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Preserving Balinese dance through hyperreal digital humans: A motion capture and projection mapping approach

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Abstract:
This research explores how motion capture and projection mapping technologies can be structured to preserve traditional Balinese dance while supporting creative education in higher learning. The project aimed to create a hyperreal digital human that authentically embodies traditional choreography, guided by the Balinese philosophy of Tri Hita Karana, which emphasizes harmony among the divine, humans, and nature. The production pipeline integrated students and professionals across all stages—from ideation and narrative development to technical execution—using an OptiTrack motion capture system, Blender for 3D modeling, and Unreal Engine for real-time rendering. The cleaned motion data was mapped onto a detailed 3D character representing a celestial Balinese dancer. This digital performance was then projection-mapped onto large structures during the Indonesia Bertutur 2024 festival, engaging audiences with a fusion of tradition and digital art. Results show that motion capture can retain the integrity of traditional movements, while projection mapping serves as a powerful medium for public storytelling. The collaborative model also provided students with direct exposure to industry workflows and cultural material. This study concludes that emerging media can meaningfully support cultural preservation and pedagogical innovation when implemented with respect, structure, and collaboration.

Introduction

In the face of rapid technological evolution, preserving intangible cultural heritage has become a global concern. Traditional performing arts, such as Balinese dance, are particularly at risk due to generational shifts and declining participation. Digital technologies offer preservation tools, but must respect cultural context and authenticity (Rizhan, 2025).

This research draws from Tri Hita Karana, a Balinese worldview emphasizing harmony among the divine (Parahyangan), human relationships (Pawongan), and nature (Palemahan). Guided by this principle, the project created a hyperreal digital human representation of a Balinese dancer—not as a technical artifact, but as a cultural narrative. Embedded in the Indonesia Bertutur 2024 festival, organized by the Ministry of Education and Culture, the project aligned with the theme "Subak: Harmoni dengan Pencipta, Alam, dan Sesama."

The central research question: How can motion capture and projection mapping be structured to preserve traditional Balinese performance while also serving as a framework for creative education in a university setting?

To address this, the project adopted an interdisciplinary pipeline, blending cultural research with industry-grade production tools. Students and professionals collaborated in the motion capture lab

and design studio to produce an animated dancer, which was projection-mapped in a large-scale public installation. This paper discusses the technical pipeline, the educational impact of integrating students into real-world creative production, and the project's role in advancing digital cultural preservation.

Methods

The process started with a collaborative ideation phase, where students and professionals came together to shape the core narrative and visual theme: **"Twin Echoes of Harmony: Humanity and Nature."** Drawing on the Balinese philosophy of *Tri Hita Karana*, the team explored the concept of duality through two celestial dancers, representing the bond between people and the natural world. Early visualizations took shape through mood boards, rough sketches, and discussions with cultural experts.

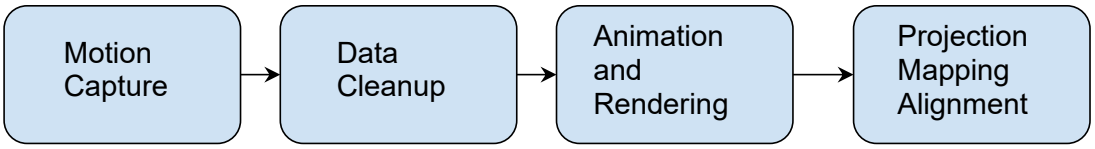


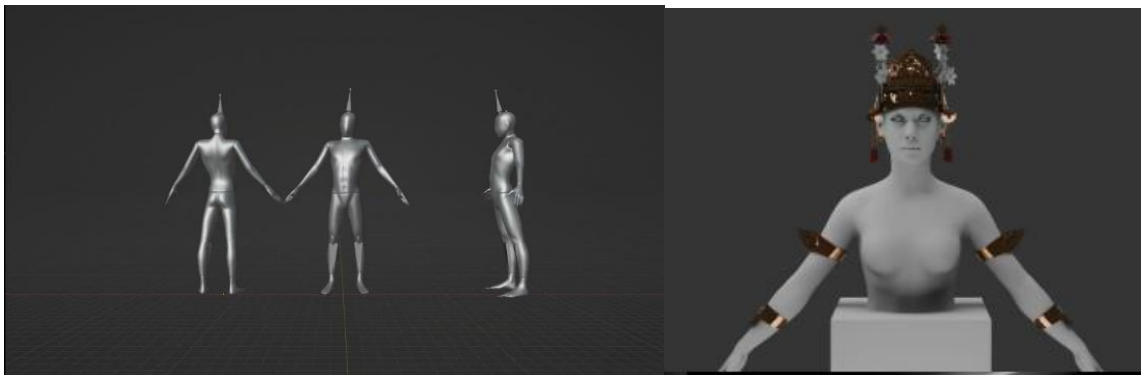
Diagram 1. Method of Working

Once the creative direction was clear, the team moved into motion capture production at the Visual Communication Design (VCD) Lab, Sampoerna University. Using an OptiTrack system equipped with 12 infrared cameras, they recorded a traditional Balinese dance performed in a full-body marker suit. Several takes were captured to ensure the movements were both accurate and expressive.

Figure 1. Motion capture setup using the OptiTrack system

3D Modeling and Animation

The captured motion data underwent a detailed cleanup process, including retargeting and keyframe refinement to ensure accuracy. The refined motion was then applied to a high-fidelity 3D character model created in Blender, designed with authentic Balinese costume details. Preliminary animation previews were conducted in Cinema 4D, after which the project transitioned to Unreal Engine for real-time rendering and precise skeletal alignment. Final enhancements included facial animation, cloth simulation, and lighting adjustments to heighten realism (Wang, 2022).



[Figure 2. 3D character rig in Blender with adding ornaments]

Data Cleanup Challenges

Cleaning raw motion capture data presented several challenges. Issues such as joint jitter, foot sliding, and missing marker information required intensive manual correction. This process, carried out in MotionBuilder, was time-consuming but critical for maintaining the performance's authenticity. Although AI-assisted cleanup tools are emerging, they are not yet effective for handling culturally specific dance movements (Mu et al., 2025; Utkarsh et al., 2017).

To test the animation, the team ran early previews in Cinema 4D before migrating to Unreal Engine for final rendering. A second round of motion adjustment was done within Unreal to fine-tune skeletal alignment. The last step involved adding digital cloth simulations, facial expressions, and lighting setups to enhance realism.

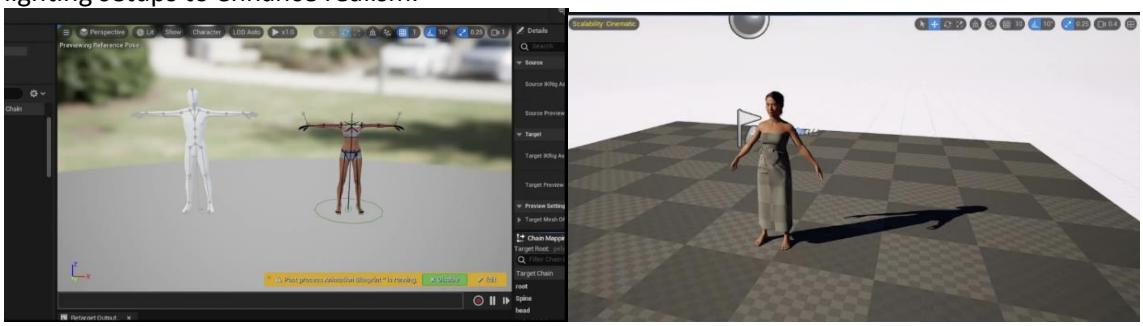


Figure 3. 3D character animation testing in Unreal Engine

The finished animation was projection-mapped onto large modular structures at the **Indonesia Bertutur 2024** festival. Audiences experienced the piece as a vibrant fusion of tradition and technology—bringing centuries-old movement into a modern, immersive format.

Results and Discussion

This study examined whether motion capture and projection mapping could be structured to preserve traditional Balinese dance while also serving as an effective model for creative education in a university context. The findings affirm both goals.

Motion Capture as a Cultural Preservation Tool

At the core of the project was the translation of Balinese dance into a digital format using motion capture. A trained dancer's performance was captured using the OptiTrack system, which utilizes reflective markers and infrared cameras to track 3D body movements in real time. The resulting skeletal data was mapped onto a digital character rig, preserving expressive gestures, postures, and movement quality central to Balinese choreography (Rizhan, 2025; Hong, 2024).

Unlike traditional video documentation, motion capture allows recorded movement to be reused across digital platforms while maintaining performance fidelity. Previous studies highlight motion capture as a powerful tool for preserving intangible cultural heritage, especially in dance and ritual contexts (Reshma, 2023; Nikolakopoulou, 2022; Boboc et al., 2022).

Moreover, mocap significantly reduced production time. Base animation was generated quickly, freeing the team to focus on design refinement and projection planning (Wang, 2022; Wang et al., 2025).

Figure 4. 3D character animation rendering final before composing in Adobe After Effects

Challenges in Motion Data Cleanup

One major challenge emerged during the cleanup of motion data. Although motion capture records movement accurately, raw data often contains errors such as jittering joints, foot sliding, and missing marker data. Manual frame-by-frame correction in MotionBuilder was required to ensure the final motion was clean and realistic.

This process was time-consuming but necessary to preserve the integrity of the performance. Studies confirm that cleanup remains one of the most resource-intensive aspects of mocap workflows (Mu et al., 2025; Utkarsh et al., 2017). While AI-based cleanup tools are in development, they currently require extensive datasets and are not yet suitable for specialized, culturally specific choreography.

Real-Time Animation and Public Projection

After cleaning and refining the motion data, the animation was imported into Cinema 4D for testing and then Unreal Engine for real-time rendering. The 3D model was enhanced with traditional costume elements, textures, and lighting setups. The final output was projection-mapped during Indonesia Bertutur 2024 in Bali as part of the Kiranamaya program (MMU Press, 2025; Nikolakopoulou, 2022).

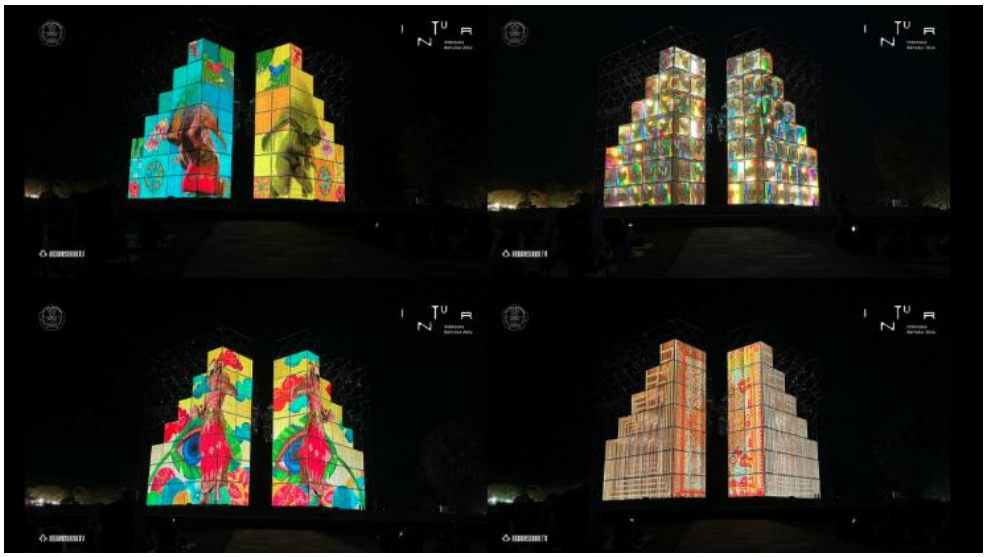


Figure 4. digital dancer performance on public display projection mapping

This public presentation connected traditional performance with contemporary audiences. As recent research suggests, projection mapping has become an increasingly relevant medium for presenting heritage in ways that engage public space and sensory experience (Chunlan, 2025; MMU Press, 2025).".

Creative Education: From Classroom to Crowd

The project also functioned as a pedagogical model grounded in the "from classroom to crowd" concept. Students from Sampoerna University collaborated with ARASxLAB professionals throughout every production stage, including motion capture, modeling, animation testing, and projection setup. Work occurred in the university's mocap lab and studio environment.

This project-based learning format provided students with hands-on experience using professional tools and cultural materials. Public presentation at a national festival gave their work broader visibility and validation (Sawhney et al., 2018; Wang, 2022).

Reflection on the Research Question

The project supports the research question: motion capture and projection mapping can be structured not only as tools for cultural preservation but also as effective frameworks for university-level creative education. While technical challenges—particularly motion cleanup—were present, the approach enabled a dynamic, collaborative production that preserved cultural meaning while providing real-world learning opportunities.

Conclusion

This project demonstrated that motion capture and projection mapping technologies can serve as powerful tools for preserving and reinterpreting traditional performance practices such as Balinese dance. By embedding cultural fidelity within a high-fidelity digital pipeline, the team created a digital human dancer that accurately reflected traditional movement and costume.

Equally significant was the project's educational impact. Through a model of collaborative, project-based learning, students experienced the entire production pipeline—from motion recording to public projection. This alignment of cultural preservation and creative education, showcased publicly at Indonesia Bertutur 2024, offers a replicable model for other institutions aiming to blend heritage and innovation.

Future iterations of this model could explore AI-assisted cleanup workflows or interactive applications that allow audiences to engage more deeply with digital heritage. However, the central achievement remains clear: that meaningful cultural storytelling can emerge from the intersection of tradition, technology, and education.

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