Engineering User Interfaces for Tailored and Monitored Movement Rehabilitation Programs

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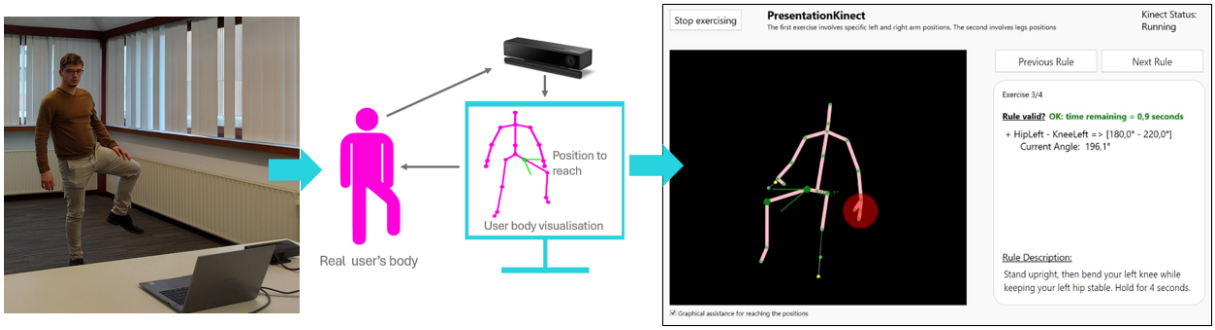

Figure 1: On the left, a patient performs in front of a Microsoft Kinect an exercise tailored and monitored by a physiotherapist. On the right, Motion Recovery provides real-time feedback.

ABSTRACT

As a commercially available gesture tracking device, the Microsoft Kinect was already used for supporting rehabilitation programs in the field of physiotherapy. However, physiotherapists found that the device and applications on offer did not allow them to tailor and monitor exercises accurately. They point out that every patient is different and requires adapted exercises with an expert eye. This paper proposes an approach to revitalize the use of this device in physiotherapy by addressing these needs. Working closely with a physiotherapist, we developed Motion Recovery, a solution that offers precise tailoring and monitoring capabilities for physiotherapy rehabilitation programs. Scoring 82.8 on the System Usability Scale, a test providing an overview of interactive system usability, our solution demonstrated strong user acceptance among 15 patients, culminating in a qualitative evaluation with the physiotherapist.

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CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; Graphical user interfaces; User interface programming; *Interaction devices.*

KEYWORDS

Gesture-based user interfaces; Gesture tracking

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1 INTRODUCTION

Over ten years ago, Microsoft Kinect [5] was introduced and quickly caught the attention of those who saw an opportunity in this gesture tracking device. One example is in the field of physiotherapy [2–4, 6–10]. However, over time, they found that the device and applications on offer did not allow them to tailor and monitor exercises accurately. Knowing that every patient is different and

requires adapted exercises with an expert eye, physiotherapists gradually put aside this technology, justifying their choice by a cautious approach to the device and related applications [4, 8].

In response to the research question, "How suitable is the use of the Kinect for a tailored and monitored rehabilitation program?", this project aims to revitalize the Kinect in this field. Collaborating closely with a physiotherapist, we developed Motion Recovery, which addresses the needs for precise tailoring and effective monitoring of rehabilitation programs. Our approach focuses on designing an interface with predefined rules to meet the demands of professionals in prescribing and monitoring patients' exercises.

2 RELATED WORK

The use of the Kinect in movement rehabilitation has attracted growing interest during the last decade. Lange et al. [4] introduce a Kinect-based low-cost game for balance rehabilitation dedicated to SCI and TBI patients. This low-cost technology helps support hospitals facing staffing shortages. Zhao et al. [9] propose a Kinect-based solution for predefined rehabilitation exercises, enabling healthcare professionals to interact with the Kinect to monitor and guide the patient. The same authors [10] propose a similar solution for at-home exercises. Park et al. [6], investigate the effect of virtual reality training using the Kinect on motor function in case of stroke patients. Using preselected Kinect Sports Pack games, they found that combining conventional physiotherapy with Kinect-based rehabilitation results in better outcomes compared to conventional physiotherapy alone. Tipton et al. [7] use the Kinect to assess the readiness of ACL patients to return to sport. The authors note some weaknesses of the Kinect for such a task. Çubukçu et al. [2] introduce a Kinect-based integrated physiotherapy mentor application for shoulder damage rehabilitation. Authors highlight the importance of collaboration with physiotherapists in designing such solutions. Finally, Xavier-Rocha et al. [8] present a systematic review on Kinect-based applications in the context of rehabilitation which concludes that the device shows interesting results for motor function and postural balance rehabilitation programs. Nevertheless, they caution on device capabilities needing further investigations.

3 MOTION RECOVERY

Meeting the demand of tailoring and monitoring, we introduce Motion Recovery. It offers physiotherapists an easy interface to create and adapt tailored exercises to the patient's pathology and capacities, which cannot be automatized. This is reflected in the duration of the exercise and the limbs' angles.

Technically, each exercise is represented by a set of rules automatically encoded and saved in an XML file [9, 10]. A rule defines duration and a position the patient must stand. A position is described with body parts and angles to reach. Listing 1 shows an example rule where the left knee and hip must hold up for 4".

Listing 1: Rule in XML

```
<rule>
  <Position>
    <Membre1>HipLeft</Membre1><Membre2>KneeLeft</Membre2>
    <AngleMin>180</AngleMin><AngleMax>220</AngleMax>
  </Position>
  <PositionTime>4</PositionTime>
</rule>
```

A second screen enables to experiment and monitor exercises while receiving real-time visual and metric-oriented feedback. As depicted in Figure 1 (left), the patient stands up in front of the Kinect. The real-time skeleton data frames are sent to the exercise analyzer thanks to the Kinect API [5] in C#. A state machine continuously analyzes whether the received position matches with the defined rules. Once angle and duration conditions are satisfied, the rule is validated and the state machine transitions to next rules. To complete an exercise, the patient must validate all the rules successfully. Skeleton data frames are also exploited to show real-time visual feedback as shown on Figure 1 (right). The added value of our solution is the ease of exercise creation and the real-time feedback.

4 PRELIMINARY EVALUATION

User tests on Motion Recovery show promising results in terms of user experience for movement rehabilitation. A System Usability Scale [1], a test providing an overview of interactive system usability, based on 15 patients (7 women and 8 men aged from 18 to 30) results in a score of 82.8. Each patient followed the same program of 5 exercises targeting the lower and upper body (shoulder, elbow, neck, knees). The exercises were designed in collaboration with the physiotherapist. The user study was followed with a semi-directive interview with the 10-years experienced physiotherapist, which revealed the strengths and weaknesses of our solution, especially about the exercise tailoring and movement accuracy in terms of pathology. The expert mostly highlighted the ease of exercise tailoring and suggested exploiting the real-time skeleton visualization to design exercises efficiently while identifying correct angles and body parts. Furthermore, she noticed notable limitations. The Kinect occasionally struggles to recognize lower body movements and hand recognition is limited to "open" and "closed" states. Additionally, facial rehabilitation exercises via the Kinect are not supported.

5 CONCLUSION

We present Motion Recovery, a solution that uses the Kinect for movement rehabilitation programs where physiotherapists can create tailored exercises for movement rehabilitation programs, while patients receive real-time feedback. Our system includes a real-time exercise analyzer using the Kinect API and XML files defining exercise rules. Evaluation resulted in a SUS score of 82.8, meeting needs for exercise tailoring and monitoring. While challenges persist in movement recognition, such as low accuracy for lower body, hand, and face, these limitations are inherent to the Kinect. Future improvements should reconsider hardware choices to enhance precision in problematic areas, while emphasizing the importance of personalization and usability in this domain.

OPEN SCIENCE

GitHub: https://github.com/MotionRecovery/MotionRecovery.
Video: https://youtu.be/kzlkOwsdWSE.

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