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Pervasive informatics and persistent actimetric information in health smart homes: different approaches

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INTRODUCTION: This paper discusses the possibility to obtain reliable pervasive information at home from a network of localizing sensors allowing following the different activity-stations at which a dependent person can be detected. Since 12 years ([1-3]), numerous experiments have been achieved for monitoring activity patterns and trends of dependent individuals, especially older and handicapped adults, at their home. For acquiring data necessary to permit the alarms triggering, various sensors dedicated to the localization of person at his/her home or surroundings. These localizers can be located (i) on the person's body (e.g., GPS, accelerometers...), (ii) at home (on the walls: e.g., infrared or radar detectors; on the ground, the bed or the chairs: e.g., pressure sensors, on the doors: e.g., magnetic switches) or (iii) outside (in gardens and streets: e.g., video-cameras).

METHODS: The data recorded could be treated as time series as the sequence of colour coding numbers of balls (symbolizing activity-stations) taken in a Polya's urn, in which the persistence of the presence in an activity-station is represented by adding a number of balls of the same colour as the ball just drawn ([5]). The sequence could also represent historical data from a model, deriving from language models and markovian processes existing in speech recognition research, where the persistence is the probability to stay at the same activity-station ([6]). Other models can also be used as well as the mean time passed or the remaining time in the activity-station. We compared to use the most representative one.

RESULTS: Using statistics, the best model offers up to 98% of good prediction location, considering only the last second of location but distinguishing days of week. Other models need to be improved. We discuss the pertinence of such procedures to early detect sudden or chronic changes in the parameters values of the random process made of the succession of ball numbers. We will use the best procedure to trigger alarms, which will occur when an incorrect prediction is made, or when the person persists at the same station more than the mean time passed in this station, or when the remaining time is passed.

CONCLUSIONS: The sensors network is very important to monitor body posture, activity and gait of dependent people inside home or outside. If the space/time data are acquired on healthy elderly adults or on patients who suffer from neurodegenerative diseases, the sensors recording must be very well calibrated, to give birth to specific profiles concerning the time series which correspond to the successive locations of the dependent person in rooms inside home or in specific places inside a room ([4]). Simpler than Polya's urns derived approach, the Markovian approach seems to be a good way of location modeling. Other models need to be improved to concurrence it. A big hope comes from the ambient information techniques to be able to detect a sudden fall on the ground or a progressive stereotyped behavior (for the early diagnosis of chronic neurodegenerative diseases like the Alzheimer or Parkinson ones).

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Wearable system for foot kinematics and pressure measurements during gait

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INTRODUCTION: In this study we introduce a wireless and portable system for gait analysis that was designed and preliminary validated. The system features two multi-sensor nodes, one for each foot. Each node can provide inertial information, by means of a 3D Inertial Measurement Unit (ADIS16350, with 3D accelerometer and gyroscope), positioned approximately at the level of the Achilles tendon, and pressure beneath the foot, by means of an insole with 24 pressure sensors placed on the most relevant foot-shoe contact region (Paromed). An external gateway acquires data at 83Hz from the two nodes and performs data storage for off-line processing.

METHODS: The preliminary validation of the system was performed through fusion of pressure and inertial information during gait, with the aims of detecting swing and support phases and of estimating the foot inclination. Data were acquired on a young healthy subject who walked along a hallway for about 10 m, performing 3 repetitions of the task. Identification of heel-strike and toe-off was performed considering pressure sensors and the acceleration along the vertical direction. Different

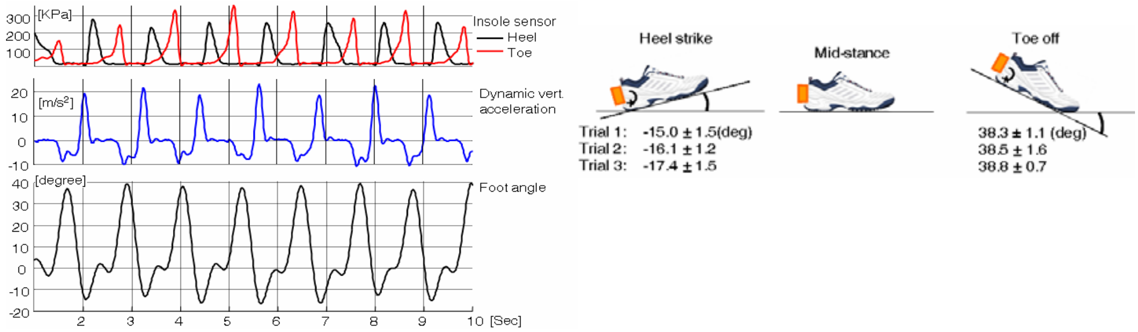

Fig.1 Left panel: representative signals. Right panel: foot angle inclination

stages of the support phase were identified through the pressure sensors and the dynamic component of the vertical acceleration. Inclination angle of the foot was estimated from the angular velocity of the gyroscope by means of an integration procedure, optimized considering the redundancy of sensors data and the gait recurring pattern [1-2]. In particular, the mid-stance phase was used to cyclically reset the integration algorithm.

RESULTS: Main results are shown in Fig. 1 (left panel: representative data of one trial; right panel: averaged data along each trial). The reliability of the results proved the adequacy of the system and of the developed procedure for foot angle estimation. Without such procedure, angle drift from actual value could even reach 15° during a single trial (lasting about 10 s).

CONCLUSIONS: Results suggest that the system with the appropriate algorithms based on sensors data fusion can be an adequate tool for gait analysis, and it can provide information both on foot-to-floor interaction and on foot kinematics, with applications in the evaluation of functional impairments to the motor system and rehabilitation outcomes. The development of more advanced procedures for kinematics estimate and their validation, by means of gold-standard systems, are under study.

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Quantitatively assessing foot placement during real-world rollator use

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INTRODUCTION: Understanding how walker-dependent individuals position their feet during the use of a rolling walker (i.e. rollator) could provide further insight into how these mobility aids enhance the stability of balance-impaired individuals. During gait, mobility impairments often become manifested as changes in step width or step width variability [1]. Therefore, by developing a method to quantify these gait characteristics during rollator walking, without the use of a laboratory-based motion capture system, we may enhance our understanding of how these devices influence their user's gait patterns in a real-world environment. The purpose of this study is to assess the validity of a novel approach to extracting step width from video data recorded directly on-board an instrumented walker (i.e. iWalker) while it is being used by able-bodied young adults. This study will establish the foundation for future work in patient populations with balance impairments, such as individuals with a traumatic brain injury (TBI), stroke, or neuromuscular disorder.

METHODS: Two able-bodied young adults were instructed to ambulate across an in-lab walkway with varying step widths: preferred, narrow, and wide. These step widths were measured concurrently using a digital video camera on board the iWalker (i.e. the footcam) and a seven-camera Vicon MX Motion Capture System as a reference. The footcam was oriented backwards towards the user's feet such that it was able to capture the position of toe markers during walker-assisted gait (Fig. 1). Parallax error in the video images was rectified and the two-dimensional coordinate position of the markers extracted using Peak Motus (Vicon, U.S.A.). Step widths were then calculated (Fig. 2) and compared with those obtained using the Vicon system (Fig.3).

RESULTS: Initial results indicate that the footcam-based step width calculations correlated strongly with those computed by the Vicon system in the lab (R^2=0.9588) (Fig.3). As a result, we believe that this method can be used to provide a quantitative assessment of foot placement during iWalker use.

CONCLUSION: Our camera-based approach to calculating step width provides an accurate assessment of foot placement during rollator use and may be used in future studies to identify differences in how this device is used by patient populations in real-world environments.