Reconstructing the Unusual Gait Events in Everyday Life

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1 Introduction

Wearable sensors are frequently used to track movement quality and quantity during activities of daily living. However, current approaches have several limitations, such as inconvenience (too many sensors [1]), oversimplicity (too few sensors, too little information [2]), and/or inapplicability to non-stereotypical motions (reliance on repetitive motion for machine learning). We sought to characterize unusual gait events, specifically minor losses of balance (LOBs) such as tripping or stumbling, which may not necessarily cause falls, but which may indicate of risk of falling in older adults. We developed and tested a protocol for achieving this characterization while balancing the competing demands for simplicity and convenience vs. data richness.

2 Methods

Four older adults, three of whom reported balance problems, wore inertial sensors (measuring 3-axis acceleration, angular rate, and magnetic field) on both feet, the lower back, and one wrist, for seven days at a time. Sensors were donned in the morning, switched among different shoes and slippers throughout the day, and charged at night. Additionally, subjects wore a voice recorder on one arm, programmed to record short messages along with time-stamps at the touch of a single button. Subjects were instructed to record a description of any event in which they felt their balance was lost or compromised.

We identified LOB events from the time-stamped voice recordings, then reconstructed body motion surrounding the events, to investigate the mechanisms of balance loss and recovery. We estimated foot motion by numerical integration of inertial signals from the foot-mounted sensors [3][4]. We estimated trunk and arm motion using pitch, roll and yaw estimates native to the trunk and arm sensors. We identified the specific timing of loss-of-balance events from the estimated velocities of the feet. Finally, we reconstructed and animated a combined estimate of the motion of all four segments, before, during and after the LOB event. The different sensors were aligned according to simple assumptions of body geometry (e.g., feet taking overlapping steps, trunk above feet, arm attached at shoulder). Motion was reanimated as videos and as sequences of still frames. Each LOB was treated as a case-study, to identify mechanisms of balance loss and subsequent recovery or falling.

3 Results and Discussion

We recorded a total of 39 LOB events across 4 subjects, during 7 total weeks wearing the sensors. Subjects reported minimal inconvenience from wearing the sensors. Fig. 1 demonstrates one case, in which the subject reported "Lost balance when I was in by the computer; regained balance without fully falling." Reconstruction shows that the event was caused by tripping on an object on or near the floor. Recovery was achieved by a rapid step-over of the tripped foot and a recovery step by the other foot, accompanied by flexing of the trunk and throwing the arm forward. Other events reported had widely varying causes such as spontaneous loss of equilibrium, navigating stairs, bumping furniture, and slipping on snow and ice.

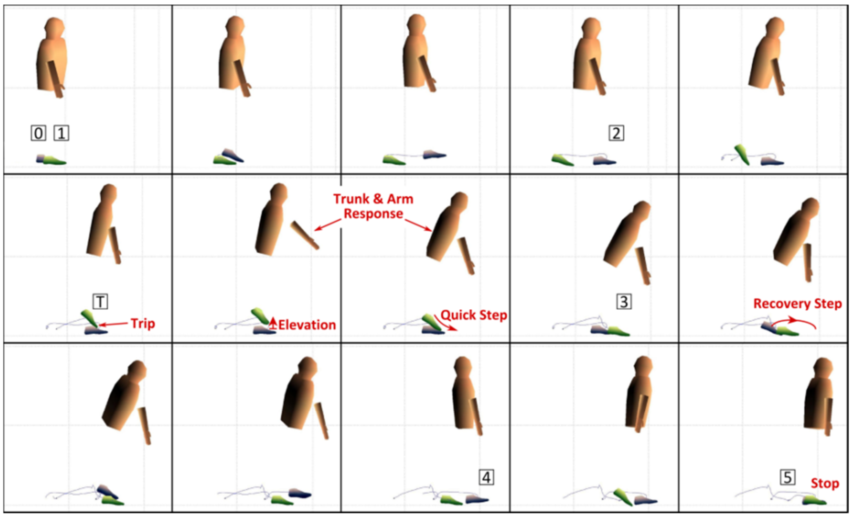

Fig. 1: Reconstruction of a trip and recovery while walking in a home office.

The technique of combining wearable motion sensors with user-initiated, time-stamped event descriptions enables new insight into the mechanisms of unanticipated LOB events in uncontrolled environments.

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References

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