# AI-Powered Immersive Assistance for Interactive Task Execution in Industrial Environments

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Abstract. Many industrial sectors rely on well-trained employees that are able to operate complex machinery. In this work, we demonstrate an immersive assistance system powered by Artificial Intelligence (AI) that supports users in performing complex tasks in industrial environments. Our system leverages a Virtual Reality (VR) environment that resembles a juice mixer setup. This digital twin of a physical setup simulates complex industrial machinery used to mix preparations or liquids (e.g., similar to the pharmaceutical industry) and includes various containers, sensors, pumps, and flow controllers. This setup demonstrates our system's capabilities in a controlled environment while acting as a proof-of-concept for broader industrial applications. The core components of our multimodal AI assistant are a large language model and a speech-to-text model that process a video and audio recording of an expert performing the task in a VR environment. The video and speech input extracted from the expert's video enables it to provide step-by-step guidance to support users in executing complex tasks. This demonstration showcases the potential of our AI-powered assistant to reduce cognitive load, increase productivity, and enhance safety in industrial environments.

#### 1 Introduction

As the industrial sector continues to embrace technological advancements, integrating Artificial Intelligence (AI) into operational processes has become a key driver of efficiency, safety, and innovation [23]. In this vein, this paper introduces an AI assistant designed for immersive training, leveraging the synergies of multimodal AI and Virtual Reality (VR) technology to support task execution within industrial environments. These tools address the increasing complexity of industrial machinery, which burdens operators with a cognitive load that can compromise both productivity and safety [4]. Additionally, there is a need to improve machine operator training and adaptability in the face of evolving industrial standards and practices, while also providing support in situations where a knowledgeable expert is unavailable [18].

Furthermore, additional challenges include the unavailability of physical machinery for training due to cost, the infrequent nature of certain tasks performed by experts only during assembly, and the significant need for upskilling in an ever-changing job market [6]. These challenges underscore the importance of creating a flexible and comprehensive virtual solution, allowing trainees to experience key activities in a safe, immersive environment [19].

In response, our approach, showcased on a virtual juice mixer testbed that is a digital twin [24] of an actual physical setup, aims to demonstrate how AI assistants can offer a scalable and effective solution to these challenges and enhance interactive task execution across a wide array of industrial applications.

The novelty of our approach lies in deploying an interactive AI assistant powered by a large language model (LLM) that uses audio transcripts to dynamically generate step-by-step guidance for immersive and intuitive training. These transcripts are extracted from a video of an expert performing the task in a VR environment and serve as context for guidance. The virtual testbed replicates the setup of its physical counterpart, ensuring that our simulations and training scenarios align with real-world operations [10]. The LLM-based assistant processes both text and speech inputs, dynamically adapting outputs to address user needs at each step.

By implementing this system on a VR platform, we demonstrate the practical application of our AI assistant in simplifying complex industrial tasks and its potential to improve operational efficiency and learning effectiveness. This paper details the implementation and use of our assistant, illustrating how it integrates with VR to provide immersive, intuitive support for industrial operations. Through this exploration, we contribute to the discourse on AI's role in industrial automation, offering insights into its potential to improve interactions with complex machinery. In the next section, we outline the challenges of integrating immersive technologies into industrial operations and the role of AI in enhancing safety and efficiency.

#### 2 Background

**Industrial Immersive Environments.** The integration of immersive technologies, such as digital twins and VR, into industrial settings marks a significant shift in operations and training. Digital twins provide a digital representation of physical systems, enabling real-time monitoring, simulation, and control without direct physical interaction [10, 25]. Meanwhile, VR has become essential for immersive training, allowing operators to interact with complex machinery in a safe, virtual environment before applying these skills in the real world [8, 20, 7]. These technologies have streamlined procedures and minimized risks, contributing to a safer and more efficient industrial environment [28, 2].

Challenges in Industrial Operations and the Role of AI. Despite advancements, industrial operations face ongoing challenges. The increasing complexity of machinery and rapid changes in technology

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and regulations demand greater expertise and flexibility from operators [21, 22, 1]. These challenges, coupled with the potential for human error under high cognitive load, underscore the need for innovative solutions to support real-time decision-making and task execution. Additionally, the unavailability of experts, due to distance or scheduling conflicts, further complicates these challenges, highlighting the need for autonomous guidance systems [27, 4, 17]. Our goal is to enable trainees to access contextualized prerecorded information on the fly. Previous approaches relied on tracking visual attention and object recognition to retrieve video snippets [14], while others explored using foundation models to tackle similar challenges [3].

AI has become key in overcoming these obstacles by augmenting human capabilities with intelligent, context-aware assistance. By leveraging AI, industries can create systems that analyze complex data, offer predictive insights, automate routine tasks, and provide adaptive, step-by-step guidance tailored to the operator's task and environment [13, 9]. The combination of AI with immersive technologies is leading to a new generation of assistance systems that are more intuitive, interactive, and capable of significantly reducing operators' cognitive load, thus mitigating the risks associated with complex industrial operations [26, 5].

This evolving landscape of industrial settings, combined with the transformative capabilities of AI, lays the groundwork for our system. Our approach allows trainees to interact with content and pose queries guided by a multimodal AI assistant.

## 3 Demo Setup

The live demonstration showcases our AI-powered immersive assistance system in VR. Users experience an interactive setup featuring the virtual juice mixer testbed, designed to simulate a complex industrial machine with containers, sensors, pumps, and flow controllers. The demo provides participants with an immersive experience that highlights the AI assistant's capabilities. The video for the demo is available on YouTube<sup>1</sup>.

**Development Framework.** The system is developed using Unity<sup>2</sup> and Oculus VR<sup>3</sup>, with Meta Quest<sup>4</sup> serving as the primary device for the demonstration. The development process involves creating an environment that accurately replicates the juice mixing operation, allowing users to interact with virtual components and understand the task's operational principles.

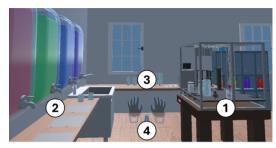
**User Comfort and Ergonomics.** VR devices like Meta Quest can cause discomfort such as neck pain or nausea [11]. To mitigate these issues, we recommend users take regular breaks and adjust the device for optimal comfort. Our system includes prompts within the VR environment to remind users to pause and rest.

**Juice Mixer Digital Twin.** The VR setup simulates the juice mixing process (Figure 1), resembling machinery used in pharmaceutical and chemical domains. This setup immerses users in understanding operational principles and functionalities.

**Operational Task Flow.** The task flow is structured to guide users through the juice mixing process in a sequential manner, utilizing VR controls for interaction with the virtual equipment:

• *Preparation:* Users select a container, place it under a spout, and automatically fill it with juice, with a visual indicator showing the fill level.

<sup>3</sup> https://developer.oculus.com/



**Figure 1**: Overview of the virtual juice mixing setup in VR. Key components are highlighted: (1) Juice Mixer, (2) Juice Station, (3) Spare Part Station, and (4) Controller/Hands as input, which illustrates the user interaction within the immersive environment.

- Assembly: Users attach the lid, sensors, and connect the pump tube, enhancing the realism of the simulation.
- Mixing: Users adjust pump settings via virtual knobs, simulating the control of mixing intensity and duration.
- Final Steps: Users assess the final mixture, reinforcing learning by observing the results of their actions.

This simulation provides users with a comprehensive understanding of the juice mixing process within a controlled, risk-free virtual environment. The interactive setup enhances training efficacy, allowing operators to master complex machinery operations without the physical risks typically associated with industrial environments.

## 4 AI-Powered Immersive Assistance

The AI assistant supports immersive and interactive juice mixer operation training. It uses a narrated expert video as input to guide trainees through an interactive assistant, allowing learning at their own pace when direct expert interaction is unavailable. Next, we delve into the implementation details (as depicted in Figure 2) of the AI assistant and user interactions within the VR environment.

**Expert Video Creation and Processing.** The development of our AI assistant for machine operation training starts with capturing a video of an expert performing the task in the VR environment. The expert narrates and explains their actions step by step during the task. This narration is essential for capturing detailed instructions and insights for learning. After recording, the audio is transcribed into text using the OpenAI speech-to-text model<sup>5</sup>, with timestamps included to preserve sequence information. This transcript is then converted into a JSON format, serving as input for generating the AI assistant's instructional content.

**Creating an LLM-Based Assistant.** Using the OpenAI Assistants API<sup>6</sup>, we employ the GPT-4 language model to power our AI assistant, which enhances the user experience by allowing interactive and intuitive communication. The transcript, already formatted in JSON from the expert's narrated video, provides a rich context that the LLM uses to guide users through the juice mixing process in the VR setting. This approach enables us to capture the expert's knowledge effectively while simplifying the user's interaction with the system, enabling them to ask questions and receive instructions that are contextually aware and precisely timed.

**Defining AI Assistant Behavior and Communication.** The AI assistant's behavior and communication style is simply defined by a set of explicit instructions using natural language within the OpenAI Assistants platform. These instructions dictate that the assistant's role is

<sup>&</sup>lt;sup>1</sup> https://youtu.be/q6zXIsVDq2o

<sup>&</sup>lt;sup>2</sup> https://unity.com/

<sup>&</sup>lt;sup>4</sup> https://www.meta.com/quest/

<sup>&</sup>lt;sup>5</sup> https://platform.openai.com/docs/guides/speech-to-text

<sup>&</sup>lt;sup>6</sup> https://platform.openai.com/assistants/

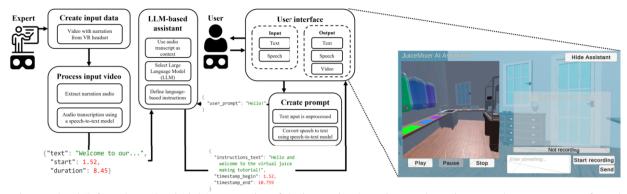


Figure 2: System-level (left) and user-level (right) perspective of the immersive AI assistant. The assistant needs an expert to perform the task, and the expert's narration is transcribed to text, which serves as context for the LLM. Given this context and text or speech input from the user, the LLM generates multimodal instructions that guide the user through the task. These instructions are presented to the user within a VR environment with media controls, text command input, and voice interaction to facilitate user engagement with the AI Assistant.

to guide users through the juice mixer operation in VR, step by step. The assistant uses a detailed transcript as context, timestamped and formatted in JSON, derived from an expert's video tutorial. The AI assistant is instructed with the following primary functions: (*i*) Guide Users - Present and sequentially navigate through the juice-making steps, prompting users to confirm completion before proceeding. (*ii*) Respond to Queries - Address user queries by referencing specific parts of the transcript, using timestamps to provide contextual accuracy. (*iii*) Troubleshoot Issues - Offer solutions for common operational challenges as outlined in the transcript.

The assistant facilitates effective communication, ensuring each user gains practical skills and deep understanding of the juice mixing process. Initially, the assistant introduces itself, outlining its role and explaining how it assists in the juice-making process. It then continues guiding the user, responding to queries and providing detailed instructions based on the structured content of the expert's narration.

Each response provides clear and detailed instructions for the current task or query and includes precise timestamps that dictate the playback window of the expert's video in the user interface. This targeted video playback visually highlights the specific step being discussed, enriching the learning experience by synchronizing instructional content with relevant visual cues. The assistant operates without external knowledge, relying entirely on the expert's video content to ensure a smooth and effective training experience.

**Interacting with the AI Assistant** The user interface for engaging with the AI assistant is designed to be both intuitive and user-friendly. Positioned next to the virtual juice mixer within the VR environment, the interface includes a dedicated panel that hosts several essential components for interaction, illustrated in Figure 2:

- *Input Textbox:* Allows users to type their prompts, facilitating textual communication with the AI assistant.
- Audio Input Option: Enables speech input, with recordings transcribed to text via OpenAI's speech-to-text model<sup>7</sup>. Transcriptions appear in the input textbox for review or editing.
- *Response Display and Audio Output:* After query submission, the AI assistant processes the prompt and displays the response in an output textbox. Simultaneously, the response is converted from text to speech<sup>8</sup>, providing audio feedback.
- *Video Panel Integration:* The video panel displays clips from the expert video based on the AI assistant's timestamped responses, visually demonstrating the specific steps being discussed.

The multimodal interface allows for flexible user interaction with the AI assistant, utilizing text, audio, and video outputs. The integration of these components ensures that all users can effectively navigate and master the juice mixing process within the VR environment, regardless of their specific learning needs or environmental conditions.

**Enhancing Trainee Interaction.** Trainees can interact with the AI assistant using voice and text inputs. For example, a user can ask, "What should I do next?" and receive step-by-step guidance. Preliminary tests indicate the relevance and accuracy of the assistant's responses are well-aligned with the tasks.

Assessing Response Relevance. Preliminary user tests have shown that the assistant's responses are relevant and accurate, effectively supporting trainees in their tasks. Further evaluations are planned to ensure comprehensive support.

#### 5 Conclusion and Future Work

In this work, we presented an AI-powered immersive assistance system to interactively support users in task training and execution in industrial settings. Using a virtual juice mixer testbed, we demonstrated the potential of our system to enhance productivity and streamline complex operational tasks.

In the future, we will investigate ways to support users in a more precise and effective way. For example, by examining how the user interface can impact user behavior, or by incorporating physiological indicators [16] to personalize the training experience further. Preliminary user tests in various settings have shown promising results. Building on this, further field trials will focus on metrics such as task completion time and user feedback to validate the system's effectiveness in real-world scenarios. Also, novel multimodal models, e.g., GPT-40<sup>9</sup>, will enable us to extract multimodal embeddings from the experts' video recordings. This approach could significantly enhance the quality of contextual information and thereby improve the precision of the assistant's guidance.

Finally, we plan to combine our data-driven AI approach with a theory-driven one, such as cognitive-inspired recommender systems [12, 15], to enhance the transparency and understandability of our AI-powered immersive assistant. This hybrid approach is expected to make the assistant not only more intuitive but also more effective in diverse industrial applications.

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<sup>7</sup> https://platform.openai.com/docs/guides/speech-to-text

<sup>&</sup>lt;sup>8</sup> https://platform.openai.com/docs/guides/text-to-speech

<sup>9</sup> https://platform.openai.com/docs/guides/vision

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