Towards Situated Knee Trajectory Visualization for Self Analysis in Cycling

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Abstract

Inflammation, stiffness, and swelling are frequently reported symptoms of patellar tendinitis among cyclists; making knee pain a consistently observed overuse injury in cycling. In this paper, we investigate the applicability of a knee trajectory visualization to self-analysis for increasing awareness of movement patterns leading to injuries. We briefly explain overuse injuries and patellar instability, describe the experiments we did with cyclists for gathering requirements, and finally illustrate an augmented reality concept. We also show two different types of visualizations with participant opinions; one being conventional and other being a video-based one and discuss how situated visualizations can be utilized for improving self awareness to injury causes.

Index Terms: Human-centered computing—Mixed / augmented reality; Human-centered computing—Information visualization—Visualization design and evaluation methods

1 Introduction

Cycling is a low-impact non-weight-bearing form of exercise due to body weight being carried by bicycle [3]. However due to its exceedingly repetitive nature, overuse injuries in lower-extremities are consistently observed [2]. This turns patellar tendinitis, injury to the tendon connecting your kneecap (patella) to your shinbone, a common problem in cycling with symptoms such as swelling, inflammation, and stiffness [2]. Furthermore, pain and discomfort around knee joint is a frequently reported problem by cyclists; making it the second most common overuse injury type following back pain in cycling [2–4].

Although lateral deviation of patella during movement is known to be a leading cause, current approaches to self analysis and assessment methods on knee movement consistently suffer from primitive problems such as high hardware requirement costs or counter-intuitiveness in graph visualizations [5, 6]. Our ultimate goal with this work is to minimize patellar tendinitis occurrences in cycling by providing cost-effective and intuitive mixed/augmented reality feedback on one's knee movement in the form of situated visualizations. Towards this approach, we investigate the applicability of 3D knee trajectory visualization. In this study, we aim to examine the validity of frequently reported problems as well as try to better understand the requirements for developing these visualizations. To achieve that, we captured knee movement data of amateur and professional cyclists and orally interviewed each participant to identify problems they face while utilizing two consistently used visualization methods. In this paper, we report the most frequently indicated problems by participants and discuss how situated visualizations can play a critical role in reaching a solution [7].

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2 Capturing Knee Movement Data

During our study, we have measured the data of seventeen amateur and nine professional cyclists. We collected informed consent and data on physical measurements before experiments. We followed orthodox bike fitting techniques to minimize fit related arguments [1]. We gathered knee movement data using a cycle ergometer (Wattbike) and six optical motion capture cameras (Optitrack Flex:V100R2). We placed six reflective markers on subject's lower body; two on knees, two on heels, and two on toes. We additionally placed one marker to each pedal for extracting a reference plane to calculate angular deviation in knee trajectories. Each experiment consisted of four phases; subject preparation, training, analysis and discussion. Participants followed the same training regime after completing necessary preparations such as warming up. We adjusted the training difficulty based on each participant's cycling experience and body weight.

Finally, we post-processed motion data to fill possible gaps and reject undesired reflections. We used this data to calculate lateral angular deviation in knee movement through the following process:

1. Accumulate marker data for one-second which contains at least one full knee movement in horizontal direction.
2. Calculate movement planes of pedals.
3. Use PCA on accumulated knee marker data and select the eigenvector with biggest eigenvalue.
4. Calculate the angular difference between pedal plane and selected eigenvector.
5. Repeat above steps until all data has been processed.

3 Visualization Results

Most commonly used visualizations represent the angular deviation in the form of a line chart. Positive values in chart represent an outwards movement trajectory compared to bicycle's frame and negative values mean knees are moving towards inside. In video-based visualizations, the trajectory of each knee is visualized in 3D; mostly in a virtual reality environment (Fig. 2).

Despite their broad application spectrum, counter-intuitive nature of graph visualizations in realizing movement patters were frequently indicated by both amateur and professional participants

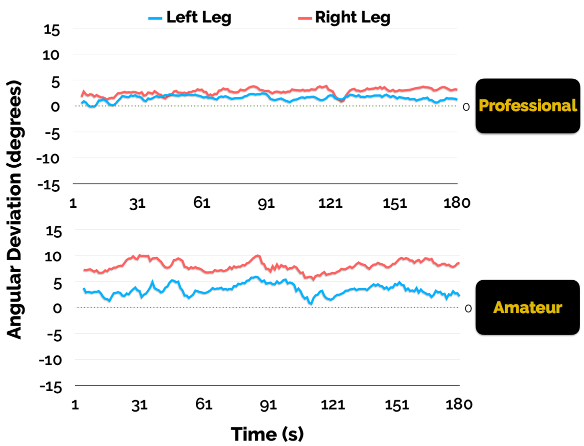

Figure 1: Comparison of lateral deviation in knee movement of a professional and an amateur level cyclist where positive angles correspond to outward trajectories and vice versa.

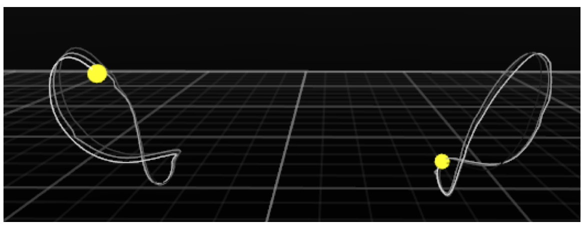

Figure 2: Single frame taken from a video where trajectories of markers attached to knees visualized in 3D.

(Fig. 1). We consistently observed significant difficulties in their comprehension regardless of participant's cycling experience level. Although efficiency in representing long-term progress was referenced as a major benefit, the level of their intuitiveness in real-time applications was largely disputable. Professional cyclists especially mentioned the negative effects of fatigue on comprehension as a crucial problem; particularly during high intensity interval training sessions.

Almost all participants favored video-based visualization of knee trajectories over graph based approach for realizing their featured knee movement (Fig. 2) given the maximum training time was less than a minute. Lengthy process of reaching a conclusion and making judgments was stated as a drawback by both professional and amateur level cyclists. Although participants had differences in ideas regarding the correctness of knee movement and how its trajectory should be, most agreed on the intuitiveness of a video-based visualization for self assessment.

Furthermore, participants were surprised to see that the video-based visualization displayed a result which contradicts with their perceived motion. We believe this could be a niche area where further studies might be required where mixed/augmented reality technologies can reveal additional unique characteristics of human perception and proprioception.

4 Concept of Situated Visualization in Cycling

Based on the initial results we have obtained, we plan to investigate the usefulness of situated visualizations in self-evaluation of knee movement in cycling. One possible application we consider is an augmented reality environment where lateral trajectory of knees are visualized on videos taken from front view of cyclists (Fig. 3). We think that this method has the potential to induce an increase in task performance similar to augmented reality based maintenance and

Figure 3: Situated visualization concept of knee trajectories.

assembly systems where users can see their own hands.

Additionally, there is strong possibility that a situated visualization approach could have significantly positive effects on lower extremity muscle memory. Motor learning can be more efficiently facilitated through an increased number of correct repetitions over a prolonged time; leading to a shorter learning process. This could also contribute to decreasing attention given to pedaling; allowing cyclists to place their focus on other aspects of their ride or training which might affect their safety.

5 Conclusion

We have investigated the applicability of a 3D knee trajectory visualization for increasing awareness to movement patterns and avoiding overuse injuries. In this study, we have tracked knee movement during indoor cycling and examined users' subjective opinions on frequently used graph visualizations. Based on our study, we may fairly conclude that unique problems arise when graph visualizations are employed in real-time training scenarios; such as fatigue-induced decline of comprehension. On the other hand, lack of a proper overview in video-based visualizations reduces their usefulness during long training scenarios. As was mentioned, our aim is to design a situated visualization to be used for self analyzing knee movement during cycling training. Since augmented reality can be used to provide intuitive feedback on actual and measured motion differences, we believe situated knee trajectory visualizations has a possibility to significantly improve one's own movement cognition. We believe this would be a crucial step for reducing the probability of knee overuse injuries in cycling.

Acknowledgments

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