Use of sensors systems to monitor the mobility of elderly

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Abstract. Even presenting risk of falls or mobility difficulties, many seniors prefer to live independently as long as possible. Thus, there is a need for solutions to enable independent living safely and to strengthen family support. Among them are the collection devices that assist in monitoring and quality of life of seniors. This paper aims to conduct a survey of devices developed to capture signal monitoring and mobility aid for the elderly. The devices were grouped into a main category (sensors) followed by secondary categories in relation to the type of use of the sensors (aid device with sensors, robotics and smart homes). Data were analyzed descriptively, listing the products with the types of use. The study raised a total of 22 products. It is observed that most of the feedback systems is to use sensor systems alone, without being used in sets with other technologies like assistive devices or robotics. Most of the technologies has been developed for detecting falls, and fewer tasks are transfer and mobility in the community. We emphasize the importance of unity of catchment systems signals with assistive technologies, in addition to monitoring the elderly provide direct aid in performing the task performed.

1. Introduction

The population aging bring consequences at a global level, which are a major challenge today. The WHO reports that in 2025 there will be 1,2 billion people over 60 years all over planet [1]. One of the effects of aging is the increase in health problems and disabilities, but there are many possibilities for prevention and improved functional capacity and physical limitations, cognitive and sensory resulting from this process [2], such as the use of technology, systems monitoring and optimization of daily activities.

Even with disabling health conditions, many seniors prefer to live independently as long as possible and thus there is a need to seek solutions to enable independent living by improving the security and family support [3].

Currently one of the areas targeted for investment in the quality of life of seniors is the gerontechnology. Some of the goals of the gerontechnology area are prevention or retardation of

declines associated with age, care conditions and deficiencies installed and improvement in quality of life [4], for example, through assistive technologies to perform daily tasks, or catchment systems for monitoring. The devices to capture signals with sensors are easy to use tools that can identify the vulnerability, functional decline, predict mortality, as well as screening of conditions of life and health, can assist in the evaluations of the elderly for optimization of health services. Therefore, can enable the prioritization of care and improve the orientation on care [5]. Recently, the use of sensors is very present to monitor elderly people mainly in their homes. Understood as an early approach of disease, disability and risks based on the assumption that patterns of abnormal behavior can be captured by environmental sensors [6].

Technological innovations such as smart homes known as Smart Houses are promising solutions. These innovations should improve the quality of housing, care and life of residents, allowing seniors to live more independently and reduce the burden on health services [7].

With the development of technologies that aim to care and due to the high frequency of falls in the elderly, a very investigated area is the monitoring of falls by sensors. The evaluation of risk of falls with simple methods and objectives are necessary and, assessment schemes based on sensors, can differentiate the elderly who fell from those who did not have [8].

Mobility is represented in the International Classification of Functioning Disability and Health (ICF) by classifier d460 – Moving around in different locations, that can be subdivided into: d4600 – Moving inside the house; d4601 - Move inside buildings than own home; d4602 - Move out of your home and other buildings [9] (Figura 1).

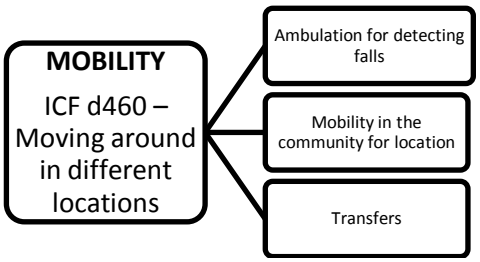


Figure 1. Classification system of the devices on the mobility activity monitored based on ICF [9]

This study was guided by the problem of elderly mobility and considering the need to investigate what has been researched and developed on this thematic. Insofar as the technological resources become important for improving quality of life and promote independent living for elderly, enabling monitoring, assistance and intervention in cases of emergency, this study aims to conduct a survey and description of devices with sensors for monitoring and assisting in the mobility of these subjects. Moreover, given the great diversity of use of the devices to capture signals, this study classified the products found according to their type of use (assistive devices with sensors, robotic systems).

2. Methods and materials

This is an exploratory and descriptive study.

For data collection, we performed a study of the mobility sensors through searching on websites of laboratories for developing technologies for the elderly, journalistic news sites, as well as in scientific papers in the area of health and bioengineering in the Pubmed and Scielo using the keywords: sensors, sensor networks, monitoring technologies; gerontotechnology; monitoring elderly and falls monitoring, in Portuguese and English. We included both devices available in the market such as those under development published from 2009 through 2013.

Were selected devices that monitored or assisted the mobility activity being excluded monitoring devices only routine, vital signs, among others. The data were classified according to their type of use as shown in Figure 2.

The main category, sensors systems, in accordance with figure 2 refers to the sensors themselves. Sensors are "devices that can detect and record the electromagnetic radiation in certain range of the electromagnetic spectrum, and generate informations that can be turned into a product that may be interpreted, either in picture form, in graphical or table". [10]

The subcategories of sensors systems were chosen in relation to the use of these devices together with other types of technology. Considering that not necessarily all sensors are used in conjunction with other technology, these, used alone, are classified in the item sensor systems. T hose who have use in other types of devices may be classified as:

1) Assistive devices with sensors: are capitation systems (sensors) associated with a support tool, such as a inteligente bengal beyond to informe the way it should be done and also assists in the gait. According to ISO 9999 [9] assistive products are "any product (including devices, equipment, tools, technology and software) especially produced or generally available, which is intended to prevent, compensate, monitor, mitigate or neutralize weaknesses, limitations in activity and restrictions in participation".

2) Robotic Systems: are machines with integrated technology systems and controlled as well as monitoring establish a direct relationship with the subject. A robot is a reprogrammable manioulator designed to move material parts, tools or special devices in variable programmed moviments for performing a variety of tasks [11].

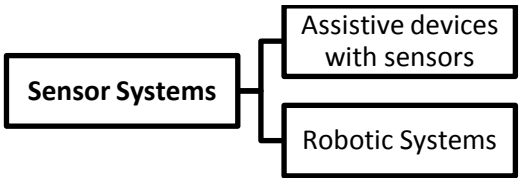


Figure 2. Classification according to the use of sensor systems

Data analysis was carried out through the description of the devices and their category was correlated with the type of use and the tasks involved.

3. Results

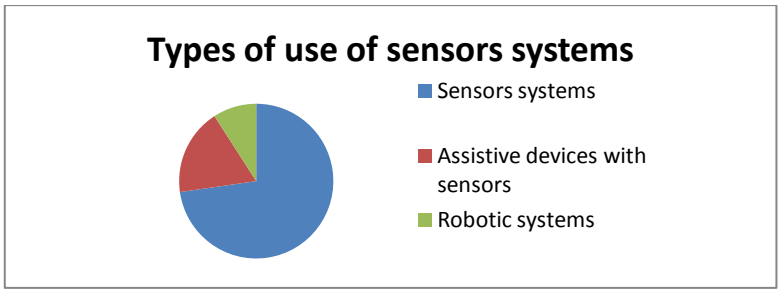
We surveyed a total of 22 sensors facing mobility, the table 1 shows the devices on the classification of the type of use and type of monitored mobility task. The devices collected in this study refers to technologies that monitor ambulation of subjects both to detect falls at home or away from home, as the mobility in the community that assist in the localization of the elderly and aid transfers (moving passage from sitting to standing and vice versa).

Table 1. Devices and classifications for the type of usage and activity monitored

SENSORS SYSTEMS	
ACTIVITY MONITORED	**DEVICES**
Ambulation for detecting falls	Sensor system adhesive skin [12]; Camera system of artificial intelligencel[13]; Pre-impact detection sensor [14]; HONEY- Ambient sensor [15]; Moviment sensor-QuietCare[16]; eNeighbor[17]; CARE system[18]; eCAALYX system[19]; HOPE system[20]; ROSETTA system[21]; SOFTCARE system[22]; Prevision system of fall [23]; Gait

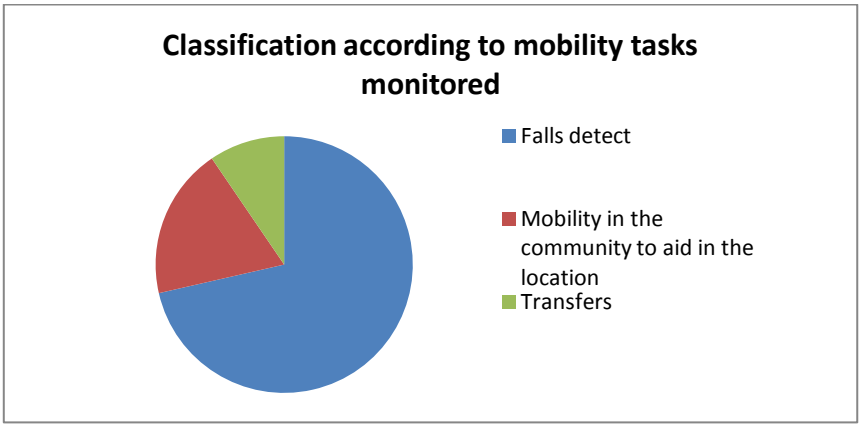
	Measurement System [24]
Mobility in the community	Smartphone app Teo My Geo[25]; REMOTE system[26]; Tactile Belt for locomotion [27]
ASSISTIVE DEVICES WITH SENSORS	
MONITORADE ACTIVITY	**DISPOSITIVOS**
Ambulation for detecting falls	Cellphone BP[28]
Mobility in the community	Intelligent Bengal "The Aid"[29]; Intelligent wheelchair[30]; VA-PAMAID [31]
Transfers	Intelligent wheelchair[30]
ROBOTIC SYSTEMS	
ATIVIDADE MONITORADE ACTIVITY	**DISPOSITIVOS**
Ambulation for detecting falls	NAO – robô[32]
Mobility in the community	
Transfers	ASTRO – robot [33]

Regarding the type of use of sensors aimed at monitoring of mobility, was observed, according to graph 1, which approximately 75% are the sensors themselves, used alone, others used in conjunction with assistive devices and robotic systems appear in smaller amounts.



Graph 1. Classification according to the type of use of sensors

Regarding mobility activities monitored or helped by the catchment signals systems, most, about 75%, is for detect falls. Already mobility in the community to aid in the location and aid in transfers appears in smaller quantities, as shown in Graph 2.



Graph 2. Classification according to mobility tasks monitored

Among the sensors systems it's possible to observe that only 3 of the 16 in the category, are for monitoring of mobility for location the person and the rest 87% are focused on the detection of falls. Most sensors to detect falls are used in systems with many interconnected sensors, as eNeighbor, CARE System, System eCAALYX, HOPE System, System ROSETTA, SoftCare System and Prediction System of falls. Some examples can be seen in figure 3.

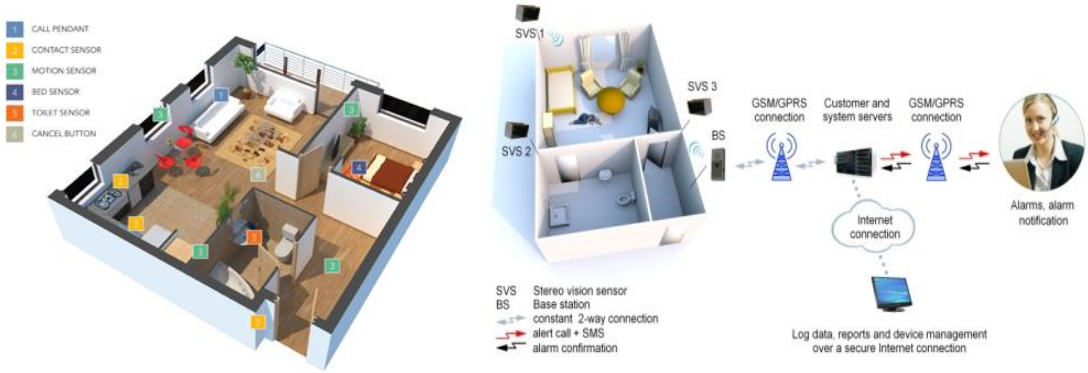


Figure 3. Interconnected sensors for detecting falls. In the left the eNeighbor System and in the right the CARESystem
Source: Health Sense (2013); Belbachir (2013)

The other devices are unique sensors that may be coupled to the subject's body or be present in the environment, as shown in Figure 4.

Figure 4. In the left the drawing of adhesive skin sensor and in the right is the motion sensor QuietCare
Source: Narasimhan (2012); GE Reports (2013)

Regarding sensor systems for localization during mobility, the program for Smartphone Teo My Geo (Figure 5) helps caregivers to locate the elderly when it leaves your home and also allows recording data of the health conditions of the elderly. Already the REMOTE system is a system that

includes sensors and actuators that monitor the movement and location of the elderly and also allows you to monitor vital signs, posture, body temperature and environment. Finally the tactile belt with sensors (right on Figura5) uses technology of GoogleMaps to set the path and through vibrations indicates to the subject how much more he must still walk and the direction, allowing caregivers to monitor the elderly and reprogram the paths. It's suitable for people with visual impairments and cognitive.

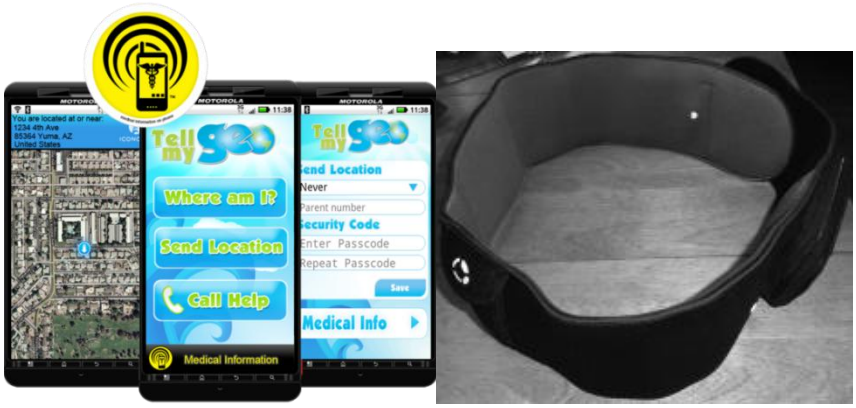


Figure 5. Program to Smartphone Teo My Geo in the left and Tactile belt in the right
Source: Moore (2013); Zelek (2012)

Among the devices with support for mobility with sensors found, has the cell phone BP used to detect falls, which detects sudden movements that may indicate a fall, and when this happens the phone automatically dials for different pre-programmed numbers to search for aid. This phone also allows you to organize schedules for drugs beyond communications activity. The other devices were found to intelligent Bengal "The aid", the intelligent wheelchair and walker robotic VA-PAMAID (Figure 6) that are geared for mobility in the community. The Bengal 'The aid " provides through a GPS system , and a wireless headset which way the elderly must take to reach its destination, and also monitor the vital signs . The intelligent wheelchair has an robotic system with detection module and information to aid in mobility, system to aid in transfers , adjustment of backrest and seat for different activities , automatic pressure relief , and a telehealth system integrated with Tablet serving as a channel communication to the distance between the subject and his family and caregivers . Already the walker with the robotic system , is a device designed to provide physical support and obstacle avoidance , as well as assistance in mobility for individuals with visual deficits. These last two devices were classified as assistive device, despite having robotic technology, because their primary objective is to assist in a specific task, the mobility.

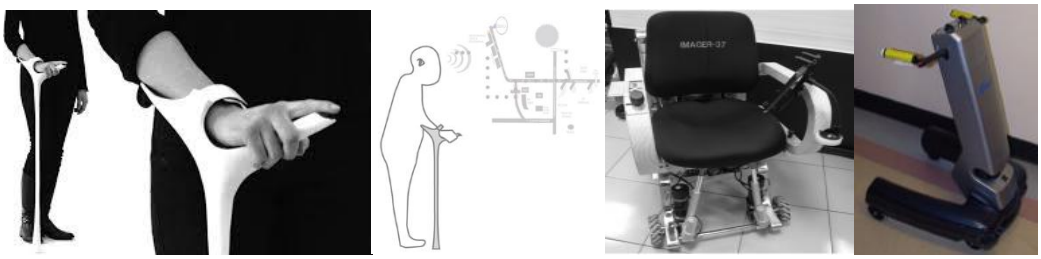


Figure 6. Bengal "The aid" in the two figures on the left, then the intelligent robotic chair and the robotic walker VA-PAMAID
Source: Designboom (2011); Hsu et al. (2012); Rentschler (2004)

Robotic systems appeared in smaller quantities, one of them, the robot NAO, is facing the detection of falls and the other, the robot ASTRO, for help in transfers (Figure 7).

The NAO robot has different sensors and devices, including cameras, microphones, distance sensors, voice synthesizer and speakers, and can capture sensor alarms at different locations in the house and getting to the location to verify one complication. The robot ASTRO has a lever technology that assists in transfers, plus a place to help to load objects during locomotion. It also allows communication with caregivers and family members remotely via a monitor that can also provide information on health care.

Figura 7. Robô NAO à esquerda e ASTRO à direita
Fonte: Bäck et al (2012); Cavallo (2013)

Thus, from this sample there is a variety of types of use of sensors and tasks related to mobility that they can help, such as detecting falls, the looking for help, assistance to locating paths during mobility in the community, assistance in transfers, and support to load objects during locomotion.

4. Discussion

Most devices were sensor systems used alone, which are used as a set of this devices. However, when used in conjunction with other technologies such as assistive devices and robotic systems appeared in smaller amounts (25% of the collected products).

The robotics itself already has into their devices the signal capture systems. On the other hand, assistive technologies (assistive devices) defined as equipment and services to optimize functional problems encountered by individuals with disabilities [34] and that aims at reducing the gap between the ability of the subject and the control their environment. [35], generally haven't sensors capturing signals in their development. The association between the sensors and the assistive technology has great potential to aid the elderly since they can promote the direct aid to tasks performance, facilitate monitoring, enable of risk perception and assistance in case of emergency.

Through the products collected, it was observed that most of the systems is directed to the detection of falls. This is in agreement with the high incidence of falls in this portion of the population. Aging is a dynamic and progressive process, which presents both morphological, biochemical and functional properties, which can generate functional losses, including postural instability, which occurs due to changes in sensory and motor systems, leading to a greater tendency to fall. [36]

Still, the task of transferring from sitting to standing and standing to sitting also creates risks for the elderly who may suffer a fall during movement due to decreased muscle strength or joint diseases. In the study of Ganança et al. [37] tasks that presented more risk for falls were: ambulation (53.1%), descending / climbing stairs (10.9%), postural transfer (9.4%) and bathing (6.3%). Thus, despite appearing less compared with ambulation, transfers are movements that deserve attention when considering the development of technologies for mobility of seniors.

In the same sense, is known about the prevalence of cognitive decline, especially memory deficits, arising from aging itself as well as chronic diseases such as Alzheimer's. Among the difficulties

presented by the elderly with memory loss has the difficulty in locating yourself at home as well as in the community [38]. In this perspective, it is important to think of technology can, through signals catchment systems, provide the location of the elderly and help you reach your destination, as well as provide information to families and caregivers of the place where the senior been to prevent that he get lost. These technologies that enable the location and direction of the elderly were seen in some of the products found in this study.

Finally, it is noteworthy that most of the products described has multiple functions, not just monitoring or assistance in mobility tasks. It is observed that many devices also monitor vital signs, health conditions, carrying out tasks in the home environment, and promote the possibility of distant communication with family members and caregivers. This shows an improvement of technologies which aim to encompass the entire subject, and can meet different demands.

This study allowed a view of the current landscape of signals catchment technologies developed to aid the monitoring of the mobility tasks of elderly, and also support for both motor and cognitive tasks of spatial orientation. From this, it is possible facilitate future studies on these equipments, enabling the identification of devices still produced in less quantities, as well as the improvement of those already deployed.

5. Finals Considerations

This study enabled the survey and description of the use of signals collection devices for monitoring and assistance for mobility tasks to the elderly. Despite the few products collected, considering the short time involved in the collection (from 2009 to 2013), the findings contributed to the reflection of aspects that can be covered by the sensor devices, for example, their use in combination with technologies assistive devices or support that may offer a wider care to family and the elderly. It was possible to verify the search for solutions for the risk of falls in the elderly, that was the task more monitored by the systems. This demonstrates the concern of researchers and development teams of technologies to meet the great demand of this population. This study suggests the need to conduct a survey with more devices to check other areas of monitoring and assistance to elderly mobility by this tecnologies.

References

[1] Sousa L, Galante H e Figueiredo D 2003 Quality of life and well-being of the elderly: an exploratory study in the Portuguese population. *Rev. Saúde Pública* **37** 363-371.
[2] Sass G G, Alvarenga M R M, Oliveira M A C e Facenda O 2012 Information system for monitoring the health of elderly. *J. Health Inform.* **4** 209-215.
[3] Popescu M and Mahnot A 2012 Early Illness Recognition Using Multiple Instance Learning. *Methods Inf Med* **4**.
[4] Fozard J L 2012 The relevance of Gerontechnology for medical, biological and behavioral studies on aging *Gerontechnology* **11** 116-117.
[5] Saliba D, Elliot M, Rubesntein L Z, Solomon D H, Young R T, Kamberg C J, Roth C, MacLean C H, Shekelle P G, Sloss E M e Wenger N S 2001 The vulnerable elders survey: a tool for identifying vulnerable older people in the commnuty. *J Am Geriatr Soc.* **49** 1691-1699.
[6] Skubic M, Alexander G, Popescu M, Rantz M and Keller J A 2009 Smart Home Application to Eldercare: Current Status and Lessons Learned. *Tech and Health Care* **17** 183 – 201.
[7] Mohammadi M, Van de Koppel J, Van Beek M and Godfroij H 2012 Future smart (care) homes: An explorative research into the future trends regarding strategies for the smart living environment for older citizens. *Gerontechnology* **11** 186.

[8] Költzsch Y, Gövercin M, Spehr J, Gietzelt M and Marschollek M 2012 Identification of sensor-based parameters that predict falls of older people. *Gerontechnology* **11** 230-231.
[9] World Health Organization (WHO). ICF - International Classification of Functioning, Disability and Health. São Paulo, Edusp, 2008, 325p.
[10] Moreira M.A. Sensors Systems. National Institute for Space Research – INPE. 2001
[11] RIA – Robotics Institute of America.Carnegie Mellon The Robotics Institute. S.d. Disponível em: http://www.ri.cmu.edu/index.html.
[12] NARASIMHAN R 2012 Skin-Contact Sensor for Automatic Fall Detection *34th Annual International Conference of the IEEE EMBS* San Diego, California USA.
[13] Belshaw M, Taati B, Snoek J, and Mihailidis A 2011 Towards a Single Sensor Passive Solution for Automated Fall Detection *Conf Proc IEEE Eng Med Biol Soc*. 1773–1776.
[14] Zhao G, Mei Z, Liang D, Ivanov K, Guo Y, Wang Y and Wang L 2012 Exploration and Implementation of a Pre-Impact Fall Recognition Method Based on an Inertial Body Sensor Network *Sensors* **12** 15338-15355.
[15] Zhang Q, Ren L and Shi W 2013 HONEY: A Multimodality Fall Detection and Telecare System. *Telemedicine and e-health* **19** 415-429.
[16] GE reports. Home health monitoring growth eyed in QuietCare buy. 2009. Disponível em http://www.gereports.com/home-health-monitoring-growth-eyed-in-quietcare-buy/. Acessado em 15 de maio de 2013.
[17] Health sense 2011 eNeighbor® Remote Monitoring System Disponível em:<http://healthsense.com/index.php/products/remote-monitoring/eneighbor> Acesso em: 15 mai. 2013.
[18] Belbachir A.N. Ambient assisted living joint Programme - CARE. 2009. Disponível em http://www.aal-europe.eu/projects/case/. Acessado em 24 de maio de 2013.
[19]Hospedales M. Ambient assisted living joint Programme - eCAALYX. 2009. Disponível em http://www.aal-europe.eu/projects/ecaalyx/. Acessado em 24 de maio de 2013.
[20] Simon J.R. Ambient assisted living joint Programme - HOPE. 2009. Disponível em http://www.aal-europe.eu/projects/hope/ Acessado em 24 de maio de 2013.
[21]Karkowski I.P. Ambient assisted living joint Programme - ROSETTA. 2009. Disponível em http://www.aal-europe.eu/projects/rosetta/. Acessado em 24 de maio de 2013.
[22]Rodriguez A. Ambient assisted living joint Programme – SOFT CARE 2009. Disponível em http://www.aal-europe.eu/projects/softcare/. Acessado em 24 de maio de 2013.
[23] Y. KÖLTZSCH, M. GÖVERCIN, J. SPEHR, M. GIETZELT, M. MARSCHOLLEK. Identification of sensor-based parameters that predict falls of older people. Gerontechnology 2012;11(2):230-231.
[24] E. STONE, M. SKUBIC. Capturing in-home gait parameters using vision-based sensing. Gerontechnology 2012;11(2):260; doi:10.4017/gt.2012.11.02.648.00.
[25] Moore E A 2010 Android app Tell My Geo helps track loved ones Disponível em:<http://news.cnet.com/8301-27083_3-20025912-247.html> Acesso em: 15 mai. 2013.
[26] Maglaveras N. Ambient assisted living joint Programme – REMOTE. 2009. Disponível em http://www.aal-europe.eu/projects/remote/. Acessado em 24 de maio de 2013.
[27] J.S. ZELEK. Tactile personal navigation belt. Gerontechnology 2012;11(2):351; doi:10.4017/gt. 2012.11.02.195.00
[28]Campi M 2011 Company launches in the country cellphone for medical purposes Available in:<http://info.abril.com.br/noticias/tecnologia-pessoal/empresa-lanca-no-pais-celular-para-fins-medicos-22032011-32.shl> Access in: 15 may. 2013.
[29] Desingboom 2011 Available in:<http://www.designboom.com/technology/the-aid-by-egle-ugintaite-fujitsu-design-award-2011-grand-prize/> Access in: 15 may. 2013.
[30] P-E. HSU, C. GEISER, K-W. CHANG, J-M. LU, Y-L. HSU. Development of an intelligent robotic wheelchair. Gerontechnology 2012;11(2):340; doi:10.4017/gt.2012.11.02.250.00

[31] Rentschler, Andrew J (2004) Engineering and Clinical Evaluation of the VA-PAMAID Robotic Walker. Doctoral Dissertation, University of Pittsburgh. Disponível em http://d-scholarship.pitt.edu/6574/
[32] Bäck I, Kallio J, Perälä S and Mäkelä K 2012 An assistive humanoid robot for elderly care *Gerontechnology* **11** 357.
[33]Cavallo F, Aquilano M, Bonaccorsi M, Mannari I, Carrozza M C and Dario P 2011 *33rd Annual International Conference of the IEEE EMBS* Boston Massachusetts USA.
[34] Cook, A.M. & Hussey, S. M. (1995) Assistive Technologies: Principles and Practices. St. Louis, Missouri. Mosby - Year Book, Inc.
[35] McCreadie C, Tinker A. The acceptibility of assistive technology to older people. Ageing and Society. 2005;25:91–110.
[36] Guimarães LHCT, Galdino DCA, Martins, FLM, Vitorino DFM, Pereira KL, Carvalho EM. Comparison of the propensity for falls among elderly people who practice physical activity and sedentary elderly. Rev Neurociências. 2004
[37]Ganança F.F. et al. Circumstances and consequences of falls in elderly with chronic vestibular disorder. Revista Brasileira de Otorrinolaringologia. 2006;72(3):388-93.
[38]Okamoto I.H.; Bertolucci P.H.F. Memory loss in the elderly. Available in http://www.unifesp.br/dpsiq/polbr/ppm/atu5_01.htm. Access in 25 may. 2013.