Hearing Instrument Fall Detection

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Remote, automatic fall detection based on wearables is an important challenge in digital health. While wrist wearables have witnessed incredible adoption in the last decade, the wrist is not an ideal location for fall detection. Hearing instruments, on the other hand, may offer better fall detection accuracy and are worn by persons who are at high risk of falling. This article describes the validation of using sensors embedded in hearing instruments to accurately detect falls in different activity contexts of older adult patients.

A third of adults above 65 years of age experience a fall on a yearly basis. A fall may lead to a devastating injury and, if unrecovered, may result in long lying times that eventually lead to institutionalization or even death [1]. Persons who are prone to falls are often older adults or people with mobility problems (e.g., neurodegenerative diseases). A challenge arises when these people live alone: how to detect if they have fallen and send a message to emergency services or caregivers.

Wearables offer a solution to this challenge. In fact, almost all wearable devices include motion sensors, mainly 3D accelerometers, capable of detecting impacts, activity, posture, and orientation. However, for the specific case of fall detection, sensor location is extremely important. For example, placing sensors on the lower limbs may be irrelevant for this use case, as lower limbs are close to the ground and therefore little impact would be registered. The wrist is the location with the most user adoption, owing to the advent of smart bracelets and smartwatches [2]. However, the wrist has such a level of freedom in daily life with possible high impacts that it may lead to many false positives (non-fall events that are detected as falls), which become a deterrent for the user.

Together with our partner Sonova, this project used hearing devices as wearables to investigate the benefits of positioning the sensor on the head for fall detection. The head is located far from the ground, has much less biomechanical freedom than the wrist, and a head impact after a fall may have drastic consequences so people try to avoid such impacts [3]. Thus, at CSEM, a fall detection algorithm based on sensors embedded in a hearing device was developed and validated in a dedicated lab study.

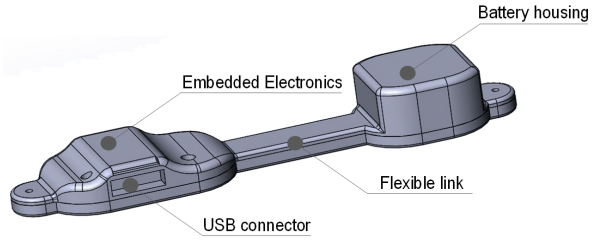

Figure 1: Device used for data collection.

The collection of raw sensor data was performed by the project partner Robert-Bosch-Hospital in Stuttgart. A device was designed and built specifically for this purpose by CSEM, containing a 3D accelerometer with a high range of ±16g and a barometer, and placed at the head near the ear (Figure 1). Data was collected in 3 different studies:

- Reenactment study to build the fall detection algorithm, consisting of 4 participants reenacting a total of 120 falls based on videos of real falls,
- In-lab study, with 42 older adults performing different activities of daily life to develop an activity classifier, and
- Inpatient study, with 14 older adult inpatients monitored over at least 1 day, to evaluate the fall detector's false positive rate.

The developed algorithm is based on biomechanical features and impact detection, which are analyzed in a machine learning model. Then, a recovery analysis is done using inputs from activity and posture context, to confirm a fall event (Figure 2).

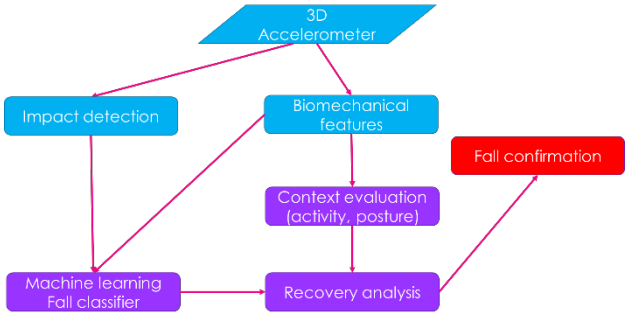

Figure 2: Fall detection algorithm flowchart.

The results of the activity classification algorithm showed excellent sensitivity/precision of 96%/96% for lying posture and 86%/95% for walking activity. The fall detection algorithm revealed a sensitivity/precision of 95% / 99%. Furthermore, the precision was confirmed in the inpatient study, with only 4 false positives in more than 400 hours of data collection.

In conclusion, the potential to detect falls with sensors at the head level is demonstrated. Furthermore, the evaluation of recovery is an important feature of this technology. For instance, an alarm could be raised when a fall is confirmed, and a verification could also be performed when a fall is recovered to check on the person. The low number of false positives reduces the deterrent effect of false alarms and increases the user acceptability of a wearable fall detection solution.

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[2] C. Moufawad el Achkar, *et al*., "Real-time Fall Detection Using Smartwatches," EU Falls Festival (2018).

[3] Lindemann, U., Hock, A., Stuber, M., *et al*., "Evaluation of a fall detector based on accelerometers: A pilot study", Med. Biol. Eng. Comput. 43, 548–551 (2005), https://doi.org/10.1007/BF02351026.