4 years of FreeMotion: towards practical large scale application of ambulatory 3D analysis of human movement

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Issue

How to transfer the state of the art decision making methods and expertise from elite motion analysis labs in to methods usable for all (peripheral) professionals as to facilitate access to optimal clinical decision making for a much larger group of patients in rehabilitation, ergonomics and sports?

Introduction

Decentralizing health care and a shift from care to prevention prompts for a shift of clinical decision making capacities from specialized motion analysis labs into the hands of the larger community of peripheral - properly educated - professionals in healthcare, ergonomics and sports. Over the last decade ambulatory 3D motion analysis methodology has natured into a potential vehicle for this transfer. This paper presents concepts, methods, technologies, potentials and challenges for ambulatory accurate 3D human motion analysis required for successful transfer resulting from the ongoing FreeMotion research effort executed by a consortium of 10 Dutch research groups and innovative companies [6].

Methods and results

To develop methods for accurate ambulatory 3D analysis of human movement at least the following 4 requirements have to be fulfilled Requirement 1: Portability, large scale applicability and independence of location or external equipment. An ambulatory, portable, wearable, low-cost concept for 3D motion analysis was developed in the form of a complete body worn system for recording 3D human movement, ground reaction forces and muscle activation patterns. This included a wireless infrastructure for peer-to-peer support [1, 3].

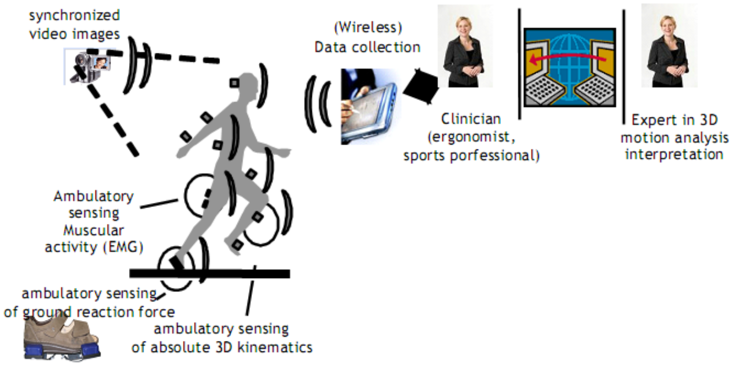

Figure 1. *FreeMotion concept for ambulatory 3D analysis of human movement combining body worn inertial sensors for kinematics, force and EMG, wireless video streams real-time wireless recording and data representation, and modern internet support.*

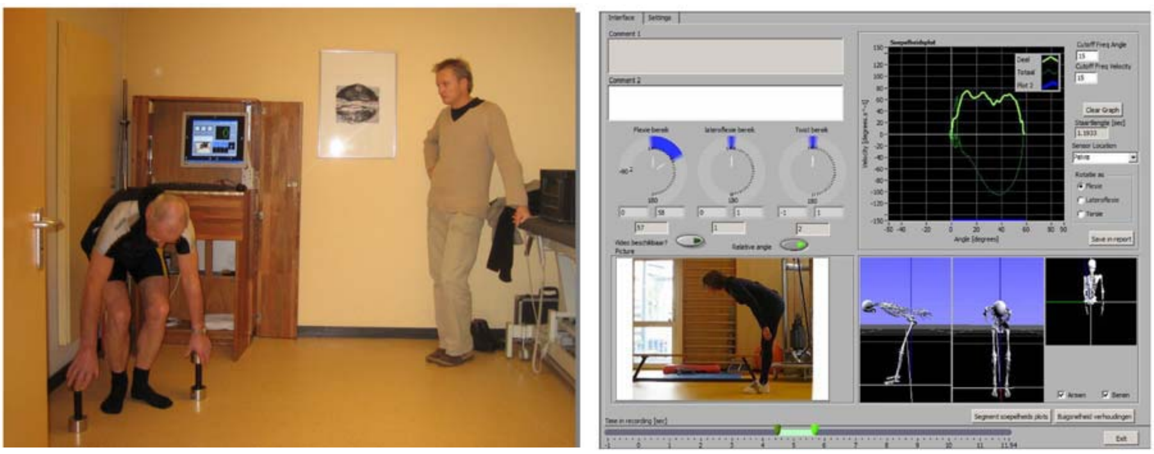

Figure 2. *Left: Real time viewer beta-GUI example for an application aiming at improving training of specific low back pain patients towards more favorable back use (IC-Coach) Clinical relevant info (ROM, kinematics phase plot) are shown synchronized with context data (video + 3D avatar). Right: Using this real-time application a patient is coached in balancing load exposure of her lower back by a physical therapist in a back school program*

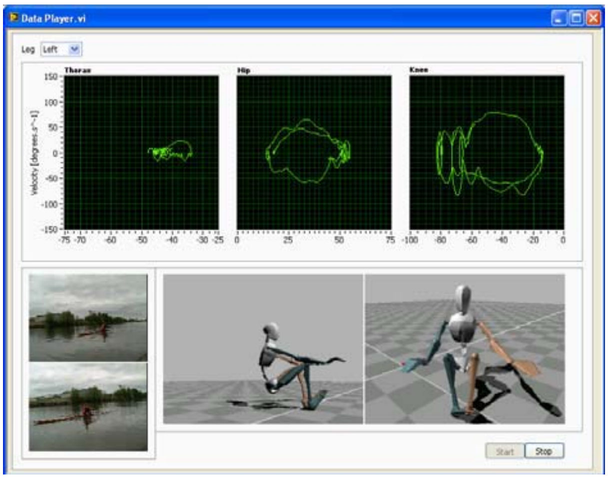

Figure 3. *Example in sports coaching (here varsity rowing), where a sports coach is assisted in real-time monitoring 3D posture, movement and timing of a rower on the water. The coach can view the rower's motion from all sides and study specific timing and kinematics parameters. 2 wireless video streams provide context awareness.*

Requirement 2: Preservation of accurate 3D kinematics assessment. Methods for this was developed (e < 3) based on sensor fusion through optimal (Kalman) estimation of 3D accelerometers, 3D rate gyroscopes and 3D magnetometer signals implemented in mini motion sensor modules for accurate rotational and eventually translational data [5].Requirement 3: Fast, reliable mounting and calibration. For this sensor embedded suits and functional calibration procedures were developed aimed at preventing and eliminating motion artifacts and estimate optimal 3D body segment kinematics from sensor casing kinematics. Great care was taken to minimize patient and clinician burden [2].

Requirement 4: Offer functionality in sensible clinical decision making. A software tool was developed to facilitate clinical sensible application, which records, processes and visualizes in real time 3D motion of up to 10 body segments plus context data (synchronized video of a remotely controlled webcam and 3D full body avatars in 3 simultaneous views). Clinically sensible data representations are added following a tedious interactive analysis of the clinical decision making process [4].

Conclusion

A fully wearable concept of location independent accurate 3D motion analysis in non-elite lab settings seems feasible. From clinical studies evaluating the added value of FreeMotion based tools (e.g. for coaching a-specific low back pain patients into different behavior, for evaluating stroke patients gait patterns, for assessing sports physiotherapy after ACL surgery and for back load monitoring on the job) follows that clinically applicable and useful, robust, affordable, quick applications are feasible Acknowledgement: This paper represents the work of all researchers active in the FreeMotion context. Funding is provided by Dutch Ministry of Economic Affairs and the Innovation Center for Pain Research and the Innovation Center for Rehabilitation Technology, both in Enschede.

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