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AUTOMATIC DETECTION OF SLIP-INDUCED BACKWARD FALLS

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INTRODUCTION

Falls are the leading cause of injury deaths among people 65 years and older. The National Safety Council reported that in 2005, 17,700 Americans met their death by falling, and of these deaths, the majority (over 80%) were people over 65 years of age [1]. It is certainly desirable to avoid the fall accidents altogether through developing a comprehensive fall prevention program [2]. However, in case of unavoidable falls, an effective injury-prevention technology is critical to minimize/reduce fall-related physical injuries. Recently, the concept of wearable airbag [3] emerged as one viable and promising injury-prevention approach.

Being able to detect fall events unambiguously and reliably is the key for the practical implementation of wearable airbag technology. Consequently, fall event detection has attracted several research attentions since early 2000s [4-7]. Despite the continuous efforts, existing fall detection technology still requires much research. First of all, previous fall detection methods have been exclusively evaluated with falling from a static posture (i.e., standing). It is unknown whether and to what extent these methods can be applied to more realistic scenarios (i.e., falls during dynamic movement). Second, previous methods have been tested with the younger adults only. Considering the age-related motion feature differences, fall detection performance evaluation has to involve the elderly who are the most likely users for this type of technology. To address these two issues, it is desirable to develop and evaluate the fall detection methods with the elderly during walking.

Therefore, the purpose of this study was to evaluate a novel fall detection algorithm in differentiating slip-induced backward falls from activities of daily living (ADLs). It was hypothesized that the new algorithm would have better performance than the existing algorithm [7] in terms of higher specificity and sensitivity.

METHODS

Participants. Ten elderly participants (> 65 years old) were recruited from the local community for this study. Their anthropometric information was summarized as: age (mean = 75 years, SD = 6.0 years), weight (mean = 74.1 kg, SD = 9.1 kg), height (mean = 1.74 m, SD = 0.08 m). They were required to be in generally good physical health. Informed Consent (Virginia Tech IRB #07-628) was approved by the IRB committee at Virginia Tech and obtained from the participants prior to any data collection.

Apparatus and Procedures. A detailed description of the experiment protocol for normal walking and slip-induced backward falls has been published previously [8]. Briefly, participants were instructed to walk at a normal pace on a linear walkway with the protection of an overhead harness system. Unexpected slips were induced by changing the dry floor surface into slippery surface (covered with 3:1 KY-Jelly and water mixture) without participants' awareness. One inertial measurement unit (IMU, Inertia-Link, MicroStrain Inc., USA) was placed close to the sternum. This IMU is capable of measuring 3D orientation, 3D acceleration, and 3D angular velocity at a sampling rate of 100Hz. The slippery surface was introduced repeatedly until three slip perturbation trials were obtained from each participant. After each trial with the slippery surface, participants were encouraged to walk continuously as normal as possible at a normal pace for 5 to 10 minutes before the next slippery trial. The participants had no knowledge regarding the exact timing of the floor surface change.

Each participant was instructed to perform the 5 types of daily activities according to randomized sequence. The activities include lying down on a bed, bending over to pick up an object from the ground, sitting down on a regular chair, sitting down into a rocking chair, and sitting into a bucket seat. At the beginning and the end of each trial, they were required to maintain the static posture for 1 second. All the timing information was provided to the participants via auditory cues by the experimenter.

Fall event detection. All of the participants were randomly assigned into two groups. The data from the first group (4 participants) were used as the training dataset to construct the new detection algorithm. The data from the second group (6 participants) were used as the validation dataset to validate the performance of the new algorithm. The quadratic form of discriminant analysis was performed on the training dataset in order to derive the discriminant function, *F(a,w)*. The optimal detection threshold was determined based on the relationship between detection thresholds and sensitivity/specificity. The baseline algorithm was formulated based on the literature [7]. The associated discriminate function, *F(w)*, took the threshold as 130°/s. Receiver Operating Characteristic (ROC) curves [9] were used to quantify the overall discrimination performance of the new algorithm and the baseline algorithm. Sensitivity and specificity associated with the specific detection thresholds were computed. Discriminant function and ROC curves were constructed in MATLAB (MathWorks, USA).

RESULTS

Training dataset includes 69 ADL trials and 6 slip-induced fall trials. The discriminant function for the new algorithm is shown below:

$$F(\alpha,\omega) = -0.5251 + \begin{pmatrix}\alpha\\ \omega\end{pmatrix} \cdot \begin{pmatrix}-0.0586\\ -0.0070\end{pmatrix} + \begin{pmatrix}\alpha\\ \omega\end{pmatrix} \cdot \begin{pmatrix}0.0246 & -0.0010\\ -0.0010 & -0.0004\end{pmatrix} \cdot \begin{pmatrix}\alpha\\ \omega\end{pmatrix}^{-1}$$

where a specific data trial was detected as fall if $F(a,w) < -4.994$.

The validation dataset including 105 ADL trials and 7 slip-induced fall trials was processed by the new algorithm and the baseline algorithm. The overall discrimination performance was illustrated in Figure 1. The performance of the new algorithm (AUC = 1.0) was slightly higher than the baseline algorithm (AUC = 0.9743). With the specific detection thresholds, the new algorithm achieved higher sensitivity (100% vs. 85.71%) and higher specificity (95% vs. 90%) compared to the baseline algorithm.

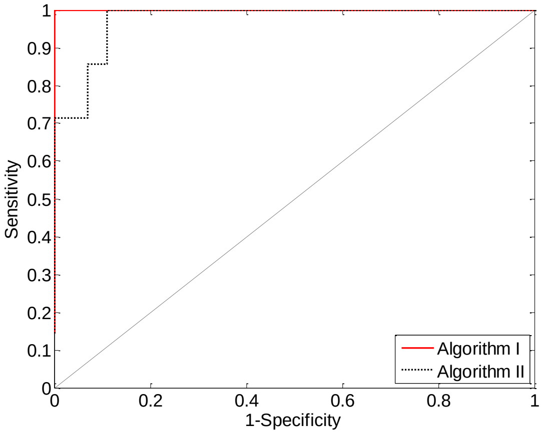

Figure 1 – ROC curves of new algorithm (I) and baseline algorithm (II)

DISCUSSIONS

(Due to space limitation, discussions will be presented in full paper.)

REFERENCES

1 National Safety Council, *Report on Injuries in America (Unintentional death)*. 2006.

2 Bell, J.L., et al., *Evaluation of a comprehensive slip, trip and fall prevention programme for hospital employees.* Ergonomics, 2008. 51(12): p. 1906-25.

3 Fukaya, K. and M. Uchida, *Protection against impact with the ground using wearable airbags.* Industrial Health, 2008. 46(1): p. 59-65.

4 Lindemann, U., et al., *Evaluation of a fall detector based on accelerometers: a pilot study.* Medical & Biological Engineering & Computing, 2005. 43(5): p. 548-551.

5 Karantonis, D.M., et al., *Implementation of a real-time human movement classifier using a triaxial accelerometer for ambulatory monitoring.* Ieee Transactions on Information Technology in Biomedicine, 2006. 10(1): p. 156-167.

6 Bourke, A.K., J.V. O'Brien, and G.M. Lyons, *Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm.* Gait & Posture, 2007. 26(2): p. 194-199.

7 Nyan, M.N., et al., *Distinguishing fall activities from normal activities by angular rate characteristics and high-speed camera characterization.* Medical Engineering & Physics, 2006. 28(8): p. 842-849.

8 Liu, J. and T.E. Lockhart. *Aging effect on joint moment generation strategy in successful reactive-recovery from unexpected slips*. in *Human Factors and Ergonomics Society 49th Annual Meeting*. 2005. Orlando, FL.

9 Zweig, M.H. and G. Campbell, *Receiver Operating Characteristic (Roc) Plots - a Fundamental Evaluation Tool in Clinical Medicine (Vol 39, Pg 561, 1993)*. Clinical Chemistry, 1993. 39(8): p. 1589-1589.