A neural network based fall detection algorithm: tested using real-world falls recorded from elderly people

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Abstract
Fall accident is one of the most common factors that threaten the health of the elderly, therefore, the development of fall detection system is essential. In this study, a Neural Network is trained with simulated falls and ADL recorded from young subjects and ADL from elderly subjects to achieve this goal.

Introduction
It is estimated that approximately one in three independent living older adults (>65 years) fall each year with this number rising to one in every two for those resident in nursing homes [1]. With this projected population increase in this age group and given the fact that falls are the leading cause of injury-related death and hospitalization [2], greater demands will be placed on care services, health budgets, nursing and care staff for the elderly.

Significant research into automatic fall-detection using body worn inertial sensors has been performed in recent years [3] as a result of the rapid decreased in form factor of micro-electronics. However even with this intense research activity, a recent systematic review demonstrated that less than 7% of studies used falls recorded from elderly people falling in real life situations [3] for algorithm development and testing.

The FARSEEING project (farseeingresearch.eu) aims to compile a database of real life falls from elderly people [4], [5] to enable the development of fall detection algorithms tailored to this population.
This study aims to validate a fall-detection algorithm capable of detecting real-world falls in elderly people.

Material and Methods
A total of 3 data sets were used in this study, these include:
- A data-set of waist tri-axial accelerometer (TA) data (sampled at 200 Hz with 12 bit resolution) recorded from ten young male volunteers described in [6].
- A data-set of normal ADL recorded from ten healthy elderly volunteers (age 73 to 90 years), who were recorded performing 240 ADL in total and also recorded for up to 8 day-time hours while carrying out their normal activities. A total of 62 hours of unscripted ADL were recorded [6].
- A data-set of real falls recorded from elderly people through the FARSEEING Project, figure 1. A total of 25 falls from 9 subjects (7 women, 2 men, age 66.4±6.2 years.

Algorithm development
A fall detection algorithm was developed for fall-detection using a Multi-Layer Perceptron (MLP) which is a feed-forward Neural Network, trained in a supervised learning way by stochastic gradient descent (figure 2). It aims to minimize the following logistic error function:

\[ E_{log}(w) = \frac{1}{n} \sum \log(1 + e^{-w \cdot x}) \]

Binary classification using the sign of the one-dimensional output \( a^{(2)} \), -1 for ADL and +1 for falls was adopted.
The root-sum-or-squares TA data were segmented in patterns of 3 seconds. The MLP was trained with 240 simulated falls and 120 ADL patterns performed by young volunteers as in [6] and 7073 unscripted ADL patterns from an elderly subject as in [6]. The training set was split into a two-thirds training set and a one-third validation set. Two convergence criteria were set, training stops when a target value of logistic error is reached or when the error starts to increase on the validation set.

Experimental Results
The classifier obtained following training was tested on the 62 hours of unscripted ADL from elderly subjects to simulate real-time conditions. A false-positive rate of one fall detected every 10.5 hours was observed. Fall-positives seem to correspond to activity transitions, like stand to sit transitions.
Using the 25 real-world falls, a sensitivity of 84% was reached, resulting in 4 falls being miss-detected, which constitute the major issue.

Discussion and conclusion
A neural network based algorithm has been developed using simulated fall and ADL recorded from young healthy subjects and normal ADL recorded from elderly subjects. After visual inspection, undetected falls appear to be rather similar to ADL patterns in terms of shape and amplitude.
An algorithm performance increase can be achieved by incorporating real-world falls from elderly people for training. Simulated falls performed by young subjects do not appear to account for all types of fall-events that occur in elderly.
A fall detection algorithm has been developed and tested using real-world falls. Further work, in the training phase, of the algorithm is required to improve detection accuracy.

References
Fig. 1 Sample of a root-sum-of-squares of a real-world fall.

Fig. 2