Use Case 18: Smart Rehabilitation: AI-Driven Exercise Assessment and Live Feedback for Enhanced Recovery

Country: India

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1 Use Case Summary Table

Item	Details
Category	Healthcare
Problem Addressed	Patients with musculoskeletal disorders lack real-time corrective feedback and progress tracking when performing rehabilitation exercises at home, which can hinder recovery and lead to improper form or ineffective therapy [1].
Key Aspects of Solution	• Real-time visual and audio cues to correct exercise through examining the extracted pose. Processing is to be done on a Raspberry Pi. • Assessment of exercise to be done through a custom Spatio-Temporal Graph Neural Network (STGCN) on the cloud
Technology Keywords	STGCN, Raspberry Pi, Mediapipe, cross-platform Neural Network PACKage (XNNPACK)
Data Availability	Public (UI-PRMD Dataset: [7])
Metadata (Type of Data)	Video data
Model Training and Fine-Tuning	• Live feedback is comparing joint angles and shifts in distance between the reference pose and the patient's pose. • STGCN is to be trained using a triplet loss where the anchor is a correctly performed exercise, the positive sample is a correctly performed exercise other than the anchor, and the negative sample is an incorrect exercise. • The final expected outcome is a latent space where correctly performed exercises are together and incorrect ones are further away from them.

(continued)

Item	Details
Testbeds or Pilot Deployments	We will use the facilities at the Media Research Laboratory of our university. Finally, we intend to test in a typical home environment.
Code repositories	STGCN: [8], Mediapipe: [9]

2 Use Case Description

2.1 Description

Our solution is one that harnesses AI in assisting individuals suffering from musculoskeletal disorders, particularly in regions where there exists a significant shortage of physiotherapists. Therapeutic exercises are frequently prescribed as part of rehabilitation; however, in India, there is an average of merely 0.36 physiotherapists per 10,000 individuals, highlighting an urgent need for a digital solution. This use case presents a system designed to deliver real-time corrective feedback during physical therapy exercises [5]. The proposed system employs a simple camera and a Raspberry Pi as in Figure 1 utilising MediaPipe for pose detection and XNNPACK to accelerate inference. The system compares live user movements against reference joint angles and variations in distance between major key points [1]. The matching process is further refined by incorporating user-specific factors such as age and historical performance to ensure a personalised experience. Feedback is conveyed in textual, auditory, and visual formats via a display connected to the Raspberry Pi. Additionally, a bespoke Spatio-Temporal Graph Convolutional Network (STGCN) [2], hosted on the cloud, evaluates the performed exercises and generates an assessment score as in Figure 2. This score is displayed to assist users in monitoring their progress. Hence, it is safe to say our solution holds the potential to democratise access to expert guidance and corrective feedback, making at-home physiotherapy both more accessible and cost-effective.

Figure 18.1: Overview of the proposed system

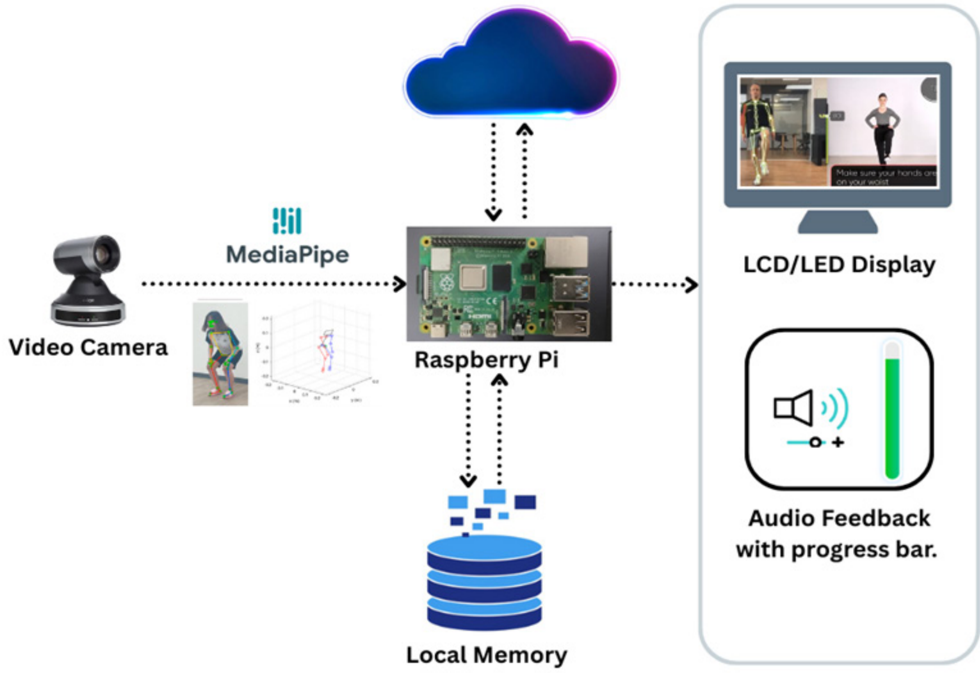
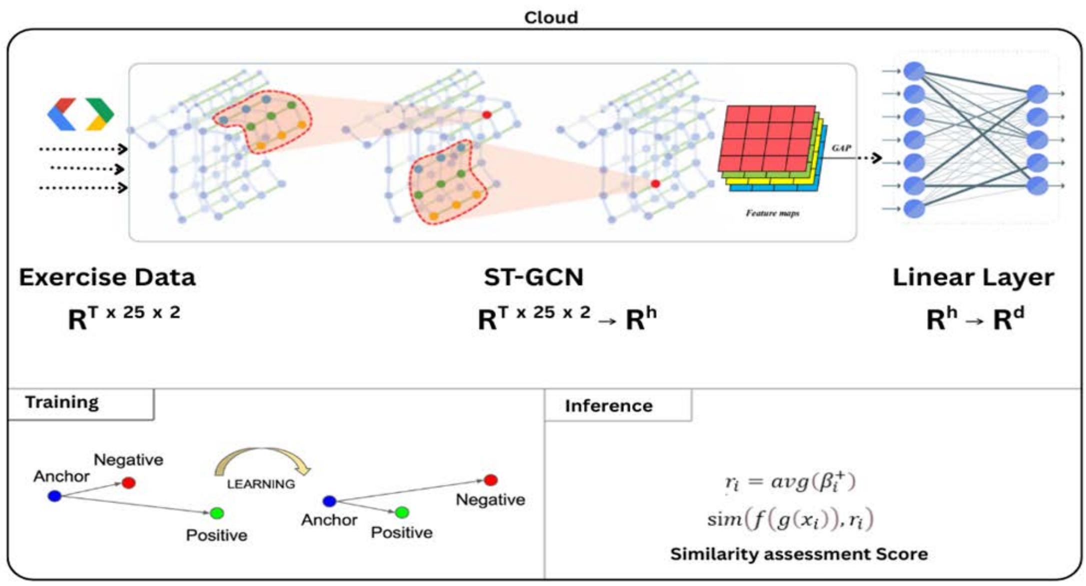


Figure 18.2: Schematics of the ST-GCN Model



Use Case Status: Ongoing–At inception stage.

Partners: We intend to get technical input and suggestions from the National Institute of Information and Communications Technology (NICT), Tokyo, Japan [6], and collaborate with them.

2.2 Benefits of use case

This system aims to reduce premature mortality from non-communicable diseases through prevention and treatment. By enabling real-time exercise assessment and adaptive rehabilitation, the system helps individuals recover from musculoskeletal disorders, post-stroke conditions, and post-surgical rehabilitation. It ensures users perform exercises correctly, reducing complications and improving health outcomes.

Traditional rehabilitation services are often inaccessible to rural populations and economically disadvantaged individuals due to high costs and limited healthcare infrastructure. By leveraging AI and automation, this system lowers the dependency on physical rehabilitation centres, making quality rehabilitation and exercise guidance available remotely through televisions, desktops, and mobile devices. This ensures that individuals, regardless of socioeconomic status or geographical location, can receive equitable healthcare support. By making rehabilitation cost-effective, scalable, and widely accessible, the system contributes to closing the health disparity gap and fostering inclusivity in healthcare

2.3 Future Work

- To overcome occlusion issues, future iterations will explore the integration of 3D sensing technologies, such as Microsoft Kinect. This will enable more accurate differentiation of complex movements (e.g., forward lean vs. backwards bend) and subtle movements that rely heavily on the trajectory rather than joint angles.
- Support for regional languages will also be extended, enhancing accessibility for non-English-speaking users.

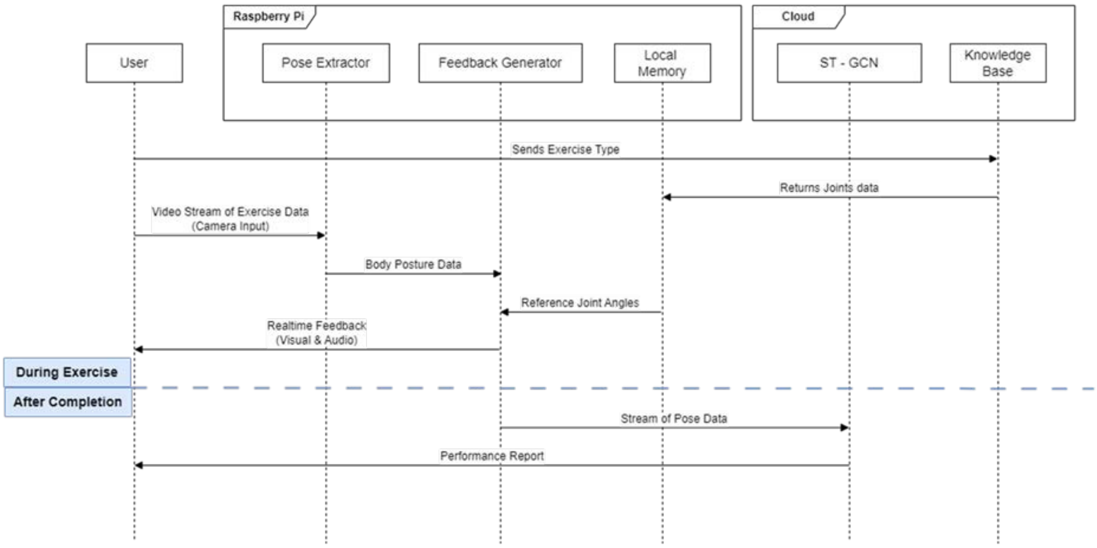
3 Use Case Requirements

- **REQ 1**: It is critical that the system is capable of tracking and analysing human body movements in real time using a reliable pose estimation pipeline.
- **REQ 2**: It is critical that the system provides instant corrective feedback (audio and visual) by comparing user movement with reference data and ensures low-latency performance using optimised inference libraries such as XNNPACK.
- **REQ 3**: It is critical that the system is capable of utilizing an STGCN (Spatio-Temporal Graph Convolutional Network) model to assess exercise correctness accurately.
- **REQ 4:** It is expected that the system is maintained in a cloud-based repository of reference joint angles and movement patterns for comparison and dynamic updating.
- **REQ 5:** It is expected that the system will adapt feedback based on historical user performance, age, and progress trends to personalize the rehabilitation experience.
- **REQ 6:** It is expected that the system will adapt to new exercises by identifying consistent variations in joint angles and movement lengths over time.

4 Sequence Diagram

The sequence diagram in Figure 3 begins with the user performing an exercise after selecting the type of exercise. The data is passed through MediaPipe to extract poses, and then the reference data is compared with this to provide audio and visual cues. After completion of the exercise, the data is sent to the cloud, where the STGCN model gives the assessment score for the exercise. This performance report is sent to the user.

Figure 18.3: Sequence Diagram of our system



5 References

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[3] S. Yan, Y. Xiong, and D. Lin, "Spatial Temporal Graph Convolutional Networks for Skeleton-Based Action Recognition," in Proc. AAAI Conf. Artif. Intell., vol. 32, no. 1, pp. 7444–7452, 2018.

[4] T. Chen, S. Kornblith, M. Norouzi, and G. Hinton, "A Simple Framework for Contrastive Learning of Visual Representations," in Proc. 37th Int. Conf. on Machine Learning (ICML 2020), PMLR, vol. 119, pp. 1597–1607, 2020

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