NeuroPose - Geriatric Rehabilitation in the Home Using a Webcam and Pose Estimation

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ABSTRACT

Many chronic diseases and common risks to elderly patients can be assessed and treated through standardized training and rehabilitation programs. Unfortunately, there is a need to make risk assessment and preventative care for the elderly more easily accessible as many programs either use specialized hardware or require human supervision. We seek to reduce the barrier to entry for patients through a portable application which enables fall risk prevention assessment and rehabilitation anywhere. Our work leverages the latest in machine learning and computer vision, accomplishing pose estimation and body tracking with a simple and ubiquitous webcam. Thus patients can be screened anywhere with the ability to get feedback in near-real time.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; Ubiquitous and mobile computing.

KEYWORDS

pose estimation, rehabilitation, fall-risk assessment, preventative healthcare

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1 INTRODUCTION

It is generally agreed that exercise and physical therapy is important for older populations to decrease the risks related to falls and complications that arise after injury [7]. Yet studies have demonstrated that only a fraction of patients recommended to preventative care

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programs actually utilize these services [6]. Hawley-Hague, et al., explore the barriers to entry that exist, and find that patients' perceptions of programs and technology which facilitate them need to be positive and easy [4]. Needing to travel to clinics or otherwise make use of specialized hardware creates a cumbersome experience patients would rather avoid.

2 RELATED WORK

Prior research has explored means for taking patient fall prevention assessment and rehabilitation and improving it through technology solutions. Schwenk, et al., and Beaulieu-Boire, et al., each focus on balance based assessment, the former using a worn sensor system and the later utilizing a Microsoft Kinect wearless solution [1, 8]. Both demonstrate the importance of real-time feedback in the process, but both also require specialized hardware to either be worn or used and as such are not easily brought out of the clinic into the home.

Pose estimation using a webcam opens up opportunities for many healthcare applications that usually require a medical professional to be physically present. This technology can be used to make prevention programs more accessible and streamlines the data analytics process for patient progress. Many of these programs have standardized tests and routines that can be implemented. The need for more accessible healthcare programs motivated our research into building applications which can perform pose estimation and body tracking with more common and ubiquitous technology.

3 THE SYSTEM

The NeuroPose system utilizes real-time pose estimation technology to make preventative care more accessible to elderly patients. The system is designed so that a patient can simply use a webcam and internet browser on a relatively modern computer to access their training programs. The minimal hardware requirements and the simple architecture allows patients to easily participate from the comfort of their homes. Once the patient opens the website, they can login and choose their exercise routine. The routines are based on standardized exercises and tests. While the patient completes their exercises, they receive ample feedback that provides a positive and reassuring environment. The system will also include a social aspect that can allow patients to connect with others so that they feel motivated and a part of a community.

The technical aspects of the NeuroPose system includes an open-source pose estimation implementation, which was selected after

evaluating a number of different options and assessing performance against accuracy. Scaling down computational complexity trades accuracy for speed, but real time feedback is essential for our application. For this reason we selected PoseNet [5] as our base model. This neural network is optimized for real time human pose estimation and is compatible with Tensorflow.js, a browser based implementation that uses common libraries like WebGL to access local GPU resources when available for machine learning, and otherwise can scale back parameters to support a wider range of hardware, including mobile devices like smartphones. We designed user tasks and an assessment pipeline based on the STEADI toolkit which addresses clinical guidance for fall prevention rehabilitation programs [9]. Isolating exercises and tasks which use the whole body allow for us to maximize impact and efficacy when building upon the PoseNet framework.

Our Graphical User Interface (GUI) provides a visualization of the body as detected by PoseNet. The front end also includes video recording features and an embedded video player for visual guidance. The application is designed to ensure that video recording from webcam and calculated pose information remain synchronized. There are also timers and countdowns to guide the patient in their exercises. We also plan to implement feedback based on posture and form, so that when the patient has good or lacking form they receive a message indicating that. There progress can be seen on a stats page, showing their scores, frequency of participation and more useful information. Finally, the scoring algorithm utilizes the joint location data to calculate key joint angles. These angles are passed to file for analysis, data is then compared with the intended/goal positions to determine accuracy scores.

4 INITIAL ASSESSMENT

After designing a user friendly GUI that leverages Tensorflow.js and PoseNet, we guided a small sample of participants (three healthy undergraduate students) through a sample exercise routine and collected data. This included exercise demos, timers to provide guidance, and feedback to potential patients. We recorded both video output and pose estimation data (temporal and positional data of all detected joints). To validate our work thus far, we were able to show that the data recorded is synchronized and useful for further analysis by calculating joint orientations and visualizing angle data as it changed over time.

5 FUTURE WORK

Our next steps include implementing and testing the autonomous feedback system. We aim to implement 1-2 fall risk assessments, providing feedback to the user visually as they follow along with guidance instructions in the form of videos. We seek to validate our method of scoring, based on the temporal signal of body angles, by assessing participant recordings with the application as well as via manual video review. Once validated with healthy participants, we will move to the target older patient population.

On the topic of design, Hamm, et al., surveyed the domain and find that most fall prevention systems address intrinsic risk rather than extrinsic risk [3], reminding us that education about reducing risk in just as important as physical therapy. This current iteration of our work also focuses on intrinsics and does not address this space,

but we see its importance and will consider additional educational design with future iterations.

Finally we note that there is potential for this kind of work to extend beyond older populations, possibly replacing other Kinect implementations such as those by Chang, Chen, and Huang in the case of patient populations with motor disabilities [2]. If an appropriate guidance and feedback metric can be generated, NeuroPose could be customized for many domains.

6 CONCLUSION

We present a working proof of concept that pose estimation technology can be used with a simple webcam within a web browser for the purpose of risk assessment and rehabilitation training. Proving this concept as feasible means that advances in machine learning and artificial intelligence can reduce the need for specialized hardware and clinical environments in order to bring rehabilitative and preventative care to patients anywhere someone can use a smartphone or laptop.

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