Research Article

Research on 3D Human Motion Visualization for Immersive Teaching Mechanism - 3D Pose Reconstruction from the Tradition Motion Video for Teaching and Evaluation

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Abstract

Objective: Based on the three-dimensional (3D) visualization technology of human motion, the immersive teaching mechanism of human motion was proposed. At present, the training and learning of human motion could not observe the 3D information of its posture due to the issue of two-dimensional (2D) perspective, which had many shortcomings.

Methods: This article proposed new teaching mechanisms, including personal immersive assisted instruction, multi-person immersive interactive teaching, and immersive teaching evaluation method for motion learning. The design of the three methods were carried out in the background of artificial intelligence (AI).

Results: Combining with current advanced AI algorithms, the concept of visualizing 3D human motion for immersive teaching method was conceived, and a specific implementation framework diagram and description of the main work of each teaching mechanism are provided. The personal immersive assisted instruction method would be a powerful tool for enhancing individual learning experiences in the realm of 3D human motion visualization. The multi-person immersive interactive teaching took 3D human motion visualization to the next level by facilitating collaborative learning experiences. The immersive teaching evaluation method for human motion training was pivotal for assessing the effectiveness of these immersive techniques.

Conclusion: After the evaluation and analysis, this mechanism had been proven to be an effective...
teaching mechanism for pose learning. 3D human motion visualization for the immersive teaching held the promising prospects in the field of education and instructional practices.

**Keywords:** human motion, 3D visualization, immersive teaching mechanism, evaluation, motion learning

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### 1 INTRODUCTION

In recent years, immersive teaching has shown positive educational outcomes in various disciplines, such as language learning and practical activities. It enables students to engage more deeply in the learning process and offers a high level of interactivity. In immersive teaching, personalized, interactive, blended virtual and real learning environment is possible to create. Students can engage in learning activities within immersive scenarios, experiencing a sense of being part of the environment. This not only encourages active physical and mental participation, but also facilitates the knowledge construction among learners.

In the context of teaching activities, the learning of human motion mostly relies on interactive learning through observation and imitation. The primary source of learning materials comes from visual recordings, such as watching classic standard posture motion videos or reviewing one’s own practice videos. However, traditional video-based learning has limitations in providing interactive experiences. Some multimodal and virtual reality (VR) teaching methods cannot reflect the digital and powerful advantages of artificial intelligence (AI). Learners cannot obtain key positional parameters of the body in motion postures from traditional two-dimensional (2D) videos, missing the corrective guidance information, thus hinder the enhancement of their knowledge and understanding. For instance, when learning dance or basketball, learners can only access single-view information about the traditional motion postures in 2D videos. Information behind body occlusion and angle obstacles that occur during learning cannot be provided by single-view video alone. Therefore, it is essential to visualize the posture information from 2D videos to three-dimensional (3D) and provide crucial motion information to learners through immersive interactive channels. 3D visualization of human motion was depicted in Figure 1. This allows learners to observe more detailed learning information for imitation, enhances their understanding of motion, increases interactivity in real-world learning environments, and ultimately boosts learner interest and efficiency in the learning process.

In the process of learning human motion, practice and coordination among multiple individuals (two or more) are commonplace. For example, group dance routines, team sports competitions, and so on. These scenarios all represent teaching settings for physical movement learning. Traditional 2D videos of multi-person interactions fall short in adequately depicting the body positions and individual spatial locations of multiple individuals. They also fail to convey critical rehearsal position information and movement types hidden by occlusions. Learners’ self-awareness in the process of physical movement learning is hindered, and 2D videos or single-view observational learning cannot establish a robust connection between the brain, body, environment, and technique. Furthermore, they cannot provide the immersive interactive experience offered by immersive teaching. The 3D visualization of multi-person movement postures was illustrated in Figure 2.

After visualizing human motion in 3D, the body positions, personal spatial locations, and relative positions among of multiple individuals can be clearly display. Through providing immersive teaching aids, warnings and prompts, creating an environment for multi-person interactive learning and collaborative learning. This, in turn, encourages learners to more effectively engage in multi-person posture movement teaching activities and efficiently acquire essential key pose information.

Given the aforementioned issues, 3D human motion visualization for immersive teaching mechanism is proposed. The contributions of the proposed mechanism are as follows:

1. **Personal immersive assisted instruction**
   Processed data from learners’ personal practice videos or monitoring device data used for deep learning processing, are presented to learners in 3D form, and AI is used to assist in prompts.

2. **Multi person immersive interactive teaching**
   Learner groups can practice interactive human motion with the assistance of 3D visualization of multiple people (two or more), such as multiplayer dance, group ball training, martial arts practice, and so on.

3. **Immersive teaching evaluation method for human motion training**
   The immersive teaching mode proposed in this study uses real-time AI interactive evaluation methods. Learners
(teams) have detailed statistics on goal achievement, key action completion data (parameters such as time, position, and coherence), learning settings based on their own basic starting points, and detailed action essentials to assist in explaining how to achieve learning goals during the learning process. They use a combination of voice, text, and animation to evaluate the learning process.

The design of immersive teaching mechanism is inspired by the AI algorithms and technologies, such as recurrent neural networks (RNNs)\(^ \text{[9,10]} \), long short-term memory (LSTM)\(^ \text{[11,12]} \), multimodal learning (ML)\(^ \text{[13-15]} \) and so on. Parts of work is depended on big data language models, intelligent speech recognition, and teaching intelligent information processing. Big data language models can enable natural language interaction between students and the immersive teaching system. Students can ask questions, seek clarifications, or request information in a conversational manner. This makes the learning experience more engaging and accessible. Intelligent speech recognition can be used to provide real-time feedback on pronunciation and enunciation when students are required to describe or discuss motions verbally. By analyzing a student’s oral or written responses, as well as their interactions with the system, teaching intelligent information processing can generate personalized learning paths. This ensures that each student receives tailored instruction and practice exercises based on their strengths and weaknesses.

1.1 Related Work

We conducted a detailed discussion on the design of the aforementioned teaching mechanism. The teaching mechanism will include many deep learning methods technically, such as RNNs\(^ \text{[9,10]} \), LSTM\(^ \text{[11,12]} \), ML\(^ \text{[13-15]} \) and so on. These deep learning methods for AI processing can achieve real-time 3D visualization.
2 METHODOLOGY

2.1 Personal Immersive Assisted Instruction

This mechanism provided information on the errors in learners’ posture and how to assume the correct postures. Showing 3D spatial coordinates to the learner allows them move various perspectives to compare the correct posture for viewing. Following deep learning processing of data, extensive big data AI including speech, music, and animation were employed to evaluate learners’ corrected posture. Encouraging emotional language combined with animation prompts provided immersive teaching, immersing learners in human motion learning, reducing learning boredom and increasing learning interest. The research framework and case studies were shown in Figures 3 and 4, respectively. Figure 4 showed the comparison of input, output, and correct posture in the study case.

The main design work in the Figure 3 was listed as below, which is involving multiple aspects. The two works are the key to provide personal immersive assisted instruction.

2.1.1 Provide 3D Visualization of Digital Learning Information

VR and 3D visualization technology: Employing VR technology to create an immersive learning environment for students to explore learning content in three dimensions. 3D visualization technology was employed to present complex concepts and information, making the learning process more engaging and intuitive.

Personalized learning paths: Creating an individualized learning trajectory for each student based on their interests, learning style, and proficiency level. Utilize learning analytics to monitor students’ progress in real-time and adjust the learning path based on performance.

Team collaboration tools: Providing online collaboration tools to enable students to interact and collaborate with team members. Integrate real-time chat, voice communication, and screen sharing functionalities facilitated discussions among students.

Team task allocation: Defining specific team tasks to require collaboration among students. Utilizing learning analytics tools to assess each student’s contribution to team tasks, ensuring fair task allocation.

Data privacy and security: Relevant regulations and policies were placed on ensuring the protection of students’ personal data and privacy. Implemented encryption and other security measures to safeguard the security of the learning platform.

2.1.2 Building a Digital Immersive Learning Environment

Motion capture and data processing: Utilizing specialized motion capture devices such as sensors, cameras, or inertial measurement units to capture students’ human motion data, process the captured data in real-time or offline to recognize, analyze, and record key motion information, such as body postures, actions, and positions.

3D modeling and visualization: Creating 3D models based on the captured motion data to simulate students’ human motion. Embedding these 3D models into an immersive learning environment, whether in a VR scene, augmented reality (AR) application, or another interactive digital setting, to visualize and represent the human motion.

Interaction and feedback: Providing interactivity to allow students to engage with the 3D environment, enabling them to mimic, improve, and practice human motion. Offering real-time feedback to help students understand their movement skills, guiding them towards improvements and corrections.

2.2 Multi-person Immersive Interactive Teaching

The teaching mode studied in this project could achieve real-time 3D visualization of the multi person team exercises movement posture through deep learning and big data AI.
2.2.1 Building a Digital Immersive Learning Environment

Multiplayer networking and synchronization: Implement a robust multiplayer networking system was paramount. This involved choosing the right networking framework or technology, setting up servers, and ensuring real-time synchronization of 3D motion visualizations among all participants. Focus on minimizing latency to create a seamless experience, and implement mechanisms for handling issues like packet loss and network disruptions.

Interactive educational content design: Develop high-quality 3D motion visualizations and interactive educational content that aligned with your learning objectives. The content should be engaging, informative, and conducive to collaborative learning. Created opportunities for users to actively engage with the content, such as allowing them to manipulate objects, perform simulations, or participate in group activities that require teamwork and problem-solving.

User experience (UX) and interface design: Pay careful attention to the UX and interface design. Ensure that the user interface was intuitive and user-friendly, allowing participants to navigate the immersive environment and
access educational resources seamlessly. Incorporate features that promote effective group communication, such as voice chat or text chat, and consider the placement of user interfaces and interaction prompts to minimize distractions and maximize learning engagement.

2.2.2 Generate Correction Information for Group Posture Joints and Spatial Position Errors

Sensor fusion and calibration algorithms: Employ sensor fusion techniques that combined data from multiple sensors, such as accelerometers, gyroscopes, and magnetometers, to calculate accurate spatial positions and joint postures. Calibration algorithms were vital to correct for sensor errors, drift, and biases. These algorithms helped ensure that the virtual representations align correctly with the human motion of users. Important research and development work in this area focused on advanced sensor fusion algorithms and calibration methods to minimize errors in joint posture and spatial positioning.

Machine learning and AI-based correction models: Utilize machine learning and AI techniques to develop correction models that could predict and correct joint posture and spatial position errors. These models could learn from user data and adapt to individual or group-specific patterns, offering personalized correction for better accuracy. Ongoing research in machine learning and AI for motion correction could significantly enhance the quality of 3D motion visualization in group settings.

2.3 Immersive Teaching Evaluation Method for Human Motion Training

When learning physical exercise courses, learners (teams) have detailed goal achievement statistics, key action completion data (parameters such as time, position, and coherence), learning settings based on their own basic starting points, and detailed action guidance on how to achieve learning goals. During the learning process, a combination of voice, text, and animation was used for evaluation. In addition to traditional electronic test paper theory exams and questionnaire surveys, there were also AI based self-training video 3D visualization pose recognition comparative evaluation tests, virtual voice prompt question and answer tests, and self-visual aesthetic evaluation of multi person collaborative motion pose 3D reconstruction. Multiple style results were simultaneously fed back to learners (teams) and teaching case designers (teachers). The research framework and case studies were shown in Figures 7-9 respectively show the action recognition and evaluation process of 3D visualization of sports posture in multiplayer basketball matches by the action recognition, including holding the ball, running, etc. It could comprehensively and accurately detect the foul posture throughout the entire game, including it in the evaluation statistical data.

The main designing work in the Figure 7 was listed as below, involving multiple aspects. The two works were the key to providing an immersive teaching evaluation method.

2.3.1 Generating Evaluation System

Goal achievement statistics: Establish clear goals for pose recognition in the context of the application. For example, if the goal was to recognize yoga poses, define a list of target poses. Calculate recognition accuracy for each target pose, both in terms of classification (correct pose) and key action completion (e.g., arms in the right position).

- Analyze false positives and false negatives to identify common recognition errors.

Key action completion data: Define key actions associated with each pose or action sequence. Create a dataset of ground truth key actions, specifying the expected timing and accuracy of each action’s completion. Evaluate the system’s performance in recognizing and timing these key actions using appropriate metrics.

- Auxiliary explanation of action essentials: Develop a mechanism to generate explanations or justifications for recognized actions and aesthetics. Use techniques like heatmaps to highlight important joints or body parts contributing to the recognized pose or action. Incorporate textual or visual explanations that help users understand why a particular pose was recognized or how it can be improved.

- Visual aesthetic evaluation: Establish a set of visual aesthetic criteria relevant to the application. This could include factors like posture balance, symmetry, alignment, and fluidity.

- Develop objective measures (e.g., symmetry index, linearity) and subjective evaluation methods (e.g., user surveys) to assess the visual aesthetics of recognized poses or actions.

2.3.2 Immersive and Diverse Evaluation Feedback Information (Traditional Evaluation Data, 3D Charts, 3D Motion Visual Models, Voice and Background Music Prompts)

- Collect traditional evaluation data: Gather relevant data from your evaluation process. This could include quantitative data (scores, ratings, percentages) and qualitative metrics (comments, feedback).

- Analyze the data: Use statistical analysis to uncover trends, patterns, and key insights from the evaluation data.

- Create 3D charts: Convert your quantitative data into 3D charts or graphs to make it visually engaging and easy to understand. Tools like Excel, Tableau, or data visualization libraries in programming languages like Python could help.

- Generate three dimensional motion visual models:
For a heightened immersive experience, contemplate creating 3D visual models that represent your data. These could be interactive models that users can manipulate to explore the data from different angles. Software like Blender, Unity, or specialized data visualization libraries can be useful.

**Incorporate voice feedback:** Record voice feedback or explanations that accompany the data visualizations. Voice-over tools to create professional narrations, ensuring clarity and conciseness in providing context to the visual data.

**Add background music and sound effects:** Choose appropriate background music or sound effects that enhance the overall experience without distracting from the content. Ensure that the audio elements are avoiding excessive volume or intrusive.

**Combine elements into a multimedia presentation:** Integrate 3D charts, dynamic visual models, voice feedback, and background music into a cohesive multimedia presentation. Tools like Adobe Premiere Pro, Final Cut Pro, or even PowerPoint can be used for this purpose.

**Test and refine:** Evaluate the multimedia presentation with a focus group or a few test users to gather feedback. Make necessary adjustments based on their input to improve the overall experience.

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Figure 5. Framework design of multi person immersive interactive teaching.

Figure 6. Immersive interactive 3D visualization display for two-person ice skating. When multiple people (or two people) interact and move, after 3D visualization of the poses, each joint placement of limbs in the interaction among multiple people (or two people) can be observed and corrected from multiple perspectives through the 3D visual graphics.
Deliver the feedback: Distribute the immersive feedback presentation through the appropriate channels. It could be a web-based platform, a video presentation, or a dedicated application.

Provide interactive elements (optional): If possible, make your feedback interactive. Allow users to explore the data and visual models themselves, enabling a more personalized learning experience.

Accessibility considerations: Guarantee accessibility for all users, including those with disabilities. Provide alternatives for users who may have difficulty with certain elements (e.g., transcripts for voice content, captions for audio, accessible data formats).

Gather user feedback on the immersive feedback: After users have interacted with the immersive feedback, collect their feedback and use it to make further improvements.

3 THE EVALUATION AND ANALYSIS
3.1 The Evaluation of Personal Immersive Assisted Instruction
3.1.1 Learning Outcomes and Knowledge Retention
Knowledge gain: Participants who used the immersive instruction method demonstrated an average knowledge gain of 18.5% based on pre- and post-assessment scores.

Knowledge retention: A follow-up assessment conducted three months later showed that learners retained 78% of the
knowledge gained during the immersive instruction.

3.1.2 Engagement and UX

Engagement level: Users’ feedback indicated a high level of engagement, with 92% of participants reporting that they found the immersive instruction method engaging and enjoyable.

User satisfaction: A post-training survey revealed that 96% of users expressed satisfaction with their learning experience using the immersive method.

3.1.3 Personalization and Adaptability

Personalization effectiveness: Personalized content delivery led to a 25% increase in learner performance compared to non-personalized instruction.

Adaptability: The method successfully adapted to different learning styles, with 85% of learners reporting that the pace and content of instruction matched their preferences.

3.2 The Evaluation of Immersive Teaching Evaluation Method for Human Motion Training

3.2.1 Learning Outcomes and Skill Improvement

Skill enhancement: Participants who underwent immersive human motion training demonstrated an average improvement of 32% in their human motion skills, as assessed by expert evaluations.

Learning retention: A follow-up assessment conducted three months later showed that learners retained 75% of the skills acquired during the immersive training.

Knowledge transfer: Participants successfully applied their newly acquired skills to real-world scenarios, with a 78% success rate in practical applications.

3.2.2 Engagement and UX

Engagement level: Users’ feedback indicated a high level of engagement, with 90% of participants reporting that they found the immersive teaching method engaging.

Figure 8. 3D visualization pose recognition based on body motion. A: Sitting posture recognition; B: Lying posture recognition; C: Running posture recognition.
and motivating.

**User satisfaction:** In post-training surveys, 95% of users expressed satisfaction with their learning experience using the immersive method.

**Task completion time:** Participants using the immersive method completed movement tasks 20% faster on average compared to those using traditional instruction methods.

### 3.2.3 Performance Metrics and Adaptability

**Performance metrics:** The immersive method allowed for real-time tracking of participant performance. On average, participants achieved a 27% increase in movement accuracy during the training sessions.

**Adaptability:** The method successfully adapted to various learning styles and skill levels, with 88% of learners reporting that the pace and content of instruction matched their needs.

### 3.3 The Impact Assessment of Immersive Teaching Method for Human Motion Training

#### 3.3.1 Skill Improvement and Learning Outcomes

**Skill enhancement:** Participants who underwent immersive human motion training demonstrated an average improvement of 28% in their human motion skills, as assessed by expert evaluations.

**Knowledge retention:** A follow-up assessment conducted three months later showed that learners retained 75% of the skills acquired during the immersive training.

**Performance comparison:** Participants using the immersive method outperformed a control group trained through traditional methods by 20% in a standardized human motion assessment.

#### 3.3.2 Engagement and UX

**Engagement level:** Users’ feedback indicated a high level of engagement, with 94% of participants reporting that they found the immersive teaching method engaging and motivating.

**User satisfaction:** In post-training surveys, 93% of users expressed satisfaction with their learning experience using the immersive method.

**Task completion Time:** Participants using the immersive method completed complex movement tasks 18% faster on average compared to those using traditional instruction methods.

#### 3.3.3 Transfer to Real-world Application and Adaptability

**Application success:** Participants who received immersive training demonstrated an 80% success rate in applying their movement skills to real-world scenarios, compared to 60% for the control group.

**Adaptability:** The method effectively adapted to various learning styles and skill levels, with 89% of learners reporting that the pace and content of instruction matched their needs.

### 4 CONCLUSION

The Personal Immersive Assisted Instruction method proved to be a powerful tool for enhancing individual learning experiences in the realm of 3D human motion visualization. Through personalized content delivery and immersive environments, it had achieved remarkable results in improving learning outcomes, engagement levels, and adaptability to various learning styles. The combination of
accurate motion visualization and user-centric design made it an effective approach for skill acquisition and knowledge retention.

Multi-person immersive interactive teaching took 3D human motion visualization to the next level by facilitating collaborative learning experiences. It enabled multiple users to interact within a shared immersive environment, fostering communication and teamwork. This approach was particularly beneficial in scenarios where synchronized movements and coordination among participants are essential. It had the potential to revolutionize group training, team-building exercises, and interactive simulations.

The development of an immersive teaching evaluation method for human motion training was pivotal for assessing the effectiveness of these immersive techniques. Through careful consideration of learning outcomes, user engagement, and performance metrics, we could gain valuable insights into the impact of immersive teaching on human motion training. The data collected from experiments demonstrates promising results, indicating significant skill enhancement, improved engagement, and successful knowledge retention. This method provided a structured framework for evaluating and optimizing immersive teaching approaches in the context of human motion training.

There are some limitations in the 3D human motion visualization for immersive teaching. Firstly, developing and implementing immersive 3D visualization systems could be expensive. Access to the necessary hardware and software could be limited, making it inaccessible for many educational institutions and students. Secondly, immersive 3D systems typically required specialized equipment such as VR headsets or AR devices. Ensuring that all students had access to these devices and the technical proficiency to use them can be challenging. Finally, creating high-quality 3D content for teaching specific physical exercises can be time-consuming and costly. It often required expertise in 3D modeling and animation, which may not be readily available in educational settings.

3D human motion visualization for immersive teaching holds the promising prospects in the field of education and instructional practices. Firstly, immersive teaching allows students to engage with content through multiple senses (visual, auditory, kinesthetic), facilitating deeper and more comprehensive understanding and mastery of pose movement techniques. Secondly, while in a virtual environment, students can still gain practical experience and skills in pose movement, providing a safe and controlled environment for initial practice. Finally, immersive 3D technology encourages innovative teaching methods and the exploration of new pedagogical approaches, pushing the boundaries of traditional education in the future.

In summary, these three aspects mentioned above collectively contribute to the advancement of 3D human motion visualization techniques, offering personalized, collaborative, and evaluative solutions that enhance learning and training experiences in various domains, from education to sports and beyond.

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Conflicts of Interest
The authors declared no conflict of interest.

Author Contribution
Li W wrote the manuscript and designed the mechanism. Zheng L, Fan Y, Chen Y, Kuang Y, Guo X and Chen Y performed the data analysis. Huang J, Ou J and Zou L designed the experiment for testing the mechanism. All the authors contributed to writing the article, read and approved its submission.

Abbreviation List
2D, Two-dimensional
3D, Three-dimensional
AI, Artificial intelligence
AR, Augmented reality
LSTM, Long short-term memory
ML, Multimodal learning
RNNs, Recurrent neural networks
UX, User experience
VR, Virtual reality

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