Yoga Pose Estimation

Subjects: Engineering, Biomedical

Contributor: Debanjan Borthakur, Arindam Paul, Dev Kapil, Manob Jyoti Saikia

Correct posture alignment is crucial in the practice of yoga. Posture is essential for all forms of exercise, but it is particularly critical in yoga to obtain the benefits and prevent yoga-related sports injuries. Yoga pose classification has been accomplished using a variety of computer vision techniques.

Keywords: yoga ; computer vision ; machine learning ; pose estimation

1. Introduction

The field of computer vision focuses on developing algorithms and systems for the automatic processing and analysis of visual data. Among its applications are image and video recognition, object detection, and human pose estimation. By analyzing images or videos of people performing yoga poses, computer vision techniques can help identify the specific pose being performed by an individual. The importance of pose estimation in computer vision cannot be overstated. Pose estimation is the process of estimating the configuration of a human body (pose) from a single (typically monocular) image [1]. This is a challenging problem as it depends on the resolution of the image, the background clutter of the surroundings, and other noise. Pose estimation has become essential in the field of sports, fitness, and wellness [2]. One of the recent applications of pose estimation is for yoga pose detection. Yoga is an ancient practice that originated in South Asia and is gaining popularity worldwide. Yoga has been found to be helpful for preventative as well as diagnostic care across physiological and mental health [3][4]. Yoga practice not only improves flexibility, strength, and mindfulness but also provides improvements in patients with hypertension and cardiopulmonary and musculoskeletal ailments [5]. Due to the COVID-19 pandemic, yoga has become increasingly popular, as people are encouraged to stay indoors and practice at-home exercises. Yoga does not require specialized equipment or a lot of space, making it a convenient form of exercise. Yoga apps offer users the ability to customize their practice by selecting the level of difficulty, duration, and focus areas. This allows practitioners to achieve specific goals and needs. Additionally, yoga apps are a cost-effective alternative to in-person classes, making it easier for frequent practitioners to maintain their practice. Many yoga apps offer tracking and goal-setting features, which are helpful in staying motivated and seeing progress over time.

Correct posture alignment is crucial in the practice of yoga. Posture is essential for all forms of exercise, but it is particularly critical in yoga to obtain the benefits and prevent yoga-related sports injuries. Yoga encompasses a range of practices, including yoga poses known asanas, breathing and mindfulness exercises (pranayama and yoga nidra), and meditation. Yoga's popularity has grown due to its potential positive outcomes in terms of physical performance and well-being [6][7]. As we live in a fast-paced society, yoga has become an increasingly popular form of exercise. Many people find yoga to be a valuable retreat from their hectic and busy lifestyles. Yoga, which comes in many forms, includes the popular style of Hatha, a blend of various styles that emphasizes physical exercises over still, meditative practices. The focus of Hatha yoga is on Pranayama, or breathing exercises, which are closely related to breathing biofeedback using auditory cues [8]. Yoga is primarily practiced for physical and mental well-being. According to their needs, people practice different kinds of yoga, such as prenatal yoga, baby yoga, children's yoga, hot yoga, couple yoga, and seniors' yoga. Yoga postures are commonly performed in all different practices. Many studies have demonstrated that yoga improves and optimizes the sports performance of athletes [9][10]. Activities that increase athletic performance are critical to maximizing training opportunities. As sport is a multidimensional endeavour, athletes may consider taking part in activities that optimize the specific dimensions of fitness as well as the aspects of performance in multiple dimensions [6].

There are several clinical studies demonstrating that home yoga practice with recommended yoga exercises lowers blood pressure and improves the quality of life in hypertensive patients [11]. For yoga trainers, health coaches, and yoga studios and students, the demand for technical assistance increased dramatically during the COVID-19 pandemic. Research analysis has found that AI helps practitioners and coaches make more personalized recommendations with different results and guidance on exercise accuracy [12]. The study found that exercise apps increased fitness and health activity by 27%, with improved health outcomes and higher levels of exercise. However, it is challenging to practice yoga

unsupervised at home. There is also the possibility of yoga-related injuries. Therefore, it is imperative to develop solutions that can facilitate people practicing yoga at home, such as by using apps like BreathHRV (https://breathhrv.com/, accessed on 1 November 2023). As a precursor to building yoga apps for unsupervised pose detection, state-of-the-art machine learning and computer vision techniques are utilized. Several existing mobile applications have pioneered this field, utilizing technologies ranging from simple image processing to complex deep learning algorithms for pose estimation and feedback. These applications use a variety of techniques to identify and evaluate yoga poses, including convolutional neural networks (CNNs), keypoint detection, and pose estimation models such as OpenPose and PoseNet [13][14]. Garg et al. [15] explored a CNN- and MediaPipe-inspired deep learning (DL) approach for real-world yoga pose classification, demonstrating the effectiveness of advanced computer vision techniques in real-time applications. Similarly, Chasmai et al. [16] developed a view-independent classification framework for yoga postures, which aligns with the goal of providing accurate pose recognition regardless of the user's position relative to the camera. Another study focused on classifying sun salutation yoga poses using machine learning techniques, achieving a remarkable accuracy of 96% with the KNN model. This research highlighted the potential of machine learning models in yoga pose classification when combined with pose estimation algorithms [17]. Additionally, a deep learning-based approach for yoga pose classification was presented at the 2022 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing, underscoring the applicability of deep neural networks in this domain [18].

2. Importance of Yoga Apps

The primary reason for practicing yoga is to improve mental and physical health. Different age groups tend to choose various yoga practices, with the most common reason for practicing yoga being to enhance physical health. When selecting yoga apps to guide their practice, users are often most concerned with the user interface and ease of use. An overview of yoga's possible benefits, as well as a framework for understanding them, can be seen in previous works [19]. The key to encouraging people to use yoga apps is to provide a better experience and a higher level of satisfaction. In one study, the Daily Yoga app was used as an object of investigation to study key factors related to the design of user experience and user satisfaction [20]. Yoga apps can also create a connection between the practitioner and their community. **Table 1** presents some available yoga pose classification or detection Apps. Yoga practitioners can access downloadable apps from anywhere at any time on any device. Some apps focusing on heart rate variability [21] emphasize the breathing aspect of yoga. While yoga apps help connect yoga communities, there are challenges encountered, such as incorrect performance leading to injuries. Alternatively, human pose estimation can be achieved through computer vision techniques, with the end goal of deploying yoga pose estimation in Android and iOS applications. Yoga pose classification uses computer vision for several reasons. One of the main motivations is the personalization and automation of yoga instruction. Computer vision systems can provide feedback on posture and alignment as well as suggest modifications or alternative poses based on an individual's performance of a yoga pose. More individualized instruction can be especially useful for beginners or those with injuries or other physical limitations. In this context, the authors of Chiddarwar et al. [22] showed that deep learning methods have proven to be extremely useful for the estimation of poses. According to their conclusions, PoseNet is the most suitable technique for implementing mobile applications, specifically for yoga. In their implementation of yoga pose classification, the authors of Long et al. [23] proposed the development of a yoga posture coaching system using an interactive display based on a transfer learning technique. Images were collected from eight volunteers (six women and two men), including yoga novices. The dataset covered 14 different postures, such as the bridge, cat-cow, child, cobra, corpse, downward-facing dog, sitting, extended side angle, warrior II, and warrior I postures. They used six transfer learning models (TL-VGG16-DA, TL-VGG19-DA, TL-MobileNet-DA, TL-MobileNetV2-DA, TL-InceptionV3-DA, and TL-DenseNet201-DA) for classification tasks to select the optimal model for the yoga coaching system based on evaluation metrics. They found the TL-MobileNet-DA model to be the optimal model, showing an overall accuracy of 98.43%, a sensitivity of 98.30%, and a specificity of 99.88%. In another study, an automated system was developed to identify and correct yoga poses which uses human action recognition (HAR) techniques [24]. The dataset included 18 yoga asanas, extending to 31 classes due to multi-facing views. The deep learning models trained included four modified and trained models: Xception, ResNet-50, VGG16, and VGG19.

Table 1. Overview of yoga apps.

App Name	Origin	Features
FitYoga	**India**	**Offers guided yoga and meditation with AI-driven real-time movement tracking for posture improvement. Features include chakra balancing and wellness practices. https://fityoga.app/, accessed on 1 November 2023**

App Name	Origin	Features
Sofia	India	AI-based yoga training with Google sign in. Features voice-assisted Asanas, real-time pose recognition, and rewards for pose accuracy. https://soumi7.github.io/project-sofia.html, accessed on 1 November 2023
YogAI	UK	Features a learning and practice module with TensorFlow PoseNet and ml5js for pose detection and classification. Requires camera access for pose matching. https://cris-maillo.github.io/yogAI/index.html, accessed on 1 November 2023.
YogaIntelliJ	India	A web-based yoga application that predicts body coordinates for yoga poses using a webcam and provides feedback on pose accuracy. https://eager-bardeen-e9f94f.netlify.app/, accessed on 1 Decemeber 2023
Yoga Studio by Gaiam	USA	Offers over 180 classes and custom flows. Includes meditations but requires a subscription for some features. Layout can be complex, and updates may cause glitches. https://yogastudioapp.com/gaiam, accessed on 1 Decemebre 2023
Down Dog	USA	Customizable practices with various styles and instructor voices. Focuses on beginner to intermediate levels but requires a membership for full access and offers limited music in the free version. https://www.downdogapp.com/, accessed on 1 November 2023
Daily Yoga	China	Features the largest global yoga community with new classes weekly. Offers extensive yoga and meditation classes but is more expensive and advanced, requiring a subscription for full access. https://www.dailyyoga.com/, accessed on 1 November 2023

Using deep learning techniques such as convolutional neural networks (CNNs) and transfer learning, the system recognizes yoga poses in real time and corrects the user with OpenPose, a multi-person 2D pose estimation algorithm. Users can practice 18 different asanas or poses with the system. Since users can face the camera from a left-hand side view, a right-hand side view, or a front view while practicing yoga, the system can predict asanas with 87.6% accuracy. Computer vision techniques have been applied to yoga pose classification in several studies, as mentioned earlier. In another study [25], a yoga pose correction system was implemented by training a model for only five distinct yoga poses using deep learning. According to the study, the deep learning model could identify these five poses with an accuracy of 95%. Although these methods are useful in yoga pose classification, they also require significant computational power, which is often lacking in smartphones, mostly when neural network models like CNNs are used. As per [26], the main challenges of deploying deep learning on mobile devices are limited computational resources such as memory and processing power, power constraints, limited storage, privacy and security concerns, and network connectivity. One study [27] stated that mobile devices often do not have much computational power, and thus it is difficult to run complex deep learning models. Power consumption is also a major problem.

3. Pose Estimation Methods

The purpose of this section is to provide a brief overview of pose estimation as well as the difficulties associated with it. Yoga pose classification has been accomplished using a variety of computer vision techniques. Deep learning is a type of machine learning based on artificial neural networks in which multiple layers of processing are used to extract progressively higher-level features from data. By learning the patterns and features in the images, the neural network can classify new images based on those patterns and features [28]. Another approach is to use pose estimation techniques, which determine poses using estimates of key body points (like body joints). Methods like template matching or skeletal tracking can accomplish this by comparing the key points' positions with predefined templates or models. It is also possible to combine these techniques, such as using deep learning to identify overall patterns in the images and using pose estimation to refine them. PoseNet is one such deep learning framework that is used for human pose identification in both image and video sequences. PoseNet has a sequence of fully connected layers. The architecture of PoseNet, based on the work in [29], is briefly described. A high-level architecture of PoseNet is discussed in [30]. The first component consists of an encoder that generates the encoding vector, which is an encoded representation of the features of the input images. The second component is the localizer, which generates another vector that denotes localization features. The last component is a regressor that is used to regress the final pose. In another work, the authors of [31] presented a real-time approach to detecting the 2D poses of multiple people in an image. In their method, body parts are associated with individuals using a non-parametric representation. As a result of their work, OpenPose [32] was released, the first open-source 2D pose detection system for multiple persons. Another work considered the task of estimating articulated human poses from real-world images. Based on CNN-based part detectors, the authors proposed a partitioning and labeling formulation of body part hypotheses. Their experiments on four different datasets showed state-of-the-art results for both single-person and multi-person pose estimation [33].

References

1. Sigal, L. Human Pose Estimation. In Computer Vision: A Reference Guide; Ikeuchi, K., Ed.; Springer: New York, NY, USA, 2014; pp. 362–370.
2. Chen, S.; Yang, R.R. Pose trainer: Correcting exercise posture using pose estimation. arXiv 2020, arXiv:2006.11718.
3. Ross, A.; Thomas, S. The health benefits of yoga and exercise: A review of comparison studies. J. Altern. Complement. Med. 2010, 16, 3–12.
4. Akhtar, P.; Yardi, S.; Akhtar, M. Effects of yoga on functional capacity and well being. Int. J. Yoga 2013, 6, 76.
5. Raub, J.A. Psychophysiologic effects of Hatha Yoga on musculoskeletal and cardiopulmonary function: A literature review. J. Altern. Complement. Med. 2002, 8, 797–812.
6. Polsgrove, M.J.; Eggleston, B.M.; Lockyer, R.J. Impact of 10-weeks of yoga practice on flexibility and balance of college athletes. Int. J. Yoga 2016, 9, 27.
7. Woodyard, C. Exploring the therapeutic effects of yoga and its ability to increase quality of life. Int. J. Yoga 2011, 4, 49.
8. Marentakis, G.; Borthakur, D.; Batchelor, P.; Andersen, J.P.; Grace, V. Using Breath-like Cues for Guided Breathing. In Proceedings of the Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems, Yokohama, Japan, 8–13 May 2021; pp. 1–7.
9. Brynzak, S.; Burko, S. Improving athletic performance of basketball student team with the classical yoga exercises. Pedagog. Psychol. Med.-Biol. Probl. Phys. Train. Sport. 2013, 17, 3–6.
10. Kanaujia, S.; Saraswati, P.; Anshu; Singh, N.; Singh, S.; Kataria, N.; Yadav, P. Effect of yoga and mindfulness on psychological correlates in young athletes: A meta-analysis. J. Ayurveda Integr. Med. 2023, 14, 100725.
11. Wolff, M.; Sundquist, K.; Larsson Lönn, S.; Midlöv, P. Impact of yoga on blood pressure and quality of life in patients with hypertension—A controlled trial in primary care, matched for systolic blood pressure. BMC Cardiovasc. Disord. 2013, 13, 1–9.
12. Litman, L.; Rosen, Z.; Spierer, D.; Weinberger-Litman, S.; Goldschein, A.; Robinson, J. Mobile exercise apps and increased leisure time exercise activity: A moderated mediation analysis of the role of self-efficacy and barriers. J. Med. Internet Res. 2015, 17, e4142.
13. Gkioxari, G.; Hariharan, B.; Girshick, R.; Malik, J. R-cnns for pose estimation and action detection. arXiv 2014, arXiv:1406.5212.
14. Anand Thoutam, V.; Srivastava, A.; Badal, T.; Kumar Mishra, V.; Sinha, G.; Sakalle, A.; Bhardwaj, H.; Raj, M. Yoga pose estimation and feedback generation using deep learning. Comput. Intell. Neurosci. 2022, 2022, 4311350.
15. Garg, S.; Saxena, A.; Gupta, R. Yoga pose classification: A CNN and MediaPipe inspired deep learning approach for real-world application. J. Ambient. Intell. Humaniz. Comput. 2022, 1–12.
16. Chasmai, M.; Das, N.; Bhardwaj, A.; Garg, R. A View Independent Classification Framework for Yoga Postures. SN Comput. Sci. 2022, 3, 476.
17. Palanimeera, J.; Ponmozhi, K. Classification of yoga pose using machine learning techniques. Mater. Today Proc. 2021, 37, 2930–2933.
18. Kinger, S.; Desai, A.; Patil, S.; Sinalkar, H.; Deore, N. Deep Learning Based Yoga Pose Classification. In Proceedings of the 2022 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COM-IT-CON), Faridabad, India, 26–27 May 2022; Volume 1, pp. 682–691.
19. Gard, T.; Noggle, J.J.; Park, C.L.; Vago, D.R.; Wilson, A. Potential self-regulatory mechanisms of yoga for psychological health. Front. Hum. Neurosci. 2014, 8, 770.
20. Yu, N.; Huang, Y.T. Important factors affecting user experience design and satisfaction of a mobile health app—A case study of daily yoga app. Int. J. Environ. Res. Public Health 2020, 17, 6967.
21. van Ravenswaaij-Arts, C.M.; Kollee, L.A.; Hopman, J.C.; Stoelinga, G.B.; van Geijn, H.P. Heart rate variability. Ann. Intern. Med. 1993, 118, 436–447.
22. Chiddarwar, G.G.; Ranjane, A.; Chindhe, M.; Deodhar, R.; Gangamwar, P. AI-based yoga pose estimation for android application. Int. J. Innov. Sci. Res. Technol. 2020, 5, 1070–1073.
23. Long, C.; Jo, E.; Nam, Y. Development of a yoga posture coaching system using an interactive display based on transfer learning. J. Supercomput. 2022, 1–16.
24. Pavitra, G.; Anamika, C. Deep Learning-Based Yoga Learning Application. In Computer Vision and Robotics: Proceedings of CVR 2021; Springer: Berlin/Heidelberg, Germany, 2022; pp. 365–380.

25. Chaudhari, A.; Dalvi, O.; Ramade, O.; Ambawade, D. Yog-Guru: Real-Time Yoga Pose Correction System Using Deep Learning Methods. In Proceedings of the 2021 International Conference on Communication information and Computing Technology (ICCICT), Mumbai, India, 25–27 June 2021; pp. 1–6.
26. Chen, Y.; Zheng, B.; Zhang, Z.; Wang, Q.; Shen, C.; Zhang, Q. Deep learning on mobile and embedded devices: State-of-the-art, challenges, and future directions. ACM Comput. Surv. (CSUR) 2020, 53, 1–37.
27. Zhao, T.; Xie, Y.; Wang, Y.; Cheng, J.; Guo, X.; Hu, B.; Chen, Y. A survey of deep learning on mobile devices: Applications, optimizations, challenges, and research opportunities. Proc. IEEE 2022, 110, 334–354.
28. Rafi, U.; Leibe, B.; Gall, J.; Kostrikov, I. An Efficient Convolutional Network for Human Pose Estimation. In Proceedings of the BMVC, York, UK, 19–22 September 2016; Volume 1, p. 2.
29. Kothari, S. Yoga Pose Classification Using Deep Learning. Master's Thesis, San Jose University, San Jose, CA, USA, 2020.
30. Shavit, Y.; Ferens, R. Introduction to camera pose estimation with deep learning. arXiv 2019, arXiv:1907.05272.
31. Cao, Z.; Simon, T.; Wei, S.E.; Sheikh, Y. Realtime multi-person 2d pose estimation using part affinity fields. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, Honolulu, HI, USA, 21–26 July 2017; pp. 7291–7299.
32. Cao, Z.; Hidalgo, G.; Simon, T.; Wei, S.E.; Sheikh, Y. OpenPose: Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields. arXiv 2019, arXiv:cs.CV/1812.08008.
33. Pishchulin, L.; Insafutdinov, E.; Tang, S.; Andres, B.; Andriluka, M.; Gehler, P.V.; Schiele, B. Deepcut: Joint subset partition and labeling for multi person pose estimation. In Proceedings of the P IEEE Conference on Computer Vision and Pattern Recognition, Las Vegas, NV, USA, 26 June–1 July 2016; pp. 4929–4937.
