Brainy A Game-based E-learning Application for Preschoolers

***Abstract*— At present, kids belong to a generation growing up with computers, tablets, and access to the internet. Game-based E-Learning applications are one of the multimedia contents developed to support their educational necessities. These applications remained the same without any technical upgrades for decades. In addition, the homogeneity of the activities associated with these applications is now negatively highlighted. Nevertheless, kids are heading back from these tedious apps and show an excessive tendency to watch television, play video games, or access social networking sites. As a result, there is a growing social discourse that kids should be kept away from technology, mainly due to addiction and wastage of time. However, it is a crucial and damaging step in a technologically evolving world. Furthermore, existing applications have failed to build a precise combination of technology and real-world activities and objects. The proposed game-based e-learning application, entitled "Brainy," is planned for preschoolers aged three to five. It can expand the kids' minds and improve their various skills with more latest and practical activities based on the four latest technological features; Augmented Reality, Voice Recognition, Camera Object Detection and Recognition, and Pose Detection. These features allow kids to interact more with real-world objects and activities. Brainy mobile application pursues to provide kids with a comparable experience of wasting time, but it effectively devotes some of that time to education and enriches preschoolers' education by incorporating the technologies mentioned above. This application can be utilized in the homeplace, preschools or any other environment over any mobile device to encourage the kid's education.**

Keywords*— *Augmented Reality (AR), Object Detection, Voice Recognition, Pose Detection, Brainy, Digital Natives, Game-Based E-Learning, Game Based Learning (GBL)

I. INTRODUCTION

During the preschool years, which encompass the first six years of life, kids inquire about and search for their environment, move, explore, discover new things, and play games. Satisfying this need implies acquiring the information, skills, attitudes, and habits that will constitute the basis for kids' life. The sort of time spent with children has been favorably associated with their educational and cognitive results [1] . However, the conflicting time demands of parenthood and employment make it difficult to establish a balance between work and family time. When parents use their professions to show a positive relationship with their phones or tablets, they will have a much easier time educating their kids on utilizing smartphones efficiently. Due to these issues, there was a need of specific applications that are appropriate for kids.

Kid's mobile applications concept have been growing globally for decades. These applications can be divided into Game-based Learning (GBL) apps for kids and kids' mobile game apps. Parents strive to advance their children's education and knowledge from an early age. As an outcome, GBL applications play a major role in application stores that are designed specifically for preschoolers and in-demand of the two categories mentioned previously. GBL is an innovative teaching approach that reinforces development and learning through gameplay [2]. Numerous experts now believe that gamification in education can more effectively encourage today's entertainment-driven learners to participate in learning more deeply using meaningful storylines and game-play activities defined within the game design context.

Nowadays, children represent a generation that grew up with computers, tablets, and internet access. In [3] ,Marc Prensky called this generation "*Digital natives*", acknowledging that digital language is an essential component of their life and that it has the potential to alter their thinking patterns. GBL apps are one sort of entertaining multimedia content developed to support digital natives' educational necessities, and these applications are used to give education effectively and in a systematic context, such as a preschool, which seriously influences a child's future life. That is why many researchers have tried to create a better kids GBL application.

In terms of E-learning concept, there are typically three major components that directly influence the development of E-learning applications: kids, technology, and educators (guider). Design procedures, teaching-learning methodologies, and content are all conditioning aspects for learning in terms of technology [4]. In terms of design, pedagogical applications for children must use graphics and actions that provide context; they must use simple and clear instructions, based on images; they must have an intuitive interface and interactivity for independent use, but also a challenging approach with multiple opportunities for success, to maintain interest [5]. GBL apps which are developed in accordance with above terms have been popular among kids for decades, relying solely on same two-dimensional space-based technology.

However, these available applications do not appear to be up to date with existing technical features. In addition, the homogeneity of the activities associated with these applications is now negatively highlighted. As a result, today's digital natives are heading back from these tedious apps, as well as tending to waste their time on other platforms. Recent studies indicates that whatever the digital media content used should be age-appropriate and meaningful to children, allowing them to explore multiple areas: intellectual, physical, and emotional while providing opportunities to enhance learning with extra-curricular activities [6]. In fact, the question is to what extent this requirement is covered by existing game-based E-learning applications.

The deficiencies of existing applications are intended to be resolved by the "*Brainy*" application which incorporates four latest technological features: Voice recognition, Augmented Reality, Object detection and Recognition, and Pose detection. These features enable children to interact with and improve their skills with real-world objects and activities. *Brainy* is a story-based game that consists of various chapters, as in **Error! Reference source not found.** . Each chapter may have various objectives/tasks built up with the support of technologies. Four subsystems manage

these activities, and the augmented Reality subsystem will be highlighted in detail in this research paper.

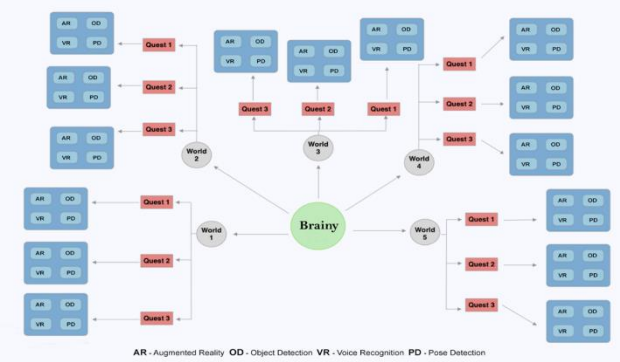


Figure 1- Game Design

II. Related Works

This section reviews the related studies on game-based learning applications that developed using each technology. Intention of this analysis is to find applications of those technologies that can apply to develop game design in **Error! Reference source not found.**.

Various game-based learning apps are available on app stores for concepts, including sorting things, classifying, studying nature and shapes, listening to stories, mathematics and other subject areas that are included and considered necessary in the preschool curriculum in any country. Most of these products were made entirely in two dimensions (often cartoons) [7]. To accomplish the game's objective, the kid may wait patiently for anything to appear, listen to something, type, click a button, or drag - and - drop; this is the earlier approach, as aforementioned. There is no correlation between the content of games and the natural world or the physical characteristics of anything.

There have been significantly lower attempts to build a GBL app for preschoolers and other games using Augmented Reality (AR). Some of the games built for non-academic purposes are outlined below.

1) AR Game for Motor Assessment of Parkinson's diseases patients [8].

2) AR Games to Assesses Upper Extremity Motor Dysfunctions [9].

3) *MoleARlert* - an augmented reality game based on lemmings [10].

Moreover, a recent study in [11] demonstrates how markers (image pointers) attached to real-world objects are captured and processed by a computer using image processing methods. After identifying the placement, a 3D virtual object is superimposed on the marker in the actual footage. This is the common approach that many AR E-learning application uses. In contrast, *Brainy* is intended to design without markers and to define scenario-based activities and three-dimensional(3D) objects. Flavor Game [12] is another application designed for children aged 10-12 that promotes autonomy and enthusiasm for making healthy food choices. It is intended to be used in schools where the instructor serves as the game master. In this study [13], shows an application that uses AR technology to teach basic mathematics for preschoolers using marker-based system as used in [11]. This outstanding game [14] , made for kids to identify animals and other objects such as vegetables and fruits, used augmented reality technology. [15] shows kind of apps uses AR to storytelling with storybooks.

ABC Mouse [16] is a complete preschool application that includes a variety of activities which are target for younger children and this application includes hundreds of interactive games, exercises, reading, arithmetic, science, art, and drawings. *Sago Mini World* is a children's learning game that offers emotional intelligence, creative problem solving, and self-confidence to children [17].

[18] shows about an application that was created to assist Arabic children in teaching other languages. The program makes use of technologies such as speech recognition, augmented reality, and object recognition. Research [19] explores an application that uses AR technology to teach Chinese characters to children. However, it shows an educational pattern that is limited to devices.

III. Proposed Solution

This section describes the proposed solution and system design that illustrated in Figure 2 and Figure 3 .

The main purpose of Brainy application is to create and deploy a game-based e-learning application for children that allows them to gain more knowledge in the most straightforward manner possible while also interacting with the real world in accordance with the four primary technologies:

1) Augmented Reality

2) Pose Detection

3) Object Detection

4) Voice Recognition

This application aims to give children comparable experiences instead of squandering time, allowing them to commit some of that time to study and enhance their academic opportunities. Therefore, our purposed solution in Figure 2 is to help develop the child's mind or boost their education via newer activities (based on or required to perform real-world activities/ physical movement) by utilizing a specific combination of technology in a controlled environment.

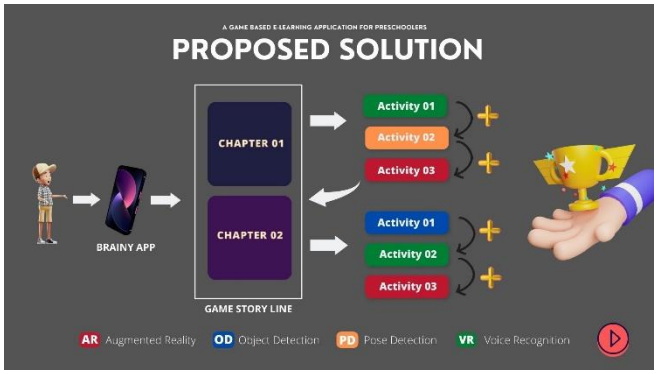


Figure 2: Proposed Solution – Brainy

As shown in Figure 2 above, this mobile GBL app is based on storylines (e.g. Story of The Tortoise and the Hare) Each storyline is classified into different chapters, each containing numerous distinct activities: voice recognition-based activities, object detection-based activities, augmented reality-based activities, and pose detection-based activities. Activities under specific chapter focuses on a teaching and enhancing the knowledge under a certain subject/ skill (Mathematics, Science, Language and Visual perceptual skills etc.)

After that, the following step consisted of designing each activity utilizing each concept. To ensure the reliability of the system design Figure 3, we followed the methods outlined in Section IV and shown in the picture below.

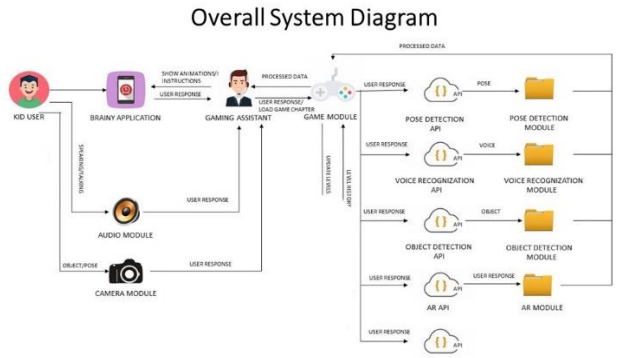


Figure 3: Overall System Diagram of Brainy Mobile Application

IV. METHODOLOGY

This section discusses the procedures used when applying each of the technologies described in Section III to the design and development of the Brainy mobile application.

A. Overall softwares used for the design and development in each core technology

A vast array of software is available to develop mobile gaming applications. However, the Brainy application developed utilizing Unity 3D, which can be downloaded and used for free. Unity Hub is an improved platform that provides a 3D game engine in a user-friendly environment throughout the development and deployment phases. Further, this directly supports the development of cross-platform augmented reality apps. The Unity engine includes essential development support for the C Sharp (C#) programming language, which is also the default language. Unity is used in several popular mobile apps, including Temple Run 2 and Pokémon Go.

Figure 4 depicts the under-development progress for the Unity 2021.3.11f1 LTS (Long-Term Support) version.

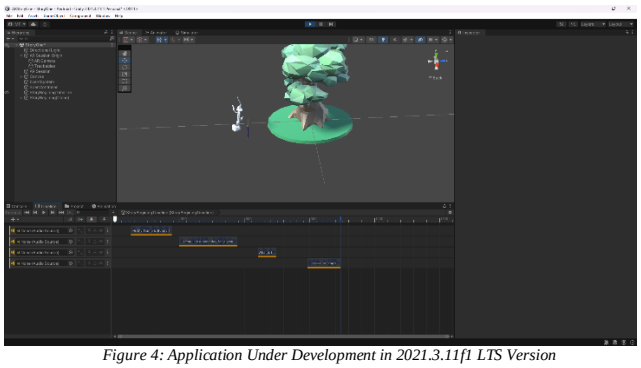


Figure 4: Application Under Development in 2021.3.11f1 LTS Version

B. Augmented Reality

Augmented reality is a technology which introduces and replaces the existing world with a simulated one or virtual contents such as 3D computer-generated data (objects, texts and sound, onto real images and video), where computer graphics objects are blended into real world footages at real time [3] Augmented reality applications improve the attention skills, motivational skills or concept skills of preschool children [4].

AR subsystem plays a vital role in developing a sense of curiosity in kids by allowing them to interact directly with 3D characters and objects generated with it in Brainy application. Below are some of the AR based activities planned to be embedded in the game

1) Storytelling
2) Math/Science activities
3) Object Identifying activities

To design such set of activities that can embedded in the game, it is necessary to accomplish the following objectives.

1) Modelling and animation of 3D models of the characters and Objects

According to Brainy's story mode, each chapter and task may contain many 3D objects and characters. These 3D elements are developed from scratch using Blender 3D software. Figure 5 shows the rigged 3d model of the popular Bugs Bunny character, made in blender 3D. Rigging a 3D model creates a skeleton that animation software can recognize all the bones and joints of a character by their vertices.

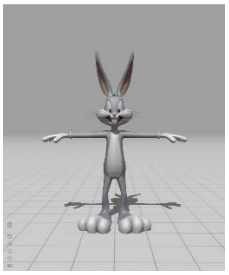


Figure 5:Rigged Bugs Bunny Character Made in Blender 3D

Furthermore, Mixamo, free software provided by Adobe CC, is used to animate these rigged 3D models. Mixamo also provides auto rigging features as well as they have over 3000+ pre-animated presets, which make it more accessible and faster to animate 3D models. Figure 6 shows

image sequence (few frames) from the animated video of the Figure 5 3D model.

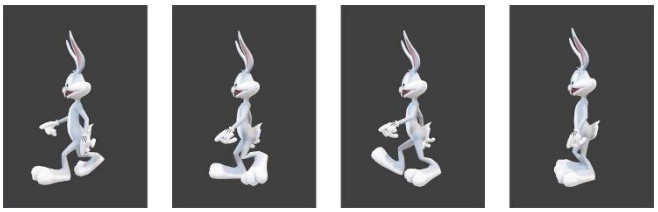


Figure 6: Bunny character animated using Adobe Mixamo (Image Frames)

2) Implement main functionalities AR subsystem:
AR implementation completely done using Unity 3D engine, with the aid of Unity AR Foundation package which is cross platform framework that allows to build either Android or iOS. In Brainy application, AR activities are accessible via two distinct methods

a)Marker-based augmented Reality: A static image or trigger photo that a game player may scan with their mobile device via an augmented reality app is required for marker-based augmented reality experiences. The animated scenes/objects generated in the previous stage will appear on top of the marker as a function of the mobile scan. Brainy marker databases are kept locally, and recognition also operates on the device.

b)Markerless augmented Reality: Markerless augmented reality works by scanning the surrounding environment and there is no trigger photo necessary to retrieve the augmented reality content.

Furthermore, to use AR foundation on target devices. It is necessary to install corresponding packages for each platform. Therefore, the ARCore XR Plugin for android & ARKit XR Plugin for iOS respectively installed to the unity project via package registry.

3) Implement AR 3D object controlling scripts:
The game player must be able to control AR 3D element (Character/Object) to play the game activities. The following actions were created using C# in unity 3D.

a) Spawn Object
b) Rotate Object
c) Scale Object
d) Remove Object
e) Lock Object

These actions represent a single script that is reusable and can be embedded into planned gameplay activities/tasks.

After completing the above objectives, after completing the above objectives, the requirements needed were met for the next step of production, which is to produce gameplay activities. The commentary on the results is depicted in Section V.

C. Pose Detection

"Position estimation" or "Human pose detection," means an artificial intelligence(AI) system that analyzes photos using machine learning methods. The concept is that using a camera and a little bit of magic, algorithms based on neural networks recognize human poses and monitor bodily motions in real time. That's a high-level summary of the computer vision algorithms used to track a person's stance at each given moment.

The pose detection module is one of the essential modules in the Brainy application and consists of several sub-modules called finger count detection and action recognition. Each model controls all the pose-related activities in the application, like finger counting, Exercises, and Hand gesture.

1) Finger Count Detection Sub Module:
This component will first accept an input image or frame and, using the solution provided by the Media pipe, identify critical landmarks on the hands in the image or frame. As shown in Figure 7 Twenty-one 3D landmarks will be generated for each hand in the image.

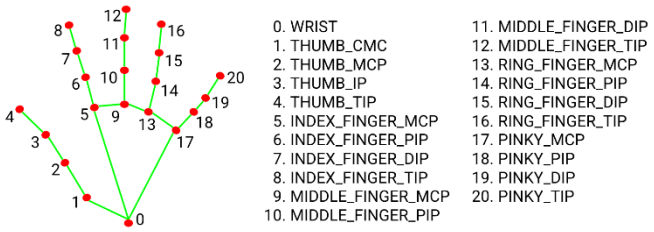


Figure 7: 21 Hand Landmarks

The module will then make use of the landmarks to count the fingers on each hand in the image or frame and preserve the count as well as the state of each finger.

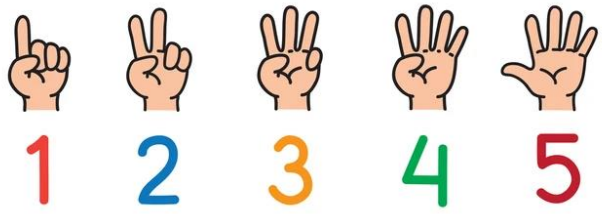


Figure 8: Numeric Hand Finger Positions 1 to 5

The module will compare the y-coordinates of each finger's FINGER_TIP landmark and FINGER_PIP landmark to determine whether each finger is active (i.e., up, or down). The y-coordinate of the landmark FINGER_TIP will always be lower than the landmark FINGER_PIP whenever the finger is up.

As shown in Figure 9, The situation will be slightly different for the thumbs, however. For the right hand, whenever the thumb is open, the x-coordinate of the THUMB_TIP landmark will be lower than the THUMB_MCP landmark, and for the left hand, the x-coordinate of the THUMB_TIP landmark will be higher than the THUMB_MCP landmark. While processing the status, the finger-counting module considers all these details.

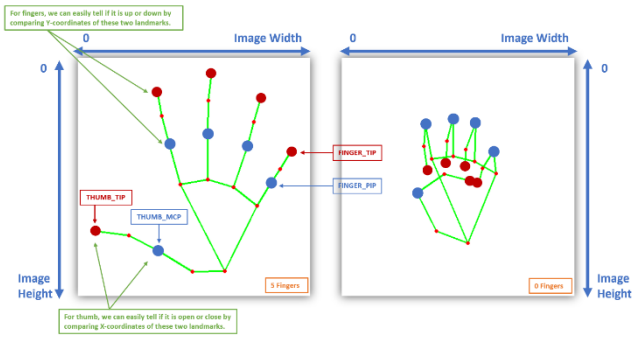
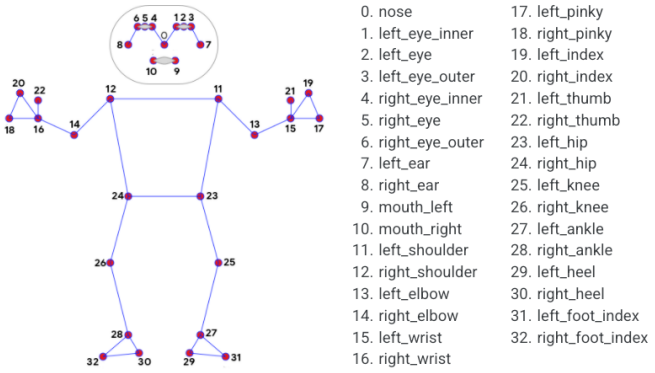


Figure 9: How media pipe process finger count

2) Action Recognition Sub Module:

This module was created using the MediaPipe pose detection facility. Media Pipe's Pose detection is a State-of-the-Art solution for high-fidelity (high quality) and low latency (very quick) for recognizing 32 3D landmarks (Figure 10) on a person in real-time video streams on low-end devices like phones and laptops. Also, Media pipe trained three models with different trade-offs between speed and performance. Media pipe's lightweight Blaze Face model inspires pose detection.



0. nose
1. left_eye_inner
2. left_eye
3. left_eye_outer
4. right_eye_inner
5. right_eye
6. right_eye_outer
7. left_ear
8. right_ear
9. mouth_left
10. mouth_right
11. left_shoulder
12. right_shoulder
13. left_elbow
14. right_elbow
15. left_wrist
16. right_wrist
17. left_pinky
18. right_pinky
19. left_index
20. right_index
21. left_thumb
22. right_thumb
23. left_hip
24. right_hip
25. left_knee
26. right_knee
27. left_ankle
28. right_ankle
29. left_heel
30. right_heel
31. left_foot_index
32. right_foot_index

Figure 10: Media Pipe Body 32 Landmarks

This module uses a python-based pose classifier which is trained using Media Pipe. As shown in Figure 11, This works as an Image classifier, where the module can pass an image to the classifier and get the class predictions out of it.

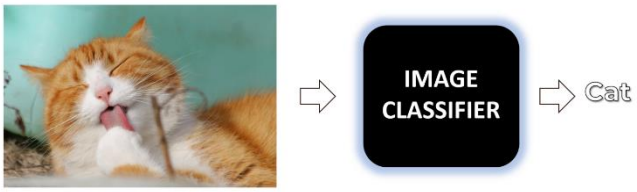


Figure 11: Image Classifier

As shown in Figure 12, Video is simply a series of several frames, or still, images, that are updated very quickly to give the impression of motion. This model takes frame by frame at a time and predicts the action. So this module uses an image classifier on each video frame to categorize each frame's action separately.

Figure 12: Video Classifier

In some frames, the classifier predicts Falling rather than Backflipping since this method disregards the temporal relationship between the frames' sequence like shown in Figure 13. And even if a person examines those frames on their own, they can believe that the subject is falling. This module's answer is to take the probabilities of the forecasts and average them to produce a more reliable result.

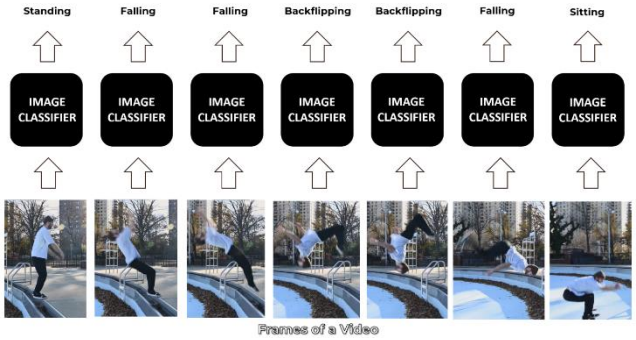


Figure 13: Frames of a Video

Both these finger count detection and action recognition modules are implemented with python and hosted in the cloud platform for use. Those modules act as APIs.

D. Voice Recognition

"Voice recognition" is the process by which a machine identifies, understands, and responds to a statement or instruction made by a human. It uses voice as a research object and uses speech signal processing and pattern recognition to allow machines to automatically detect and understand words spoken by humans. It is a multidisciplinary field that covers many topics and closely related to the fields of acoustics, phonetics, linguistics, information theory, pattern recognition theory, and neuroscience [14].

Machine learning is employed to develop the Voice recognition feature of this GBL application. Unity game engine Does not directly support a python-based machine-learning model; this machine-learning model is hosted on the AWS cloud and then interacts with the game via API calls.

The first challenge encountered while developing this application was the inability to recognize a child's voice. It is because kids' voices differ from ordinary people's voice patterns. Finding a data set generated using children's voices was not straightforward during this machine learning module's implementation. Consequently, a data set containing children's voices had to be formed. Based on this data set, the machine learning module was trained, and its accuracy is depicted in Figure 14.

NumPy, Wave, and PyTorch are just a few Python libraries that played a role in creating this ML model. Then, an interface was built to include the machine learning component in the Unity framework.

However, integrating this freshly trained model into Unity proved a bit of a challenge. As a solution, The team came up with the idea of putting the machine learning model on the AWS cloud and interacting with the game using its APIs.

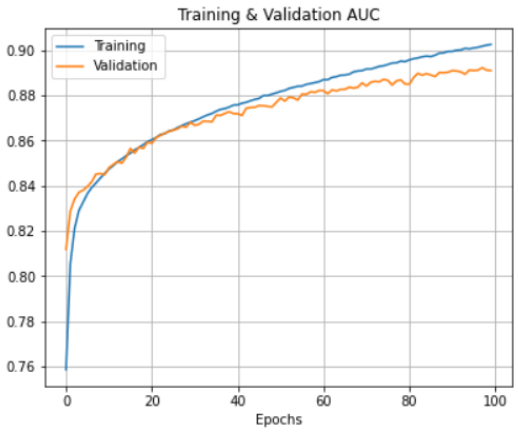


Figure 14: Accuracy of Voice Recognition Data Set

E. Object Detection and Recognition

Object detection and recognition technology is a modern visual technology that is used to identify and recognize objects. This visual object detection field is used to train computer machines to recognize the content of visual images as a human. Convolution Neural Network (CNN) is the regular way of doing object detection and it is used image classification techniques to process the given input.

The brainy application contains activities based on object detection and recognition technology that allows to recognize and find object in moving scenes. The brainy application uses a unity assets plugin for using OpenCV. This plugin support cross platform and it helps to implement object detection-based activities on the unity platform. Mainly OpenCV version 4 and Mobile SSD use to create the object detection model and many optimization techniques have been used when object detection-based activities design to increase the performance in the application. Object detection activities are designed based on following techniques.

1) Image classification:

It is the initial step of the object detection model. This is the process of categorizing and labeling the given input. The classification model takes the given image as the input and the primary goal of the image classification is to assigns specific labels to images and, processes the given input to calculate the probability and the accuracy to achieve maximum possibility accuracy

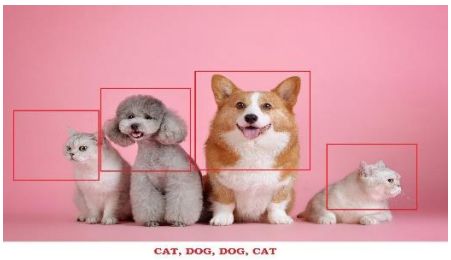
2) Image Localization:

It is a one of image recognition task in OpenCV. This process takes classified images data as input and the localization algorithm precents a bounding box based on the image and the detected objects.

3)Object Detection Algorithm

Object detection algorithm works as the final stage to generate an image with a combination of image classification and image localization.

The algorithm works to produce bounding boxes with object class labels and finally generates images with the detected objects as the output.



V. RESULTS AND DISCUSSIONS

The game-based learning application named "Brainy" **Error! Reference source not found.**, featured in this research, has been utilized to evaluate the capabilities of children in the preschool learning stage (ages 3 to 6). This section covers the findings that were acquired and a discussion of those results. For the best possible experience, the kid's first attempt at playing the game must assist with mastering the fundamentals of the application; it is preferred that the game be played under the supervision of an adult at the beginning, so they are comfort with the gameplay controls. Furthermore, the presented application will be enhanced to satisfy the international criteria of a preschool so that it may be incorporated into its curriculum.

Figure 15:Brainy Application Loading Screen

Figure 15 shows the loading page with the logo of application.

Figure 16: Main Screen of the developed application

The game's main menu screen, depicted in Figure 16, is where the player can start gameplay. The "Start" button initiates gameplay in the game's Story or Campaign mode. In addition, the menu lists the current score, the completed achievements, and all other typical game settings. The next screen, shown in ss, reveals the campaign map; nevertheless, access to some chapters is restricted until specific in-game objectives have been met.

Figure 17: Hare and the Tortoise Story - Campaign Map

Here begin the activities comprised of the methodologies outlined in Section IV; AR is the story's primary narrator and continues to do so throughout each chapter. In the middle of the story, several preschool curriculum-related questions are asked, and the child is expected to perform/answer the issue via activities made of three other technologies. This first tale is about "The Tortoise and the Hare" this actual story has been expanded, and questions have been formed from it. The first narrative scenario is depicted in Figure 5.

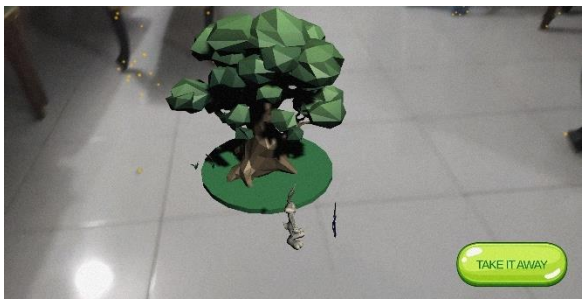


Figure 18: First AR Story Scene

In the first story rabbit ask the player to take away the scissor shown in Figure 18, in order to perform that player needs to find a real scissor from the real world and take a picture of it. Figure 19 shows the object detection screen.

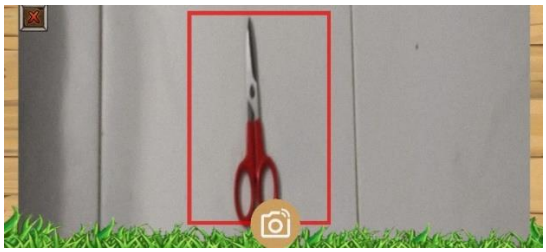


Figure 19: Capturing a Scissor Using Object Detection

Correspondingly, the story continues in AR, as shown in Figure 20 , and another question again asks from player to identify the AR element (Hints provided) and spell the word correctly in Figure 21. And another one to calculate the shown Number of carrots an perform hand pose activity like depicted in Figure 22.

Figure 20: Story Scene 2

Figure 21: Spell word CARROT Screen- Voice Recognition

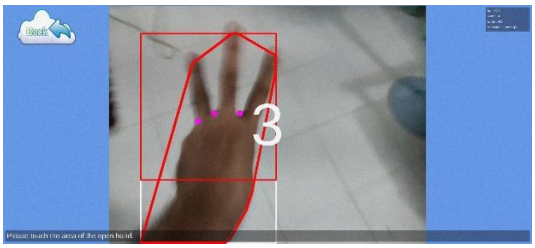


Figure 22: Finger Pose Detection

One of the most effective of playing this game is to have the children engage with real-world-based things and physical activities. Also, children can fulfil their curiosity by playing the game and interacting with 3D characters and objects thanks to AR. There are various activities that use the voice, such as the correct pronunciation of a word, simple math problems, and dictation. Children may benefit from this experience in developing their talents, particularly visual perception, memory, and endurance.

Figure 23: Level completed Screen

VI. Conclusion and Future Works

"Brainy-*Your kid's smart friend*", the game-based Learning application designed to assist preschoolers aged 3 to 6, has been successfully developed and implemented in this study.

In addition, this application was created with a distinctive façade and a new concept based on the most recent technology, which distinguishes it from the existing apps on the market and the traditional approaches employed in the preschool setting. A design like Brainy, which aids preschoolers in developing their minds or enhancing their education through seamless integration of technology and real-world activities, is necessary. The Brainy GBL program can detect and recognize objects, assess children's voices, and improve their vocabulary/listening skills. Detect and analyze kids' postures and engage kids in physical activities. Engage interactively via AR-generated 3D elements. Existing GBL applications previously limited to the scope of game designers will gain a new definition with the Brainy approach. Thus, "Brainy" will redefine the companionship offered by traditional GBL applications. The "Brainy" would be the next era of GBL apps, which will resolve various concerns in addition to the ones mentioned above.

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