Chapter 3

Review of Scientific Literature

3.0 REVIEW OF SCIENTIFIC LITERATURE

3.1 SCIENTIFIC RESEARCH ON YOGA POSTURE AND POSE ESTIMATION

Yoga Biomechanics: Biomechanics provides a unique evidence-based exploration into the complexities of human movement and what a safe, effective yoga practice entails. The emphasis is taken off flexibility and centered on a narrative of body tissue adaptation. Conventional approaches to modern yoga are examined through a biomechanics lens, highlighting emerging perspectives in both the rehabilitation and sport science literature. Artfully woven throughout the book is a sub-text that improves the reader's research literacy while making an impassioned plea for the role of research in the evolution of how teachers teach, and how practitioners practice. Yoga teachers and yoga practitioners alike will discern yoga *āsana* for its role in one's musculoskeletal health. Yoga therapists and other allied healthcare providers can apply the principles discussed to their respective professions. All readers will understand pose modifications in the context of load management, reducing fears of injury and discovering the robustness and resilience of the human body (Goyal & Jain, 2021).

Artificial neural network (ANN) for human pose estimation

The current study presents an approach to localizing human body joints in 3D coordinates based on a single low-resolution depth image. First, a framework to generate realistic depth images from a 3D body model is described. The data pre-processing and normalization procedure, and deep neural network (DNN) and MLP artificial neural networks architectures and training are presented. The robustness against camera distance and image noise is analyzed. Localization accuracy for each joint is reported and application for low resolution and large distance pose estimation is proposed (Szczuko, 2017).

TensorFlow

For understanding neural network model, differentiable programming software named TensorFlow will be used in this study. TensorFlow is an end-to-end open source platform which has a comprehensive, flexible ecosystem of tools, libraries and community resources that lets researchers push the state-of-the-art and develop powered applications(Abadi, 2016).

Deep Pose: Human Pose Estimation via Deep Neural Networks (DNN)

Deep poses are formulated as DNN-based regression problem towards body joints. It presents result of high precision pose estimates. The approach has the advantage of reasoning about pose in a holistic fashion and has a simple but yet powerful formulation which capitalizes on recent advances(Alexander Toshev, 2014).

Three-dimensional motion capture of *Suryanamaskar* was performed on 10 healthy trained yoga practitioners with 12-camera Vicon System (Oxford Metrics Group, UK) at a sampling frequency of 100 Hz using 39 retro-reflective markers. Data were processed using plug-in-gait model. Analog data were filtered at 10Hz. Joint angles of the spine, upper, and lower extremities during 12-subsequent poses were computed within Vicon Nexus. Joint motion was largely symmetrical in all poses except pose 4 and 9. The spine moved through a range of 58° flexion to 44° extension. In the lower quadrant, hip moved from 134° flexion to 15° extension, knee flexed to a maximum of 140°, and 3° hyperextension. Ankle moved in a closed kinematic chain through 40° dorsiflexion to 10° plantarflexion. In the upper quadrant, maximum neck extension was76°, shoulder moved through the overhead extension of 183°–56° flexion, elbow through 22°–116° flexion, and wrist from 85° to 3° wrist extension. Alternating wide range of transition between flexion and extension during *Suryanamaskar* holds potential to increase the mobility of almost all body joints, with stretch on anterior and posterior soft tissues and challenge postural balance mechanisms through a varying base of support (Mullerpatan et al., 2019). Hatha Yoga's effects on the posture of 15 ten-year-old children and also its effects on the psychophysical condition of 15 grown-ups was studied. As symptoms, during the first examination, 12 of the 15 children had head protrusion, 14 had shortened back extensors, all 15 had bent shoulders, relaxation of the frontal abdominal wall and shortened flexors of both the calf and thigh. The condition of all the children was remarkably better after six months of practice, some of the symptoms having completely disappeared (head protrusion, asymmetry of the shoulders, mamillas and hips, shortening of the pectoralis and back extensors), 9 children still had slight to medium relaxation of the frontal abdominal wall, 8 children still had bent shoulders, and 1 child still had shortened calf and thigh extensors. The adults were in a weak or very weak psychophysical condition, they tired easily, they complained of sleep disturbances, fluctuation of emotional state and irritability. After 3 months of practice, the vital capacity of 8 of the adults tested (53.3%) had increased by 435 ml. The time duration of apnea had lengthened for all of the practicing adults, but with a truly large variation among them (a median of 14%). The deep waist-bend length of all the practicing adults had lengthened by an average of 9.5 cm, and the average length increase for the 3-minute running test was 42 m. All those who practiced, had experienced an alleviation of psychic difficulties (Savić, Pfau, Skorić, Pfau, & Spasojević, 1990).

3.2 SUMMARY TABLE OF SCIENTIFIC RESEARCH ON YOGA POSTURE AND POSE ESTIMATION

Sl No.	Title	Author, Year & Journal	Sample Size	Variable	Assessment Tools	Outcome	Conclusion
1	Yoga posture recognition and quantitative evaluation with wearable sensors based on two-stage classifier and prior Bayesian network.	Wu, Z., Zhang, J., Chen, K., & Fu, C. (2019). Sensors, 19 (23), 5129.	n=11	multidimensional Gaussian variable to build a Bayesian network	fuzzy C-means (FCM) (BP-ANN) Bayesian network	BP-ANN and FCM; Bayesian network; inertial measurement unit; yoga posture recognition and evaluation	The authors proposed a full-body posture modelling and quantitative evaluation method to recognize and evaluate yoga postures and provide guidance to learner. BP-ANN and FCM were employed to construct a two-stage classifier to model and recognize full-body postures
2	Deep pose: Human pose estimation via deep neural networks.	Toshev, A., & Szegedy, C. (2014). In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 1653-1660).	n=20	7-layered generic convolutional DNN	Deep Neural Networks (DNNs).	Human pose estimation, the formulation of the problem as DNN-based regression to joint coordinates and the presented cascade of such repressor's	This paper suggests application of Deep Neural Networks (DNNs) to human pose estimation.

						has the advantage of capturing context and reasoning about pose in a holistic manner.	
3	The biomechanical demands of standing yoga poses in seniors: The Yoga empowers seniors study (YESS)	Wang, M. Y., Yu, S. S., Hashish, R., Samarawickrame, S. D., Kazadi, L., Greendale, G. A., & Salem, G. (2013). BMC Complementary and Alternative Medicine, 13 (1), 1-11.	n=20	7 commonly-practiced standing yoga poses in older adults.	Electromyography (EMG)	There was a significant main effect for pose, at the ankle, knee and hip, in the frontal and sagittal planes (p = 0.00 – 0.03). The Crescent, Chair, Warrior II, and One-legged Balance poses generated the greatest average support moments. Side Stretch generated the greatest average hip extensor and knee flexor JMOFs. Crescent placed the highest demands on the hip flexors and knee extensors. All of the poses produced ankle plantar-flexor	Musculoskeletal demand varied significantly across the different poses. These findings may be used to guide the design of evidence-based yoga interventions that address individual-specific training and rehabilitation goals in seniors.

						JMOFs. In the frontal plane, the Tree generated the greatest average hip and knee abductor JMOFs; whereas Warrior II generated the greatest average hip and knee adductor JMOFs. Warrior II and One-legged Balance induced the largest average ankle evert or and invertor JMOFs, respectively. The electromyographic findings were consistent with the JMOF results.	
4	Human posture recognition based on images captured by the Kinect sensor	Wang, W. J., Chang, J. W., Haung, S. F., & Wang, R. J. (2016). International Journal of Advanced Robotic Systems, 13(2), 54.	n=5	Three posture recognition methods involving body width and height ratio,	Kinetic senor, Silhouette's centre of gravity & LVQ neural network	Only one Kinect sensor is used, so the participant does not need to wear any sensors on their body.	The proposed recognition procedure first uses background subtraction on the depth image to extract a silhouette contour of a human.

				neural network and length ratio are combined to recognize total five postures even when the subjects are facing in different directions.			This paper has proposed an effective procedure to recognize the five human postures of standing, sitting, stooping, kneeling and lying, even when the human subjects have different statures or orientations.
5	Yoga Āsana Identification: A Deep Learning Approach	Jose, J., & Shailesh, S. (2021, March). In IOP Conference Series: Materials Science and Engineering (Vol. 1110, No. 1, p. 012002). IOP Publishing.	n=200	Estimate 2D and 3 D pose features along with identifying all visible joints of the individuals	3D CNN architecture	To get better results we have used transfer learning with VGG16 architecture and pretrained ImageNet weights along with a DNN classifier. The results were quite promising; it gave 82% prediction accuracy.	The architectures like 3DCNN, Deep – Pose Estimators, LSTM, GRUs are well suited for video-based analysis.

6	Epipolar constraint of single-camera mirror binocular stereo vision systems	Chai, X., Zhou, F., & Chen, X. (2017). Optical Engineering, 56(8), 084103.	Not applicable	geometric principles of the feature-matching process of a mirror binocular stereo vision system	realistic matching experiments and analysis using a mirror binocular stereo vision system	Our results demonstrate the feasibility of the proposed model	suggesting a method for considerable improvement of efficacy of the process for matching mirrored features
7	TensorFlow: Learning Functions at Scale	Abadi, M. (2016, September). In Proceedings of the 21st ACM SIGPLAN International Conference on Functional Programming (pp. 1-1).	Not applicable	dataflow graphs	TensorFlow	TensorFlow is not purely functional, many of its uses are concerned with optimizing functions (during training), then with applying those functions (during inference). These functions are defined as compositions of simple primitives (as is common in	TensorFlow supports a variety of applications, but it particularly targets training and inference with deep neural networks. It serves as a platform for research and for deploying machine learning systems across many

						functional programming), with internal data representations that are learned rather than manually design	areas, such as speech recognition, computer vision, robotics, information retrieval, and natural language processing
8	AI-Based Yoga Pose Estimation for Android Application	Chiddarwar, G. G., Ranjane, A., Chindhe, M., Deodhar, R., & Gangamwar, P. (2020). Int J Inn Scien Res Tech, 5, 1070-1073.	Not applica ble	human pose estimation	Deep Learning (CNN) to pose estimation	This paper surveys the various technologies that can be used for pose estimation and concludes the best method based on the usability for an android application	We have concluded that PoseNet is, by the current standards, the best technique for implementing mobile applications, specifically for yoga.
9	Kinematics of Suryanamaskar Using Three-Dimensio nal Motion Capture	Mullerpatan, R. P., Agarwal, B. M., Shetty, T., Nehete, G. R., & Narasipura, O. S. (2019). International Journal of Yoga, 12(2), 124.	n=10	kinematics of spine, upper, and lower extremity during Suryanamaska r	12-camera Vicon System (Oxford Metrics Group, UK) at a sampling frequency of 100 Hz using 39 retro-reflective markers.	Joint motion was largely symmetrical in all poses except pose 4 and 9. The spine moved through a range of 58° flexion to44° extension. In the lower quadrant, hip moved from 134° flexion to 15° extension, knee flexed toa maximum of 140°, and	Suryanamaskar holds potential to increase the mobility of almost all body joints, with stretch on anterior and posterior soft tissues and challenge postural balance mechanisms through a varying base of support.

					Data were processed using plug-in-gait model. Analog data were filtered at 10Hz. Joint angles of the spine, upper, and lower extremities during 12-subsequent poses were computed within Vicon Nexus	3° hyperextension. Ankle moved in a closed kinematic chain through 40°dorsiflexion to 10° plantarflexion. In the upper quadrant, maximum neck extension was76°, shoulder moved through the overhead extension of 183°–56° flexion, elbow through 22°–116° flexion, and wrist from 85° to 3° wrist extension	
10	Ergonomic postural assessment using a new open-source human pose estimation technology (OpenPose)	Kim, W., Sung, J., Saakes, D., Huang, C., & Xiong, S. (2021). International Journal of Industrial Ergonomics, 84, 103164.	n=10	Observationalp ostural assessment	OpenPose-based system for computing joint angles and RULA/REBA scores and validate against the reference motion capture system, and compare	OpenPose showed good performance under all task conditions, whereas Kinect performed significantly worse than OpenPose especially at cases with body occlusions or non-frontal tracking	OpenPose could be a promising technology to measure joint angles and conduct semi-automatic ergonomic postural assessments in the real workspace where the conditions are often

					its performance to the Kinect-based system.		non-ideal.
11	Three-dimensional cameras and skeleton pose tracking for physical function assessment: A review of uses, validity, current developments and Kinect alternatives	Clark, R. A., Mentiplay, B. F., Hough, E., &Pua, Y. H. (2019). Gait & posture, 68, 193-200.	Not applicable	physical function assessment using depth cameras	Microsoft Kinect devices and associated artificial intelligence, automated skeleton tracking algorithms alternative hardware, including other structured light and time of flight methods, stereoscopic cameras and augmented reality leveraging smartphone and tablet cameras to perform measurements	The clinical and non-laboratory utility of these devices holds great promise for physical function assessment	Recent developments could strengthen their ability to provide important and impactful health-related data

					inthree-dimensional space are summarised. Software options related to depth sensing cameras		
12	Self-Supervised Learning of 3D Human Pose using Multi-view Geometry	Kocabas, M., Karagoz, S., &Akbas, E. (2019). In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 1077-1086).	N=2	self-supervised learning method for 3D human pose estimation	EpipolarPose estimates 2D poses from multi-view images, and then, utilizes epipolar geometry to obtain a 3D pose and camera geometry	Our self-supervised (SS) model performs quite well compared to the recent fully 3D supervised methods. 3D depth information learned by our SS training method provides helpful cues to improve the performance of 2D-3D lifting approaches. Our method yields 4mm less error than their approach.	EpipolarPose achieved state-of-the-art resultsin Human3.6M and MPI-INF-3D-HP benchmarks among weakly/self-supervised methods.
13	Multi-task Deep Learning for Real-Time 3D	Luvizon, D. C., Picard, D., & Tabia, H. (2020). IEEE transactions on pattern analysis and	n=250 0 (MPII)	mean per joint position error	A) 2D pose estimation and action recognition, on which we use respectively	The proposed CNN architecture, along with	With a single training procedure, our

	Human Pose Estimation and Action Recognition	machine intelligence, 43(8), 2752-2764.			MPII and Penn Action datasets, and B) 3D pose estimation and action recognition, using MPII, Human3.6M, and NTU datasets	the pose regression method, allows multi-scale pose and action supervision and re-injection, resulting in a highly efficient densely supervised approach.	multi-task model can be cut at different levels for pose and action predictions, resulting in a highly scalable approach.
14	Single-Network Whole-Body Pose Estimation	Hidalgo, G., Raaj, Y., Idrees, H., Xiang, D., Joo, H., Simon, T., & Sheikh, Y. (2019). In Proceedings of the IEEE/CVF International Conference on Computer Vision (pp. 6982-6991).	Not applicable	2D whole-body pose estimation	multi-task learning combined with an improved model architecture to train the first single network approach for 2D whole-body estimation	This work directly results in a reduction of computational complexity for applications that require 2D whole-body information	it yields higher accuracy, especially for occluded, blurry, and low resolution faces and hand
15	ANN for human pose estimation in low resolution	Szczuko, P. (2017, September). In 2017 Signal Processing:	n=80000	human pose estimation	data pre-processing and normalization	A very fast regression on body joints locations in 3D space is achieved, even in case of sensor	The observed small differences in accuracy between

	depth images	Algorithms, Architectures, Arrangements, and Applications (SPA) (pp. 354-359). IEEE.			procedure, and DNN and MLP artificial neural networks architectures and training	noise, large distance and reaching off the screen	elaborated DNN dedicated to image processing and simple MLP will be explored. Longer network training exploiting GPU acceleration is planned, as expected to improve DNN accuracy
16	ExNET: Deep Neural Network for Exercise Pose Detection	Haque, S., Rabby, A. K. M., Laboni, M. A., Neehal, N., & Hossain, S. A. (2018, December). In International Conference on Recent Trends in Image Processing and Pattern Recognition (pp. 186-193). Springer, Singapore.	N=2000	Exercise Pose Detection	ExNET: Deep Neural Network	We have conducted various experiments with our model on the test dataset, and finally got the best accuracy of 82.68%.	This proposed model presenting a better performance of classification of human poses exercise. As a result, we are able to achieve state-of-art resultson several challenging exercise pose datasets.

17	Pose Estimated Yoga Monitoring System	Anilkumar, A., KT, A., Sajan, S., & KA, S. (2021). Available at SSRN 3882498.	Not applicable	yoga monitoring system	pre-trained pose estimation model namely MediaPipe	The user is then notified of his/her error in the posture through a display screen or a wireless speaker. The inaccurate body pose of the user can be pointed out in real-time so that the user can rectify his/her mistakes.	Our system will make it easier to do exercises without the need for a special trainer. Reduce injuries due to improper technique. By porting the system to an android app and as a webapp along with personalised account creation for progress tracking, can help in reaching a wider audience