Title:
Patients' Evaluation Based on Digital Motion Acquisition

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Introduction:

The development of mobile health systems has inspired a patient-centric approach to measure and monitor health metrics. The use of portable and wireless devices impacts on health outcomes, services and research [2]. Sensors can be used to track basic parameters such as blood pressure, heart rate and body temperature but with the advent of motion capture sensors, also mobility, gait and the frequency, intensity and duration of physical activity can be measured, stored or transmitted.

The emerging technologies pulled by the video gaming industry open a wide range of opportunities. New ways can be used to assess the performance and the level of disability or function in a patient after an adverse health event. Rehabilitative or disease progress as well as therapeutic impact can be assessed in a quantitative and ubiquitous mode. Different monitoring systems can be used by technicians in rehabilitation centers and hospitals or by patients themselves at home in everyday life.

Within this context, the paper shows a novel approach aimed at increasing automatization in acquiring and using patient's data referring to mobility so that the whole process requires human intervention only for the decisional steps. An application will be shown in the analysis of gait for people with a lower limb external prosthesis by means of optical and inertial motion capture sensors.

State of the art:

Literature shows a number of applications of high-tech sensors to monitor health metrics. The most diffused are used to control acute or chronic conditions mainly due to cardiovascular or neurological disease. Crisis prevention and treatment are focuses of telemedicine in heart failure and [1] proposes a classification of available methods. In [6] tele-care and conventional self-monitored blood glucose programs for titrating the addition of one bolus injection of insulin are compared. In [4] it is described a novel ambulatory system based on inertial sensors for accurate measurement of every stride taken over extended periods for patients affected by Parkinson disease. According to [9] a portable technology provides mobility data that may represent a useful outcome measure for early mobility changes in multiple sclerosis. Accelerometers have been used to assess physical activity that people with stroke undertake in the community and its relationship with walking capacity [3].

Analyzing the gait can be an indirect way to measure people activity and in such a case only global measures are performed (walking speed, balance) [9]. On the contrary, patient's gait can be acquired in much more detail for orthopedic purposes. This is the case of people having walking disorders due do different pathologies or accidents. In particular, the focus of this paper is put on people who had a lower limb loss and use a leg prosthesis, either above or below the knee.

For this kind of applications, both sensors and post-processing of data may be considerably more complex and, thus, may require a structured approach to acquire data correctly and to extract the right output. This is intrinsic to the fact that each step a person performs is a combination of a number of single coordinated movements done in a certain time frame each of which must be captured properly, while in some other medical applications the measure to be taken is much simpler (e.g., body temperature, blood pressure, heart rate).

In order to acquire gait several motion capture (Mocap) techniques can be used. The evolution of Mocap systems as well as of Digital Human Models (DHM) allows a tight integration between the two and, nowadays, in several applications virtual humans are driven by data grabbed from real scenes with people playing a specific role (e.g., in videogames and movie industry). According to the working principles, four main categories can be identified: mechanical, inertial, magnetic and optical. Mechanical ones are the most direct motion capture solutions for gathering human body movements. By the way, it is hard to track the entire body because of the limitations of the sensing devices. The tracking exoskeleton is generally uncomfortable and may limit the range of movements but its overall use is very easy. There are commercial systems available, such as the Gipsy system by Animazoo (www.metamotion.com/gypsy/Animazoo.html). Inertial solutions are based on the use of gyroscopes and accelerometers, usually combined into single inertial measurement units placed on the different body segments. This kind of sensors can only report relative positions of the body and generally suffer of drift problems. Inertial solutions are preferred whenever the person needs to move for long distance or far from the monitoring console, because data can be stored on a memory in the inertial units. Magnetic systems are based on the use of magnetometers or electromagnetic coils to detect the orientation or movement in a magnetic field. This kind of Mocap systems are diffused for tracking body movements of athletes or dancers in reduced volume spaces, while they are not suitable for remote monitoring. Optical systems rely on cameras or other optical sensors to track light sources or reflections or to identify profiles from video frames. Recently, marker-less based systems are becoming more interesting due to their low cost, simplicity and portability. RGB systems without markers rely on the identification of human body silhouette to identify joints and, thus, body segments. Low cost cameras can be simply connected to a generic PC to collect data that can be post processed with free or low-cost software. RGB-D sensors, based on infrared technology are becoming more and more interesting in the research community as well as in industry [3]. The most diffused is Microsoft Kinect, and its use is frequently reported in literature [8],[5],[10]. RGB-D cameras are still less performing than traditional expensive solutions but the huge research effort on both hardware and software development is going to make it the winning solution in the near future.

In this work we applied both RGB-D and inertial sensors. As optical sensors we used and compared MS Kinect v1, whose working principle is based on the projection and acquisition of an infrared pattern, and MS Kinect v2 based on the Time of Flight principle. The inertial sensors belongs to the last generation of devices and allows an accurate measure of movements by means of tridimensional accelerometers and gyroscopes.

(a) (b) (c)

Fig. 1: Motion capture devices: a) MS Kinect v1, b) MS Kinect v2, c) wearable inertial sensors.

<u>New proposal:</u>

Nowadays, due to a higher complexity, the digital acquisition and analysis of the gait is less diffused compared to other physiological activities. In the majority of medical structures, both hospital and rehabilitation centers, the way a patient walk is assessed empirically by expert personnel eventually supported by low technology means such as video cameras. Tele-monitoring for gait analysis as well is well known but still not widespread, due to the difficulty of measuring and processing of large amount of data.

The novelty proposed by this work consist in easing both hospital and home acquisition of people's movement by using last generation of optical and inertial sensors and to create an almost automated method to gather simple medical indications by processing large amount of geometric data. In this way, the output of a Mocap system can be elaborated to determine the presence of a pathology or a specific deviation from the standard behavior. Gait index can be calculated on quantitative data and some new and more reliable indications can be provided automatically to physicians or orthopedic technicians.

To reach this goal the system must be designed so that it is able to analyze raw data, and to this aim, the knowledge of the expert personnel must be captured, formalized and reused. Thus, the principles of Design Automation must be applied.

Application:

The paper shows the application of the new method to the analysis of the walking capabilities of people with a lower limb prosthesis. Motion capture technologies, both optical and inertial, are used on amputee and non-amputee people and results are compare in order to assess reliability and precision of different sensors. The results of the acquisition are then used to automatically determine whether the walk is affected by one or more deviation from the standard reference. Amputee recover most the functionality but some harms are still frequent and they can be automatically diagnosed. Moreover, some deviations can be reduced or solved by making some fine regulations on the prosthesis settings or by replacing the socket. Also in this case the system can provide the technicians with suggestion to improve patient's condition.

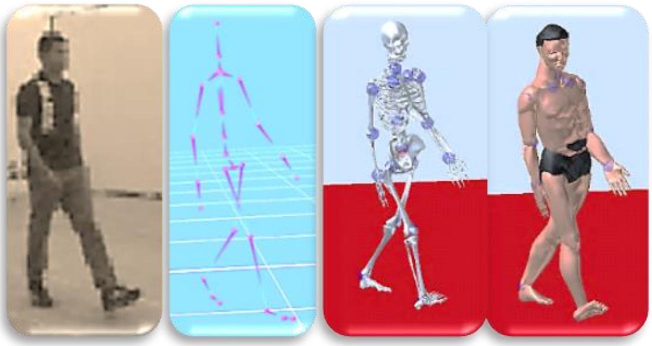

Fig. 2: Motion acquisition and data used to drive a Digital Human Model.

Conclusions:

The paper shows a way to ease, and indirectly promote, the use of motion acquisition and data elaboration in a medical patient-centric approach to rehabilitation. In particular the method, based on design automation prescriptions, is applied to the case of the gait evaluation of lower limb amputee patients. The results obtained with the experimental tests consist in an automatic detection of walking defects on able people and of major defects on people with a leg prosthesis.

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