Interactive Augmented Reality Using Multi-Marker Interaction for Virtual Object Modification

ABSTRACT

In this paper, I propose a novel approach to interactive augmented reality (AR) by leveraging multi-marker interaction for the modification of virtual objects linked to physical markers. The method involves using one physical object marked with virtual images on multiple sides, which can be dynamically altered using a second physical object. The virtual object displayed corresponds to the specific side of the first physical object with which the second physical object interacts. This method enhances the flexibility and interactivity of AR environments by enabling users to manipulate virtual objects in real-time. I detail the concept, implementation, and potential applications in educational tools and immersive simulations.

KEYWORDS

Augmented Reality, Multi-marker Interaction, Virtual Object Modification, Interactive AR, Physical-Virtual Interaction, Marker-based tracking, 3D model visualization, Real-time object manipulation, AR object collision, Spatial interaction, HCI (Human-Computer Interaction), Immersive technology, Object detection and tracking.

1. INTRODUCTION

Augmented reality (AR) has become a transformative technology that integrates digital components into the physical world. By enhancing users' interaction with virtual objects, AR opens a wide range of possibilities in fields like education, simulation, gaming, and more. In traditional AR setups, a single marker or object is often used to trigger virtual content. However, there remains an opportunity to enhance interactivity through more complex marker systems and dynamic object manipulation. This paper introduces a multi-marker interaction system that allows for real-time modification of virtual objects based on the physical positioning of other objects. The core of this research revolves around using one physical object marked with multiple virtual objects, with a second physical object being used to interactively modify the displayed virtual content.

2. RELATED WORK

Existing AR systems typically focus on single marker or image-based tracking, wherein physical markers trigger corresponding virtual images or animations. Studies like that of Kato and Billinghurst's ARToolKit emphasized marker-based interaction but were limited to single markers controlling static

virtual objects. Recent advancements, such as multi-marker and fiducial systems, have enhanced object recognition capabilities. However, these approaches still lack the dynamic interactivity that allows users to modify virtual objects through spatial manipulation of multiple physical objects. Additionally, works in fields such as tangible user interfaces (TUI) have explored physical-virtual interactions but often with specific-purpose devices rather than general objects, making this research unique in its flexibility and user adaptability.

3. CONCEPT BEHIND THE IDEA

The concept for this project is built on the foundation of multi-marker AR interaction. One physical object, typically a rectangular structure, is marked with virtual objects on three of its sides. A second physical object is introduced as a tool to modify the virtual objects by interacting with the sides of the first object. The virtual object corresponding to the side where the second physical object is brought into proximity is displayed. This creates an intuitive, hands-on approach to modifying and interacting with virtual environments, where real-world physical interactions directly impact virtual outcomes. The multi-marker system recognizes which side of the object is active, providing a seamless and natural user experience.

4. DEMONSTRATING THE IDEA

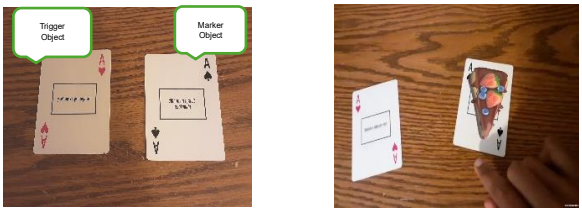

Figure 1: Two physical objects (Marker object and Trigger object) used. The Marker object serves as the primary AR marker holder. It is marked on three sides with distinct markers or areas that are linked to different virtual objects. Tigger object This object functions as an interaction tool that, when brought close to any side of the rectangular marker object, triggers the corresponding virtual image(left), No interaction detected: No virtual object is displayed, emphasizing controlled virtual responses(right).

The proposed system works by embedding multiple markers on the surfaces of a rectangular physical object. Each side of the object corresponds to a unique virtual object or image. When the second physical object is brought close to one side of the rectangular object, the AR system recognizes the interaction and displays the corresponding virtual image. Moving the second object to another side changes the displayed virtual content, allowing users to dynamically switch between different virtual representations without the need for direct manual input or screen-based controls. This system enables real-time,

interactive learning, exploration, and gaming applications where users can physically manipulate the environment.

Figure 2: 1) bringing the Trigger object on top of the rectangular Marker Object displays the corresponding virtual image of a cappuccino , highlighting the augmented content associated with the top (left), 2) when the Trigger object is brought near the left side of the Marker object, a virtual object resembling an omelet appears on top of the marked area, demonstrating the interaction between the two physical objects and the virtual augmentation(middle), upon bringing the Trigger object to the right side of the rectangular Marker object, the corresponding virtual image of a cupcake is displayed, highlighting how each side is associated with different augmented content(right).

5. IMPLEMENTATION

The system is implemented using an AR toolkit capable of recognizing multi-marker configurations. The primary physical object is a rectangular marker that houses multiple virtual objects on different sides.

Using AR software, the interaction between the second physical object and the marker object is detected via marker recognition algorithms. Once the software determines the position of the second physical object relative to the rectangular marker, it modifies the displayed virtual object accordingly. The virtual objects are pre-mapped to the sides of the rectangular marker, ensuring a seamless transition between virtual images as the second physical object is moved around. The setup includes:

- **Marker Tracking:**

Utilizing computer vision-based marker detection.

- **Object Interaction**:

Identifying the spatial relationship between the two objects.

- **Real-time Rendering**:

Displaying the appropriate virtual object based on the interaction.

6. APPLICATIONS

This system has several potential applications:

6.1. Education:

The interactive nature of the system can be applied to educational AR environments, where students can learn about 3D objects and spatial relationships by physically interacting with models.

6.2. Simulation Training:

Professionals in fields like engineering or medicine can interact with virtual models of equipment or anatomy to better understand how modifications affect outcomes.

6.3. Entertainment and Gaming:

AR games could implement this multi-marker approach to create immersive and dynamic experiences where players interact with physical objects to control virtual elements.

6.4. Marketing:

Businesses can use interactive AR displays where users can manipulate physical objects to view different products or services dynamically.

7. DISCUSSION AND FUTURE WORK

The system proposed in this paper introduces a new dimension of interaction in AR by utilizing multiple physical markers to control virtual objects. However, there are limitations, such as the need for precise object positioning and the dependence on marker visibility. In future work, I aim to enhance the robustness of marker detection under variable lighting conditions and improve the system’s responsiveness. Another direction involves integrating haptic feedback, allowing users to "feel" the virtual objects they interact with, further enhancing immersion.

8. CONCLUSION

This research presents an innovative AR interaction system that allows users to modify virtual objects by interacting with physical objects. By using a multi-marker approach, I offer a dynamic and intuitive way to interact with AR environments. This system holds promise in educational, entertainment, and professional training fields. Future advancements will focus on improving object detection, marker robustness, and adding more complex interaction techniques to expand the system's capabilities.

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