論文 / 著書情報
Article / Book Information

題目(和文)	スポーツ技能獲得における段階的訓練手法に関する研究
Title(English)	A Progressive Training Method for Sports Skill Acquisition
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種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation proposes a novel, multi-phase approach to democratizing motor skill acquisition, with a particular focus on golf swing training. Grounded in the concept that beginners often struggle to bridge the gap between rudimentary motions and expert-level form, the work introduces two complementary systems, Coach Navi and AI Coach, which facilitate a smooth, user-centric progression from novice to advanced performance levels. At the outset, the thesis contextualizes the broader goal of democratizing skill acquisition. Traditional coaching arrangements rely heavily on expert instruction and specialized facilities, making skill development in sports both expensive and logistically challenging. However, advancements in motion capture and machine learning now permit flexible data-driven training systems. The introduction outlines how novices often face difficulties in mimicking professional athletes' motions directly, especially when critical "intermediate" steps or personalized feedback are absent. Hence, the thesis proposes an integrated pipeline that offers more accessible, more adaptive approaches to motor skill training.

In reviewing existing literature, it becomes clear that while numerous sports training systems exist, most focus on either generic templates or single-frame corrections. Furthermore, adaptive or transitional tasks do appear in some works, but rarely does one see the explicit generation of an intermediate-level form for novices to imitate. This gap highlights a niche for approaches that can systematically create mid-tier motions aligned with a user's current skill, ensuring neither an oversimplified nor a dauntingly high-level target.

Against this backdrop, the thesis introduces a three-step training proposal: (1) selecting or creating an intermediate-level motion target, (2) adapting that motion target to the user's physical attributes for improved realism, and (3) detecting and highlighting fine-grained discrepancies for actionable corrections. Two systems embody this approach. Coach Navi primarily addresses the challenge of finding an appropriate learning target for each user's skill level. By leveraging a Variational Autoencoder combined with Motion Style Transfer, Coach Navi identifies a skill-appropriate motion from a large dataset, then morphs it into a personalized "ideal me" avatar that matches the user's body proportions. This helps users move away from the disconnect that arises when asked to imitate a high-level motion that is physically or skill-wise out of reach. The user study results indicate that showing an intermediate motion, rather than a purely expert template, significantly enhances motivation and engagement. Participants reported better alignment with the "ideal me" concept, as they found it easier to imagine themselves performing the suggested improvements. Notably, the user study measuring aspects such as Mean Per Joint Angle Error showed noticeable improvements compared to conventional video playback or mesh-only methods, demonstrating Coach Navi's viability of intermediate-level form imitation.

AI Coach, on the other hand, focuses on pinpointing and correcting fine-grained discrepancies within a user's motion. Through a Temporal Cycle-Consistency network that incorporates attention, AI Coach synchronizes the user's swing with an expert reference and provides real-time or replay-based feedback. The attention mechanism assigns greater weight to critical frames and joints, improving the correlation between latent-space distances and actual positional errors. The system flags precisely which frames or poses deviate most, thereby helping the user focus on meaningful corrections. Multiple user studies confirm that AI Coach outperforms traditional video and skeleton methods by offering concise, frame-specific guidance and higher accuracy in capturing subtle errors. This leads to stronger user engagement and a clearer sense of how and when to adjust posture or joint angles.

Combining these two systems yields an adaptive, end-to-end pipeline. Coach Navi provides learners with an approachable mid-tier target motion, while AI Coach delivers high-resolution feedback for polishing the resulting form. The thesis's Discussion chapter positions these developments within

the framework of internal models, covering both the motor model and the sensory model. The synergy of a personalized intermediate motion with precise discrepancy detection fosters a more nuanced alignment between AI-based analysis and the typical priorities of human coaches. Nevertheless, certain limitations remain. The user studies feature a relatively small participant pool, limiting statistical power in measures such as NASA-TLX workload scores. Moreover, the work primarily focuses on pose-level differences without explicitly analyzing force or muscle activations, which could reveal further subtleties in skill acquisition. Future expansions might incorporate biomechanical data, haptic feedback, or outcome-based metrics like golf ball flight trajectories to confirm improvements in actual performance, not just form approximation.

In conclusion, this thesis demonstrates how personalized intermediate-level motion targets (Coach Navi) and detailed pose-correction feedback (AI Coach) can lead to more effective and less intimidating motor skill training experiences. By bridging novices' present abilities and expert-level ideals in progressive steps, the approach reduces frustration and improves user motivation. Evaluations confirm the systems' efficacy, and the latent-space methodology points the way toward increasingly flexible and comprehensive motion training solutions. Through broader integration with VR environments, outcome-based evaluations, and more advanced bioinformatics, the proposed pipeline stands poised to expand the frontiers of democratized skill acquisition in sports and beyond.

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