Fraunhofer AICOS 360º approach on technology for falls detection, risk assessment and prevention

Falls are the predominant cause (58%) of injury related emergency department attendances for older people within the EU, according to a recent factsheet from EuroSafe (EuroSafe, Amsterdam 2015).

Fraunhofer Portugal AICOS has developed a complete technological ecosystem capable of continuously monitoring the elderlies at risk of falling, analyzing their normal activity, fall risk status and suggesting fall prevention strategies as well as detecting falls when they could not be prevented. This complete falls management solution is based on processing the data obtained from the smartphone built-in inertial sensors and makes use of the remaining smartphone capabilities to transmit alerts and give feedback to the user. Moreover, it contains interrelations between the different modules, which exchange inputs and outputs, in order to achieve a comprehensive and fully integrated solution, as depicted in Figure 1.

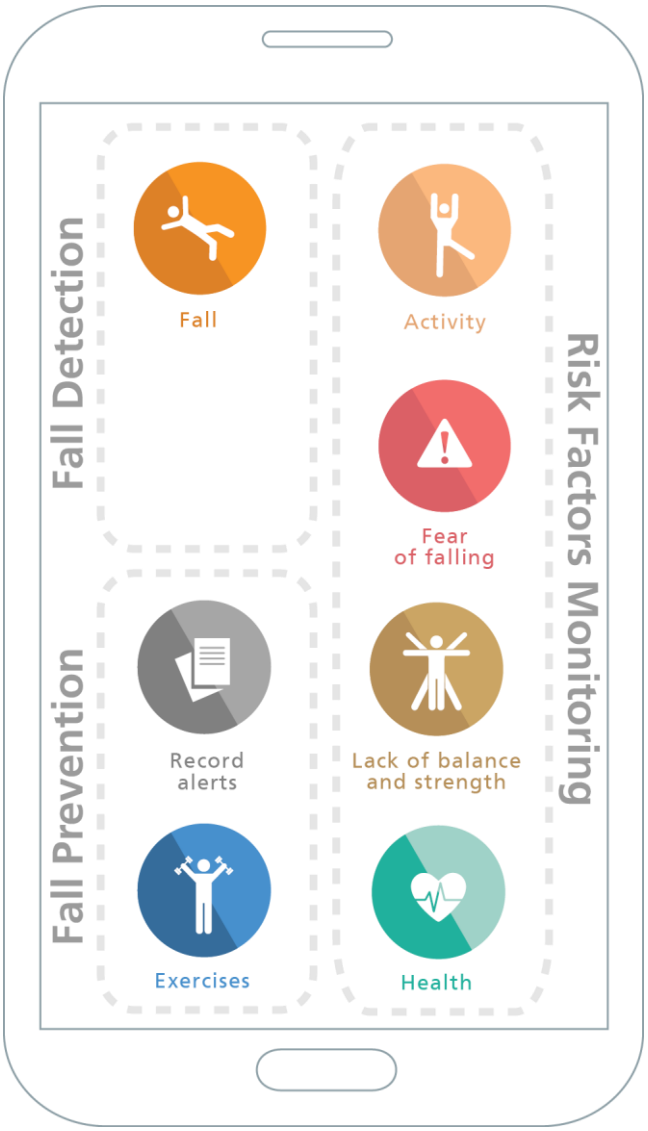

Figure 1: Scheme of Fraunhofer AICOS integrated falls management solution based on smartphones.

The consequences of a fall have a great impact on the older person's quality of life, besides the physical injury, falls can lead to fear of falling, restriction of movements and physical activity which may result in social isolation, depression and even cognitive decline, and these are in turn also fall risk factors. The negative cycle of falls is illustrated in Figure 2. Falls are currently considered a major cause of loss of independence and nursing home admission.

Figure 2: The negative cycle of falls in the elderly population.

At Fraunhofer AICOS we have been researching and developing technologies to better manage and minimize the negative effect of falls for older people since 2011. On a first stage, with the advent of smartphones, which brought pervasive inertial measurement units and computational power, Fraunhofer AICOS proved the feasibility of a phone-based fall detection system[1].

The prognosis of fall victims is significantly better if appropriate assistance is provided in a short period of time after the fall, as the delay between the fall and the intervention has been found to be related with morbidity and mortality rates. Automatic Fall Detection technology allows to reduce the assistance response time and, therefore, reliable fall detection and emergency assistance notification are essential to provide adequate care and to increase the quality of life after the fall.

The fall detection algorithm developed at Fraunhofer AICOS for smartphones continuously screens the data from the smartphone built-in accelerometer when the phone is in the user's belt or pocket. Upon the detection of a fall event, the user's location is tracked and SMS and email notifications are sent to a set of pre-defined emergency contacts. The scheme of the fall detection solution based on smartphones is presented in Figure 3. This fall detection system has

[1] M. Silva, P. Teixeira, F. Abrantes, and F. Sousa, *Design and Evaluation of a Fall Detection Algorithm on Mobile Phone Platform*, in Ambient Media and Systems, vol. 70, S. Gabrielli, D. Elias, and K. Kahol, Eds. Springer Berlin Heidelberg, 2011, pp. 28–35.

been improved and validated ever since[2] [3] [4]. At the moment, a smarter fall detection algorithm, with automatic adjustment of algorithm's sensitivity, considering the profile of the user, his behavior and activities is available.

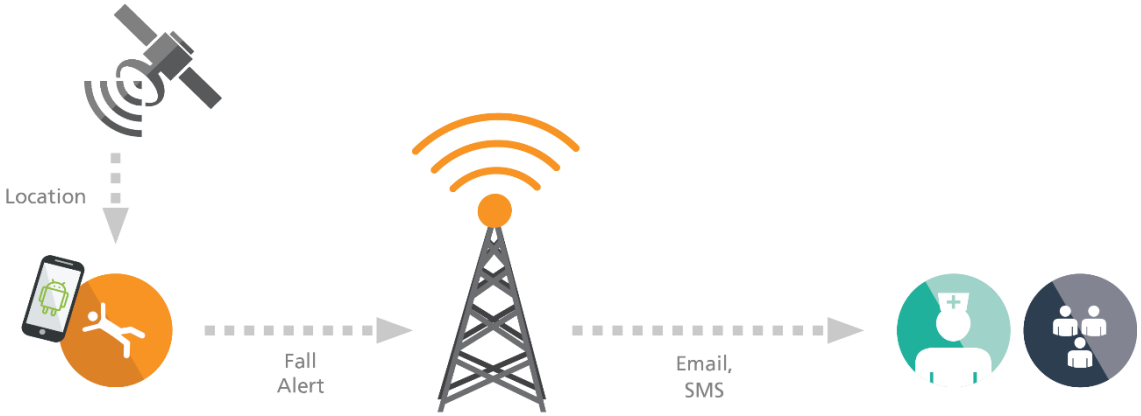

Figure 3: The AICOS Fall Detection System is based on the movement sensing, computational processing, location and communication capabilities of smartphones.

The multifactorial origin of falls is nowadays recognized as well as the reversibility of most fall risk factors, therefore, an enhanced knowledge of the nature of the risks is of paramount importance to enable a proper design of preventive schemes.

Traditional fall risk assessment tests based on measurement equipment such as force platforms and cameras or observation of movements by an experienced physiotherapist were adapted to the smartphone. The smartphone inertial measurement unit (IMU) has been used to collect movement data during Gait, Voluntary Stepping, One Leg Standing, Ankle Flexibility and Sit-to-Stand tests. After processing the data collected processed we have obtained metrics that are correlated with of most of the variables derived from force platforms or cameras systems[5] [6]. An illustration of a fall risk test performed using by force platforms, high-speed cameras and smartphone sensors is presented in Figure 4.

[2] B. Aguiar, T. Rocha, J. Silva, and I. Sousa, *Accelerometer-based fall detection for smartphones*, in 2014 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 2014, pp. 1–6.
[3] J. Vermeulen, S. Willard, B. Aguiar, and L. P. de Witte, *Validity of a smartphone-based fall detection application on different phones worn on a belt or in a trouser pocket*, Assistive Technology, vol. 27, no. 1, pp. 18–23, 2014.
[4] J. Silva, B. Aguiar, T. Rocha, F. Sousa, and I. Sousa, *Smartphone-based Fall Detection Algorithm and Validation*, presented at the International Conference on Ambulatory Monitoring of Physical Activity and Movement (ICAMPAM), Limerick, Ireland, 2015.
[5] V. Guimaraes, D. Ribeiro, and L. Rosado, *A smartphone-based fall risk assessment tool: Measuring One Leg Standing, Sit to Stand and Falls Efficacy Scale*, in 15th IEEE International Conference on e-Health Networking, Applications Services (Healthcom), 2013, pp. 529–533.
[6] V. Guimarães, D. Ribeiro, L. Rosado, and I. Sousa, *A smartphone-based fall risk assessment tool: Testing Ankle Flexibility, Gait and Voluntary Stepping*, in 2014 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 2014, pp. 1–6.

Figure 4: Gait tests analyzed by force platforms, high-speed cameras and a smartphone IMU showed good correlation between metrics obtained.

At AICOS we have been exploring the sensing capabilities of the smartphone as a fall risk assessment tool[7]. Specific mobility and balance impairments are assessed using exercises or serious games delivered in the smartphone, as shown in Figure 5. Questionnaires to evaluate the fear of falling, home hazards, medical conditions and medication history are also presented via the smartphone to the user in a simple and engaging way, examples of questionnaires screenshots are shown in Figure 6.

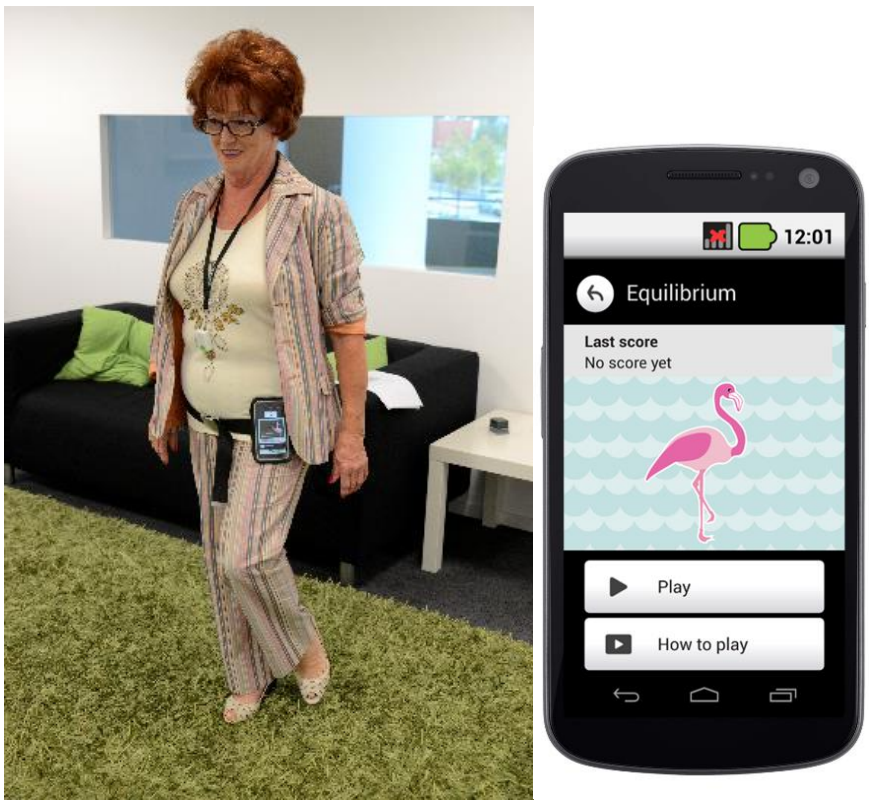

Figure 5: Example of the use of a smartphone to assess equilibrium during the one-leg-standing exercise.

[7] V. Guimarães, P. M. Teixeira, M. P. Monteiro, and D. Elias, *Phone Based Fall Risk Prediction*, in Wireless Mobile Communication and Healthcare, K. S. Nikita, J. C. Lin, D. I. Fotiadis, and M.-T. A. Waldmeyer, Eds. Springer Berlin Heidelberg, 2012, pp. 135–142.

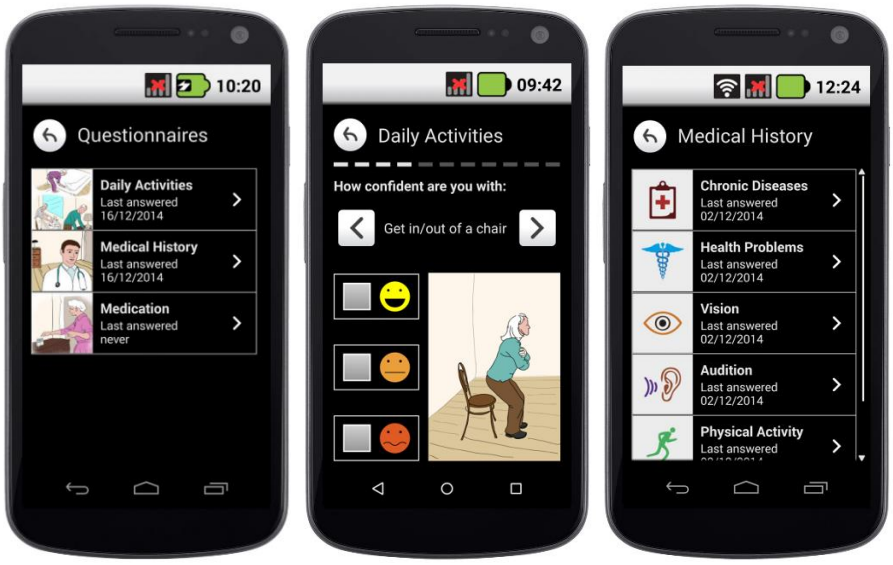

Figure 6: Screenshots of the questionnaires used to evaluate health and behavioral fall risk factors.

By implementing efficient management of the smartphone built-in sensors energy consumption, the users' movements can be continuously monitored and evaluated. At Fraunhofer AICOS we have been developing this continuous monitoring of the users' activities and postures with the aim of raising awareness and encouraging physical activity and active lifestyle[8] [9]. Screenshots of the application for activity monitoring are displayed in Figure 7.

Figure 7: Screenshots of the activity monitoring application developed at Fraunhofer AICOS.

[8] B. Aguiar, J. Silva, T. Rocha, S. Carneiro, and I. Sousa, *Monitoring physical activity and energy expenditure with smartphones*, in IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), 2014, pp. 664–667.

[9] S. Carneiro, J. Silva, B. Aguiar, T. Rocha, I. Sousa, T. Montanha, and J. Ribeiro, *Accelerometer-based methods for energy expenditure using the smartphone*, in IEEE International Symposium on Medical Measurements and Applications (MeMeA), 2015, pp. 151–156.

Monitoring the users' physical activity is useful, not only for the stated purpose, but also to infer patterns and detect changes over time. In the current Fraunhofer Fall Risk Assessment solution the smartphone built-in inertial sensors are used to continuously assess the mobility of elderly users, as they perform their usual daily activities. Moreover, it is also possible to characterize some of the movements performed and associate the metrics extracted to the personal information, medical conditions, medication and responses to questionnaires to obtain a daily estimate of the risk of falling, as shown in Figure 8.

Figure 8: Screenshots of the continuous fall risk assessment application developed at Fraunhofer AICOS.

The risk of falling may be minimized by behavioral changes, adaptation of medication plans and specific physical activity plans aiming at improving mobility, equilibrium and muscular strength[10]. However, physical activity encouragement and exercise programs must be carefully tailored for individuals at risk of falling, since they are mostly elderly, often frail, and may present several co-morbidities.

At Fraunhofer AICOS we have been developing personalized actions taking into account multiple fall risk factors and dimensions of the person's life. The smartphone may play a key role in these actions as alerts and recommendations based on the current status of the person can be triggered and, moreover, the device is already being used as a sensor to monitor exercise interventions for balance, strength and flexibility based on exergames.

The exercises for balance control, mobility and flexibility and muscular strength are implemented as interactive games, in a user-friendly way. Inertial sensors are used to evaluate the performance of the person during the game as well as his/her movement quality[11]. The solution for fall prevention is depicted in Figure 9.

[10] B. N. Ferreira, V. Guimaraes, and H. S. Ferreira, *Smartphone based fall prevention exercises*, in IEEE 15th International Conference on e-Health Networking, Applications Services (Healthcom), 2013, pp. 643–647.

[11] A. Santos, V. Guimarães, N. Matos, J. Cevada, C. Ferreira , I. Sousa, *Multi-sensor Exercise-based Interactive Games for Fall Prevention and Rehabilitation*, in Proceedings of PervasiveHealth, 2015.

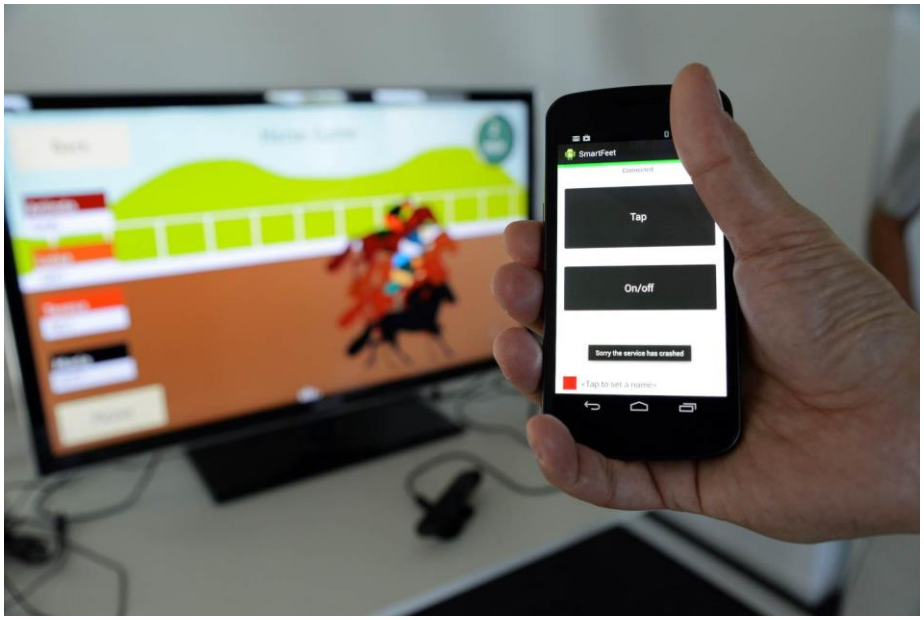

Figure 9: Fraunhofer AICOS Fall Prevention Exergames system delivers exercises for improving balance, mobility and strength as interactive games and uses the inertial sensors built-in the smartphone to assess movement quality.

Several trials and data collection sessions have been carried on with the support of the Colaborar users' network and participation 121 elderly people during the development of solutions for Fall Risk Assessment, Fall Detection and Fall Prevention based on smartphones. Fraunhofer AICOS fall management solution was also demonstrated during the "Health Week" at Coimbra organized by ESTeSC Coimbra Health School students association. The solution was explained to 50 elderly people, who could also try the available features, as shown in Figure 10.

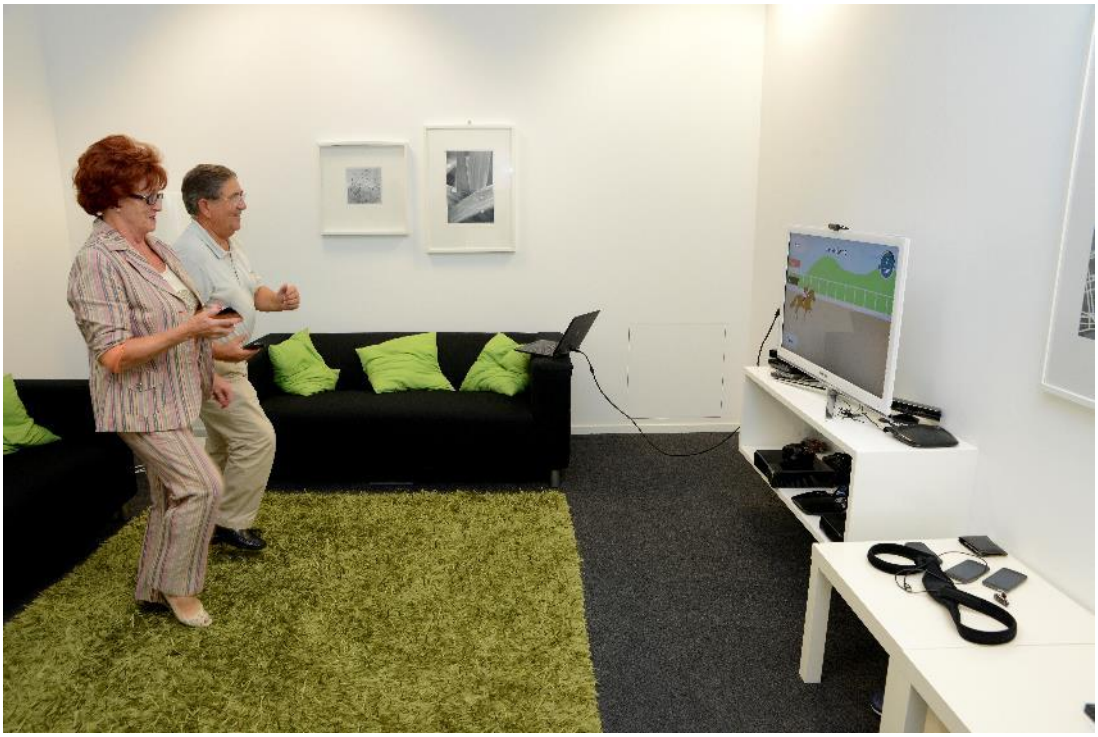

Figure 10: Example of Fraunhofer AICOS Fall Prevention Exergames usage.

Fraunhofer AICOS Fall Competence Center and the participation on European networks such as the E-NO FALLS: European Network for FALL Prevention, Intervention and Security, ProFouND: The Prevention of Falls Network for Dissemination, EIP-AHA: European Innovation partnership on Active and Healthy Ageing - Action Group A2 and, more recently, the Portuguese network Ageing@Coimbra, have greatly contributed to the conception of the 360º vision on technology for falls presented and development of the complete falls management technological solution described herein.

At the moment Fraunhofer has already established partnership with two companies on this topic. Gociety is a Dutch company currently licensing and deploying in the market the smartphone-based fall risk assessment and fall detection modules for personal use in the 'GoLive Phone'. Sensing Future Technologies is a Portuguese company, which has been developing rehabilitation solutions and will be starting a new PT2020 co-promotion project with AICOS for the development, testing and deployment to the market of an integrated solution for fall risk assessment and falls prevention meant not only for personal use, but also for clinics and nursing homes.

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