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Algorithm of Behaviour of Virtual Avatars During Public Speaking Training in a VR Environment

Algorytm zachowań wirtualnych awatarów podczas szkoleń z wystąpień publicznych w środowisku VR

ABSTRACT

Purpose: This article aims to explore and advance the field of public speaking training through the use of virtual reality (VR) and virtual avatars. The focus is on addressing the challenges faced in traditional public speaking training methods by leveraging the capabilities of VR technology.

Project and methods: The project involved developing an innovative algorithm designed to control the behaviour of virtual avatars during public speaking training in a VR environment. This algorithm integrates multiple aspects of human communication, including posture modelling, voice modulation, greetings mannerisms, eye contact management, gestural communication and interactive responsiveness. The methodology combined theoretical research and practical implementation, involving a comprehensive review of existing solutions and the development of a sophisticated, integrated algorithm. The project utilised advanced programming techniques and the latest VR technology, tested in simulated public speaking scenarios.

Results: The results of implementing this algorithm in VR-based training applications showed a significant improvement in the authenticity and effectiveness of public speaking training. The virtual avatars, powered by the algorithm, were able to simulate realistic human behaviours and responses, thus providing a more engaging and immersive learning experience for users. The application offered a variety of realistic training scenarios, interactive avatar feedback, customisation options, and progress tracking and analysis features. The study found that the algorithm successfully enhanced participants' public speaking skills, reducing anxiety and improving their overall communication abilities.

Conclusions: The research conducted in an "e-Zawody" project concludes that the integration of VR and virtual avatars significantly enhances public speaking training, offering a novel, effective and engaging approach. The development of the algorithm marks a pivotal advancement in educational technology, providing a platform that surpasses traditional training methods. However, the study acknowledges technological limitations and the need for ongoing research and development. Future efforts should focus on enhancing the realism and interactivity of virtual avatars and expanding the application of VR-based training across various fields. The findings suggest a promising direction for the future of public speaking training, with VR technology poised to play a crucial role in the evolution of educational methodologies.

Keywords: public speaking training, virtual reality, opportunity to practise, behaviour synthesis, virtual avatars
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ABSTRAKT

Cel: Niniejszy artykuł ma na celu przedstawienie badania i rozwoju szkoleń z zakresu wystąpień publicznych z wykorzystaniem wirtualnej rzeczywistości (VR) i wirtualnych awatarów. Skupiono się na rozwiązywaniu problemów napotykanych w tradycyjnych metodach szkoleń z zakresu wystąpień publicznych poprzez wykorzystanie możliwości technologii VR.

Projekt i metody: Projekt obejmował opracowanie innowacyjnego algorytmu zaprojektowanego do kontrolowania zachowania wirtualnych awatarów podczas szkolenia z wystąpień publicznych w środowisku VR. Opracowany algorytm integruje wiele aspektów komunikacji ludzkiej, w tym modelowanie postawy, modulację głosu, powitania, zarządzanie kontaktem wzrokowym, komunikację gestykulacyjną i interaktywną responsywność. Metodyka łączyła badania teoretyczne i praktyczne wdrożenie obejmujące kompleksowy przegląd istniejących rozwiązań i opracowanie wyrafinowanego, zintegrowanego algorytmu. W projekcie wykorzystano zaawansowane techniki programowania i najnowszą przetestowaną technologię VR.

Wyniki: Wyniki wdrożenia tego algorytmu w aplikacjach szkoleniowych opartych na VR wykazały znaczną poprawę autentyczności i skuteczności szkoleń z zakresu wystąpień publicznych. Wirtualne awatary, zasilane przez algorytm, były w stanie symulować realistyczne zachowania i reakcje człowieka, zapewniając w ten sposób użytkownikom bardziej angażujące i immersyjne doświadczenie edukacyjne. Aplikacja oferowała różnorodne realistyczne scenariusze szkoleniowe, interaktywne informacje zwrotne awatara, opcje dostosowywania oraz funkcje śledzenia i analizy postępów. Badanie wykazało, że algorytm skutecznie poprawia umiejętności wystąpień publicznych uczestników, zmniejszając niepokój i poprawiając ich ogólne zdolności komunikacyjne.
Wnioski: Badania przeprowadzone w ramach projektu „e-Zawody" dowodzą, że integracja VR i wirtualnych awatarów znacząco poprawia szkolenie w zakresie wystąpień publicznych. Opracowanie algorytmu stanowi kluczowy postęp w technologii edukacyjnej, zapewniając platformę przewyższającą tradycyjne metody szkoleniowe. Jednak badanie potwierdza ograniczenia technologiczne i potrzebę ciągłych badań i rozwoju. Przyszłe wysiłki powinny skupić się na zwiększeniu realizmu i interaktywności wirtualnych awatarów oraz rozszerzeniu zastosowania szkoleń opartych na VR w różnych dziedzinach. Wyniki sugerują obiecujący kierunek dla przyszłości szkoleń w zakresie wystąpień publicznych, przy czym technologia VR jest gotowa odegrać kluczową rolę w ewolucji metodologii edukacyjnych.
Słowa kluczowe: rzeczywistość wirtualna, szkolenie z wystąpień publicznych, możliwość ćwiczenia, synteza zachowań, wirtualne awatary
Typ artykułu: oryginalny artykuł naukowy

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Introduction

Mastering the art of public speaking is an invaluable asset in the contemporary world, profoundly impacting both the personal and professional realms. The ability to articulate thoughts and ideas confidently in front of an audience is not just a desirable skill; it is a fundamental tool for effective communication, leadership and influence. We start by exploring the multifaceted importance of public speaking, highlighting its role as a critical skill for personal development and career advancement. Public speaking extends beyond mere verbal communication; it encompasses the ability to connect with an audience, to persuade, and to convey messages in a clear and impactful manner. The relevance of this skill is evident across various sectors, including business, education, politics and even social settings. Whether it is a CEO presenting to stakeholders, a teacher engaging with students or an individual advocating for community change, the ability to speak well in public settings is a determinant of success and influence [1]. However, the journey to becoming an effective public speaker is often fraught with challenges. One of the most prevalent issues faced by many is the fear of public speaking, also known as glossophobia [2–3]. This fear can manifest in various forms [4], ranging from mild anxiety to debilitating nervousness, often impacting the speaker's ability to perform effectively. Other common challenges include difficulty in organising thoughts coherently, dealing with distractions and maintaining audience engagement. These obstacles can be daunting, but they are not insurmountable. The nature of distractions faced during public speaking is diverse. External factors such as audience behaviour, environmental noise and technical difficulties can significantly impact a speaker's concentration and delivery [5]. Moreover, internal factors like self-doubt, lack of preparation and inadequate mastery of the topic can further exacerbate the challenges. Understanding these barriers is crucial in developing strategies and training programs that address them effectively.

The enhancement of oral presentation abilities is often perceived as a labour-intensive endeavour, incongruent with the prevailing shift in tertiary education towards minimising face-to-face teaching hours. The burden of extensive curricular demands leaves educators with limited scope to impart oral presentation techniques, compelling a majority of students to resort to autodidactic methods for skill acquisition. Consequently, augmenting avenues for practice and feedback via increased human intervention emerges as an impracticable and economically unviable strategy. This paper proposes that academic institutions embrace contemporary pedagogical technologies to address this challenge. Such technologies facilitate learning and practising opportunities that are not constrained by time or location. In this context, virtual reality (VR) emerges as a particularly promising educational technology, offering learners a comprehensive and immersive experience akin to real-world scenarios.

In the realm of training, the advancement of technology has opened up new frontiers for public speaking education. Traditional methods, such as classroom-based learning and mentorship, have been the bedrock of public speaking training for years. These approaches provide foundational skills and face-to-face interaction, which are essential components of learning. However, the integration of technology in training has introduced innovative and effective ways to enhance learning experiences. Online courses, interactive software and virtual environments have made public speaking training more accessible and engaging. One of the most promising developments in this field is the use of virtual reality (VR) [6] and augmented reality (AR) [7] technologies. These technologies offer immersive and interactive environments where learners can practise public speaking skills in a variety of simulated scenarios. This method of training allows for a safe space to practise, receive feedback and gradually build confidence without the immediate pressure of a real audience.

It is a groundbreaking approach that combines the benefits of traditional methods with the interactivity and versatility of modern technology [8]. Furthermore, these new technologies are not just beneficial for individuals aiming to improve their public speaking skills. They offer significant advantages for various groups, including business professionals, educators, students and even individuals in the public sector. Efficient training using VR and AR can help these individuals refine their communication skills, prepare for diverse speaking scenarios and ultimately enhance their effectiveness in their respective fields.

In conclusion, public speaking, essential for effective communication and leadership, remains a vital skill in the 21st century. While challenges in public speaking are common, they are not insurmountable. With the advent of new technologies and innovative training methods, there are more opportunities than ever to master this skill. As we proceed, this article will delve deeper into the technological advancements in public speaking training, particularly focusing on the use of virtual avatars and VR environments, and how they are transforming the landscape of communication training. Specifically, it will focus on identifying factors important to the effectiveness of public speaking training, and then propose an algorithm for the behaviour of virtual avatars, which was then tested using a VR simulator.

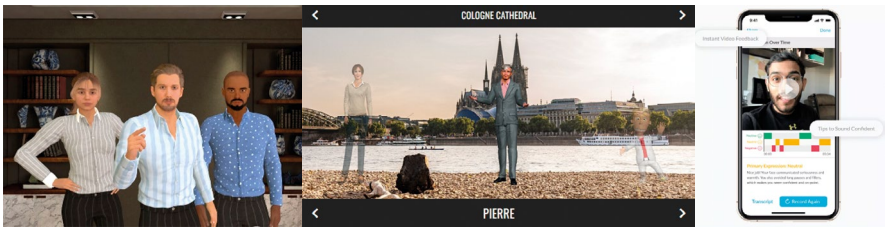
The proposed algorithm distinguishes itself through its integration of advanced posture modelling, dynamic voice modulation, precise eye contact management and responsive gestural communication, therefore creating a training tool that far surpasses existing methods in terms of realism and interactivity. These features collectively enhance the authenticity of public speaking scenarios, offering users an unparalleled level of immersion and effectiveness as regards skill development.

Review of existing solutions using virtual avatars in public speaking training

The integration of virtual avatars into public speaking training marks a significant stride in the convergence of technology and educational methodologies [9]. This chapter offers an exploration of the current landscape, encompassing both commercially available products and scholarly research. In the commercial realm, a plethora of innovative tools and programs have emerged, harnessing the power of virtual avatars to facilitate public speaking training. These solutions range from immersive VR environments that simulate real-world audiences to interactive software platforms that provide instant feedback on various aspects of public speaking. One notable category is VR-based training programs, which immerse users in a virtual environment where they can practise public speaking in front of a computer-generated audience. These programs allow for the customisation of avatars, environments and scenarios, offering a practical experience that is close to reality. The primary strength of such programs lies in their capacity to provide a safe, controlled space for users to hone their public speaking skills without the immediate stress of a live audience. However, their reliance on VR technology means they often require expensive hardware, and the experience might not completely capture the unpredictable nature of human audience reactions.

For instance, VR Speaking Pro by VirtualSpeech [10] is a prominent example in this category. It combines VR technology with interactive elements, allowing users to practise in various settings and receive feedback on their performance. The program also includes features like eye-tracking and speech analysis, making it a comprehensive tool for users looking to improve their public speaking skills. Another significant category is interactive avatar software [11]. This software employs virtual avatars that interact with users in real time, offering feedback on speech clarity, pacing and body language. The advantage of these tools is their accessibility, as they can be used on various devices, making them readily available to a broader audience. Despite their convenience, one limitation is that their algorithms may not fully capture the complexities and subtleties of human communication. A prime example in this category is Orai - AI Speech Coach [12]. This app uses artificial intelligence to analyse speech patterns and provides users with detailed feedback on areas like filler word usage, pacing and clarity. It's an accessible tool for individuals looking to improve their speaking skills, but it might not fully replicate the experience of speaking in front of an actual audience.

Shifting focus to the academic sector, numerous studies and projects have investigated the use of virtual avatars in public speaking training [13]. This body of research is crucial for understanding both the theoretical framework and practical potential of avatar-based training methodologies [14]. One area of academic interest is research on avatar interactivity [15]. These studies examine how interactions with virtual avatars can aid in enhancing public speaking skills, focusing on user engagement, anxiety reduction and skill development. The empirical nature and data-driven approach of these studies provide valuable insights into the effectiveness of avatar-based training. However, they may be constrained by limited sample sizes and the controlled conditions of research environments. For example, a notable study in this field explored the effectiveness of virtual reality exposure therapy in public speaking anxiety [16]. This research demonstrated how VR environments, populated with interactive avatars, could significantly reduce anxiety levels in individuals with a fear of public speaking. The study provided empirical evidence supporting the use of VR and virtual avatars in public speaking training, though it also acknowledged the need for further research in diverse real-world settings. Another critical area of scholarly work involves the development of avatar algorithms [17]. This research focuses on creating sophisticated algorithms that enable virtual avatars to respond in a lifelike manner to human faces, speech and gestures [18]. Such advancements are essential for creating more realistic and effective training environments. The challenge here is often the technological limitations and the nascent stage of these developments [19]. An instance of such research includes projects focused on algorithm development for gesture recognition in public speaking training [20–21]. These projects aim to enhance the responsiveness of avatars to the physical movements and gestures of the user, thereby providing a more interactive and engaging training experience.



(A) (B) (C)

Figure 1. (A) VirtualSpeech: A VR-based training program offering immersive public speaking scenarios with customisable environments and audience feedback. (B) Avatar Software: An interactive platform enabling real-time engagement and response analysis for skill enhancement in various contexts, (C) Orai – AI Speech Coach: A mobile application providing AI-driven feedback on speech clarity, pacing and filler word usage for personal improvement
Source: [10–12].

In summary, this chapter provides a comprehensive overview of the ways in which virtual avatars are currently being utilised in public speaking training. It sets the foundation for understanding the potential of these technologies and prepares the ground for subsequent chapters that propose a novel approach to avatar-based public speaking training.

Development of an integrated algorithm for virtual avatar-based public speaking training

This chapter introduces an innovative algorithm that synthesises the strengths of various existing solutions in virtual avatar-based public speaking training. The cornerstone of this sophisticated training system is the use of virtual avatars to simulate a wide range of public speaking scenarios. The focus is on key aspects such as the avatar's posture, voice, greeting, eye contact and gestural communication, aiming to create a training experience that is not just realistic and responsive but also highly interactive. This platform is designed to closely mirror the dynamics of real-world public speaking, providing users with a practical and immersive learning environment. The R&D centred on creating the algorithm for the behaviour of virtual avatars during public speaking training in a VR environment. The proposed algorithm of the virtual avatar's behaviour is as follows:

1. Posture modelling:
    a. Define a posture matrix P, where each element P_i represents a specific posture attribute (e.g. standing up straight, hand placement).
    b. Utilise a posture adjustment function $f_p(P)$ to dynamically alter the avatar's posture based on the context of the speech.

The concept of posture modelling is pivotal in creating a virtual avatar that exhibits realistic human-like behaviours. To achieve this, we define a posture matrix P, where each element P_i represents a specific attribute of posture, such as standing upright, the positioning of hands or the overall body stance. This matrix is not static but is designed to evolve and change in response to the context of the speech being delivered. The posture adjustment function $f_p(P)$ plays a crucial role in this process. It dynamically alters the avatar's posture based on the context and content of the speech. For instance, during a speech that demands assertiveness, the function might adjust the avatar to adopt a more upright and open stance, whereas a more contemplative speech might see the avatar assuming a relaxed posture. This dynamic adjustment not only contributes to the realism of the avatar but also aids in conveying the intended message and emotion of the speech.

2. Voice modulation:
    a. Implement a voice modulation function $V(s,t)$, where s represents speech content and t represents tone. This function adjusts pitch, pace and volume to suit the speech.

Voice modulation is another critical element in mimicking human speech patterns. The voice modulation function $V(s,t)$, where s represents the speech content and t the tone, is designed to adjust the pitch, pace and volume of the avatar's speech. This function ensures that the avatar's voice changes in response to the emotional content of the speech, the intended audience and the context of the presentation. For example, an inspiring speech would require different voice modulation compared to a technical presentation. The modulation function, therefore, enhances the authenticity of the avatar's speech, making the VR training experience more engaging and effective.

3. Greetings mannerisms:
    a. Define a greeting protocol G that varies based on the perceived audience type (formal, informal).
    b. Employ a function $F_b(G)$ to execute the greeting with appropriate gestures and verbal cues.

Greetings play a significant role in establishing a connection with the audience. The greeting protocol G varies based on the perceived audience type, be it formal or informal. This protocol includes not just verbal greetings but also non-verbal cues such as handshakes, nods or smiles. The function $F_b(G)$ is employed to execute these greetings with appropriate gestures and verbal cues. This aspect of the algorithm ensures that the avatar can appropriately initiate interactions, setting the tone for the remainder of the presentation.

4. Eye contact management:
    a. Create an eye contact matrix E, with parameters like the duration, frequency and direction of eye movements.

b. A function $F_e(E,t)$ modulates eye contact over time t, ensuring natural and engaging gaze behaviour.

Effective eye contact is a key component of engaging public speaking. The eye contact matrix E is developed to manage parameters such as the duration, frequency and direction of eye movements of the avatar. The function $F_e(E,t)$ modulates eye contact over time t, ensuring natural and engaging gaze behaviour. This function allows the avatar to mimic human eye behaviour, such as making eye contact with different sections of the audience, thereby enhancing the realism of the avatar's interactions.

5. Gestural communication:
   a. Develop a gesture library GL containing a range of hand and body gestures.
   b. Use a gesture selection function $f_{gL}(G\,L,c)$, where c is the context or emotion to be conveyed, to choose appropriate gestures.

Gestures are integral to conveying emotions and emphasising points during speech. The gesture library GL contains a wide range of hand and body gestures. The gesture selection function $f_{gL}(G\,L,c)$ is used, where represents the context or emotion to be conveyed, to choose appropriate gestures. This function enables the avatar to use gestures that are congruent with the speech content and emotional tone, thereby enriching the communication process.

6. Interaction and responsiveness:
   a. Implement an interaction function $I(u,a)$, where u is user input (like questions or reactions) and a is the avatar's response.
   b. This function ensures the avatar's behaviour is responsive and interactive, simulating a real-world conversation.

Interactive and responsive behaviour is essential for a realistic avatar. The interaction function $I(u,a)$, where is user input (such as questions or reactions) and a is the avatar's response, is implemented to simulate real-world conversations. This function allows the avatar to respond in a manner that is consistent with human responses, thereby enhancing the training experience.

7. Overall behavioural algorithm:
   a. The final behaviour B of the avatar is a composite function:
   b. An avatar controlled by this equation is ensured to dynamically simulate all aspects of a real person's behaviour during public speech, offering a realistic and immersive training experience.

The final behaviour B of the avatar is a composite function of all the previously mentioned elements. This comprehensive algorithm ensures that the avatar controlled by this equation dynamically simulates all aspects of a real person's behaviour during public speech. The aim is to offer a realistic and immersive training experience that closely mirrors real-life public speaking scenarios.

```
Initialise avatar posture, voice, gestures

FOR each interaction in presentation:
     Analyse context (e.g. speech tone, audience behaviour)
     Adjust posture using function P(context)
     Modulate voice using function V(speech_content, tone)
     Update eye contact using function E(duration, direction)
     Select gesture using function G(context, emotion)
     Generate response using function R(user_input)
END FOR
```

Figure 2. Pseudocode illustrating the main steps of the behaviour algorithm for virtual avatars during public speaking simulations in a VR environment. The algorithm dynamically adjusts posture, voice modulation, eye contact, gestures and avatar responses based on context analysis and user interactions

Source: Own elaboration.

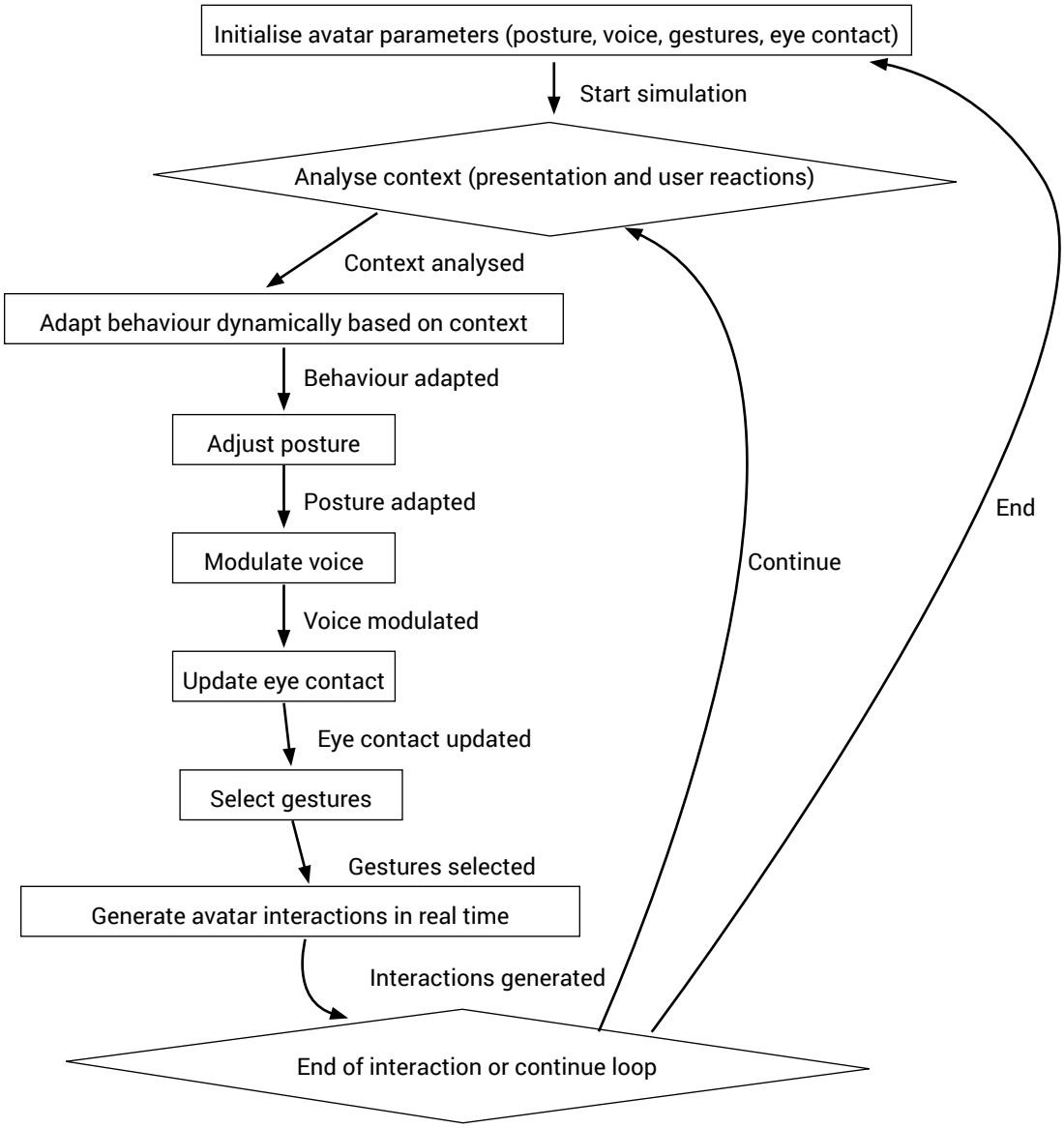


Figure 3. Flowchart illustrating the key steps of the virtual avatar behaviour algorithm in a VR-based public speaking simulation. The diagram outlines the initialisation of avatar parameters, context analysis, dynamic adaptation of behaviours (posture, voice modulation, eye contact, gestures) and real-time generation of interactive responses

Source: Own elaboration.

This algorithm (see Fig. 2 and 3), when integrated into a graphic engine like Unity 3D or Unreal, can effectively simulate the nuanced behaviours necessary for an interactive and realistic experience in a VR environment.

Implementation of the algorithm in public speaking and professional skills training applications

In this chapter, we delve into the practical application and implementation of the innovative algorithm developed in Chapter III. This phase marks a significant step in the evolution of virtual reality (VR) and virtual avatar technologies, applied in the realms of public speaking and professional skills training. The development of this application, supported by the National Centre for Research and Development (NCBiR) under the "e-Zawody" project, embodies a pioneering approach to skill enhancement through advanced technological means.

The application boasts an array of features that make it a comprehensive tool for learning and development:

– Realistic training scenarios: Users are presented with a variety of scenarios, each designed to mimic real-life public speaking environments. These range from formal business presentations to informal group discussions, allowing users to practise and hone their skills in diverse settings.

- Interactive virtual avatars: The avatars, powered by the algorithm, interact with users in a dynamic and realistic manner. They provide reactions and feedback that reflect typical audience responses, offering a unique opportunity for users to experience and adapt to different public speaking dynamics.
- Customisation options: The application allows users to tailor their training experience. This includes adjusting the virtual environment, selecting different types of avatars and choosing specific public speaking scenarios based on individual learning objectives.
- Progress tracking and analysis: A key feature of the application is its ability to track user progress. It provides detailed analytics on various aspects of public speaking, such as speech clarity, pacing and audience engagement, thereby enabling users to track their improvement over time.

The development and integration of the algorithm into a user-friendly VR application were not without their challenges. One of the primary challenges was ensuring the realism and responsiveness of the virtual avatars. Achieving a lifelike interaction required sophisticated programming and continuous refinement of the avatar's AI-driven responses. Another challenge was creating an intuitive user interface that could be easily navigated by individuals with varying levels of technological proficiency.

To overcome these challenges, the development team employed an agile methodology, allowing for continuous testing and iteration based on user feedback. Collaboration with VR experts and user experience designers was crucial in refining the application's interface and ensuring a seamless experience for the end users. The implemented application (see Fig. 4) represents a significant advancement in the field of educational technology and public speaking training. By harnessing the power of VR and AI, it provides an immersive and interactive platform that goes beyond traditional training methods. The realistic scenarios and personalised feedback offered by the application have the potential to greatly enhance users' public speaking and professional skills.

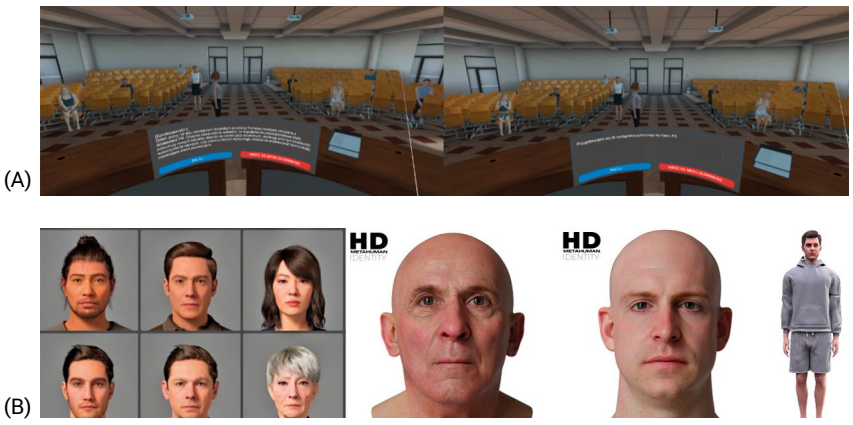


Figure 4. (A) Example screens from the implemented VR-based public speaking training application, showcasing a simulated audience environment with real-time feedback for users. The interface allows users to practise speech delivery with immersive and interactive scenarios. (B) Examples of virtual meta-humans with varying graphical quality used as avatars, ranging from standard models to highly detailed HD representations. These avatars enhance the realism of simulations and offer diverse customisation options for tailored training experiences

Source: [22].

Conclusions

The presented research results have highlighted the immense potential of VR and virtual avatars in enhancing public speaking skills. This novel approach transcends the boundaries of traditional training methods, offering an experience that is both interactive and immersive, while also allowing for extensive customisation. The development of a sophisticated algorithm that intricately models aspects such as posture, voice modulation and gestural communication represents a significant leap in creating virtual environments that are not only realistic but also responsive to the nuances of human interaction. Despite these advancements, the research also acknowledges the existing technological limitations as regards fully capturing the complexities of human behaviour and communication. This points to a need for ongoing research and development to refine the algorithms and technologies underpinning virtual avatars, with the aim of achieving a higher degree of realism and interactivity. Moreover, the study recognises the challenges related to user accessibility and the affordability of VR technology. The current reliance on potentially expensive hardware could limit the reach of this innovative training method. Therefore, future efforts should be directed towards making VR-based public speaking training more accessible, both in terms of cost and user interface design. Looking forward, the research suggests several avenues for further exploration. One key area is the enhancement of the realism and interactivity of virtual avatars. Improving aspects such as gesture recognition, facial expression dynamics and the overall interactive capabilities of these avatars is crucial for creating an experience that more closely mirrors real human interactions. Additionally, the application of VR-based public speaking training could be expanded beyond its current realms. Investigating its utility in

diverse fields such as education, business and healthcare could provide valuable insights into its broader impacts and potential applications. Conducting longitudinal studies to assess the long-term effectiveness of this training approach, as well as incorporating continuous user feedback, are also essential steps. These initiatives would not only validate the efficacy of VR-based training but also ensure that future developments are aligned with user needs and preferences.

While the algorithm represents a significant technological advancement, the development and implementation process presented several challenges. One major issue was ensuring the seamless integration of the avatar's behavioural elements – such as posture, voice modulation and gestural communication – into a cohesive and responsive system. Synchronising these elements in real time required addressing computational limitations and optimising the algorithm to minimise latency. Another challenge involved balancing the realism of avatar responses with computational efficiency. Achieving lifelike gestures, accurate voice modulation and dynamic eye contact required iterative testing and refinement of algorithms to ensure that the VR experience remained smooth and immersive, even on less advanced hardware. Furthermore, user feedback highlighted the importance of intuitive interface design. Initial versions of the application faced usability challenges, particularly for users with limited familiarity with VR technology. Addressing these issues necessitated close collaboration with user experience designers and iterative testing to refine the interface and training scenarios.

In summary, this research marks a pivotal advancement in the integration of virtual reality and avatar technology into public speaking training. It presents an innovative, effective and engaging approach to mastering a skill vital to personal and professional development. As technology continues to evolve and intersect with educational methodologies, new opportunities and challenges will undoubtedly emerge, reshaping the landscape of learning and skill enhancement.

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