基于深度学习的太极拳动作姿态识别与规范性评估系统开发与应用

刘源慧，郭妙华

吉林农业大学国际足球教育学院，吉林省长春市　130118

摘要：目的：太极拳作为中华民族传统武术的瑰宝，其动作姿态的规范性直接影响着锻炼效果和健身养生功效的发挥。然而，太极拳动作复杂且对姿势规范性要求较高，初学者和非专业人士在练习过程中常难以准确掌握其精髓。目前，传统太极拳教学与评估方式主要依赖于教练现场指导和主观评判。这种方式存在效率低、主观性强、受地域和时间限制等问题，难以满足大规模人群练习太极拳的需求。随着全民健身计划推进和太极拳运动广泛普及，专业运动员的技能提升和普通大众日常健身都对太极拳动作姿态的精准识别与科学评估提出更高要求。本研究通过构建基于深度学习的太极拳动作姿态识别与规范性评估系统，旨在利用深度学习强大的特征提取和模式识别能力，突破传统方法的局限，实现太极拳动作姿态的高精度识别与客观、高效的规范性评估，为太极拳教学、训练和健身指导提供智能化支持，推动太极拳运动的科学化发展，助力提升全民健身的质量和水平。**方法：**(1) 数据采集与预处理① 数据采集：采用多源数据采集方式。通过多个高清摄像头采集不同水平练习者太极拳动作视频数据。同时，结合惯性传感器等设备获取人体关节的运动数据，实现对太极拳动作姿态的全方位记录。为确保数据的多样性和代表性，本研究与专业太极拳教练和学员合作，收集涵盖流不同派和难度等级的太极拳动作视频数据集。② 数据标注：组建专业标注团队，包括太极拳教练和计算机视觉领域专家，按照严格的标注规范对采集到的视频和传感器数据进行动作姿态标注。标注内容包括关键关节点位置、动作类型、动作起止时间等信息，为后续的模型训练提供准确的标签数据。③ 数据预处理：对采集到的视频数据进行裁剪、降噪等处理，去除无关背景信息；对视频数据进行帧提取、归一化处理，调整图像分辨率和帧率；对传感器数据进行滤波、插值等处理，确保数据的质量和一致性。利用人体姿态估计算法从视频帧中提取人体关键点坐标，将视频数据转化为可用于深度学习模型训练的结构化数据。(2) 深度学习模型构建与训练① 姿态识别模型构建：选用基于卷积神经网络的深度学习模型作为基础架构，结合太极拳动作姿态特点，对网络结构进行优化和改进。在网络中引入注意力机制，增强模型对太极拳动作关键部位和关键姿态变化的关注能力，提高姿态识别的准确性。同时，采用多尺度特征融合技术，将不同层次的特征图进行融合，充分利用图像的多尺度信息，提升模型对复杂动作姿态的识别性能。在模型训练过程中，采用迁移学习方法，利用在大规模人体姿态数据集上预训练的模型参数，初始化太极拳姿态识别模型，减少训练时间和数据需求。② 规范性评估模型：在姿态识别基础上，构建基于深度学习的规范性评估模型。将姿态识别结果与预先设定的太极拳动作标准姿态数据库进行对比分析，利用

循环神经网络或长短时记忆网络对动作序列进行建模，学习太极拳动作的时间序列特征和规范动作模式。通过训练，使模型能够根据动作姿态的偏差程度，自动评估太极拳动作的规范性，并给出相应的评分和改进建议。③ 模型训练与优化：采用大规模的标注数据集对深度学习模型进行训练，使用随机梯度下降及其变种算法进行模型参数优化，以最小化损失函数为目标，不断调整模型参数，提高模型的泛化能力和性能表现。同时，运用数据增强技术扩充训练数据集，防止模型过拟合，提升模型实际应用效果。(3) 系统集成与开发① 硬件环境搭建：选择高性能服务器或边缘计算设备作为系统运行的硬件平台，配备 GPU 加速卡，以满足深度学习模型的计算需求，确保系统能够快速高效地处理大量动作数据。同时，部署高清摄像头和惯性传感器等数据采集设备，构建稳定的数据采集网络。② 软件系统开发：基于 Python 语言和深度学习框架开发太极拳动作姿态识别与规范性评估系统。系统主要包括数据采集模块、数据预处理模块、深度学习模型推理模块、规范性评估模块和用户交互界面模块。数据采集模块负责实时采集视频和传感器数据；数据预处理模块对采集数据进行清洗和预处理；深度学习模型推理模块利用训练好的模型对预处理后的数据进行姿态识别和规范性评估；规范性评估模块根据模型输出结果，生成详细的评估报告；用户交互界面模块提供友好的操作界面，方便用户进行数据查看、评估结果查询和系统参数设置等操作。③ 系统测试与优化：对开发完成的系统进行全面功能测试、性能测试和稳定性测试。通过模拟不同的使用场景和用户需求，检验系统的准确性、可靠性和响应速度。根据测试结果，对系统进行优化和改进，调整模型参数、优化算法流程、提升系统的用户体验，确保系统能够满足实际应用要求。**结果：**(1) 姿态识别性能 基于深度学习的太极拳动作姿态识别与规范性评估系统可在多种测试数据集上取得优异性能表现。在公开的人体姿态识别数据集以及自建的太极拳动作姿态数据集上，该系统对太极拳关键关节点的识别准确率可达到较高水平，能够精准捕捉太极拳动作中的细微姿态变化。(2) 规范性评估效果 规范性评估模型能够准确地对太极拳动作规范性进行评估，其评估结果与人工评估可具有高度一致性。该系统可以根据不同流派、不同难度级别的太极拳动作标准，对练习者的动作进行个性化评估，不仅能够给出整体的规范性评分，还能针对每个动作环节存在的问题进行详细分析，并提供相应的改进建议。(3) 系统应用效果 将太极拳动作姿态识别与规范性评估系统应用于实际的太极拳教学和训练场景中，可取了良好的应用效果。在教学方面，教师可以利用系统实时监控学生的动作姿态，及时发现问题并进行针对性指导，提高教学效率和质量；在训练方面，运动员和爱好者可以通过系统进行自我评估和训练效果跟踪，制定个性化的训练计划，提升训练的科学性和有效性。**结论：**基于深度学习的太极拳动作姿态识别与规范性评估系统的开发与应用，可为太极拳教学、训练和健身指导提供一种创新的智能化解决方案。通过多源数据采集、深度学习模型构建和系统集成开发，实现太极拳动作姿态高精度识别和客观、科学的规范性评估，可有效解决传统评估方法存在的问题。该系统可具有较高准确性、和实用性，从而满足不同用户群体在太极拳学习和训练过程中的需求。

关键词：深度学习；太极拳；动作姿态识别；规范性评估；系统开发

The development and application of Taijiquan action posture recognition and normative evaluation system based on deep learning

Yuanhui Liu, Miaohua Guo

College of International Football Education, Jilin Agricultural University, Changchun City, Jilin Province 130118

Abstract: Research Purpose: Tai Chi, as a gem of traditional Chinese martial arts, has its exercise effectiveness and health benefits directly influenced by the standardization of its movements and postures. However, Tai Chi movements are complex and require a high degree of posture standardization, which often makes it difficult for beginners and non-professionals to master its essence accurately during practice. Currently, traditional Tai Chi teaching and assessment methods mainly rely on coach-led guidance and subjective judgment. This approach faces issues such as low efficiency, high subjectivity, and limitations due to regional and time constraints, making it difficult to meet the needs of large-scale Tai Chi practice. With the advancement of national fitness programs and the widespread popularity of Tai Chi, both the skill enhancement of professional athletes and the daily fitness of the general public place higher demands on the precise identification and scientific assessment of Tai Chi movements and postures. This study aims to develop a system for Tai Chi motion posture recognition and standardization evaluation based on deep learning, leveraging the powerful feature extraction and pattern recognition capabilities of deep learning to overcome the limitations of traditional methods, achieving high-precision recognition and objective, efficient standardization assessment of Tai Chi movements, providing intelligent support for Tai Chi teaching, training, and fitness guidance, promoting the scientific development of Tai Chi, and improving the quality and level of national fitness. **Research Methodology :** (1) Data Collection and Preprocessing ① Data Collection: A multi-source data collection approach is used. Video data of Tai Chi movements from practitioners at various skill levels are captured using multiple high-definition cameras. At the same time, inertial sensors and other devices are employed to gather motion data of body joints, achieving a comprehensive recording of Tai Chi movement postures. To ensure data diversity and representativeness, this study collaborates with professional Tai Chi coaches and students to collect a video dataset covering different schools and difficulty levels of Tai Chi movements. ② Data Annotation: A professional annotation team is formed, consisting of Tai Chi coaches and computer vision experts. They follow strict annotation guidelines to label the collected video and sensor data with information such as key joint positions, movement types, and start/end times, providing accurate labeled data for subsequent model training. ③ Data Preprocessing: The collected video data is processed through cropping, denoising, and other techniques to remove irrelevant background information. Frame extraction and normalization are applied to the video data, adjusting image resolution and frame rate. Sensor data is filtered and interpolated to ensure data quality and consistency. A human pose estimation algorithm is used to extract key point

coordinates from the video frames, converting the video data into structured data for deep learning model training. (2) Deep Learning Model Construction and Training ① Pose Recognition Model Construction: A deep learning model based on convolutional neural networks (CNNs) is selected as the foundational architecture. The network structure is optimized and improved based on the characteristics of Tai Chi movement postures. Attention mechanisms are introduced within the network to enhance the model's focus on key body parts and posture variations in Tai Chi movements, improving the accuracy of pose recognition. Additionally, multi-scale feature fusion techniques are applied, combining feature maps from different layers to fully leverage multi-scale information in the images and improve the model's performance in recognizing complex movement postures. During model training, transfer learning is employed, utilizing pre-trained model parameters from large-scale human pose datasets to initialize the Tai Chi pose recognition model, reducing training time and data requirements. ② Normative Evaluation Model: Based on pose recognition, a deep learning-based normative evaluation model is constructed. The pose recognition results are compared and analyzed with a pre-defined standard Tai Chi posture database. Recurrent neural networks (RNNs) or long short-term memory (LSTM) networks are used to model the action sequences, learning the time-series features and normative movement patterns of Tai Chi actions. Through training, the model can automatically evaluate the normative quality of Tai Chi movements based on the deviation in posture and provide corresponding scores and improvement suggestions. ③ Model Training and Optimization: The deep learning model is trained using a large-scale annotated dataset. Stochastic gradient descent (SGD) and its variants are employed to optimize model parameters, aiming to minimize the loss function while continuously adjusting the model parameters to improve generalization and performance. Additionally, data augmentation techniques are used to expand the training dataset, preventing model overfitting and enhancing its practical application effectiveness. (3) System Integration and Development ① Hardware Environment Setup: High-performance servers or edge computing devices are chosen as the hardware platform for system operation, equipped with GPU acceleration cards to meet the computational demands of deep learning models and ensure the system can process large amounts of movement data quickly and efficiently. At the same time, high-definition cameras and inertial sensors are deployed to collect data, establishing a stable data collection network. ② Software System Development: The Tai Chi posture recognition and normative evaluation system is developed using Python and deep learning frameworks. The system mainly consists of a data collection module, data preprocessing module, deep learning model inference module, normative evaluation module, and user interface module. The data collection module is responsible for real-time collection of video and sensor data; the data preprocessing module cleans and preprocesses the collected data; the deep learning model inference module performs pose recognition and normative evaluation on the preprocessed data using the trained model; the normative evaluation module generates detailed evaluation reports based on model output; the user interface module provides a user-friendly interface for users to view data, query evaluation results, and adjust system parameters. ③ System Testing and Optimization: Comprehensive functional testing,

performance testing, and stability testing are conducted on the developed system. By simulating different usage scenarios and user needs, the system's accuracy, reliability, and response speed are evaluated. Based on the test results, the system is optimized and improved by adjusting model parameters, refining algorithm processes, and enhancing user experience to ensure that the system meets practical application requirements. **Research Results:** (1) Pose Recognition Performance The deep learning-based Tai Chi motion posture recognition and normative evaluation system performs excellently across various test datasets. On both publicly available human pose recognition datasets and the custom-built Tai Chi posture dataset, the system achieves high accuracy in recognizing key Tai Chi joint points, and is capable of precisely capturing subtle posture changes within Tai Chi movements. (2) Normative Evaluation Performance The normative evaluation model can accurately assess the normative quality of Tai Chi movements, with results highly consistent with human assessments. The system can provide personalized evaluations of practitioners' movements based on Tai Chi movement standards across different schools and difficulty levels. It not only provides an overall normative score but also offers detailed analyses of issues in each movement phase and provides corresponding improvement suggestions. (3) System Application Effectiveness The Tai Chi motion posture recognition and normative evaluation system has been effectively applied in real-world Tai Chi teaching and training scenarios. In teaching, instructors can use the system to monitor students' posture in real-time, identify problems promptly, and provide targeted guidance, improving teaching efficiency and quality. In training, athletes and enthusiasts can use the system for self-assessment and tracking training progress, developing personalized training plans to enhance the scientific and effective nature of their training. **Research Conclusions:** The development and application of a deep learning-based Tai Chi motion posture recognition and normative evaluation system provides an innovative and intelligent solution for Tai Chi teaching, training, and fitness guidance. Through multi-source data collection, deep learning model construction, and system integration, high-precision recognition and objective, scientific normative evaluation of Tai Chi movements are achieved, effectively addressing the limitations of traditional evaluation methods. The system offers high accuracy and practicality, meeting the needs of various user groups in Tai Chi learning and training. **Research Recommendations:** (1) System Performance Optimization The development team should continue to monitor the latest research in deep learning, incorporating more advanced network architectures and algorithms to further enhance the model's recognition accuracy and evaluation efficiency. To address the system's real-time performance requirements, the team should explore model optimization techniques such as pruning, quantization, and knowledge distillation, allowing the system to run efficiently on resource-constrained devices (e.g., mobile terminals) and expand its application range.(2) Technology Integration and Expansion The project team should strengthen integration with virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies to create an immersive learning and training environment for users. Using VR/AR/MR technology, the team can visually present standard posture images as virtual avatars, overlaying them in real-time onto users' actual movements, helping users better perceive the differences between their movements and the standard movements, enhancing the learning

effect. At the same time, the team should integrate Internet of Things (IoT) technology to enable multi-device collaboration and build an intelligent Tai Chi movement monitoring and evaluation ecosystem. (3) Promotion and Application Strategy The operations team should actively collaborate with Tai Chi training institutions, schools, sports event organizations, and others to expand the system's promotion and application. The operations team should conduct system application training to improve users' operational ability and application level. The team should collect user feedback, continually optimize the system's functionality and user experience, and develop customized versions based on different user needs to meet the diverse market demands. (4) Data Resource Development The data management team should continuously expand and improve the Tai Chi posture dataset, adding data from practitioners of different ages, genders, and body types, and covering more complex scenarios and special cases. The team should establish a data-sharing mechanism to promote data exchange between academic research and industrial applications, attracting more research power to engage in Tai Chi posture recognition and normative evaluation technology, thus driving the development and advancement of the entire field.

Keywords: deep learning; tai Chi; action posture recognition; normative assessment; system development