Identification of Medically Relevant Application Scenarios for A Wearable Motion Analysis System

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Abstract: This abstract presents an iterative and multi-perspective context of use analysis approach for identifying medically relevant application scenarios and required features for a motion analysis system based on inertial motion capture technology. Different iterations of one underlying process are described and discussed. The focus is on how all participating research disciplines as well as potential users in terms of healthcare providers can be involved in this process on equal footing.

Keywords: inertial motion capture, locomotion analysis, context of use analysis, observation, contextual inquiry, qualitative interview

1 Introduction

The overall goal of the junior research group wearHEALTH – a team of computer scientists, mathematicians, psychologists, cognitive scientists, movement scientists and control engineers – is the user-centered design, development, and evaluation of personalized health systems based on mobile and wearable technologies. In this context, one primary aim of the group is to develop a motion analysis system based on lightweight body-worn inertial measurement units (IMUs) in order to support healthcare providers and patients, especially in the process of rehabilitation. From a medical point of view, given the rapid increase in diseases in the course of the demographic change, the research is motivated through an increasing need for objective, lightweight, affordable, easy-to-use and location-independent (measurement, feedback) tools to support and optimize assessments, diagnosis, and therapies [Ch16, MKH16]. From a technical point of view, inertial motion capture, in combination with suitable user interfaces, poses a way to meet these demands (see Fig. 1) [Bl17]. While several challenges related to this technology are being tackled by the research team [Bl17], a multi-perspective context of use analysis is an essential step to drive a user-centered development process. This abstract describes and discusses the approach of the junior research group wearHEALTH to such an analysis.

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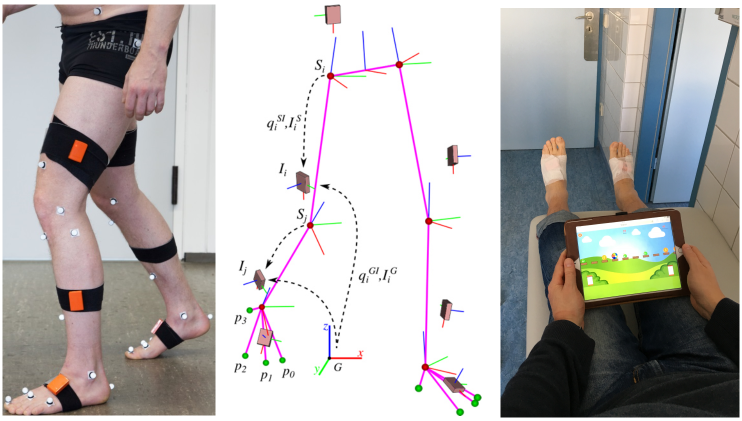

Fig. 1: Left: Hardware setup with seven IMUs for ambulatory tracking of the lower body, in comparison to an established marker protocol with 32 skin markers used by a gold standard laboratory based optical system. The figure has been taken from [Bl17]. Middle: Biomechanical model used by the tracking algorithm. The figure has been taken from [MTB17]. Right: Mobile exergame to motivate movement exercises for thrombosis prophylaxis controlled by two IMUs on the feet [SCB17].

2 Approach

The major goal of the conducted context of use analysis was to identify medically relevant application scenarios in terms of main users, patient groups/medical indications, locations/contexts of usage, parameters to be measured, system functionalities, and boundary conditions. For this, an iterative and multi-perspective approach involving all participating research disciplines as well as potential users in terms of healthcare providers (e.g. physicians, physiotherapists, orthopaedic technicians), who were also considered as experts for their respective professional fields, was developed. Note that patients, who will have to wear the system, will be more actively involved when progressing to the next steps of the development process, in particular when it comes to developing user interfaces. In the following, four iterations of the context of use analysis are exemplified, before the underlying process is described.

In a *first* step, the following two approaches were chosen and conducted in an outpatient rehabilitation center: (1) a focus group, where potentials/limitations of the technology and research objectives presented by the research team and statements concerning medically relevant application scenarios contributed by senior physicians and therapists from the center were initially discussed; (2) a contextual inquiry, where the research team attended two therapy sessions with the possibility to ask questions to both the therapist and the patient. The *second* step consisted of broad-based contextual inquiries during single and group therapy sessions combined with interviews with physicians, physiotherapists, sports scientists, nutritionists and psychologists at the same center. These were mainly conducted by a participating cognitive scientist. The information gathered based on a jointly developed protocol template (medical indications, therapeutic exercises, feedback, etc.) were continuously evaluated by the research team through extraction of relevant system goals and the results were discussed with senior physicians from the center in order to validate medical relevance and feasibility of implementation. The result from this communication was the joint decision to focus on a system to support gait analysis and gait rehabilitation. This was considered as particularly relevant from the application, research and technology perspectives; e.g. due to its high relevance for different patient groups/medical indications (such as osteoarthritis, endoprosthesis), its potential benefits for both healthcare providers and patients, and mobile motion analysis being a key requirement for such a system. The *third* step then consisted of focused observations of group gait training sessions with a logging of patient groups, procedures and exercises, conducted by a participating computer scientist who will be involved in the user interface development. Based on this, a use case description “Smart training clothes for patients with lower body impairments” was developed together with two orthopedic senior physicians from the rehabilitation center. These results were then integrated by the whole research team with information from (a) specialist literature on gait [SB13, Lu15, Gö15], (b) a systematic literature review on exergames for physical activity promotion, and (c) the technical implementation perspective. Based on these results it was decided to use expert interviews for further substantiating system goals and collecting technical requirements for a mobile gait analysis and gait rehabilitation system. Hence, in a *fourth* step, the research team jointly prepared an interview guideline based on [Po07]. The detailed procedure and results are described in [B117]. The gathered information was discussed with the whole research team as well as with interested medical experts. The result was the joint decision to focus on the application scenario “multi-modal treatment of the locomotor system”[2], which is particularly relevant for painful illnesses (e.g. osteoarthritis and low back pain), and to develop mobile systems (mobile motion analysis to support interactive assessments, mobile exergames to motivate self-training (cf. Fig. 1), mobile apps to train self-monitoring, stress management and relaxation techniques) to support this scenario. Moreover, cooperation was established with the contributing medical experts.

Each of the above described iterations of the context of use analysis followed the process illustrated in Fig. 2 in order to support integration of the perspectives of all participating research disciplines as well as consulted healthcare providers.

[2] cf. http://www.icd-code.de/ops/code/8-977.html

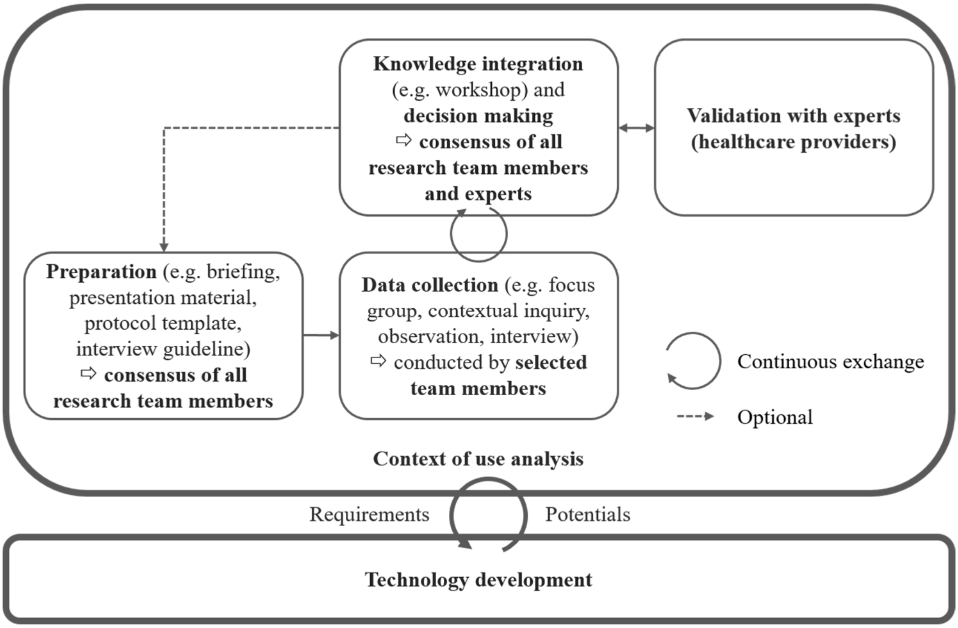

Fig. 2: Iterative and multi-perspective context of use analysis.

3 Discussion

The iterative and multi-perspective approach to the context of use analysis allowed the team to gradually substantiate the considered application scenarios in consensus with all participating research disciplines and the involved healthcare providers/experts. This process resulted in an application scenario (multi-modal treatments), which extends the initial physiological perspective (focused on movement) with the psychological perspective (education, self-monitoring, stress management and relaxation techniques). It also resulted in the required application-oriented focus of the technical developments of the motion capture system. Moreover, the common approach contributed to a better understanding of the perspectives, methods, goals and interests of the different research disciplines. Also, different ways of thinking were identified in the research group, e.g. system-/method-oriented (Which innovative features/solutions can the system/method provide?) vs. application-/study-oriented (Which user should have which benefit and through which study design can this be validated?), and these were synthesized, leading to the insight that only through a cooperation of the different perspectives, innovative and useful systems can be developed. Furthermore, the personal interviews lead to the establishment of new collaborations, they provided a pool of ideas for future projects and they became an act of transdisciplinary science communication.

One critical point in the above described approach is to maximize the amount of information being picked up during the (qualitative) data collection and being transferred to the whole research team. Interdisciplinary preparation and continuous knowledge integration have been used to reduce information loss. Another challenge stemmed from the limited availability of expert users, which requires their efficient integration into the process.

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