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Interactive Multimodal Photobook Co-Creation in Virtual Reality

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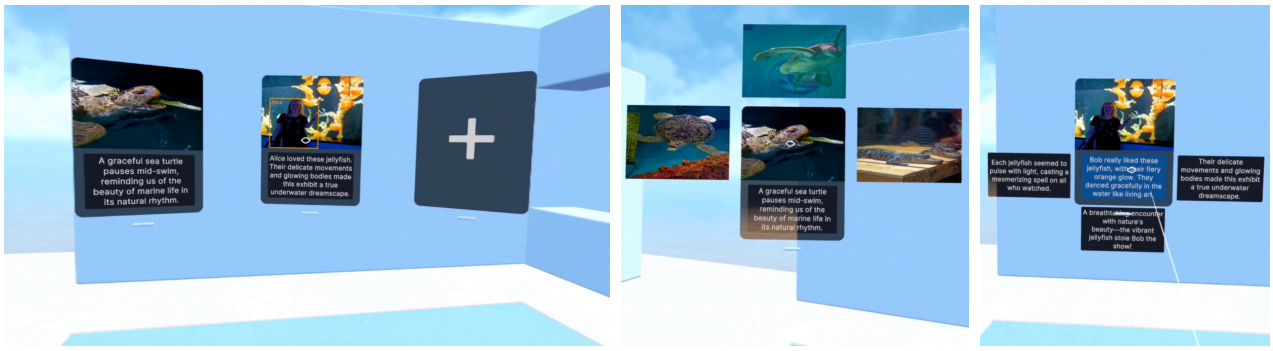

(a) Page overview **(b) Image selection** **(c) Caption selection**

Figure 1: Screenshots of our VR setup showing the chapter overview in 1a, and the actions for image selection in 1b and caption selection in 1c triggered upon selection using gaze or controller input.

Abstract

The integration of Multimodal-Multisensor Interface (MMI) technologies into Virtual Reality (VR) enables users to engage with computational systems in a natural and immersive way. However,

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these technologies remain underexplored when applied to deep learning (DL) systems in VR. This paper introduces a VR-based system designed to evaluate how users interact with DL models in virtual environments using MMI technologies, demonstrated through a photobook co-creation use case. The system facilitates human-AI collaboration (co-creation) by allowing users to work with DL models to create photobooks and supports incremental model learning based on user behaviour (Interactive DL) to produce personalised outputs. The tool features a Unity VR frontend that incorporates speech, gaze, and controller inputs. It has a modular backend architecture that allows seamless integration and testing of different DL models. This tool serves as a testbed for exploring MMI in immersive VR environments for both IDL and co-creation.

CCS Concepts

• **Human-centered computing** → **Interactive systems and tools**; **Interaction techniques**; **Virtual reality**; • **Computing methodologies** → *Machine learning*.

Keywords

Virtual Reality, Interaction Design, Co-Creation, Interactive Deep Learning, Photobook Creation

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1 Introduction & Related Work

Multimodal-Multisensor Interfaces (MMI) leverage human senses and behaviour observations, such as speech, gestures, eye movements, and touch, in user-system interaction [35, 46]. By integrating diverse input modalities, MMI can increase flexibility [49], user satisfaction, and task efficiency when interacting with a model [22]. In the context of Virtual Reality (VR), where increasingly realistic, immersive experiences are prioritised [13], researchers have explored a variety of multimodal techniques in virtual environments [27, 30, 34, 37]. For example, combining gaze and speech inputs can simplify virtual interfaces by creating shortcuts (e.g., issuing a spoken instruction rather than navigating through menus), thereby reducing interface complexity and improving overall usability. Such natural interaction methods offer many advantages in VR. Speech-based interfaces, for instance, lower the barriers to expressing intent [3] and enable flexible, natural language interactions [14]. Similarly, eye tracking offers hands-free, intuitive interactions by allowing users to engage with digital elements simply through gaze [16, 25, 28, 44]. The combination of immersiveness and advanced interaction techniques in VR presents unique opportunities for enhancing Interactive Deep Learning (IDL) and human-AI co-creation systems.

IDL systems mainly focus on incremental model updates driven by user feedback, actively involving users in the machine learning process [1]. Conversely, co-creation emphasises continuous, iterative collaboration between humans and Artificial Intelligence (AI), where users provide intuition, guidance, and adaptability, while AI generates diverse artefacts and explores possibilities [32, 38, 45, 48]. Integrating VR's immersive and natural interaction methods into IDL and co-creation processes has the potential to enhance the engagement of human-AI partnerships. However, IDL remains largely confined to 2D interfaces and conventional input methods such as mouse and keyboard [47].

In this paper, we introduce a system that supports speech, gaze, and controller-based interaction to enable multimodal IDL and co-creation in VR. The system is demonstrated through a photobook creation scenario, which serves as an ideal testbed due to its inclusion of various DL-related tasks such as image retrieval and selection, and caption generation [40, 42, 43]. Prior research has explored related tasks, including methods for user-guided image selection [31], iterative feedback to generate personalised captions [2], and multimodal approaches for identifying individuals within photobook collections [23]. However, existing tools like photobook.ai[1] primarily focus on 2D environments. While these tools provide automation, they often lack the flexibility and interactive depth required for effective co-creation [7, 19, 26]. By contrast, 3D environments in VR have demonstrated significant potential to enhance engagement and creativity. For example, transitioning 2D images into 3D exhibitions has been shown to increase audience interaction and immersion [10], while dynamic presentation methods, such as augmented informational text, have improved comprehension in virtual spaces [39]. Building on these insights, this work introduces a novel DL-supported co-creation system designed to personalise photobook creation based on real-time human feedback. By leveraging the immersive and natural interaction capabilities of VR, our system facilitates richer collaboration between users and AI, providing an intuitive, multimodal framework for creative and iterative tasks. Our future goal is to explore novel MMI and fusion methods for engaging with DL in VR while also investigating the human factors critical to fostering effective and meaningful human-AI collaboration in such immersive setups.

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2 Photobook Creation System

We present a VR-based photobook creation system that leverages MMI—using speech, gaze, and controller inputs—to enable collaborative, human-in-the-loop generation of personalised photobooks with DL-supported features like chapter creation, image retrieval, and contextualised captioning.

2.1 Architecture

The system employs a modular architecture, as shown in Fig. 2, comprising a VR frontend and a Python-based DL backend. The frontend, developed with Unity 2022.3.37f1[2], operates on the Vive XR Elite headset[3]. Gaze and controller-based interactions are implemented using the XR Interaction Toolkit v3.0.3[4], while speech

[1] https://photobook.ai/

[2] https://unity.com/releases/editor/whats-new/2022.3.37

[3] https://www.vive.com/de/product/vive-xr-elite/overview/ (Accessed January 07, 2024)

[4] https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@3.0/manual/index.html (Accessed January 07, 2024)

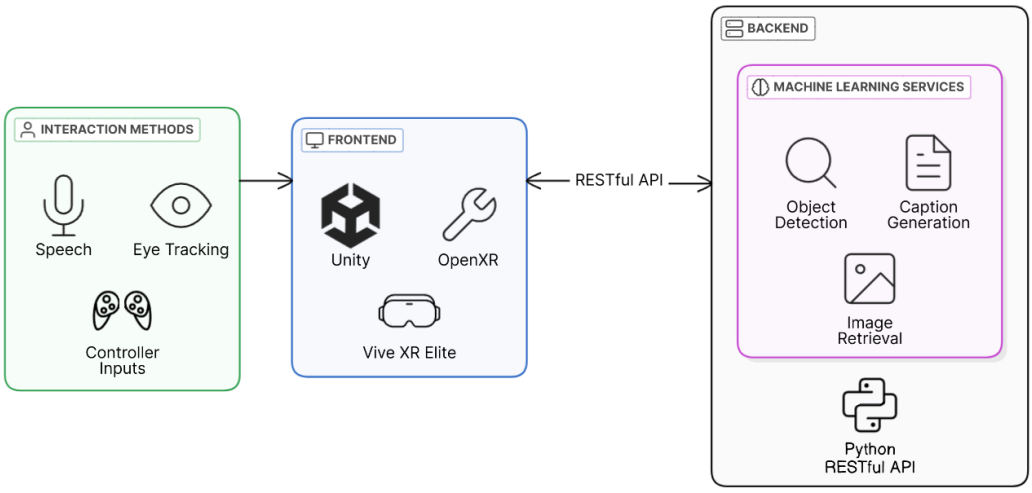

Figure 2: Overview of the architecture. The user can interact with the frontend via multiple modalities. The frontend and backend communicate to enable the co-creation process.

recognition is supported by the huggingface library[5]. These modalities are combined to enable seamless multimodal interactions within the virtual environment. The VR frontend communicates with the backend via a RESTful interface managed by a Python-based server. Session management and data persistence are handled within the backend layer. Computationally intensive tasks, such as object detection and caption generation, are delegated to specialised machine learning services connected through gRPC[6]. These services are modular, allowing for replacement or updates to models without affecting the user interface. Furthermore, they can be distributed and executed locally or in the cloud. By isolating machine learning components, the architecture supports incremental updates and ensures system stability without requiring major reconfigurations.

2.2 VR Frontend

The VR frontend facilitates co-creation through two phases: *initialisation* and *creation*. During the initialisation phase, users provide images and voice commands to generate photobook content. In the creation phase, users iteratively refine outputs—such as chapters, images, and captions—using multimodal inputs (i.e., gaze, speech, and controller interactions) to align the photobook content with their expectations dynamically.

The VR interface comprises three main stages: *Photobook Overview*, *Chapter Overview*, and *Page Overview*. In each stage, content is displayed as interactive floating cards arranged circularly around the user, as shown in Fig. 1a. In the Photobook Overview, users can view existing photobooks or create new ones using voice commands or by selecting an empty card marked with a plus sign via gaze or controller input. Once a photobook is selected, the system transitions to the Chapter Overview, where users can create or revise chapters by providing descriptions and specifying the number of pages. Selecting a chapter advances the system to the Page Overview, as shown in Fig. 1a, where users interact with image-caption cards, each representing chapter pages. Users can open a radial menu to explore replacement options for images or captions through MMI techniques, as shown in Fig. 1b and Fig. 1c, respectively.

The VR system supports various MMI techniques, detailed in Table 1, which outline how gaze, speech, and controller inputs can be used independently or in combination. Table 2 highlights specific actions enabled by these techniques, such as object highlighting and selection, image and caption replacement, and content modification or addition. These different interaction techniques allow us to explore more natural and intuitive ways for users to interact with IDL within an immersive VR environment, laying the groundwork for future studies on human factors. For example, the backend detects instances within images, highlighting them with bounding boxes when the user dwells on an image. Users can correct mislabelled instances, such as changing "Bob" to "Alice," using voice commands. These corrections are processed by the backend to update bounding box labels and regenerate captions accordingly.

2.3 Evaluation Plan

The proposed personalised photobook creation scenario will serve as a testbed for studying MMI and human-AI co-creation in immersive environments. We plan to conduct a set of empirical user studies: (i) assessing the usability and effectiveness of different MMI techniques (as shown in Table 1); and (ii) comparing the VR interface with a conventional 2D interface (i.e., utilising mouse and keyboard). In both studies complementary objective and subjective data will be measured: The objective data collection will include metrics to evaluate efficiency and effectiveness (e.g., completion time and error rate) and, implicit human behaviour (e.g., interaction logs and multimodal data like eye and facial tracking [24, 33]). Subjective data will be measured via self-reported questionnaires and

[5]https://huggingface.co/ (Accessed January 07, 2024)
[6]https://grpc.io/ (Accessed January 07, 2024)

Table 1: Interaction techniques categorized by their Primary and Secondary modalities.

Secondary \ Primary	Gaze	Speech	Controller
Gaze	gaze-based pointing and selection	contextual voice commands	gaze-aware controller-based selection
Speech	gaze-based selection + voice commands	voice commands	controller-based selection + voice commands
Controller	gaze-based pointing + controller-based selection	contextual voice commands	controller-based pointing and selection

Table 2: Actions supported by the VR frontend.

Action	Gaze	Speech	Controller
Pointing and Selecting	● □		● □
Image/Caption Replacement	○ ● □	○ △	△ ● □
Add new image/caption	○ ● □	○ ● △	△ ● □
Add new photobook/chapter	○	○ △	△
Modify existing content	○	○ △	△

Legend:
●: Unimodal (single modality) interaction
○: Multimodal interaction involving **Gaze + Speech**
△: Multimodal interaction involving **Speech + Controller**
□: Multimodal interaction involving **Gaze + Controller**

qualitative methods. Self-reported questionnairs will include human factors which have a significant impact on the successful use of user interfaces and tools,such as usability (e.g., the System Usability Scale [9]) and mental load (e.g., NASA-TLX [21]), and factors relevant to AI-supported co-creation, such as creativity support (e.g., Creativity Support Index [11]) and user experience (e.g., User Experience Questionnaire [36, 41]). In comparison, qualitative methods will provide insights to ground the objective findings with actionable implications from a human perspective (e.g., semi-structured interview [6], think-aloud protocol [36] and the reflective thematic analysis as formalisation method [8]). We aim to investigate human factors critical to fostering effective and meaningful human-AI collaboration in immersive setups.

2.4 Limitations

While the system includes basic error-handling mechanisms, such as allowing users to cancel voice commands in case of transcription errors and enabling corrections to images, captions, and instance labels (e.g., updating bounding boxes and regenerating captions), it lacks more advanced features like undo and redo functionality. Such capabilities could improve user control and flexibility during iterative co-creation tasks. Additionally, the system currently supports only image-based content. Although this aligns with existing tools like photobook.ai[7], VR environments offer the potential for integrating alternative media types, such as videos or RGBD, wide-angle, or 360°content, which could leverage the spatial affordances of immersive 3D spaces to potentially enhance user engagement and creativity [20]. The system also has limitations when onboarding new users. While it supports intuitive interactions through multimodal inputs, a guided "getting started" phase—such as written/oral instructions supported by visual aids or an avatar-based assistant [12]—could help users familiarize themselves with the system more effectively. Furthermore, adaptive help based on detecting the user's state, e.g. user disagreement with the system output [4, 5] could address user challenges dynamically.

In terms of accessibility, the system provides features that may benefit users with auditory or motor impairments (e.g. gaze-based interaction and speech input [17, 18]). However, it is not well-suited for users with visual impairments. While haptic feedback via controllers and adjustable diopters in the headset may assist users with corrected vision, VR systems, in general, are not optimized for visually impaired users [15, 29]. Addressing these accessibility gaps would require further research and design considerations.

[7]https://photobook.ai/

3 Conclusion

This paper introduced a VR-based photobook co-creation tool that combines MMI techniques with DL models to enable intuitive and immersive human-AI collaboration. The system supports iterative human-in-the-loop workflows for tasks such as image retrieval, caption generation, and content refinement using different unimodal and multimodal combinations of speech, gaze, and controller inputs. The modular backend architecture allows seamless integration and testing of different DL models while maintaining system functionality. This setup enables natural and intuitive user engagement with IDL and co-creation, offering a rich testbed for exploring MMI in immersive VR environments in future user studies. Future work will involve conducting user studies to assess different factors of MMI in immersive VR environments, integrating error-handling methods and alternative media types.

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