6-2016

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Citation

XIE, Binbin; Jie XIONG; FANG, Dingyi; CHEN, Xiaojiang; WANG, Anwen; and TANG, Zhanyong. Poster: A device-free evaluation system for gymnastics using passive RFID tags. (2016). *MobiSys '16: Companion Proceedings of the 14th Annual International Conference on Mobile Systems, Applications, and Services: Singapore, Singapore, June 25-30, 2016*. 89-89.
Available at: https://ink.library.smu.edu.sg/sis_research/3392

Poster: A Device-free Evaluation System for Gymnastics using Passive RFID Tags

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1. INTRODUCTION

Gymnastic evaluation is emerging as an important application of activity recognition. However, current activity recognition solutions fail in gymnastics evaluations. Specifically, device-based applications require the users to carry the wearable devices, which is infeasible and even prohibited in gymnastic exercises and competitions. Additionally, device-free schemes are not able to capture the detailed movement information so the quality evaluations of the gymnastic movements are missing.

In this paper, we propose DEGY, an automatic Device-free Evaluation system for GYmnastics, which leverages the phase measurements of the reflected RFID signal to accurately characterize each gymnastic movement. DEGY employs reference profiles from a professional trainer's movements including the giant swing on the parallel bars *etc.*, which are taken as the ground truths. To evaluate the quality of a movement for an athlete during the gymnastic exercises, both the measured profile and the corresponding reference profile are queried. Then the evaluation from three perspectives (regularity, continuity, duration) are identified.

2. DESIGN AND IMPLEMENTATION

Two challenges are addressed to realize DEGY including handling the noisy phase readings due to hardware imperfections and evaluating the athlete's performance in details.

1) Noise Reduction: Consider the Gaussian noise in the phase readings of RFID devices [1], DEGY mitigates the noise using a threshold-based denoising approach. We first employ Discrete Wavelet Transform (DWT) to recursively decompose the phase readings into detail coefficients and approximation coefficients at multiple frequency levels. We then minimize the Stein's unbiased estimator (SURE) of risk to remove the noise from the detail coefficients at each level. Finally, we obtain the denoised phase values by reconstructing all the thresholded detail coefficients with the highest level approximation coefficients.

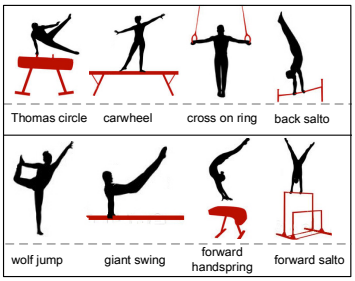

Figure 1: Diagrams of the athletic gymnastics

2) Movement Evaluation: ***Regularity*** – Regularity depicts how this movement matches the standard specification (the ground truths). A high quality movement should have a similar trend compared to the standard. For this purpose, DEGY adopts Dynamic Time Warping (DTW) to compare the measured profile with the corresponding reference one.

Continuity – It quantifies the uniformity of the gap between different movements. A higher uniformity indicates a better pace-control ability. To detect the gap, we exploit a wavelet-based detection technique with the Doppler information deduced from the phase readings. Our design is based on that different movements have different speeds. Further, the standard deviation σ of the gap vector S is reported to each athlete for the continuity evaluation.

Duration – Duration reflects how long a movement is performed by an athlete. A longer duration means lower effectiveness. DEGY estimates the duration difference d_{MR} between each performed movement and the corresponding reference profile, and then provide the result to the athlete.

We implement our system with the commercial RFIDs. For verification, we ask 30 athletes to test DEGY and give their qualitative feedback on quality evaluation based on their true experience. The investigation on these athletes indicates that DEGY could be an effective gymnastics helper with an average satisfying score of 92.7 in quality evaluation and 87.2 in continual using where the highest score is 100. Moreover, the continuity and duration estimation achieve high levels with the corresponding accuracy of 90% and 97%.

3. ACKNOWLEDGMENTS

This work is supported by Graduate Technology Innovation Project YZZ15093, Project NSFC (61272461, 61572402) and foundation of Northwest University ND14041.

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MobiSys'16 Companion June 25-30, 2016, Singapore, Singapore

ACM ISBN 978-1-4503-4416-6/16/06.
DOI: http://dx.doi.org/10.1145/2938559.2948805