The Use of Machine Learning Algorithms for Remote Fall Detection Monitoring in Elderly People

Daniel Veiga, André Monteiro e Felipe Henriques

***Abstract*— The remote monitoring of the elderly and patients with diseases that promote physical weakness are a relevant trend in healthcare. This work presents a smartphone based tool to assist these people, which is capable for detecting a fall of monitored patient and to alert the responsible, enabling an agile medical assistance. Moreover, we analyzed and implemented machine learning algorithms to increase the accuracy of the monitoring process, in order to avoid false alarms and fall detection misses. The initial results show that the selected algorithms provide better results than models based on smartphone's accelerometer upper and lower thresholds to trigger the fall alarms, which are the main approaches observed in the literature.**

***Keywords*— Home care, mobile computing, machine learning.**

I. Introduction

The remote monitoring of the elderly and patients, called Home Care, becomes an important approach due its low costs, and also presents more comfortable scenario for patients in general. One of most relevant topics on Home Care is the monitoring of falls, since elderly and patients with physical weakness compose a risk group regarding fall from own height. These events lead to several bone fracture and other consequences, such as loss of consciousness and disorientation, for instance, as described in [1]. In order to provide an agile rescue and minimize the consequences of a fall, several real time monitoring approaches are observed in literature, which aim to notify immediately the responsible or healthcare public agents when a fall is detected. Nowadays, most of these approaches are smartphone-based, which is a popular device and is provided with the sensors needed for the fall detection process, such as accelerometer, cameras, among others.

The work described in [2] presents a model based on smartphone's accelerometer upper and lower thresholds to trigger the fall detection. Although threshold-based approaches are easy to implementation in mobile devices, they often present fall detection misses and false alarms. It is important to notice that a fall detection miss is a very relevant failure as serious injury may have occurred to the monitored patient. To overcome this lack of accuracy, the state-of-the-art models implement machine learning algorithms to minimize the occurrence of the mentioned errors. In [3], [4] and [5] the use of machine learning algorithms enables a better accuracy when compared with threshold-based solutions.

This work proposes a model where the fall detection process is based on machine learning techniques. In addition to achieve better accuracy than threshold-based approaches, our implementation provides a lightweight App which runs on the monitored patient's smartphone. Thus, the machine learning algorithms run on a Web Server connected to the App through the internet. This architecture enables high energy saving on the mobile device, which means more availability of the fall detection process. The proposed solution and an analysis of the initial tests performed are presented in the next sections.

Daniel Veiga, André Monteiro and Felipe Henriques, CEFET/RJ campus Petrópolis, Petrópolis - RJ, e-mail: daveigantu@gmail.com, andre.monteiro@cefet-rj.br, felipe.henriques@cefet-rj.br. The authors acknowledge the financial support from the PIBIC – CEFET/RJ.

II. The Proposed Model

Our proposed model performs the smartphone's accelerometer monitoring at real time, and sends the measured values to a web server through HTTP requests. The web server runs the machine learning algorithms based on the training data in order to detect if a fall occurred or not. Then, the web server responses the App the result of the fall detection process. This proposed architecture is depicted in Fig. 1.

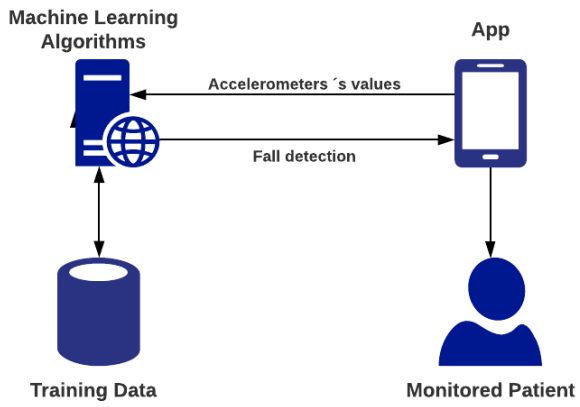

Fig. 1. Fall detection process architecture.

It is important to notice that the App is responsible for collecting data from the accelerometer and to trigger alarms of fall detection. As mentioned earlier, the implementation of the decision maker process on the web server enables energy saving in the battery of the smartphone. When a fall is detected, the App sends a notification to the patient's responsible along with the patient location on a interactive map. This enables that the patient's responsible can call a rescue on an efficient and agile manner.

We implemented and evaluated four machine learning algorithms: Random Forest (RF), K-Nearest Neighbors (KNN), Gaussian Naive Bayes (GNB) and K-Means. The first three are

supervised algorithms, while the K-means is a unsupervised algorithm. The difference between these two approaches is how the training data is presented for each algorithm. The supervised process uses labeled data, which is a data set that has been classified, to train a learning algorithm. Thus, the data set is used as the basis for predicting the output classification of other unlabeled data. Unlike supervised process, the unsupervised algorithms have no idea what the values for the output data might be, and is used to discover the underlying structure of the data (patterns, common characteristics, etc.).

III. Initial Results

The machine learning processes was implemented using the Pythons Scikit-Learn library. The four algorithms were evaluated by their classification accuracy on selected movements. The accuracy is related with the capacity of the algorithm to differ a fall from an ADL (Activities of Daily Living) such as run, walk, sit down, etc. Once the ADLs have very similar accelerometer values with a fall, to differ both scenarios with a good accuracy still remains an open problem in fall detection approaches, as described in [6].

To obtain the training data of the machine learning processes, we defined nine different movements: front fall, back fall, side fall, sit down, lay down, stand up, jump, run and walk. The three first represent real fall events, while the others are usual ADLs. Then, we performed 180 events for each movement with a smartphone located on a person's waist. This location is related with a pants or shorts pocket, where the smartphones are usually putted in. From these 180 records, 135 were used on the training stage of the machine learning algorithms. The 45 remaining records were reserved for the performance evaluation of each algorithm, where the results were compared with a threshold based approach. The accuracy rates of each algorithm are depicted in Table 1.

Movement	**Threshold**	**RF**	**KNN**	**GNB**	**K-Means**
Front Fall	93%	98%	96%	98%	96%
Back Fall	94%	99%	97%	97%	94%
Side Fall	93%	99%	96%	97%	94%
Sit Down	89%	96%	95%	96%	92%
Lay Down	87%	96%	94%	95%	90%
Stand Up	90%	97%	96%	97%	93%
Jump	88%	98%	97%	98%	92%
Run	93%	99%	98%	97%	94%
Walk	95%	99%	98%	98%	96%

TABLE I
RESULTS OF PERFORMANCE EVALUATION.

As observed, the machine learning algorithms are able to improve the classification accuracy of the evaluated movements when compared to the threshold-based approach. The classification accuracy is a very relevant metric to evaluate the fall detection solutions, since they avoid false positives (ADLs detected as falls). Moreover, the fall detection misses are minimized as well, which is even more important metric since serious injury may have occurred to the monitored patient and none rescue procedures were triggered.

When only the machine learning algorithms are analyzed, the supervised processes provide better results than the unsupervised one. This better performance of the supervised algorithms are ratified by the literature , as shown in [7], and occurs due to the quality of the training data. As we trained the supervised processes with real falls and ADLs events, the algorithms enable better classification accuracy of the described movements.

IV. Final Considerations

This work proposes a fall detection system based on machine learning algorithms. The initial results show that the selected algorithms provide better results than a model based on smartphone's accelerometer upper and lower thresholds to trigger the fall alarms. More to the point, the results also indicate that the supervised machine learning algorithms provide a better accuracy than the unsupervised process. Besides that, the patient location is sent to his responsible when a fall is detected, which minimizes the chance of serious consequences from the fall events.

As future work we intend to analyze heuristics and other artificial intelligence techniques to improve the accuracy of the machine learning algorithms. To this end, the literature indicates that is possible to improve the quality of the training data using adaptive filtering among other solutions, as described in [8]. Moreover, we also plan to evaluate the energy consumption of the smartphones battery when the decision maker process is locally implemented on the smartphone instead of the web server. The main benefit of this approach is the independence of the Internet to detect the fall events, once the whole system will be embedded on the smartphone, enabling the running of the Fall Monitor even if the lack of connection signal is observed.

REFERENCES

[1] M. G. d. Freitas, P. d. F. Bonolo, E. N. d. Moraes, and C. J. Machado, "Elderly patients attended in emergency health services in brazil: a study for victims of falls and traffic accidents," *Ciencia & saude coletiva*, vol. 20, pp. 701–712, 2015.

[2] A. M. F. H. Lukas Torquato, Henrique Ribeiro, "Fall monitor: Uma ferramenta em dispositivos móveis para detecção de quedas de pacientes monitorados e acionamento de socorro," *In XXXVI Simpósio Brasileiro de Telecomunicações e Processamento de Sinais SBrT 18, Campina Grande, PB*, 2018.

[3] A. Hakim, M. S. Huq, S. Shanta, and B. Ibrahim, "Smartphone based data mining for fall detection: Analysis and design," *Procedia computer science*, vol. 105, pp. 46–51, 2017.

[4] G. Serpen and R. H. Khan, "Real-time detection of human falls in progress: Machine learning approach," *Procedia Computer Science*, vol. 140, pp. 238–247, 2018.

[5] I. Putra, J. Brusey, E. Gaura, and R. Vesilo, "An event-triggered machine learning approach for accelerometer-based fall detection," *Sensors*, vol. 18, no. 1, p. 20, 2018.

[6] O. Aziz, M. Musngi, E. J. Park, G. Mori, and S. N. Robinovitch, "A comparison of accuracy of fall detection algorithms (threshold-based vs. machine learning) using waist-mounted tri-axial accelerometer signals from a comprehensive set of falls and non-fall trials," *Medical & biological engineering & computing*, vol. 55, no. 1, pp. 45–55, 2017.

[7] A. Singh, N. Thakur, and A. Sharma, "A review of supervised machine learning algorithms," in *2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom)*, pp. 1310–1315, Ieee, 2016.

[8] B. Chen, L. Xing, H. Zhao, N. Zheng, J. C. Pri, *et al.*, "Generalized correntropy for robust adaptive filtering," *IEEE Transactions on Signal Processing*, vol. 64, no. 13, pp. 3376–3387, 2016.