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ANIMATION GAME ENGINE FOR INTERACTIVE PRESENTATION OF EDUCATIONAL MEDIA

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Abstract - Education is constantly evolving, with a growing emphasis on technology-driven solutions to enhance learning outcomes. Traditional teaching methods, while effective in some contexts, often struggle to convey complex concepts in subjects like mathematics, science, and computing. These subjects involve dynamic processes, abstract relationships, and step-by-step transformations that are difficult to represent using static images or text-based explanations. Concepts such as the behavior of algorithms, the motion of celestial bodies, or the principles of calculus require more than simple visuals or verbal explanations to be fully understood. Without dynamic representations, students may find it challenging to grasp these intricate ideas, leading to gaps in comprehension. Most conventional educational tools, such as PowerPoint presentations or printed materials, have limitations in illustrating dynamic processes. These materials often provide a passive learning experience, where the teacher presents information and students absorb it without direct engagement.

This one-directional approach has several shortcomings, including a lack of interactivity, limited visualization capabilities, and an inability to personalize learning. Static slides fail to show how a concept unfolds over time, making it difficult for learners to develop an intuitive understanding. Additionally, traditional teaching tools do not provide real-time feedback, making it harder for educators to assess student progress and adapt their instruction accordingly. To address these challenges, this project introduces a versatile animation engine, developed using the Godot Engine and GDScript, specifically designed for educational media. Unlike conventional presentation software, this engine creates a dynamic and interactive learning environment, allowing educators to incorporate animations, quizzes, real-time feedback, and personalized learning paths into their lessons. With a focus on accessibility and ease of use, this tool empowers educators to design engaging, interactive presentations without requiring advanced programming knowledge. One of the key features of this animation engine is its support for keyframe-based animations, which allow for smooth, precise motion to illustrate complex ideas. Mathematical transformations, physics simulations, and algorithm visualizations can be demonstrated with fluid animations, making abstract concepts easier to understand. Educators can create these animations with minimal effort, using a simple scripting interface that does not require extensive coding expertise. By providing a movie-quality animation system, the engine bridges the gap between theoretical learning and practical visualization.

Beyond animation, interactivity plays a crucial role in enhancing student engagement. The engine supports interactive elements such as quizzes, clickable objects, and user-driven animations, allowing students to explore concepts at their own pace. Instead of passively watching a presentation, students can interact with the material, manipulate variables, and receive immediate feedback. This hands-on approach fosters active learning, which has been shown to improve comprehension and retention compared to traditional lecture-based methods. Another important feature of this engine is its ability to track and analyze user interactions. The system records quiz responses, engagement levels, and input patterns, providing educators with valuable insights into student progress. This data-driven approach enables real-time feedback, helping students correct mistakes immediately and reinforcing learning. Educators can use this information to identify individual learning needs, adjust lesson plans, and offer personalized support. This adaptive learning model ensures that each student receives a tailored educational experience, catering to different skill levels and learning paces. Accessibility is a fundamental consideration in this project. The engine is designed to be lightweight and easy to use, making it suitable for a wide range of devices — from high-end computers to basic classroom setups. Built using GD Script, the tool maintains a balance between powerful scripting capabilities and user-friendly design, ensuring that even educators with limited programming experience can create engaging content. By lowering the technical barriers to animation and interactivity, the engine democratizes the creation of high-quality educational materials.

The potential applications of this animation engine span multiple disciplines. In mathematics, it can visualize complex equations, geometric transformations, and calculus concepts. In physics, it can simulate forces, motion, and energy interactions. In computer science, it can demonstrate algorithms, data structures, and programming logic through step-by-step animations. In biology, it can illustrate cellular processes, genetic sequences, and ecological interactions. This versatility

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makes it a powerful tool for educators across various fields, helping students visualize and engage with concepts in ways that static materials cannot achieve. The introduction of adaptive, interactive, and animated learning materials represents a significant shift in educational methodologies. Traditional teaching tools, which rely heavily on passive learning, often fail to engage students effectively. By integrating real-time animations, interactivity, and personalized feedback, this Godot-based animation engine transforms the learning experience, making it more engaging, intuitive, and effective. As education continues to evolve, tools like this will play a crucial role in bridging the gap between theory and application.

Whether used for in-person classrooms, self-paced online courses, or STEM outreach programs, this engine has the potential to revolutionize the way complex subjects are taught and understood. By providing a visually rich, interactive, and adaptive learning experience, this project empowers both educators and learners, paving the way for a more engaging and effective future in education.

I. INTRODUCTION

In modern education, effectively communicating complex concepts in subjects like mathematics, science, and computing demands more than static materials; interactive and dynamic visualizations play a crucial role in enhancing comprehension and retention. Traditional educational approaches, while valuable, often rely heavily on text-based explanations and static images, which can make it challenging for learners to grasp abstract ideas or visualize step-by-step processes. This project introduces an Animation Game Engine, developed using the Godot Engine and GDScript, specifically designed to revolutionize the way educational content is delivered. The engine empowers educators to craft engaging, interactive presentations without requiring advanced programming skills. It integrates features such as key frame-based animations, real-time quizzes, and feedback systems, making it easier to explain intricate topics through dynamic visuals and interactive activities.

One of the standout aspects of this engine is its focus on learner engagement. By enabling user-driven interactions and tracking learner progress, the system personalizes the learning journey, providing valuable insights into each student's comprehension level and areas requiring reinforcement. This not only aids educators in adapting their teaching strategies but also motivates learners to actively participate in their learning process.

Moreover, the engine's lightweight and resource-efficient design ensures accessibility across a wide range of devices, making it suitable for educational institutions with limited computing resources. Its scalability allows for broad applications from primary education to specialized training in higher education and professional settings.

In essence, this animation engine represents a significant advancement in educational technology, offering a versatile and powerful tool for delivering intuitive, engaging, and effective teaching content in a digital format.

II. LITERATURE SURVEY

1) The Efficacy of Animation and Visualization in Teaching Data Structures: A Case Study
Authors: Genady Kogan, Hadas Chassidim, Irina Rabaev (2024)
This paper highlights the effectiveness of animation and visualization techniques in improving student engagement and retention when teaching data structures. It demonstrates how visual aids help bridge the gap between theoretical concepts and practical understanding.

2) Algorithm Animations for Teaching and Learning the Main Ideas of Basic Sortings
Authors: LadislavVe´gh, VeronikaStoffova´(2017)
This research focuses on using algorithm animations to teach basic sorting algorithms. The study emphasizes how visualization helps make abstract ideas more accessible and improves learners' comprehension and problem-solving skills.

3) GILP: An Interactive Tool for Visualizing the Simplex Algorithm
Authors: Henry W.Robbins, Samuel C.Gutekunst, David B.Shmoys, David P.Williamson(2023)
This paper introduces GILP, an interactive tool for visualizing the Simplex algorithm. It demonstrates how graphical representations enhance understanding by al- lowing learners to engage with algorithmic processes dynamically.

4) A Review of The Algorithm Visualization Field
Authors: SarthakGoel, Vanshika Varshney, Shubham Dikshant, Akhil Sharma, Sherish Johri (2023)

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This review paper surveys various algorithm visualization tools and methodologies, reinforcing the effective- ness of well-structured visual aids in improving learners' problem solving abilities and conceptual understanding.

5) Augmented Reality with Algorithm Animation and Their Effecton Students' Emotions

Authors: Maximiliano Paredes-Velasco, A´ngel J. Velázquez-Iturbide,MónicaGómez-R´ıos(2022)

This study explores the use of augmented reality(AR) combined with algorithm animation to enhance student engagement. It finds that AR-based visualizations positively influence cognitive load management and emotional response.

6) Deep Reinforcement Learning with Godot Game Engine

Authors: Mahesh Ranaweera, Qusay H. Mahmoud (2024)

This research examines integrating deep reinforcement learning within the Godot Engine to create intelligent, adaptive learning experiences, emphasizing the engine's flexibility in educational applications.

7) Using Student-Built Algorithm Animationsas Learning Aids

Author: JohnT.Stasko(1997)

This foundational study encourages learners to create their own algorithm visualizations, leading to deeper engagement and improved conceptual grasp of computational problems.

8) Visualizations and Animations in Learning Systems

Author: Andreas Kerren(2012)

This paper advocates for integrating animations and visualizations across various educational domains, emphasizing their adaptability and benefits in learning environments.

III. PROPOSED SYSTEM

The proposed system is an advanced animation game engine specifically designed to elevate the delivery of educational content. The primary focus of this system is to transform conventional, static learning experiences into highly interactive, engaging, and adaptive environments that foster deeper understanding and active learner participation. Leveraging the Godot Engine and its flexible scripting language, GDScript, the system provides educators with a powerful, user-friendly platform to create visually rich and pedagogically effective content.

A key challenge in the current educational technology landscape is the high level of technical expertise required to develop interactive and animated learning materials. This engine addresses that gap by offering intuitive tools that simplify the process of crafting dynamic keyframe-based animations, integrating real-time interactivity, and tracking user engagement. Through its modular design and accessible scripting interface, the engine lowers the technical barrier for educators, allowing them to focus on the pedagogical aspects of content delivery rather than the complexities of software development.

Furthermore, the system incorporates mechanisms to capture and analyze learner interactions. Data such as quiz responses, engagement patterns, and real-time input are recorded and processed to provide valuable feedback to both educators and learners. This data-driven approach supports personalized learning by identifying individual learner progress, strengths, and areas needing improvement. The engine's lightweight and optimized design ensures compatibility with a wide range of hardware platforms, making it accessible to institutions with varying technological resources.

By merging animation, interactivity, and data analytics, the proposed methodology aims to create a versatile educational tool that enhances comprehension, increases student engagement, and facilitates personalized learning experiences across various domains such as mathematics, science, and computing.

IV. IMPLEMENTATION

The implementation of the animation game engine is carried out using the Godot Engine, which offers a modular, scene- based architecture. The scripting is done using GDScript, allowing easy control over animations, interactive features, and data collection. Each module is implemented with clarity, ensuring educators can customize or extend the engine's capabilities without deep technical expertise.

A. Initialization and Setup

The initial setup of the engine involves configuring the project settings, preparing the scene hierarchy, and defining global resources. The following steps

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out line the setup process:

- CreatingarootMainScenecontainingprimaryUI elements, animation objects, and input handlers.
- Settingup ControlNodesfor organizing user interface components like buttons, quiz panels, and progress indicators.
- Defining singleton autoload scripts for managing global variables, user data, and settings.
- Loading essential assets such as textures, fonts, and animations during the ready()function of the root scene.

```
//SampleGDScriptforinitialization func
_ready():
    load_resources()
    setup_ui()
    initialize_variables()
```

B. Key frame Animation System

Godot's Animation Player node is utilized to create smooth, movie-quality animations. Educators define key frames visually through Godot's editor or programmatically via GDScript.

- Animations control properties such as position, scale, rotation, opacity, and more.
- Animation tracks can be added for multiple objects within a scene.
- The engine interpolates between key frames to generate fluid transitions.

```
//SampleGDScripttoplayanimation func
play_animation(anim_name):
    $AnimationPlayer.play(anim_name)
```

C. GD Script Scripting Interface

The scripting inter face allows educators to embed inter activ- ity and control animation flow without complex programming:

- Signal connections handle user interactions like button presses, mouse clicks, or touch gestures.
- Quizlogic, variable manipulation, and real-time feedback are defined via simple GDScript functions.
- State management is implemented using enums or finite state machines to control different stages of the presentation.

```
//SampleGDScriptforquizresponsehandling
func_on_QuizButton_pressed(answer):
    if answer == correct_answer:
        show_feedback("Correct!")
    else:
        show_feedback("TryAgain!")
```

D. Data Collection

One of the key features of the engine is the real-time tracking of learner interactions. GDScript is used to record events such as quiz responses, time spent on tasks, and engagement metrics.

- Data is stored in structured CSV format using Godot's File class.
- Each interaction is time stamped, providing detailed logs for analysis.
- Data can be exported at the end of the session for further machine learning processing.

```
// Sample GDScript to write data to CSV
funcrecord_data(interaction_type,result):
    var file = File.new()
    file.open("user://interaction_data.csv",
    File.WRITE_APPEND)
    vartimestamp=OS.get_system_time_secs()
    file.store_line(str(timestamp) + "," +
    interaction_type + "," + result)
    file.close()
```

E. Machine Learning Integration

Though the engine itself is implemented in Godot, the collected data is exported and used externally for machine learning analysis. Python-based models (such as Decision Trees, Random Forests) process the CSV data to evaluate learner performance and provide insights.

- After exporting, the CSV data is fed into machine learning pipelines.
- Classification and regression models are applied to predict learner progress and recommend feedback.
- Results of the analysis can be re-imported to adapt future sessions.

F. Executable Export

The Godot Engine's export functionality allows the entire project to be compiled and distributed as a standalone executable:

- The engine is exported as an .exe file for Windows, ensuring educators and learners can run the presentation without needing the

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Godot environment.

- Export templates provided by Godot ensure compatibility across multiple platforms (Windows, Linux, mac OS).

V. RESULTS AND DISCUSSION EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

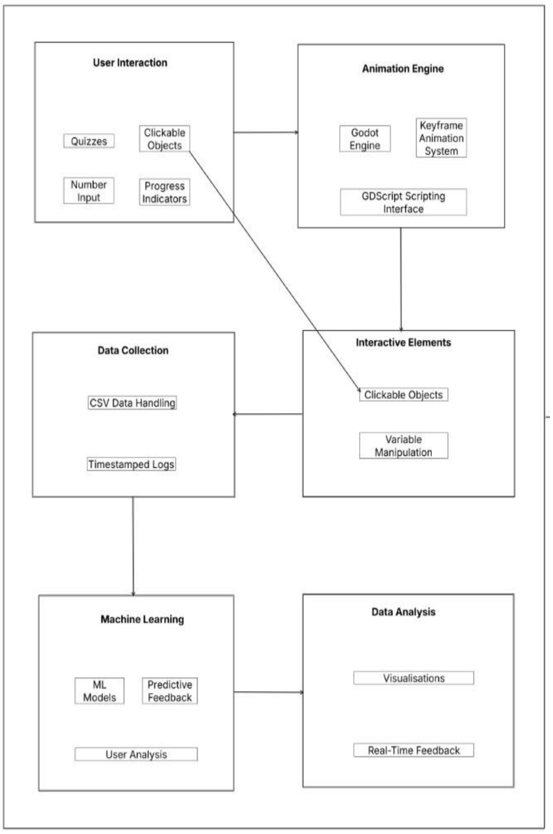

Fig.1.ArchitectureDiagram

VI. DUTCHNATIONAL FLAG

The DNF Problem model achieved excellent accuracy, with an R-squared score of 1.00, indicating near-perfect prediction capability. The analysis shows the Random Forest Regressor effectively identifying whether the color sorting was successful. The model's error metrics, such as Mean Absolute Error (MAE)of0.06 and Root Mean Squared Error(RMSE)of0.12, suggest a high level of precision in score prediction. Predicted entries for players exhibits core variations ranging from2 to 9, accompanied by remarks like "Correct! The colors are properly sorted!" and "Not quite right. Keep trying!" Despite occasional fluctuations, the model consistently offers valuable insights into sorting accuracy and performance trends.

Metric	Value
MeanAbsoluteError(MAE)	0.06
MeanSquaredError(MSE)	0.01
RootMeanSquaredError(RMSE)	0.12
R-squared(R^2Score)	1.00

TABLE I Performance Metrics for Dutch National Flag Algorithm using Random Forest Regressor

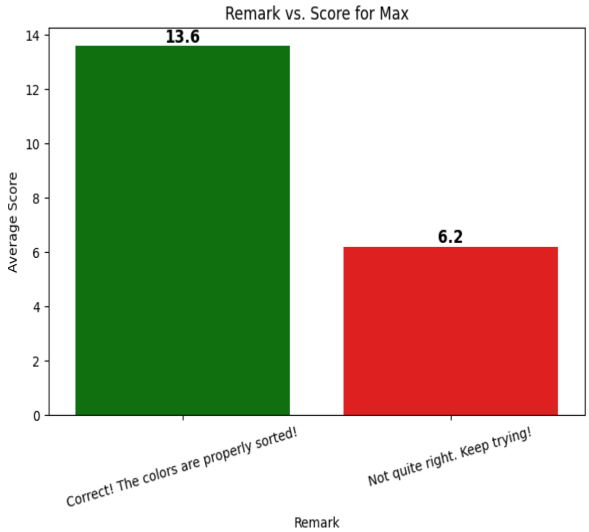

Fig.2.RemarkvsScoreForMaxInDNF

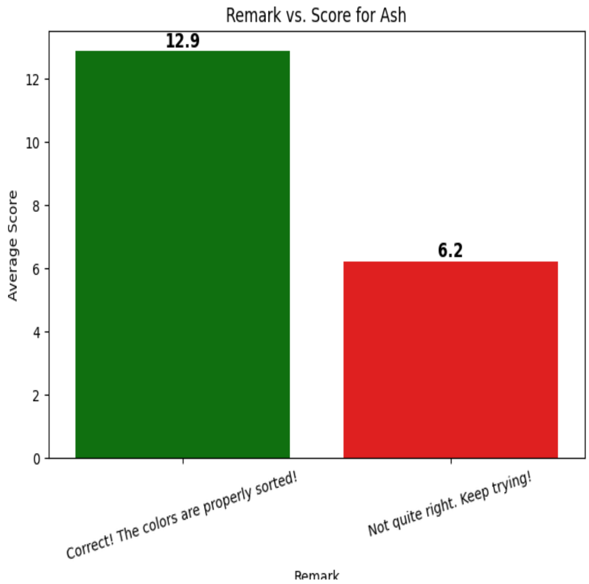

Fig.3.RemarkvsScoreForAshInDNF

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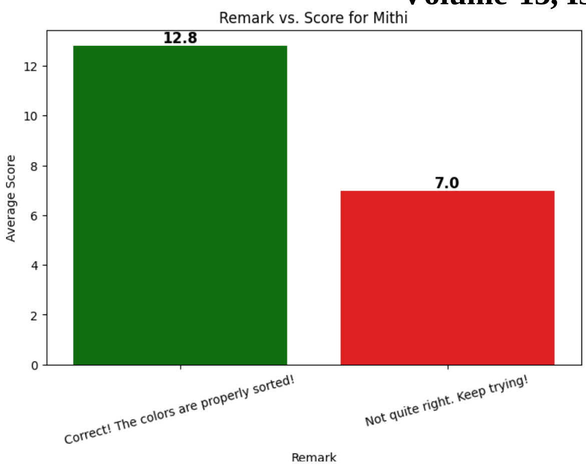

Fig.4.RemarkvsScoreForMithiInDNF

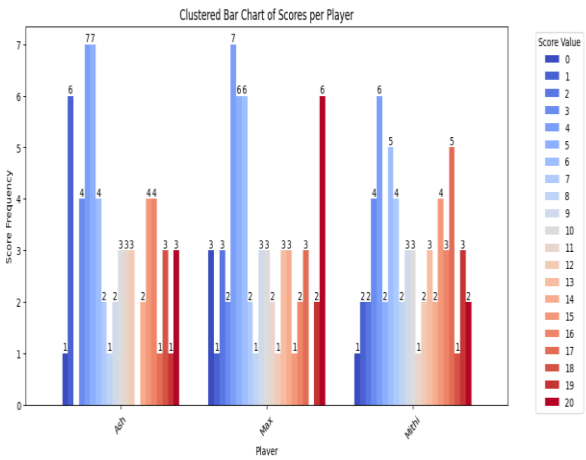

Fig.5.ClusteredBarChartOfScoresPerPlayerInDNF

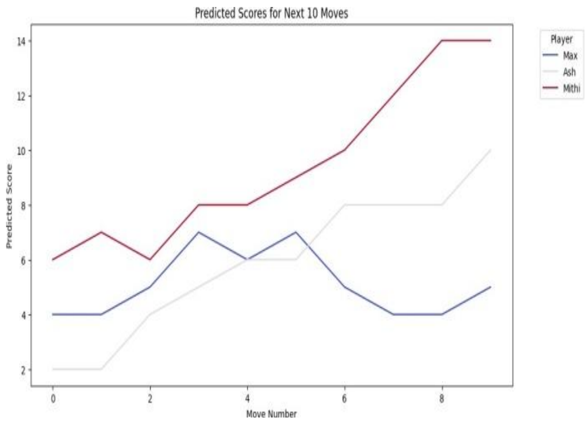

Fig.6.PredictedScoresForNext10Moves(Dynamic)InDNF

VII. TOWERS OF HANOI

The Tower of Hanoi model was evaluated using Decision Tree Classifier and Support Vector Machine (SVM) Classifier approaches. The Decision Tree Classifier achieved high classification accuracy of 95% , correctly distinguishing between ”Solved!” and ”Keep trying” outcomes in most cases. The classification report indicates strong precision and recall for the ”Keep trying” class, with slightly lower recall for ”Solved!”cases. In contrast, the SVM Classifier demonstrated lower accuracy of 43%, with inconsistent performance, particularly in identifying ”Solved!” cases. Overall, the Decision Tree Classifier outperformed the SVM Classifier, providing reliable classifications of learner performance across varying disk counts.

Decision Tree Classifier				
Class	Precision	Recall	F1-Score	Support
Keeptrying	0.94	1.00	0.97	17
Solved!	1.00	0.75	0.86	4
Accuracy	-	-	0.95	21
Macroavg	0.97	0.88	0.91	21
Weighted avg	0.96	0.95	0.95	21

TABLEII
Classification Report for Tower of Hanoi using Decision Tree Classifier

SVMClassifier				
Class	Precision	Recall	F1-Score	Support
Keeptrying	0.86	0.35	0.50	17
Solved!	0.21	0.75	0.33	4
Accuracy	-	-	0.43	21
Macroavg	0.54	0.55	0.42	21
Weighted avg	0.73	0.43	0.47	21

TABLEIII
Classification Report for Tower of Hanoiusing SVM Classifier

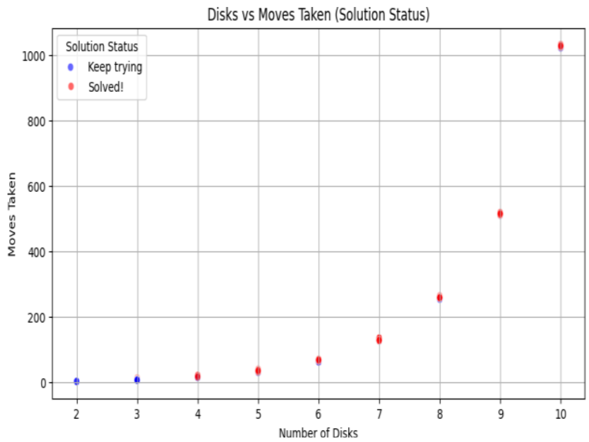

Fig.7.DisksvsMovesTakenInTowersOfHanoi

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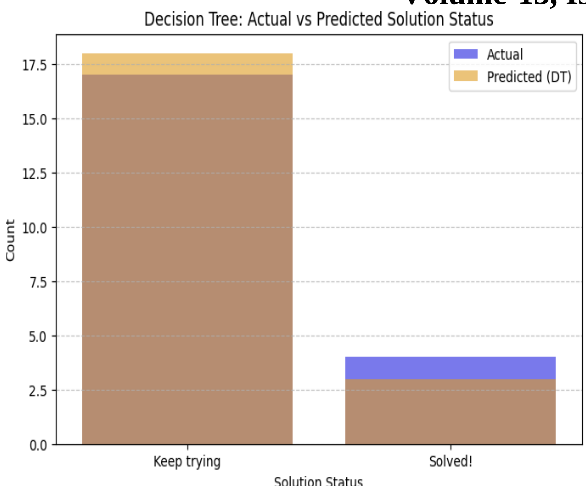

Fig.8.ActualvsPredictedSolutionStatusInTowersOfHanoi

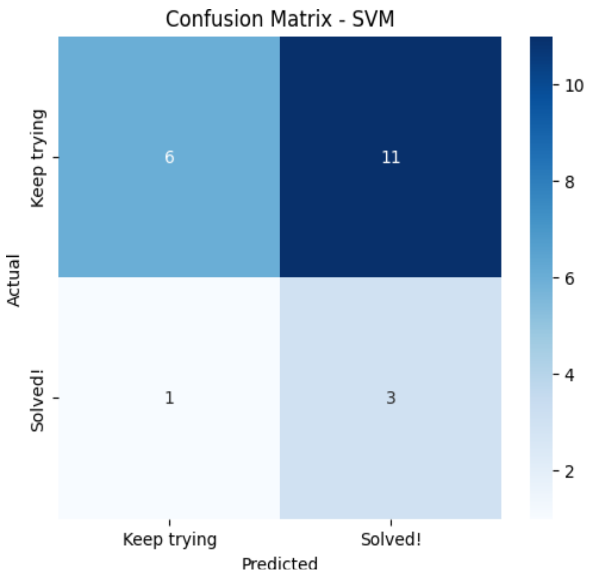

Fig.9.ConfusionMatrixForActualvsPredictedInTowersOfHanoi

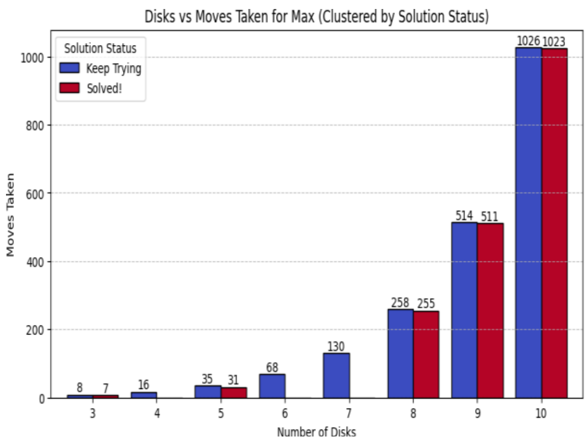

Fig.10.DisksvsMovesTakenForMax

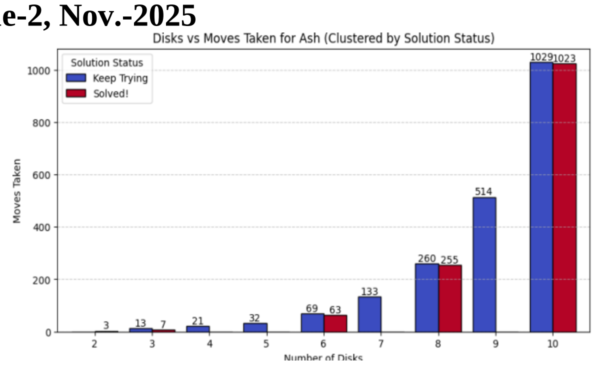

Fig.11.DisksvsMovesTakenForAsh

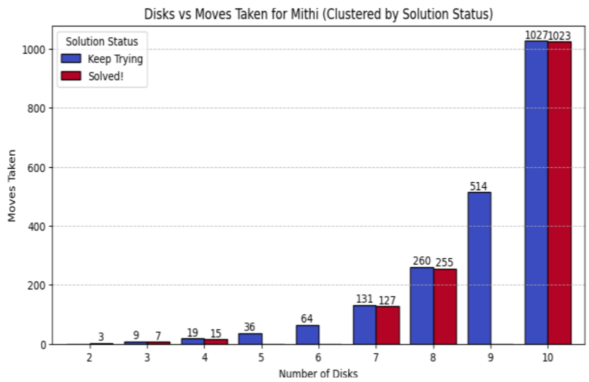

Fig.12.DisksvsMovesTakenForMithi

VIII. JOSEPHUS PROBLEM

The Josephus problem model demonstrated high classification accuracy of 94% using Random Forest Regression as indicated by the evaluation metrics. The classification report reveals strong precision and recall for predicting wrong moves, especially for classes with higher support counts. However, certain classes such as those representing fewer wrong moves exhibited lower predictive precision due to imbalanced data distribution. Predicted results for different players showcased variability in the number of wrong moves across rounds, highlighting the inherent complexity and randomness of the problem. Despite occasional misclassifications, the model provides valuable insights into learner behavior and areas prone to errors in the Josephus problem.

Metric	Precision	Recall	F1-Score	Support
Accuracy	-	-	0.94	31
MacroAvg	0.73	0.77	0.75	31
WeightedAvg	0.91	0.94	0.92	31

TABLEIV
Classification Report Summary for Josephus Problem using Random Forest Regression

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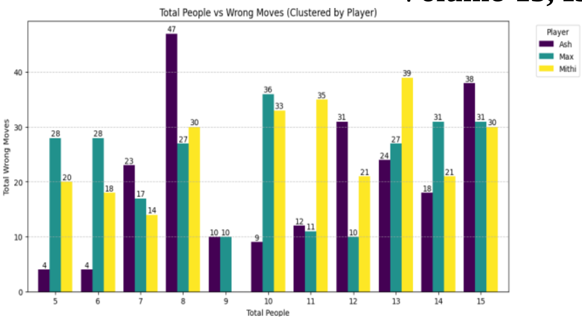

Fig.13.TotalPeoplevsWrongMovesForEveryPlayer(Clustered)InJosephus Problem

Fig.14.TotalPeoplevsWrongMovesForMaxInJosephusProblem

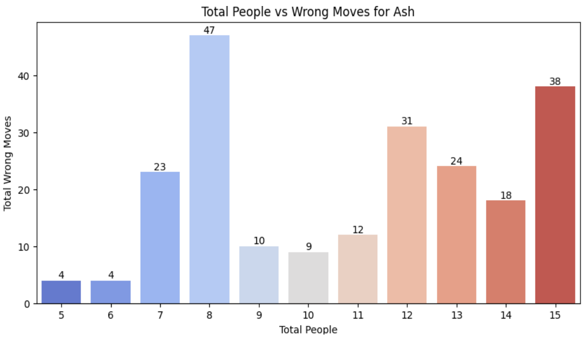

Fig.15.TotalPeoplevsWrongMovesForAshInJosephusProblem

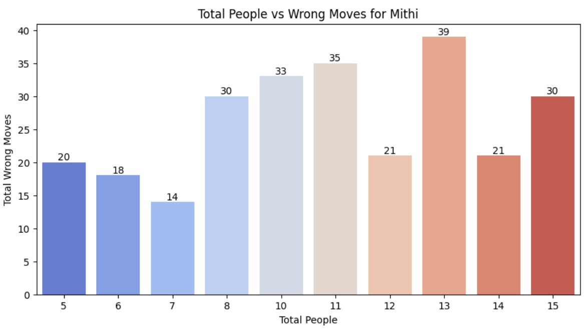

Fig.16.TotalPeoplevsWrongMovesForMithiInJosephusProblem

IX. N-QUEENS

The N-Queens problem model achieved a moderate clas- sification accuracy of 56% using Decision Tree Classifier effectively distinguishing between “Correct placement” and “Invalid placement” scenarios to some extent. The classi- fication report shows balanced yet slightly lower precisionand recall scores, especially for the class representing invalid placements, which is likely due to data imbalance. The model demonstrates reliable predictions for smaller board sizes, though the variability increases as complexity rises. Player- specific analysis indicates that most predicted outcomes align with the actual queen placements, offering useful feedback, although there is room for improvement to enhance model consistency across larger board configurations.

Class	Precision	Recall	F1-Score	Support
0(CorrectPlacement)	0.70	0.59	0.64	27
1(InvalidPlacement)	0.39	0.50	0.44	14
Accuracy	-	-	0.56	41
MacroAvg	0.54	0.55	0.54	41
WeightedAvg	0.59	0.56	0.57	41

TABLEV
Classification Report for N-Queens Problem using Decision Tree Classifier

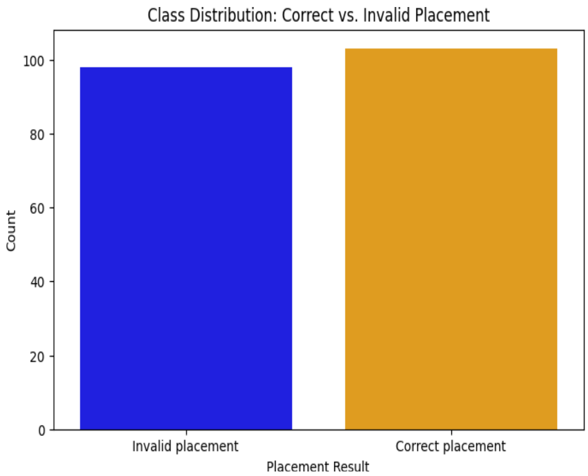

Fig.17.CorrectvsInvalidPlacementInN-Queens

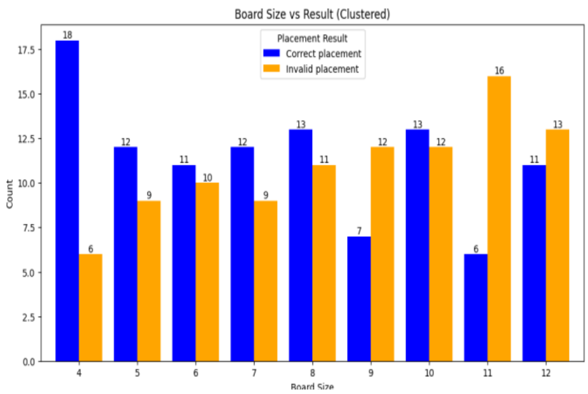

Fig.18.BoardSizevsResultInN-Queens

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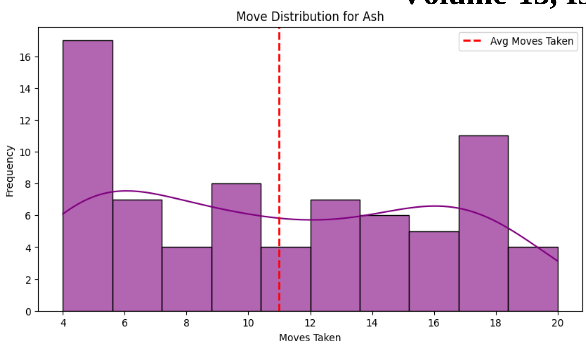

Fig.19.MoveDistributionForAshInN-Queens

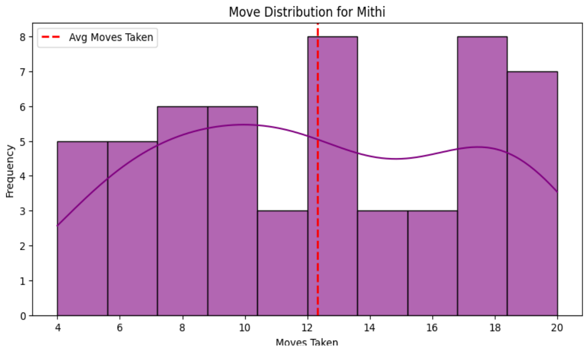

Fig.20.MoveDistributionForMithiInN-Queens

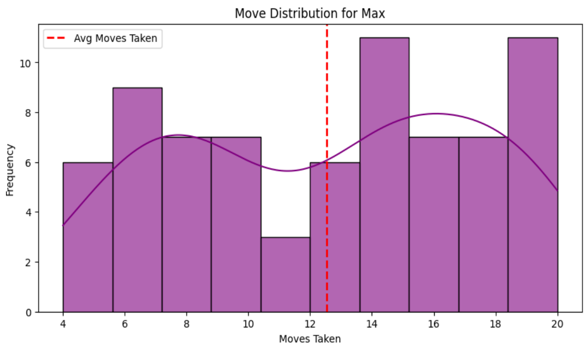

Fig.21.MoveDistributionForMaxInN-Queens

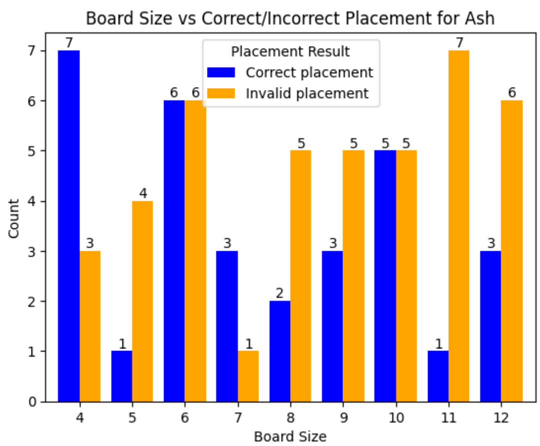

Fig.22.BoardSizevsResultForAshInN-Queens

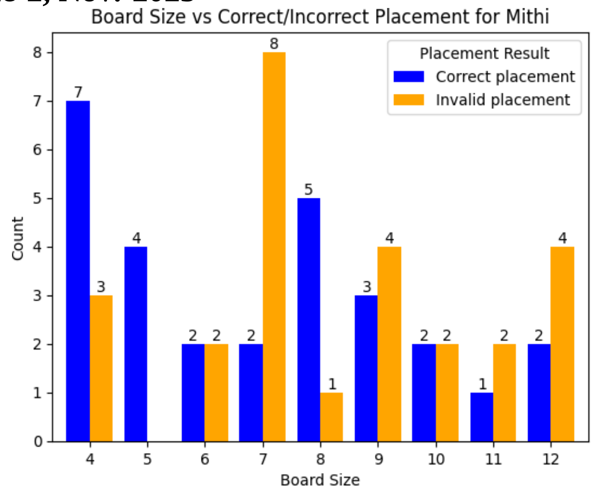

Fig.23.BoardSizevsResultForMithiInN-Queens

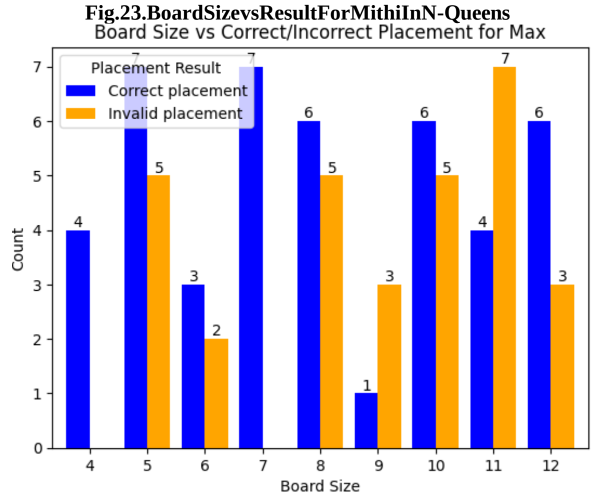

Fig.24.BoardSizevsResultForMaxInN-Queens

X. CONCLUSION

The development of the Animation Game Engine for Interactive Presentation of Educational Media represents a substantial contribution to the advancement of educational technology. By integrating animation, interactivity, and data-driven feedback into a unified platform, the engine addresses key challenges in modern education, particularly in conveying complex concepts in mathematics, science, and computing.

The current implementation has demonstrated effectiveness in delivering dynamic and engaging educational content. Testing confirms the engine's ability to render smooth keyframe animations, capture user interactions, and

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provide personalized feedback based on learner performance. Furthermore, the engine's user-friendly interface ensures that educators with minimal technical expertise can create interactive presentations, fulfilling the project's core objectives.

However, there remain significant opportunities for future enhancements. One primary area for future development involves expanding the interactivity within the engine. Planned features include additional interaction types such as drag-and-drop capabilities, annotation tools, and collaborative learning environments where multiple users can interact simultaneously within the same presentation. These enhancements will further enrich the learning experience by allowing students to engage actively and collaboratively.

Another focus will be on improving the adaptability of the engine. Enhancements to the keyframe parser are anticipated, allowing for the support of more complex animations and transitions. This will offer educators greater flexibility and creativity when designing lesson content, making it easier to represent intricate processes or step-by-step algorithmic solutions.

Additionally, refining the data analytics module remains a priority. Incorporating advanced machine learning techniques will allow for deeper analysis of student engagement patterns, helping predict areas where learners may need additional support. Enhanced data privacy protocols will also be implemented to align with evolving data protection standards, ensuring the security and confidentiality of user data in educational contexts.

Finally, continued optimization efforts will focus on ensuring the engine remains lightweight and resource-efficient, maintaining compatibility with basic computing infrastructure. This will uphold the engine's commitment to supporting sustainable, low-cost, and eco-friendly digital education solutions, especially in regions with limited technological resources.

Through these ongoing improvements, the animation engine is positioned to evolve into a scalable, adaptable, and impactful tool, redefining interactive education for a diverse range of learners and educators.

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