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ORIGINAL

Optimized design of digital animation based on virtual reality technology

Diseño optimizado de animación digital basada en tecnología de realidad virtual

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ABSTRACT

Introduction: the production of moving images using computer systems is referred to as digital animation, or laptop-generated imagery (LGI). By using virtual landscapes and devices to create immersive settings, virtual reality (VR) improves this experience. The application of virtual reality (VR) technology and optimization algorithms to digital animation character technology is investigated in this study.
Aim: the study aims to enhance the shape, motion, and interplay of animated characters using an upgraded Penguin Search Optimization (UPSO) algorithm, while also employing VR for motion design and scene communication.
Method: the research employs motion captures facts, scenario descriptions, and the character models to optimize the shape, actions, and interactions of animation characters. To improve those components, the UPSO set of rules is applied, and the efficiency of the optimized animation in realistic virtual worlds is accessed via VR generation.
Results: the adoption of the UPSO algorithm resulted in a significant improvement in the realism of character actions (95 %), character quality (92 %), and overall product satisfaction (93 %). The UPSO algorithm also achieved an accuracy of 97,03 %.
Conclusion: this study contributes to the advancement of animation by combining optimization algorithms with VR technology, resulting in a more immersive and appealing visual experience for users.

Keywords: Digital Animation; Virtual Reality (VR); Upgraded Penguin Search Optimization (UPSO); Computer-Generated Imagery (CGI).

RESUMEN

Introducción: la producción de imágenes en movimiento utilizando sistemas informáticos se conoce como animación digital, o imágenes generadas por ordenador (LGI). Mediante el uso de paisajes virtuales y dispositivos para crear entornos inmersivos, la realidad virtual (VR) mejora esta experiencia. En este estudio se investiga la aplicación de la tecnología de realidad virtual (VR) y algoritmos de optimización a la tecnología de personajes de animación digital.
Objetivo: el estudio tiene como objetivo mejorar la forma, el movimiento y la interacción de los personajes animados utilizando un algoritmo de optimización de búsqueda de pingüinos actualizado (UPSO), mientras que también emplea VR para el diseño de movimiento y la comunicación de la escena.
Método: la investigación emplea capturas de movimiento de hechos, descripciones de escenarios, y los modelos de personajes para optimizar la forma, acciones e interacciones de los personajes de animación. Para mejorar esos componentes, el conjunto UPSO de reglas se aplica, y la eficiencia de la animación optimicen mundos virtuales realistas se accede a través de la generación VR.

Resultados: la adopción del algoritmo UPSO resultó en una mejora significativa en el realismo de las acciones de los personajes (95 %), la calidad de los personajes (92 %) y la satisfacción general del producto (93 %). El algoritmo UPSO también alcanzó una precisión del 97,03 %.
Conclusión: este estudio contribuye al avance de la animación al combinar algoritmos de optimización con tecnología VR, resultando en una experiencia visual más envolvente y atractiva para los usuarios.

Palabras clave: Animación Digital; Realidad Virtual (VR); Pingüino Actualizado Optimización de Búsqueda (UPSO); Imágenes Generadas por Ordenador (CGI).

INTRODUCTION

The performance and experience of the history are modified dramatically with the progression of digital animation. The VR technique is significant because it provides a multimedia platform for digital animation, allowing creators to cooperate with customers in ways before unattainable.[1] VR and digital animation are fused to enhance the interactive understanding and make it visually attractive by letting users get concerned with the story instead of simply monitoring from a distance. Innovative and inspired possibilities have been completely probable by the combination of VR technology and digital animation.[2] Animation has frequently depended on depictions that are seen on screens in two and three dimensions (2D and 3D). Because of VR, it's possible to discover animated landscapes in 3D, giving consumers a sensation of presence that wasn't possible previously.[3] Interacting with animated situations and characters allows for a modified and attractive experience for customers. Using VR to create an immersive narrative is one of the largest benefits of digital animation.[4]

The usage of VR assessable users to enter imaginary worlds produced by animation, complete with imaginative creatures. A greater emotional reaction and a closer bond with the story might be elicited by comprehensive interaction.[5] Through animated simulations, educational programs could employ VR to teach complicated issues, increasing student engagement and efficiency. Digital animation in VR has been utilized beyond entertaining. The technique is utilized by the healthcare, architectural, and educational sectors to enhance simulations that develop learning results, educate experts, and visualize improvements.[6] The VR technology gives gamers access to vibrantly rendered environments, enhancing gameplay through an innovative degree of engagement. An interactive adventure can be created from narrative by animators who craft incredibly complex environments for players to explore.[7] Users feel more like active players than passive viewers at that stage of involvement, which strengthens emotional bonds. VR animations have the potential to enhance learning by experiencing involvement in educational activities by simulating the settings.[8]

The potential to combine animation with VR is going to increase as technology develops, opening up opportunities for creative applications that revolutionize learning, and instruction finally changing the way people engage with digital information.[9] The incidents are observed and have been revolutionized by the combination of VR technology and digital animations. The objective of the research is to investigate how VR and digital animation might work together to improve user engagement and immersive animation. It explores how audience experience, interaction, and applicability in a range of industries such as training, amusement, and education are affected by convergence

The increased real-time collision accuracy and improvement in VR settings, a depth image-based 3D modeling system is combined with an intelligent alternate crash identification method. The technology creates individual role models and incorporates them into 3D settings. Character behavior management and collision detection efficiency are improved by the combination of hybrid and intelligent methods of collision detection.[10] The quantum behavior particle swarm optimization (QPSO) technology outperforms other techniques in terms of speed, stability, and durability. To develop an effective animation regime for human faces, present a hybrid animation technique that blends example-based and neural animation methodologies.[11] Performing annotated sequences and smooth concatenation is made possible by the use of a lightweight auto-regressive network that integrates facial expression dynamics. The combination of visual speech and generic facial emotions was helpful. A VR classroom that uses DL algorithms was taking the role of the conventional classroom. Utilizing software to provide interactive assessments, it separates instructional activities into in-class and after-class activities. The development of the VR-interactive classroom takes emphasis and difficulty into consideration.[12] Experiments using VR classroom participation indicate that analytical output for assessing the quality of instruction can be obtained through the elements involved. To enhance learning quality and professional performance, the application of VR to physical training and sports-specific training. Virtual Reality-based Physical Training (VR-PT) technology employs a semi-supervised system of instruction and virtual simulation to determine students who have exceptional autonomous learning potential.[13] The findings of the experiment indicate that student efficacy in athletics, participation, and conviction in the use of VR technology in college sports training have increased.

The dimensional integration of image texture is ignored by the image visual communication technologies in use, producing visual effects. For use in movies and television shows, a 3D visual communications design technique is suggested that conveys projections using 3D vision, projection mapping, and stitching.(14) To improve visual transmission and quickly achieve high-precision restoration, deep learning (DL) is utilized to extract complex characteristics from and recreate multi-frame animation and animated video images. A method for video-based animation creation called Video Pose VR leverages internet videos to generate VR character animations. It creates captions for films, stores them in a motion dataset, and utilizes DL to recreate 3D motions from them. In addition to importing films, creators can also search, edit timelines, and combine many motions.(15) Video Pose VR was simple to use even for inexperienced users, according to user research, and it enables quick prototyping for a wide range of uses, such as crowd simulations, skill training, and entertainment. Medical models are anticipated to be integrated with VR technology, which makes use of computer systems, image displays, and sensors. Virtual medical content learning and skill training are made possible by the creation of 3D character models with 3D animation technology.(16) The use of VR and 3D animation modeling in medical systems that was examined. The implicit approach is more stable, but the difference between the real value and the technique is greater, according to experimental simulations.

The aim of the research is to improve the shape, motion, and interplay of animated characters through the use of an improved Penguin Search Optimization (UPSO) algorithm, as well as virtual reality (VR) for motion design and scene communication.

METHOD

Through motion capture data optimization, immersive settings, and character models, the technique uses a UPSO algorithm to improve digital animation in VR. The constantly modified animation settings accurately reflect the unpredictable nature of real-world behaviors, while the enhanced animation sequences and excellent resource management improve user involvement and satisfaction. Figure 1 shows the flow of suggested method.

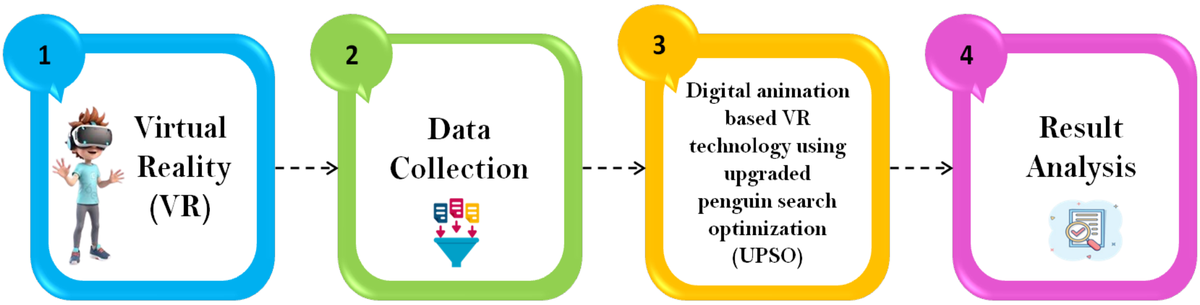

Figure 1. Flow of suggested method

Data collection

A wide range of digital animation character models are included in the dataset, emphasizing characteristics like color, texture, and form for efficient design optimization. To examine how characters move and interact in completely immersive virtual worlds, it integrates motion capture data. The realism of animations is improved by scenario descriptions, which give characters' actions crucial context. The efficiency of digital animations in VR environments is improved by this organized dataset, which aids in character design and interface optimization.

Upgraded Penguin Search Optimization (UPSO) using digital animation-based VR

The UPSO metaheuristic algorithm improves search efficiency for challenging optimization issues in VR settings by social behavior and foraging strategies of penguins. It optimizes different VR features with different learning rates and search algorithms, which leads to smoother animations and more realistic experiences for users. The exploration aspect of the algorithm enables dynamic modifications, which enhance realism in digital animations by modeling unexpected real-world behaviors.

Penguin Search Optimization (PSO)

The Penguin Search Optimization (PSO) approach dynamically modifies animation settings in VR to improve digital animation, inspired by the foraging behavior of emperor penguins. A more realistic and immersive user experience is made possible by this method's improved optimization of character initiatives and interactions. The virtual characters are initialized with PSO, and their behavior is shaped by their initial design elements and their environment. User engagement metrics are used to assess the quality of animations, and the method finds the best animation sequences while taking-stopping criteria into account to guarantee the production of the most powerful and visually appealing animations. A polygon-shaped huddle barrier is represented by penguins, a digital animation analogy used to create dynamic settings for VR activities. The behavior of Hutch boundary formation is shown using a complicated variable. Considering that φ indicates the wind's gradient and velocity and that Ø stands for equation (1):

$$\boldsymbol{\varphi} = \nabla \emptyset \qquad (1)$$

Equation (2) illustrates the gradient of the function *0 = Ø + jμ*, which is commonly used to identify the direction of the greatest ascent or fall in optimization problems.

$$\boldsymbol{O} = \emptyset + \boldsymbol{j\mu} \qquad (2)$$

Equation (3) is used to modify the weight or scale according to the maximum number of continues.

$$\boldsymbol{S} = \left(\boldsymbol{s} - \frac{\boldsymbol{Max_{iteration}}}{\boldsymbol{w} - \boldsymbol{Max_{iteration}}}\right) \qquad (3)$$

Binary thresholding uses a threshold to detect if a variable s is set to 0 or 1. Equation (4) illustrates that PSO is a static task-graph scheduling technique appropriate for set tasks and specified processors in static contexts.

$$\boldsymbol{s} = \begin{cases} \boldsymbol{0}, \boldsymbol{Q} > 1 \\ \boldsymbol{1}, \boldsymbol{Q} < 1 \end{cases} \qquad (4)$$

Equation (5) computes the discrepancy between the expected values $\vec{C}$ and the actual $\vec{Y}.\overrightarrow{R_{ep}(t)}$ of $Abs(A(\vec{Z})$.
This is used to monitor thechanges to increase accuracy and gauge the existing solution meets the intended outcomes:

$$\vec{C} = Abs(A(\vec{Z}).\overrightarrow{R(t)} - \vec{Y}.\overrightarrow{R_{ep}(t)} \qquad (5)$$

The distance across animated characters is computed as the virtual environment is being created, and the location of the best-fit character is important to this calculation. To ensure precise character placement inside the confines of the animation, equation (6) utilizes the distance calculation to determine the straight-line distance between two space positions. Equation (7) illustrates *M* stands for the movement parameter that maintains character deficiencies.

$$\vec{Z} = \left(M \times \left(S + R_{grid}(Accuracy)\right) \times Rand()\right) - S \qquad (6)$$

$$R_{grid}(Accuracy) = Abs(\vec{Z} - \overrightarrow{Z_{ep}}) \qquad (7)$$

Equation (8) uses the current value of $\vec{Z}.\vec{C}$, and the error of $\vec{Z}(t)$ to update the anticipated value of $\overrightarrow{Z_{ep}}(t+1)$ for the subsequent iteration. Adding modifications based on detected faults improves the solution and directs the optimization process in the direction of greater results.

$$\overrightarrow{Z_{ep}}(t+1) = \vec{Z}(t) - \vec{Z}.\vec{C} \qquad (8)$$

To create more immersive experiences, PSO can be used to increase the efficiency of digital animation systems. By optimizing rendering processes and enhancing user engagement in VR settings, this technique dynamically modifies distribution based on indicators of efficiency.

Upgraded Penguin Search Optimization (UPSO)

A metaheuristic algorithm called UPSO was developed in response to penguin social behavior and foraging tactics. With the addition of improvements like varied search algorithms and adjustable learning rates, it increases search efficiency in difficult optimization issues. Combining VR-based digital animation with UPSO allows for the optimization of several VR environment features, including immersive experiences, illustration, and user interaction. Through improved resource management and smoother animations made possible by optimization approaches, this synergy enhances the user experience and pleasure of VR apps by creating more interactive and enjoyable virtual worlds. The exploration operator has not been taken into account in this method was stated in the explanation of the original version. This choice might be attributed to the creators' desire for simplicity as well as the algorithm's adequate performance. To improve the algorithm's performance, though, probabilistic search in the decision space is essential, particularly intricate applications in VR. To make VR experiences more realistic, it is imperative to imitate real-world behaviors. The program can integrate unforeseen motions to enhance animation flow and realism, like how UPSO can suddenly shift its hunting itinerary. As an exploratory method, this behavior can be incorporated into the algorithm. To make the system more flexible in VR settings, an exploration function was incorporated in this research. Equation (9) explains how this modification enables dynamic changes in the choice variables.

$$\boldsymbol{Sol_{new}^{i,j} = Sol_{old}^{i,j} + \sigma \times randn} \quad \textbf{(9)}$$

The exploration parameter is denoted by . then shows many normal distributions with zero mean and one average deviation, and $Sol_{new}^{i,j}$ the i^{th} modified decision variable related to the i^{th} solution, and $Sol_{new}^{i,j}$ the i^{th} decision variable before modification related to j^{th} solution. Algorithm 1 shows the pseudocodein UPSO.

Algorithm 1: UPSO

Algorithm UPSO:
Initialize population of solutions Sol
Set exploration parameter σ
Set number of iterations max_iter
Set the number of penguins N
For each iteration from 1 to max_iter:
For each penguin in the population:
Evaluate the fitness of Sol[i]
If fitness of Sol[i] < best_fitness:

best_solution = Sol[i]
best_fitness = fitness of Sol[i]

For each j in 1 to N:
If the random condition for foraging behavior is met:
Update Sol[i] using exploration:

$$Sol_{new}^{i,j} = Sol_{old}^{i,j} + \sigma \times randn$$

Else:
Update Sol[i] using the existing UPSO strategy:
Sol[i] Update using standard UPSO procedure
Improve resource management
Enhance animation quality using updated solutions
Return best_solution

This section's findings from the original algorithm and its updated version are shown next, demonstrating how this exploration mechanism affects the VR digital animation quality. Through improved resource management and speedier animation delivery, the UPSO dramatically improves the quality of VR digital animation. It improves search effectiveness in challenging optimization tasks, resulting in VR experiences that are more dynamic and engaging. Adding an exploration capability increases realism even more by simulating erratic real-world behavior. Broadly, UPSO maximizes enjoyment and enhances user experience in applications that use VR.

RESULTS

This research made considerable use of Python 3.13. Give 30GB of storage and Windows 7 pre-installed on Intel Core i7 laptops. In evaluating the efficacy of the proposed system, assessment parameters like accuracy

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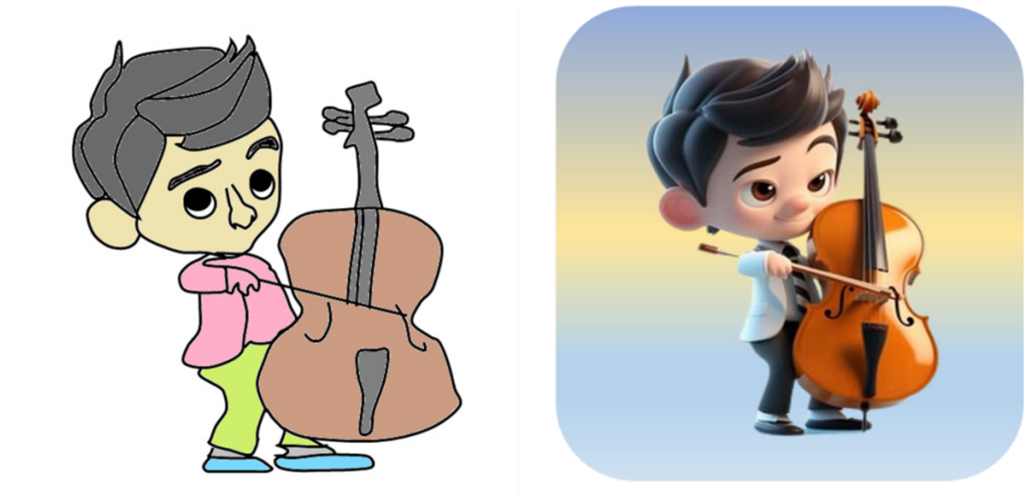
are used. Comparing VRsystems based on a predictive correction method (VR-PCM),[17] the proposed methodis UPSO. Comparing digital animation design with conventional approaches, the UPSO algorithm produces notable gains in action realism, character quality, and user satisfaction. This development highlights how well-optimized VR technology can produce more visually attractive and engaging animation experiences.

Before and After using Optimized in digital animation-based VR Technology

Character interactions and motions were frequently less realistic in the period before VR technology was optimized for digital animation. This also resulted in inferior visual quality and obvious rendering latencies. It was difficult for animators to create realistic landscapes and fluid character movements, which made watching less engrossing. Digital animations gain from improved realism, quicker rendering times, and more natural character interactions after using VR technology that has been optimized. Advanced algorithms enable smoother interaction inside virtual settings, more intricate character design, and better motion capture integration, which contribute to give consumers an incredibly rich and immersive visual experience. Figure 2 shows the before and after using optimized digital animation-based VR technology.



(a) (b)

Figure 2. (a) Before and (b) After using optimized in digital animation-based VR

Performance Comparison

The UPSO algorithm's performance is contrasted with and without its application in digital animation design. High-quality character creation, action realism, and user satisfaction all dramatically increase with UPSO in VR scores of 95 %, 92 %, and 93 %, respectively, in contrast to lesser scores of 72 %, 75 %, and 70 % without UPSO using in VR. These findings show that using UPSO in the digital animation process produces more realistic animations, higher-quality characters, and more user satisfaction as a whole. Table 1 and figure 3 shows the outcome of the performance comparison.

Table 1. Performance comparison

Measure	With UPSO	Without UPSO
Realism of actions	95	72
High quality character	92	75
User satisfaction	93	70

Accuracy

The degree of accuracy and realism which animated thecharacters and settings reflect real-world movements and conversations is referred to as accuracy in digital animation according to VR systems. To provide immersive experiences and animations precisely correspond to user actions and ambient dynamics, this entails utilizing innovative algorithms and rendering. The suggested UPSO algorithm has the greatest accuracy of 97,03 % and another existing method like VR-PCM scored 95 %. Table 2 and figure 4 shows the outcome of accuracy.

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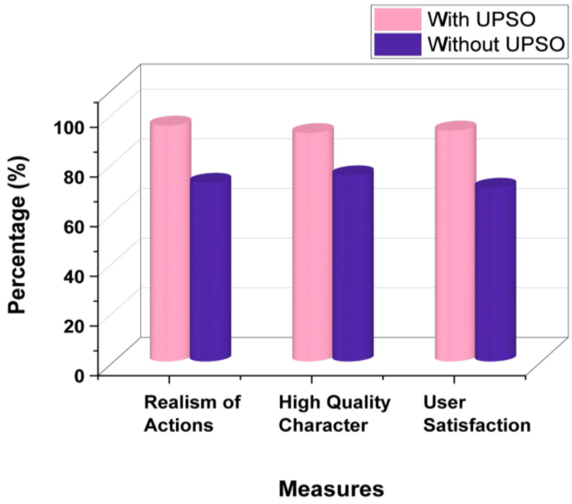

Figure 3. Outcome of performance comparison

Table 2. Comparison of Accuracy

Method	Accuracy (%)
VR-PCM [17]	95
UPSO [Proposed]	97,03

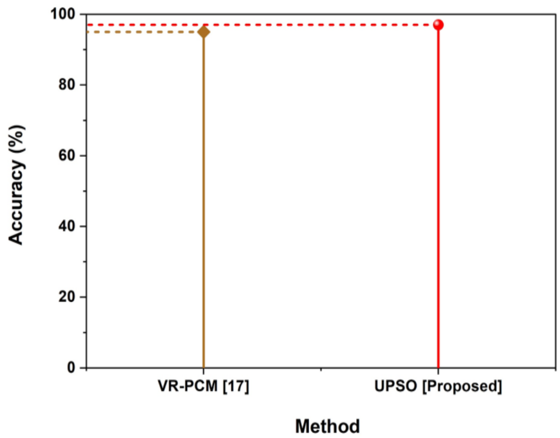

Figure 4. Outcome of Accuracy

DISCUSSION

The possibility for users to experience when utilizing VR-PCM with digital animation is a disadvantage that can reduce participation. The accessibility and flexibility of VR-based solutions may be restricted by the expense of development and technological complexity. Character interactions and motion realism have significantly enhanced with the shift to VR technology that is optimized for digital animation. The results of the performance comparison demonstrate how much the UPSO algorithm improves action realism, character quality, and user satisfaction. The UPSO algorithm has shown incredible accomplishments by improving the accuracy of animated figures in representing real-world dynamics. With enhanced user engagement and overall satisfaction, this development highlights how VR technology can be optimized to produce realistic and engaging animation experiences. The findings of this study are consistent with and extend existing studies in the field of digital animation and VR technologies. Existing research has highlighted the difficulties of achieving realistic character movements and interactions in early VR implementations, which frequently resulted in lower quality animations and rendering delays. Our findings confirm that optimizing VR technology significantly improves these aspects, with smoother character interactions and faster rendering, supporting the conclusions of and others who demonstrated that superior algorithms can enhance realism in digital animation. Furthermore, the overall performance improvements found with the upgraded Penguin Search Optimization (UPSO) algorithm (95 % action realism, 92 % character quality, and 93 % user satisfaction) are consistent with existing research, which showed that optimization techniques improve the overall quality and user engagement of VR-based animations. The proposed UPSO algorithm's accuracy (97,03 %) outperforms that of existing approaches such as VR-PCM (95 %), which is consistent with existing research, that has established the importance of high accuracy in creating immersive, realistic VR experiences. These findings show the importance of optimization techniques in improving both the technical and experiential aspects of digital animation in VR.

CONCLUSION

This research explores the use of optimization algorithms and VR technology in digital animation character generation. The proposed technique uses an UPSO algorithm to optimize shape and action, utilizing motion capture data, scenario descriptions, and character models. VR is used to understand the character's scene communication and action design. The results show significant improvements in action realism (95 %), character quality (92 %), and user satisfaction (93 %), with an accuracy of 97,03 %, thereby achieving the research aim of optimizing digital animation character technology using VR and UPSO. This study while, demonstrating the effectiveness of the UPSO algorithm in enhancing digital animation, has some limitations. The optimization process is based on precise motion capture facts, which may not capture the overall range of man or woman moves, potentially limiting the variety of actions generated. Additionally, the VR integration used for character interaction and scene communication may not fully replicate real- world dynamics, impacting immersion. Future studies may want to cognizance on expanding datasets to include a much broader range of movements and enhancing VR technology to offer more realistic interactions. Further development of the UPSO Algorithm could also refine animation exceptional and realism in greater complex scenarios.

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CONFLICT OF INTEREST
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Formal analysis: Chen Guo.
Research: Chen Guo.
Resources: Chen Guo.
Drafting - original draft: Chen Guo, Surendheran Kaliyaperumal.
Writing - proofreading and editing: Chen Guo□Surendheran Kaliyaperumal.