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Real-time object detection and augmentation

Saikumar P * and Divya TL

Master of Computer Applications, RV College of Engineering, Bengaluru, India.

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Abstract

This study presents the development of a real-time object detection and augmentation system using TensorFlow and Unity it leverages TensorFlow model to identify and classify objects in real-time from a camera feed, and Unity to integrate and display corresponding 3D virtual objects in an augmented reality environment. By creating a mapping system to pair detected objects with their virtual counterparts, the system aims to enhance user interaction through dynamic and immersive AR experiences. The study addresses the challenges of real-time processing and seamless integration, demonstrating the potential of combining machine learning and augmented reality to enrich interactive applications across various domains.

Keywords: Augmented Reality (AR); Machine Learning (ML); Object Detection; Object Recognition; Real-Time Object Detection; TensorFlow.

1. Introduction

Augmented reality (AR) and machine learning (ML) technology have been used in recent years to greatly expand the potential of immersive and interactive applications. The goal of this project is to improve object recognition skills by utilizing cutting-edge augmented reality techniques. It investigates the creation and execution of a real-time object detection and augmentation system utilizing TensorFlow and Unity. This aims to create an interactive AR environment where virtual elements are seamlessly incorporated into the real world, driven by real-time object detection, by utilizing a pretrained TensorFlow model and integrating 3D virtual items.

Combining machine learning (ML) and augmented reality (AR) has become a game-changing method for improving immersive and interactive experiences in a variety of industries. Digital content is superimposed on top of the real world, developing an interactive setting that can improve functionality and user engagement.

Real-time recognition of items in the real world has become increasingly sophisticated and accurate thanks to recent advances in machine learning, especially in the field of object detection. The goal of this research is to create an augmented reality system that uses Unity's 3D rendering skills to add virtual components to physical things and TensorFlow's object identification capabilities to recognize and categorize them.

Object recognition has become a pivotal component of modern AR systems, enabling applications that range from educational tools to industrial automation. TensorFlow, an open-source machine learning platform, offers powerful tools for developing and deploying neural network models that can classify and detect objects with high precision. The MobileNet model, a lightweight neural network designed for mobile and edge devices, provides a practical solution for real-time object detection due to its balance between accuracy and computational efficiency. Unity, a leading platform for AR and VR development, facilitates the creation of interactive 3D environments and the integration of virtual objects into real-world scenes.

* Corresponding author: Saikumar P

The ability to create dynamic and interactive applications is greatly enhanced by the combination of Unity's augmented reality features and TensorFlow's object identification. Through the seamless integration of virtual elements, users can have improved interaction with their surroundings by utilizing real-time object identification. This has applications in education, retail, and industry. In education, augmented reality (AR) can make learning more engaging. In retail, virtual try-ons can improve the purchasing experience. In industrial settings, real-time data visualization can boost productivity.

This work aims to investigate the viability and efficiency of utilizing a pretrained TensorFlow model for real-time object recognition and augmentation in Unity. The study seeks to accomplish a number of important goals:

1.1. Real-Time Object Detection

To implement a system that continuously analyzes camera feed frames using TensorFlow's MobileNet model to detect and classify objects with high accuracy.

1.2. Augmentation of 3D Virtual Objects

To import and organize 3D models in Unity, creating a mapping system that pairs detected objects with their corresponding virtual representations.

1.3. Interactive AR Experience

To develop an interactive AR environment where virtual objects are dynamically added, moved, or removed based on real-time object detection, enhancing user engagement and interaction.

2. Material and methods

We first define meaning of some meterials and methods of object detection and augmentation that are used in the literature.The following are the materials that are used in the object detection and augmentation.

2.1. TensorFlow

An open-source machine learning platform developed by Google, used for building and deploying machine learning models. TensorFlow provides the infrastructure for implementing the object detection model. This work aims to investigate the viability and efficiency of utilizing a pretrained TensorFlow model for real-time object recognition and augmentation in Unity. The study seeks to accomplish a number of important goals:

2.2. Unity

A flexible and popular platform for game development that makes it possible to create engaging augmented reality (AR) content. The pretrained TensorFlow model is integrated using Unity, enabling the display of objects that have been detected in an augmented reality setting. It can handle interactions in the augmented reality scenario, render virtual objects, and import and manage 3D files.

2.3. Pretrained MobileNet Model

TensorFlow offers a convolutional neural network (CNN) model that is small, effective, and tailored for mobile and edge devices. Because MobileNet strikes a compromise between computing economy and performance, it is deemed appropriate for real-time object recognition in augmented reality applications. With little computing cost, objects are detected and classified from camera feeds using the pretrained model.

2.4. 3D Models

items from the actual world that are represented virtually and used in the AR environment. These models can be made specifically for the purpose or obtained from the Unity Asset Store. By superimposing precise three-dimensional depictions of identified objects, they improve the augmented reality experience. The MobileNet model maps the 3D models to items that are identified and integrated into Unity.

2.5. Camera

For analysis purposes, real-time video feeds are captured via an external or front-facing camera. The TensorFlow model uses the camera as its input device to receive the visual data required for object detection. The accuracy and functionality of the object detection system are influenced by the camera's quality and resolution.

The following are the Methods that are used in the object detection and augmentation.

2.6. Integration of TensorFlow with Unity

TensorFlowSharp, a.NET connector for TensorFlow that enables TensorFlow models to be run inside the Unity environment, was used to integrate TensorFlow with Unity. After being loaded into Unity, the TensorFlowSharp library was set up to communicate with TensorFlow. Furthermore, the suitability of Unity Barracuda, a lightweight cross-platform neural network inference library, was assessed. If necessary, the pretrained MobileNet model—which is renowned for its effectiveness and precision in real-time object identification tasks—was transformed into a format that was compatible with TensorFlow. The smooth loading and utilization of the model for processing the camera feed within Unity was guaranteed by this conversion.

2.7. Real-Time Object Detection

To facilitate real-time object detection, a continuous video feed was captured using a front-facing or external camera connected to the Unity application. The camera feed was processed frame by frame, with each frame being passed to the MobileNet model for analysis. TensorFlow's inference engine evaluated the frames to detect and classify objects present in the environment. The output from the model included detected object names, bounding box coordinates (defining the location and size of the detected objects), and confidence scores indicating the model's certainty about each detection. This data was parsed and interpreted within Unity to identify which 3D models should be augmented based on the detected objects.

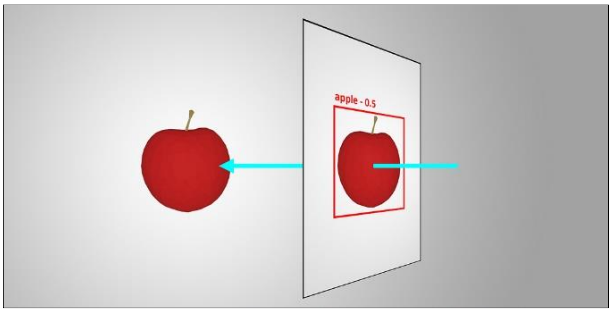

Figure 1 working of Tensor Flow

Figure 2 Results of Object Detection with Tensor Flow

Importing and Organizing 3D Virtual Objects: To depict the objects identified by TensorFlow, virtual 3D models were either specially made using 3D modeling software or taken from the Unity Asset Store. After being imported into Unity, these models were arranged inside a certain directory structure. Every 3D model was given a precise name and tag to correspond with the things that the TensorFlow model identified. To guarantee visual accuracy and consistency, this structure involved specifying the scale, orientation, and texture of each model. The effective retrieval and application of these models during the object detection and augmentation was made possible by good asset management.

Figure 3 Augmentation of Digital object after Detection

2.8. Mapping Detected Objects to Virtual Models

In Unity, a thorough mapping system was created to connect the names of identified objects with the matching 3D models. For this system, a lookup table or dictionary had to be developed, linking the name of every object that was recognized to a particular 3D model. The mapping procedure made sure that TensorFlow could swiftly consult the table to choose and become ready to augment the right virtual model when it spotted an object. The mapping system offers versatility in connecting detected items with the appropriate 3D representations because it was built to handle a variety of object types and variants.

2.9. Augmenting 3D Objects in the AR Environment

After a 3D model was found using the mapping system, it was created in the Unity scene using the bounding box coordinates that TensorFlow had supplied. The bounding box's coordinates and dimensions were used to precisely align the virtual model's position and orientation with the detected real-world object. Proper lighting and shadows were produced on the virtual objects to improve the AR experience's authenticity. The implementation of real-time interaction enabled the dynamic addition, relocation, or removal of virtual items from the scene in response to the detection of new objects or modifications to preexisting detections. An engaging and adaptable augmented reality was made possible by this dynamic augmentation.

3. Unity Setup

3.1. Development Environment and Tools

The "Advanced real-time object detection and augmentation" was developed using an NVIDIA GTX 1660 graphics card, 16GB of RAM, and an Intel Core i7 processor, which is a high-performance computer. Operating Windows 10 (64-bit) on the system guaranteed TensorFlow and Unity compatibility. Unity 2021.3.18f1 (LTS version) was chosen as the primary development platform for its strong support for augmented reality (AR) applications, while Visual Studio 2019 was utilized for C# scripting and debugging. Git, with GitHub for remote repository management, facilitated version control and collaboration, essential for tracking changes and coordinating efforts among team members.

3.2. Machine Learning and Model Integration

TensorFlow 2.x was employed for the machine learning component, particularly for object detection and classification tasks. TensorFlowSharp was integrated with Unity to enable model inference directly within the AR environment, though Unity Barracuda was also used as an alternative for some cases. The utilized 3D models imported from the Unity Asset Store, which were customized with Blender to match the specifications. C# was used for scripting within Unity, managing AR functionalities and interactions, while Python was used for model retraining and data preprocessing, leveraging TensorFlow's capabilities for adapting the model to specific objects.

3.3. Integration

The pretrained package from TensorFlow is integrated with Unity via TensorFlowSharp or Unity Barracuda. Unity can handle live video feeds for object detection with this configuration, producing object names and confidence ratings. This information is used by Unity to map identified objects to appropriate 3D models from the Asset Store, which are then dynamically positioned and placed within the augmented reality environment. As a result, virtual items can interact and be precisely augmented with real-world settings.

4. Results

An extensive summary of the Advanced real-time object identification and augmentation system's performance and efficacy is given in this results section. It draws attention to important elements like user experience, recognized problems, 3D model integration, processing speed, and accuracy of detection.

4.1. Real-Time Object Detection Accuracy

The TensorFlow MobileNet model was successfully integrated with Unity to provide real-time item identification in the augmented reality (AR) environment. In well-lit environments, the model consistently showed confidence scores above 85% for the majority of objects, indicating great accuracy in real-time detection and classification of a wide range of objects. When there was partial obscuration of objects or poor light, the accuracy decreased marginally and the confidence scores decreased to about 70%. Notwithstanding these difficulties, the model demonstrated its efficacy in real-time applications by consistently detecting and classifying objects in a variety of settings.

4.2. Performance and Processing Speed

In order to preserve the immersive experience of augmented reality, the system processed each frame in real time without noticeably lagging. This was accomplished by keeping a constant frame rate. With an average processing speed of about 50 milliseconds per frame, augmented reality could be experienced smoothly and continuously. The effectiveness of the MobileNet model in managing real-time tasks was demonstrated by this performance, which was attained even in the presence of several objects within the frame. Because a front-facing camera requires less computing power than more complicated camera setups, it improved the system's overall performance.

4.3. 3D Model Augmentation

In the augmented reality environment, the technology precisely superimposed the relevant 3D virtual models on the observed objects. Using TensorFlow's bounding box coordinates, each 3D model was instantiated in the exact location and orientation with respect to the object that was recognized. The augmented reality experience was made more realistic by the virtual objects' visual alignment with their real-world counterparts. In order to provide a responsive and interactive user experience, the system also featured dynamic interaction, which enabled 3D models to be added, moved, or removed in reaction to changes in the identified objects.

4.4. User Interaction and Experience

The augmented reality setting made it easier for people to interact naturally with virtual things. The enhanced 3D models' position and orientation were modified by the system in response to real-time inputs, such as moving or rotating the camera. The accuracy of the augmented objects and the system's responsiveness were rated highly by users. The promise of combining machine learning with augmented reality for interactive applications was highlighted by the interactive features and the real-time detection and augmentation, which combined to produce an immersive and captivating experience.

4.5. Challenges and Limitations

Notwithstanding the system's general success, many drawbacks were noted. Sometimes, complicated backgrounds or poor lighting would influence the accuracy of object detection, resulting in lower confidence scores or items being misclassified. Reducing the computing load could further improve the system's performance, particularly when identifying many objects at once. These difficulties point to potential directions for future development, such strengthening the object detection model's resilience or adjusting the setup to work in more complicated settings.

5. Conclusion

For real-time object identification and augmentation in augmented reality (AR) situations, the integration of TensorFlow MobileNet with Unity has shown to be a reliable method. According to the study, the system can reliably identify and categorize items with high accuracy and maintain effective operation even in a variety of environments. The technology constantly provides a smooth augmented reality (AR) experience by precisely placing and enhancing 3D models based on identified items, even in the face of occasional difficulties with lighting and complicated backgrounds.

The outcomes show the promise of sophisticated augmented reality applications, where interactive augmentation and real-time object recognition can greatly improve user experience. Through accurate alignment of virtual objects with their physical counterparts, the system provides a convincing illustration of how augmented reality technology may be utilized to generate immersive and engaging worlds. Subsequent research endeavors may concentrate on mitigating present constraints, like enhancing the precision of identification under less than optimal circumstances and refining system efficiency for intricate situations.

In conclusion, this work highlights how well TensorFlow's pretrained models work in tandem with Unity to provide real-time object identification and augmentation. More research into augmented reality applications is made possible by this, especially in areas where dynamic and interactive virtual features might improve real-world experiences.

Compliance with ethical standards

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I declare that there is no conflict of interest regarding the publication of this paper.

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