Low-cost Motion Analysis for Cardiovascular Disease Patients

Anargyros Chatzitofis, Dimitrios Zarpalas, Petros Daras

Information Technologies Institute, Centre for Research and Technology Hellas, Greece, 6th km Charilaou-Thermi Rd, P.O. Box 60361, GR 57001 Thermi, Thessaloniki

Abstract: The aim of this abstract is to present a low-cost human motion analysis application for (tele)rehabilitation that consists of motion capturing, repetition detection and exercise evaluation components. Each component constitutes a new scientific approach developed to serve effectively the needs of a low-cost rehabilitation system.

Concerning the motion capturing component, a novel approach is presented that fuses information provided from low-cost motion capturing devices, i.e. one Kinect v2 [1] and 3 Wireless Inertial Measurement Units (WIMUs) [2]. WIMUs are placed on the thorax and the forearms, as depicted in Figure 1a. The WIMUs are utilized in order to enhance the accuracy of the skeleton tracking, mainly when self-occlusions are present, while they increase the tracking stability by removing possible "jumps" of the Kinect estimated joint positions during fast movements or temporary occlusions. A new real-time approach for skeleton tracking is offered by fusing the Kinect skeleton tracking with the WIMU orientations, extracted by applying Madgwick [3] orientation filter on "inertial" data. More specifically, the orientations provided by the WIMUs are spatially aligned/calibrated to the Kinect body structure and are used to animate the bones, on which the sensors are placed (Figure 1b). The novelty of this approach is that it prevents the WIMU orientation from drifting by applying an on-the-fly update/calibration of the WIMU orientations based on the Kinect joint orientations, once the Kinect skeleton is considered stable.

Having accurately captured motion data allows for the subsequent motion analysis, whose aim is to recognize and extract analytics concerning the physical exercising. The pipeline of this analysis consists of two phases: i) the detection of the time interval during which a repetition of a specific exercise is performed and ii) the motion evaluation of each exercise repetition, compared to reference motion data. The repetition detection algorithm is a continuous indicator based on multiple machine-learning techniques (e.g. RFRProgress), which extracts the progress of a person to reach a specific pose in percentage (confidence, shown in Figure 1c). Thus, weighting specific poses/key-frames allows for repetition detection. Sequentially, considering the time interval of a repetition, the included motion data are compared to pre-recorded reference motions by using and comparing motion features, i.e. relative angle, angular velocity and acceleration per joint over time, using dynamic weighting. After applying the evaluation, the component returns numerical and textual feedback concerning the patient's performance.

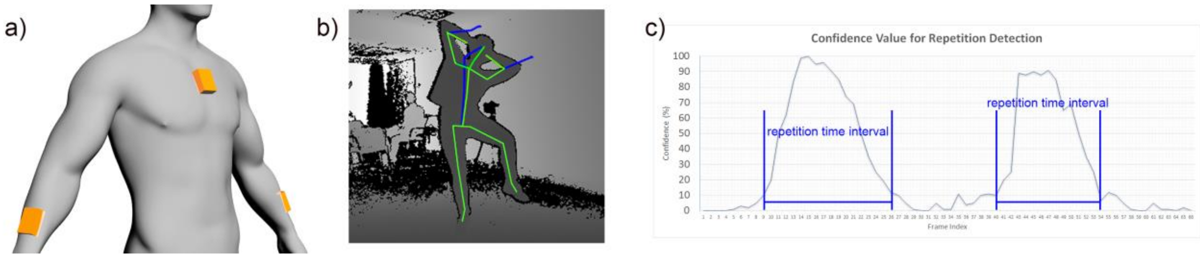

Figure 1 a) 3-WIMU body placement (on thorax and forearms). b) The blue skeleton and the green skeleton represent the Kinect Skeleton tracking and the enhanced fused skeleton estimation using Kinect/WIMUs, respectively. c) Detected time intervals based on confidence values.

Such an application enables the usage of robust, low-cost system for motion capturing and analysis in (tele)rehabilitation applications, since it allows for monitoring the physical exercising and automating the training procedure, without supervising. This application has already been integrated and is utilized in the EU project PATHway [4]. PATHway proposes a new approach to Cardiac Rehabilitation (CR) to enhance patient engagement in rehabilitation through social exergaming. Moreover, in PATHway Phase 3, the CVD patients will use the platform to exercise at home, using also the components described above. This work was supported by EU PATHway project, under contract 643491.

References

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