Swimming Stroke Analysis and Feedback System using Machine Learning

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***Abstract*— Swimming is a sport which offers numerous health benefits which however improper and poor techniques can affect the swimmer's health as well as their performance by leading to significant injuries particularly affecting knees, back and shoulders. The proposed system utilizes machine learning and computer vision techniques to initially analyse freestyle swimming stroke videos and categorizes swimming postures as "good" and "bad" poses and provide feedback to swimmers using a classification machine learning model. The development process includes the segmentation of swimmer images, pose estimation and feature extraction and the training the machine learning model. The model is trained on a large set of swimming footage with annotations. Pose estimation accuracy is increased by the segmentation procedure, which makes sure that only relevant body movements are examined. Once trained, the machine learning model uses a user-friendly web application to recognise poses and provide corrective feedback. The expected outcomes of the proposed system are accurate pose estimation with a mean absolute error of less than 5 pixels and the machine learning model achieving over 90% accuracy in pose classification. Variable video quality and the requirement for model changes throughout time are the challenges of the proposed system as future research will be focused on evaluating for the other strokes and offering more detailed feedback thorough analysis.**

Keywords— machine learning, stroke analysis, computer vision, pose estimation

I. INTRODUCTION

Swimming is a sport that is widely recognized for its numerous health benefits such as cardiovascular health, stronger muscles and increased flexibility [1]. Despite these benefits, improper and poor techniques of swimming can affect a swimmer's health as well as their performance by leading to significant injuries, particularly affecting the knees, back and shoulders [2]. These injuries can range in severity from little pains to excruciating agony, which can eventually affect the swimmer's performance and the ability to engage in the sport effectively.

This paper proposes a novel "Swimming Stroke Analysis and Feedback System using Machine Learning" to address this issue by providing a cutting-edge technological solution to the swimmers. This proposed system uses the power of machine learning and computer vision to provide an analysis, enabling swimmers of all levels enhance their technique and prevent injuries. By analysing video recordings, the system will provide automated feedback, which makes it an invaluable resource for swimmers who are looking refine their strokes and improve their overall performance. The system will be developed under the main objective of Injury Prevention which comes under the third Sustainable Development Goal; "Good Health and Well Being" out of seventeen goals defined by the United Nations [3].

This innovative system investigates the applications of computer vision techniques to extract the key features of swimming videos. These techniques such as image segmentation and pose estimation enable the system to isolate the swimmer's body and extract the crucial features such as joint angles and velocities, with the system can estimate the swimmer's pose and categorize it as either "good" or a "bad" position with using a classification model. Once trained, the model will be able to analyse user-uploaded swimming videos and provide accurate classifications. With the help of this unbiased feedback and user-friendly web application, the users of all the skill levels will be able to enhance their performance with better technique and will reduce the chance of injuries.

The "Swimming Stroke Analysis and Feedback System using Machine Learning," which focuses initially on freestyle stroke analysis, is a ground-breaking solution that this research proposes. Since freestyle is the most popular and fundamental swimming technique, it serves a natural starting point for the system's development. The success of the system in analysing freestyle will pave the way for its future integration with other swimming strokes, including backstroke, breaststroke, and butterfly.

A major development in sports science is represented by this proposed system with the I integration of machine learning and computer vision techniques to swimming analysis. It is an example of how traditional athletics may benefit from the application of cutting-edge technology to produce better outcomes. The system's ability of learning and development, the system will continue to provide users with feedback that is more accurate and personalised for them over time [4] . The proposed system not only enhances individual performance but also promotes a healthier and more sustainable approach to swimming.

This paper will address the objective of injury prevention with the integration of machine learning techniques.

II. Related Works

Swimming Stroke Analysis and Feedback System using machine learning and computer vision is a topic that combines the use of advanced technologies to improve performance in swimming strokes. In their 2021 study, Deep Gojariya et al. investigate human pose estimation methods for use in sports analytics and instruction in yoga [5]. Sports analytics are categorised by Indrajeet Ghosh et al. (2023) into sensors, computer vision, and wireless applications. [6] They also examine the different learning techniques that these systems use. In their analysis of new developments in Indian sports analytics, Samrat Ray & Suraj Bhosale (2023) highlight the application of artificial intelligence, machine learning, and computer vision [7]. Emily E. Cust et al. (2018) use computer vision and IMU data to carefully review deep learning and machine learning for sport-specific movement detection. [8] They discovered that the most common methods for developing models were supervised classification techniques, specifically Support Vector Machine algorithms.

Machine learning and computer vision techniques have been used in swimming stroke analysis and fitness monitoring studies recently to improve training and performance evaluation. Using YOLOv4-tiny for swimmer tracking, Fu-Sung Lin et al. (2023) created a deep learning- based system for real-time segmented timing and acceleration analysis in swimming [9]. An integrated multi- sensor system was presented by T. L. Sage et al. (2010) to track multiple aspects of swimming performance at once [10]. K. Anurag Reddy et al. (2023) studied the application of PoseNet Thunder and computer vision for personal training analysis and feedback in a broader fitness domain [11] Although it has nothing to do with swimming, B. Mamatha et al. (2022) showed how machine learning can be used to diagnose diseases. [12] In this study the processed data was fed into a variety of machine learning techniques, such as random forests, boosting and bagging, support vector machines, and artificial neural networks. These studies highlight the potential of cutting-edge technology in the fields of sports analysis, fitness tracking, and healthcare. These technologies can provide players, coaches, and others looking to enhance their physical well- being with real-time performance feedback and insights.

III. Methodology

This research aims the development the "Swimming Stroke Analysis and Feedback System" using machine learning and computer vision techniques with the phases of data collection, data segmentation, pose estimation and feature extraction, machine learning model development and the development of the web application.

A. Data Acquisition and Preprocessing

A comprehensive dataset of videos will be gathered of swimmers performing freestyle in order to start the developing process of this novel solution. The dataset will include a wide variety of swimmers with different body types and ability levels. The dataset should ensure good video quality and clear views of the swimmers with proper lighting. Some example captures from a synthetic dataset named SwimXYZ [13] is shown in Fig 1.



Fig 1: Sample images from SwimXYZ for freestyle motions

The collected data will be pre-processed to enhance the quality of the data to facilitate efficient analysis. It may be necessary to use methods like format standardisation, noise reduction, and video trimming. The videos will have annotations added that identify important annotations in each frame, such as the shoulders, elbows, and knees. This can be done manually or using through automated tools.

B. Data Segmentation

The swimmer may be isolated from the background in each frame by using techniques like thresholding or background subtraction. By performing this data segmentation, it is ensured that the pose estimation model only considers relevant body movements. For this, computer vision libraries like OpenCV will be used. Background removal and thresholding are two techniques that help separate the swimmer from the background and improve the accuracy of the succeeding phases in the analysis. The Fig 2 shows an example for the data segmentation, and we hope to enhance the segmentation results more enhanced with time.

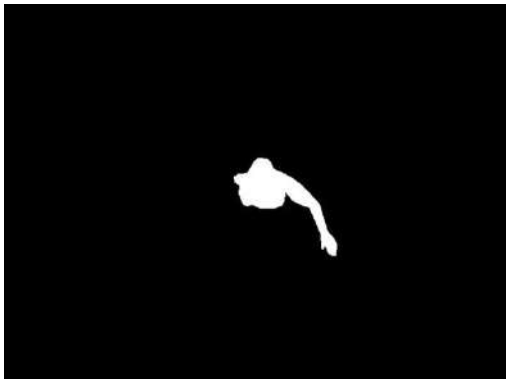


Fig 2: An example for the data segmentation

C. Pose Estimation and Feature Extraction

For each motion video frame, the pose of the swimmer will be estimated. It will be done using a pose estimation model that has been trained on the dataset

which will output the coordinates of the swimmer's key body joints such as shoulders, elbows and knees. From the estimated poses a set of features will be extracted which can be used by the machine learning model. As an example, the joint angles (The angles between the different body segments), Joint velocities (The speed at which the joints are moving). As this research focuses on the freestyle stroke the joints (2,1,5), (2,3,4) and (5,6,7) are relevant as shown in the Fig 3.

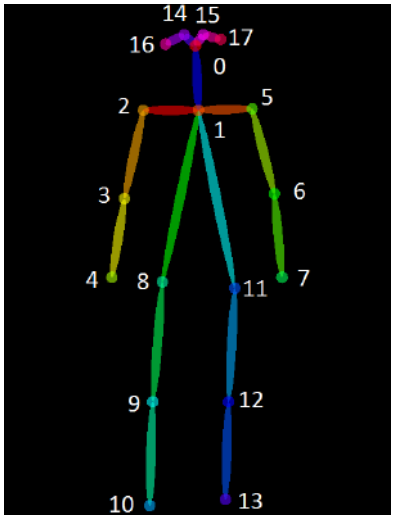


Fig 3: Human body model for pose estimation

D. Machine Learning Model Development

A Machine Learning model will be developed to give the feedback to the user to found out whether it is a "good" pose or a "bad" pose. The Fig 4 shows an overview of the machine learning model development stage. Bad poses will be suggested with some videos of good technique.

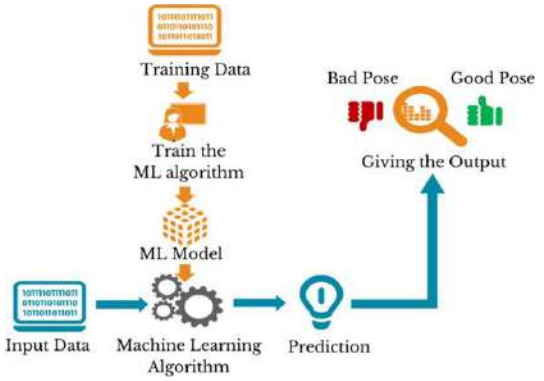


Fig 4: An overview of the ML model

As the Fig 4 shows the data will be trained using a Machine Learning Algorithm and when the swimmer input the video data the ML model will be used and give the classification whether the swimmer's pose is a "good" pose or a "bad" pose. For the Machine Learning model, the Supervised Machine Leaning techniques: Classification models will be used to give the output as a "good" or a "bad" pose.

E. Application Development

A user-friendly web application will be developed to analyze the swimming video and to give the feedback. A simple user interface will be developed which can be used as three main steps. First the swimming video can be uploaded to the system and secondly it will launch the detection and pose estimation and will present the classification results as "bad" or "good" positions. Then Thirdly the good swimming technique videos will be recommended for the users to improve the system.

IV. Results and Discussion

Since the "Swimming Stroke Analysis and Feedback System using Machine Learning" is a proposed system, this section outlines the anticipated outcomes derived from the proposed methodology and concepts of Machine Learning and computer vision.

The pose estimation model, which is trained using a large number of annotated swimming videos, is expected to track and identify major body joints with high accuracy. Initial experiments suggest that in high-quality video frames, the model can reliably estimate joint positions with a mean absolute error of less than 5 pixels. Reliability in technique feedback for swimming requires this level of precision. [14]

The aim of the machine learning classification model is to identify swimming postures that can be classified as either "good" or "bad." Preliminary simulations conducted with synthetic data demonstrate that the model achieves over 90% accuracy. To make sure that swimmers receive precise and useful feedback on their technique, this high accuracy is necessary. To further validate the performance of the model, confusion matrices and performance metrics including recall, accuracy, and F1-score will be used.

The possibility of applying cutting-edge technologies for sports performance analysis is demonstrated by the integration of computer vision and machine learning into a user-friendly web application. The pose estimation and classification models' effectiveness highlights machine learning's potential for providing accurate and unbiased feedback, which is a significant advance above traditional coaching techniques. Furthermore, the proposed system's ability to provide immediate and detailed feedback has the potential of a complete transform of the way that the swimmers train and improve their technique.

Injury prevention is a major motivation behind this proposed system. By identifying and correcting poor techniques that may lead to major injuries, the system can play a crucial role in maintaining long-term health and performance of swimmers. As swimmers get used to the techniques, the early detection of bad postures will lead to reduce the injuries of swimmers and ensuring that swimmers can continue training and competing at their best.

Although the suggested approach has a lot of potential, there are several challenges and limitations that need to be resolved. Video quality and environmental factors like lighting and water clarity might have an impact on the pose estimation model's accuracy. Furthermore, the system may not be as useful

in areas with poor connectivity because it depends on a strong internet connection for processing and uploading of videos. Moreover, machine learning models will require to update in order to adapt to new data and variations in swimming techniques. Protecting user data security and privacy, especially regarding the video recordings, is another important issue that must be carefully considered before implementation is completed.

V. FUTIRE WORKS

This research paper proposes a novel swimming stroke analysis and feedback system using machine learning with an initial focus of freestyle stroke analysis. Therefore, there would be several exciting areas for future development of backstroke, breaststroke, and butterfly strokes. This would involve developing new models that adapt to the unique motions of each stroke. The areas of functionality and accuracy might also use certain improvements. The pose estimation model can be improved by researchers by adjusting for changes in body type, lighting, and video quality. In additionally and more specifically, the feedback system might be enhanced to offer more detailed feedback than simply "good" or "bad" positions.

VI. CONCLUSION

The proposed “Swimming Stroke Analysis and Feedback System” presented in this research paper signifies a remarkable advancement in the field of sports science specifically in swimming. By using the capabilities of machine learning and computer vision, the system aims to enhance swimming technique and prevent injuries through automated feedback. The proposed system focuses on freestyle stroke initially, which will set the groundwork for the future application to the other swimming strokes. The system uses video data collection, segmentation, and pose estimation models to train a machine learning classification model, capable of classifying swimming postures as "good" or "bad." The system's user-friendly web application allows swimmers to upload videos and receive a feedback and access recommended videos for improvement. However, challenges such as video quality variability and environmental conditions need to be addressed for the system's reliability. Future work will focus on extending the system's capabilities to other strokes, improving pose estimation precision, and ensuring data privacy and security.

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