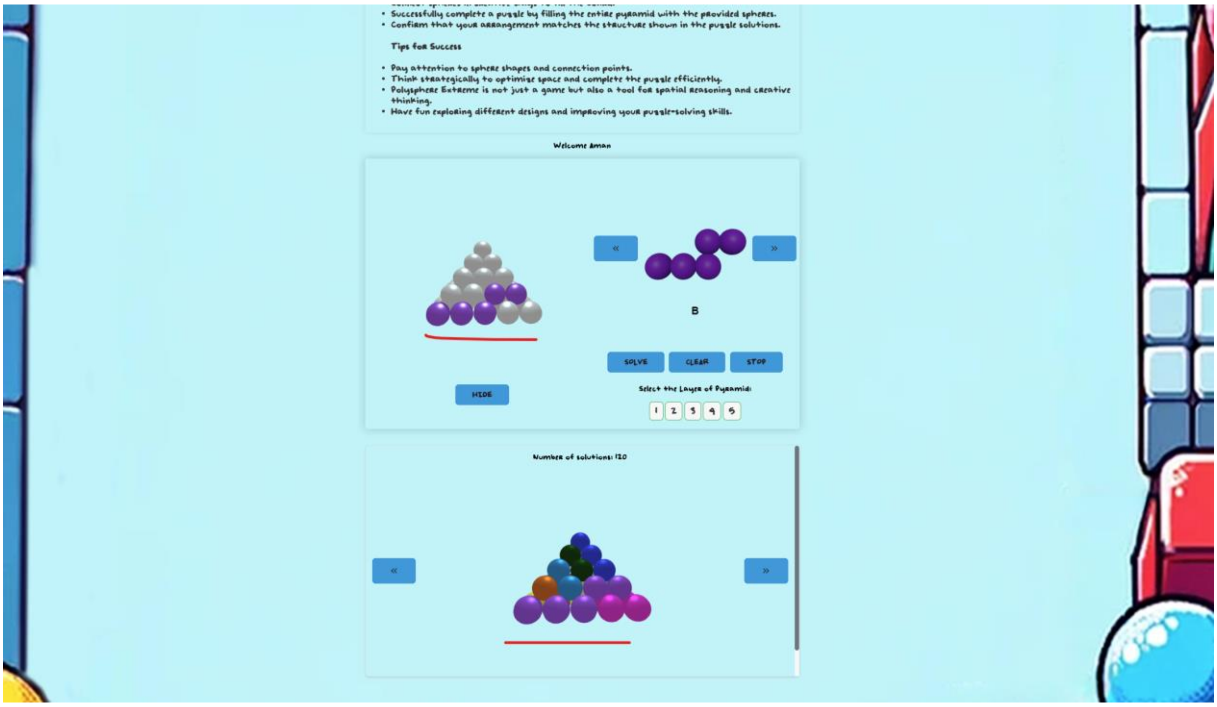
Welcome Aman

Number of solutions: 0

Figure 30

S.No.	Test Case	Expected Result	Results
5	To test the Solve, Clear and Stop functions.	Case 1: "Solve" button should give the number of solutions as well as visual representation of the solutions on the pyramid for partial and empty configuration.	Successful implementation. [Fig 31]
		Case 2: "Stop" button will stop the listing of solutions and Clear button should clear all the coloured spheres in the pyramid to reset the game.	Successful implementation. [Fig 32 & 33]



- Successfully complete a puzzle by filling the entire pyramid with the provided spheres.
- Confirm that your arrangement matches the structure shown in the puzzle solutions.

Tips for Success

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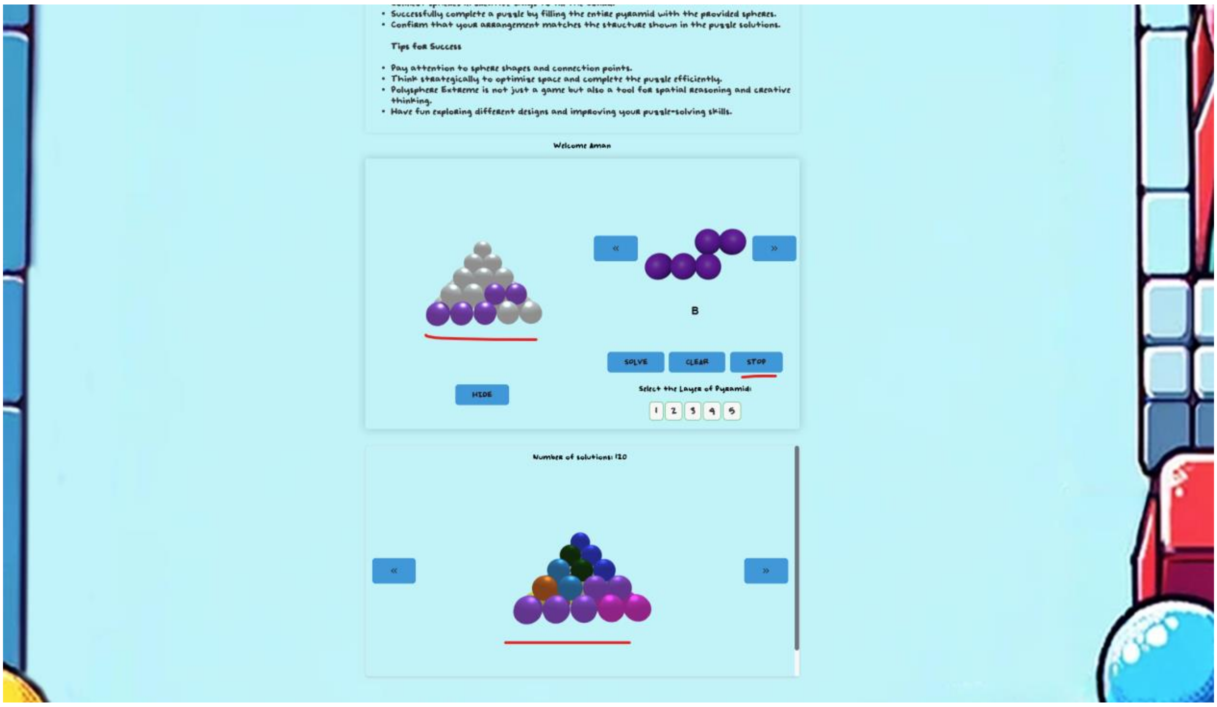
Welcome Aman

Select the Layer of Pyramid:

Number of solutions: 120

Figure 31



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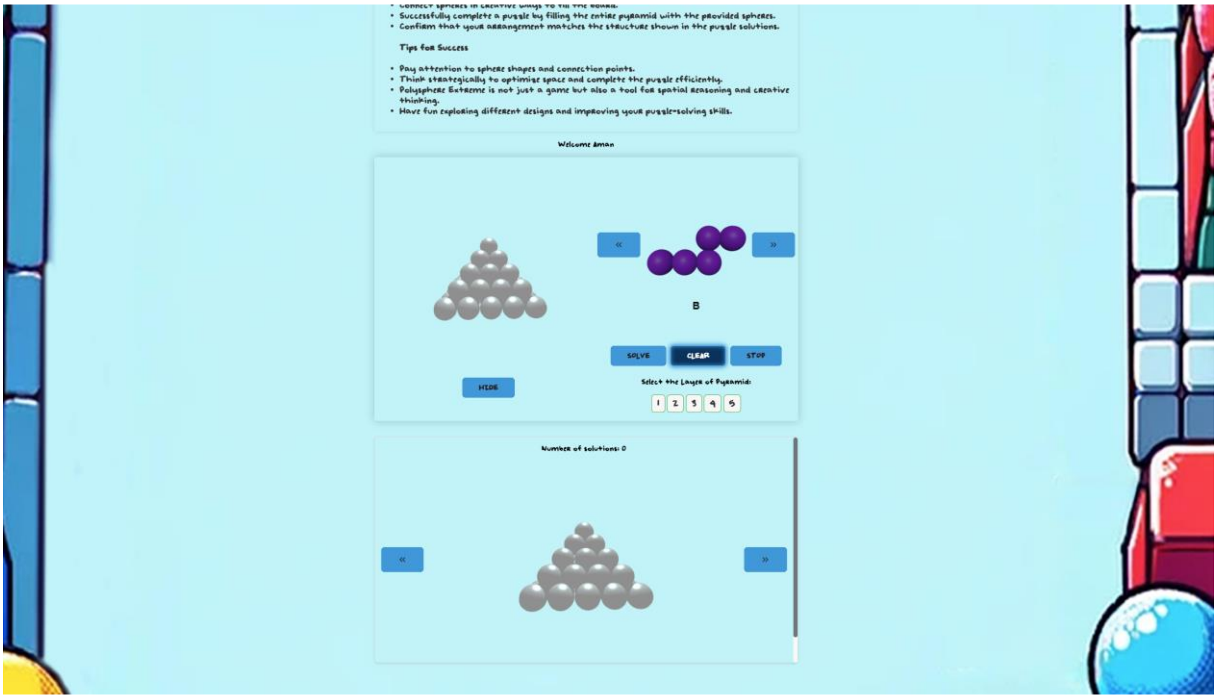
Select the Layer of Pyramid:

Number of solutions: 120

Figure 32



- Connect spheres in creative ways to fill the board.
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Tips for Success

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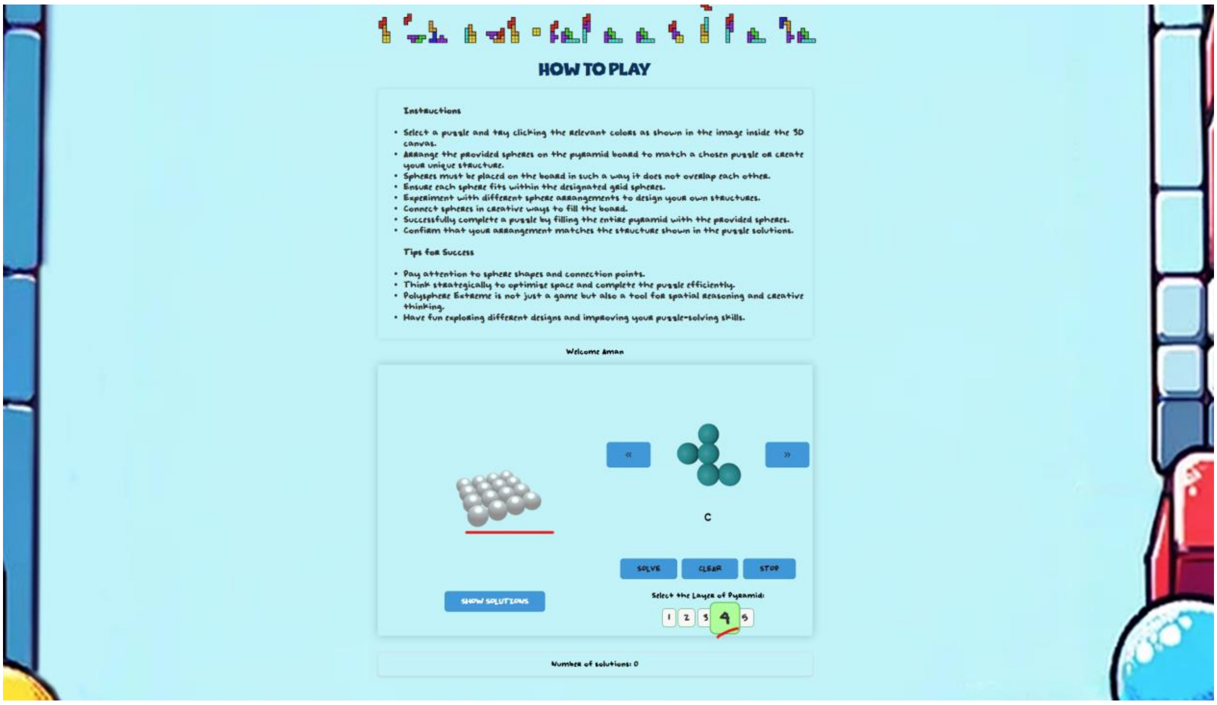
Welcome Aman

Number of solutions: 0

Figure 33

S.No.	Test Case	Expected Result	Results
6	To test the visual aspects of the pyramid.	The layer selection button should display the visual representation of the pyramid according to the number of layers selected in 2-D as well as 3-d layer wise.	Successful implementation. [Fig 34 & 35]



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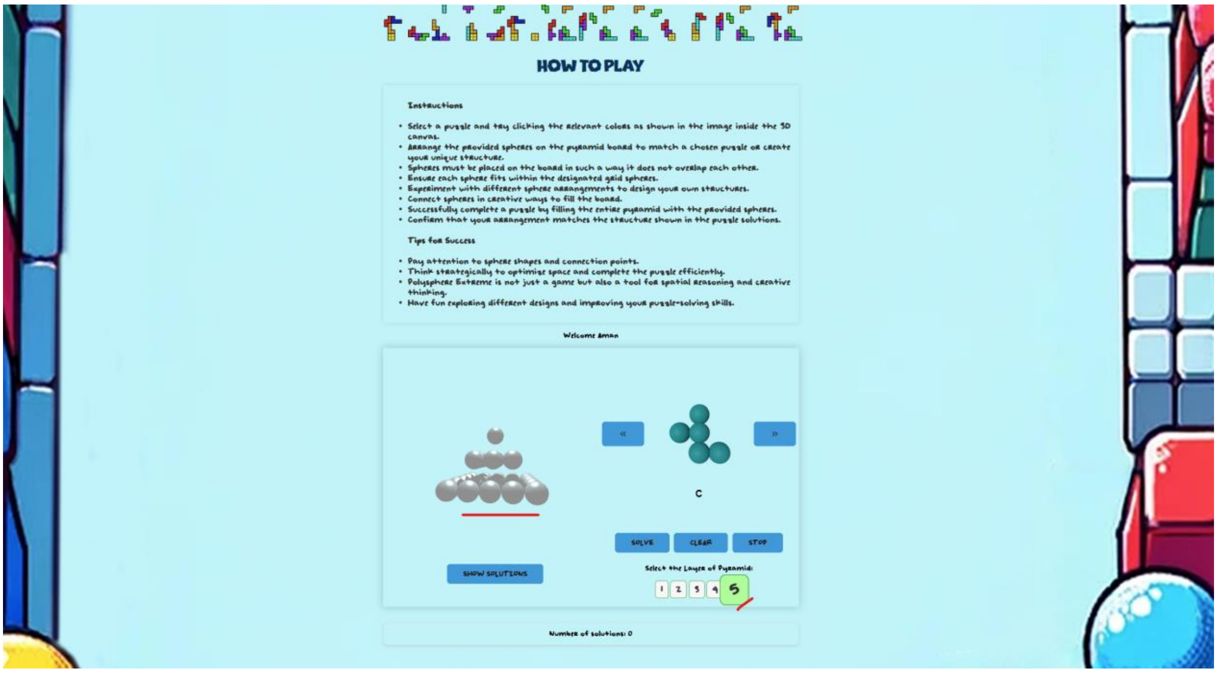
Welcome Aman

Select the Layer of Pyramid: 1 2 3 [✓ 4] 5

Number of solutions: 0

Figure 34



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Welcome Aman

Select the Layer of Pyramid: 1 2 3 4 [✓ 5]

Number of solutions: 0

Figure 35

4 CONCLUSION

In conclusion, this comprehensive report outlines a purposeful software initiative focused on the development of a web-based game application, emphasizing interactive puzzle resolution. The project's central objective is to empower users to independently engage with and solve intricate puzzles, including the N-Queens puzzle and the Polysphere Puzzles in both 2D and 3D dimensions. The web application is designed to facilitate active user participation in the puzzle-solving process, allowing navigation through chessboard scenarios, strategic queen placements, and the placement of various shapes on grids for Polysphere Puzzles. The is project is implemented through agile methodology to provide requested features and feedback from the client. Utilized GitHub as the central platform for tracking all development activities in collaboration with the customer. The project also underwent thorough testing to verify reliability and functionality of the web-based game application.

4.1 Limitations

4.1.1 N-Queens Puzzle

- The Chessboard size is limited to 10 Queen pieces due to computation complexities emerging with higher size boards as heavy resources are consumed when computing the solutions.

4.1.2 Polysphere Pro

- While dragging of the shapes, image of the shape while being dragged cannot change according to rotations and flips performed by the user. Although the placement of the shape remains accurate.

4.1.3 Polysphere Extreme

- Placement of the shapes can only be done unidirectional relative to the initial placement of the first sphere.
- Users cannot place the pieces diagonally as the shape of pieces cannot be skewed from its original shape.
- The user cannot drag and drop the pieces on the pyramid. The game relies on the User’s understanding of the 3-d structures and visual knowledge of the shapes. The limitation is caused due to heavy reliance on libraries such as Three.js and Orbit Controls that are used to generate the 3-D elements of the Game.

4.2 Future Improvements

To improve the puzzle-solving capabilities, the optimization of time complexity and the enhancement of algorithmic efficiency in the computation of solutions for each puzzle will be required in the project. The primary goal is to guarantee the time required for solving puzzles is minimized, and the implemented algorithms show efficiency in delivering accurate solutions. By improving the time complexity, the overall performance of the puzzle-solving mechanisms will be enhanced, providing users with a smoother experience in navigating through complex problems. Furthermore, enhancement in both the user experience and the visual features of the system can also be implemented. This improvement can elevate the overall usability and aesthetics of the application. Enhancing the user experience requires improving the interface, navigation flow, and overall interaction design for a more intuitive, efficient, and satisfying engagement for the users.