University of Coimbra

Faculty of Sciences and Technology

AAL Safe

Daily Activity Monitoring and Fall Detection

Software Module

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Master Degree of Biomedical Engineering

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"The art and science of asking questions is the source of all knowledge"

Thomas Berger

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Firstly, I would like to thank all the support and patience that my family and André have given me during this important period of my life.

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And last, but definitely not the least, I want to thank my teammate Ricardo Amaro for all the good work, dedication and support until the very end.

Resumo

As quedas são uma das maiores dificuldades vividas pelos idosos. Estas são a maior causa de lesões e traumas dentro da faixa etária da terceira idade, e isto acoplado ao tempo que os idosos esperam por socorro aumenta o risco de morbilidade e incapacidade nos mesmos. Para tentar solucionar o problema das quedas vamos tirar partido de uma tecnologia recente e de alto nível que é o Wiimote. Este dispõe entre outras coisas de um acelerómetro e através do processamento da aceleração é possível detectar quedas e identificar as diferentes Actividades de Rotina Diária (DRA).

Assim o AAL Safe consiste numa prova de conceito que tem como objectivo ser uma solução dinâmica e útil, virada para o utilizador e que monitoriza a sua rotina diária em tempo real e acima de tudo detecta situações de risco como é o caso das quedas, melhorando deste modo o estilo de vida de um idoso.

Este documento tem como objectivo descrever o sistema e explicar as diferentes fases do seu desenvolvimento.

ABSTRACT

Falls are one of the major difficulties lived by the elderly. They are the main cause of injuries and traumas among the eldest age group, which combined with the waiting time for the health care providers increases morbidity risk and their inability. In order to solve the fall related problem, it's been used a recent and high level technology which is the Wii remote control. The wiimote contains among other things an accelerometer and through the processing of accelerations obtained it is possible to detect a fall and identify different Daily Routine Activities (DRA).

Thus, the *AAL* Safe consists of a proof concept that has the objective of being a dynamic and useful solution, user oriented that monitors his daily routine activities in real-time and above all detect risky situations as it is the case of a fall, improving as a result the elderly lifestyle.

The purpose of the present document is to describe the system and clarify the different stages of its development.

ACRONYMS

CEI	Centro de Electrónica e Instrumentação
ISA	Intelligent Sensing Anywhere
Wiimote	Nintendo Wii Remote Control
ICT	Information and Communication Technologies
INE	Instituto Nacional de Estatística
EC	European Commission
FP6	Sixth Framework Programme
VoIP	Voice over IP
GSM	Global System Position
DRA	Daily Routine Activities
PIR	Passive Infra Red
C#	CSharp
VS2008	Visual Studio 2008
API	Application Programming Interface
HID	Human Interface Device
PC	Personal Computer
PDF	Portable Document Format
DB	Database
BT	Bluetooth

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1. INTRODUCTION

1.1 MOTIVATION

The Ambient Assisted Living (AAL) Programme was founded in 19 September 2007 and consists of a fund that finances companies and entities which main objectives are to provide eldercare to the senior society.

Eldercare is a recent preoccupation from the general population towards the elderly. It requires a fulfillment of special needs and requisites that are unique to that part of the population and include services such as assisted living, nursing homes and adult day care (1). The form of provided elderly care differs significantly among countries and it is changing rapidly. The eldercare emphasizes the personal requirements of senior population which requires assistance through their daily routines. Assisted living represents a middle ground for the elderly (2) since the senior population is allowed to receive assistance and remain independent as long as possible.

Nintendo has launched the Wii remote control, commonly known as Wiimote and since then a grand curiosity has begun to know how its mechanism work. This device main feature is its motion sensing capacity due to the existence of an accelerometer and an optical sensor.

So, using and thinking in these subjects the students aimed the development of a fall detector, using as a sensing device the Wiimote and as a concept the AAL Programme.

1.2 OBJECTIVE

In the beginning of the present project it was given to the students a Wiimote and was solicited for them to exploit its appliance to the biomedical field and if could be inserted in the concept of Ambient Assisted Living. Throughout the first semester the students explored the AAL concept and possible ideas that could implement the Wiimote's accelerometer. Finally, they decided to use the device's accelerometer on an elderly concern, the falls.

The *AAL* Safe System has an experimental purpose; however during its development new ideas have surfaced. The ultimate objective of the project is to create an accurate system which can both monitor daily activities as well as fall occurrences. The system's scope is the elderly, particularly a Nursery House where the senior populations will be under constant monitoring in order to prevent a hazardous situation.

In order to achieve this objective, the Nintendo Wii remote is used to acquire acceleration data from the patient and send it via Bluetooth communication to an Interface placed on the host's PC. Particularly, the student has the objective to create the Interface between the processed data and the user. It will be a user friendly system which will allow the user to interact with the Wiimote, manage the patients from a database, show the processed signal in real-time with a visual and sound alarm as well as daily routine activities, provide multi-monitorization option and reporting service which is responsible for displaying statistics.

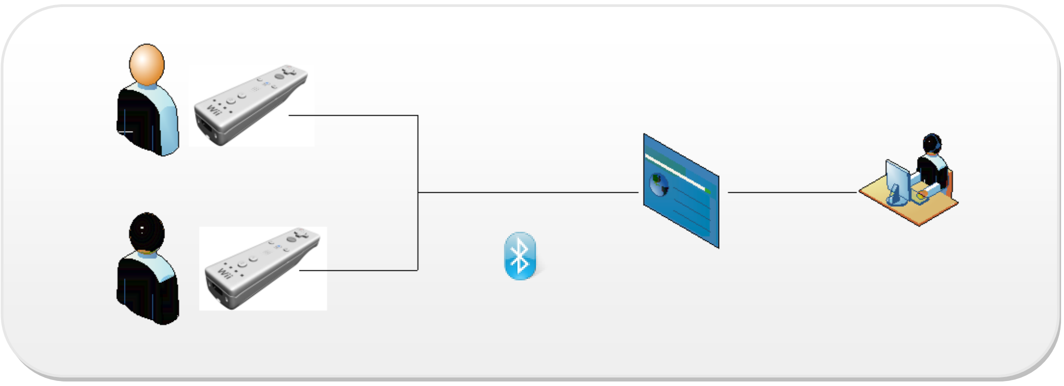

Figure 1- Global Aspects of AAL Safe

1.3 Scope

This project was developed in a master's degree of Biomedical Engineering lectured in University of Coimbra in the academic year 2008/2009 resulting of a partnership between this University, ISA (Intelligent Sensing Anywhere) and CEI (Electronic Instrumentation Center).

1.4 Audience

This document mainly recipients are the supervisors and juries addressed to this project as well as the academic circle of biomedical engineering and informatics.

1.5 The Document Structure

The present document was divided into eight main chapters, following a logical sequence:

Chapter 1 – Introduction consists of a brief thematic introduction of the project, its main objectives and scope.

Chapter 2 - Project Management presents the entities responsible for the development of the project, the team's work division and final scheduling planning.

Chapter 3 - Related Works displays the background problem description, state of art analysis of fall detectors and daily routine monitor and their comparison to the AAL System.

Chapter 4 - Software Requirements describes the main features of the system.

Chapter 5 - System Architecture exhibit the Physical and Logical architecture analysis.

Chapter 6 - Software Development consists of a description of the steps regarding the development of the *AAL* Safe Solution and its modules.

Chapter 8 – Tests regarding the project's specification and results;

Chapter 9 – Conclusion is a final consideration of the work done during the development of the project and a future work deliberation.

2. PROJECT PLANNING AND MANAGEMENT

2.1 ENTITIES INVOLVED IN THE PROJECT

2.1.1 ISA

ISA, Intelligent Sensing Anywhere, is a global technology leader company with expertise in the fields of telemetry, energy efficiency monitoring and solutions spread all over the world. It was the main partner for the development of this project since it was the one who released the human resources that made this project possible. Furthermore, it was very important in the integration of the students in the enterprise environment that will be very useful in future projects. The permanency in the company was made intercalary between all the students.

Entity Name	Main Responsible	Website
Intelligent Sensing Anywhere	Engineer José Basílio	http://www.isa.pt/

2.1.2 CEI

CEI, Centro de Electrónica e Instrumentação is a research group located on the Physics Department in University of Coimbra. The main research areas of investigation are Biomedical Engineering, Atomic and Nuclear Instrumentation and Telemetry and Industrial Control. The CEI keeps a close cooperation with several national and international organizations, including ISA, which develop work in common research areas with incontestable scientific results. CEI has been the intermediary between ISA and University of Coimbra. It was there that the students spent most of their time, studying and developing the project with the always available help from Professor Carlos Correia.

Entity Name	Main Responsible	Website
Electronic Instrumentation Center	Professor Carlos Correia	http://lei.fis.uc.pt/

2.2 Team

AAL Safe project was developed by two students assisted by their supervisors. The project was divided in the beginning of the second semester in which Cátia Costa was made responsible for the Software module and has the objective to provide a supporting platform which allows the storage, and visualization of the acceleration data as well as enabling the user to configure the wiimote. As for Ricardo Amaro, he was made responsible for the processing algorithm that would distinguish the falls and the different daily routine activities. Engineer Soraia Rocha had an important role in the development of the present project as the project manager.

Table I – Assigned Tasks

Student	Assigned task	E-mail
Cátia Costa	User interface and database development	catiapfc@hotmail.com
Ricardo Amaro	Development for the algorithms to process acquired data	amaro-ricardo@hotmail.com

Table II - Student's Supervisors

Supervisor	E-mail
Engineer Soraia Rocha	srocha@isa.pt
Professor Carlos Correia	correia@lei.fis.uc.pt
Professor José Basílio Simões	jbasilio@isa.pt
Engineer José Malaquias	jmalaquias@isa.pt
Engineer Paulo Santos	psantos@isa.pt
Engineer Rafael Simões	rsimoes@isa.pt

2.3 SCHEDULING

Table III - Scheduling for the First Semester

ID	Task Name	Start	Finish	Duration
1	Gather bibliography of Wii Remote and acelerometers	01-10-2008	09-10-2008	1w 2d
2	Market Search about weight sensors	01-10-2008	03-10-2008	3d
3	Meeting with Professor Norberto Pires	02-10-2008	02-10-2008	1d
4	Robotics-related bibliography study	06-10-2008	10-10-2008	1w
5	Introduction to Microsoft Visual Studio 1008	13-10-2008	16-10-2008	4d
6	Microsoft Visual Basic 2005 – Step by Step . Introduction	13-10-2008	24-10-2008	2w
7	Study of Robotics projects	13-10-2008	16-10-2008	4d
8	Market Search on how to aply a Wiimote in Biomedical Engineering	15-10-2008	21-10-2008	1w
9	Meeting with Engineer José Malaquias	21-10-2008	21-10-2008	1d
10	Web search for wireless technologies	22-10-2008	24-10-2008	3d
11	Microsoft Visual C# 2005 – Step by Step	22-10-2008	14-11-2008	3w 3d
12	Meeting with Professor Norberto Pires	28-10-2008	28-10-2008	1d
13	PLCs, Sockets and Ethernet Study	29-10-2008	29-10-2008	1d
14	GlovePie Study	31-10-2008	05-11-2008	4d
15	Tutorial with Pedro Neto on how to command a robot and itsC# guide lines	05-11-2008	05-11-2008	1d
16	Market Search on how to aply a Wiimote in Biomedical Engineering	05-11-2008	14-11-2008	1w 3d
17	Meeting with Engineer José Malaquias	07-11-2008	07-11-2008	1d
18	"WiimoteLib" Study	10-11-2008	21-11-2008	2w
19	C# Tutorial	13-11-2008	05-12-2008	3w 2d
20	Market Search on how to aply a Wiimote in Biomedical Engineering – Expose Ideas	01-12-2008	05-12-2008	1w
21	Study of Wiimote Properties	08-12-2008	11-12-2008	4d
22	Definition of the Project	10-12-2008	10-12-2008	1d
23	Fall-related state of art devices	15-12-2008	19-12-2008	1w
24	Development of a C# Program to solidify the students knoledge and aply the "WiimoteLib" library	17-12-2008	19-12-2008	3d

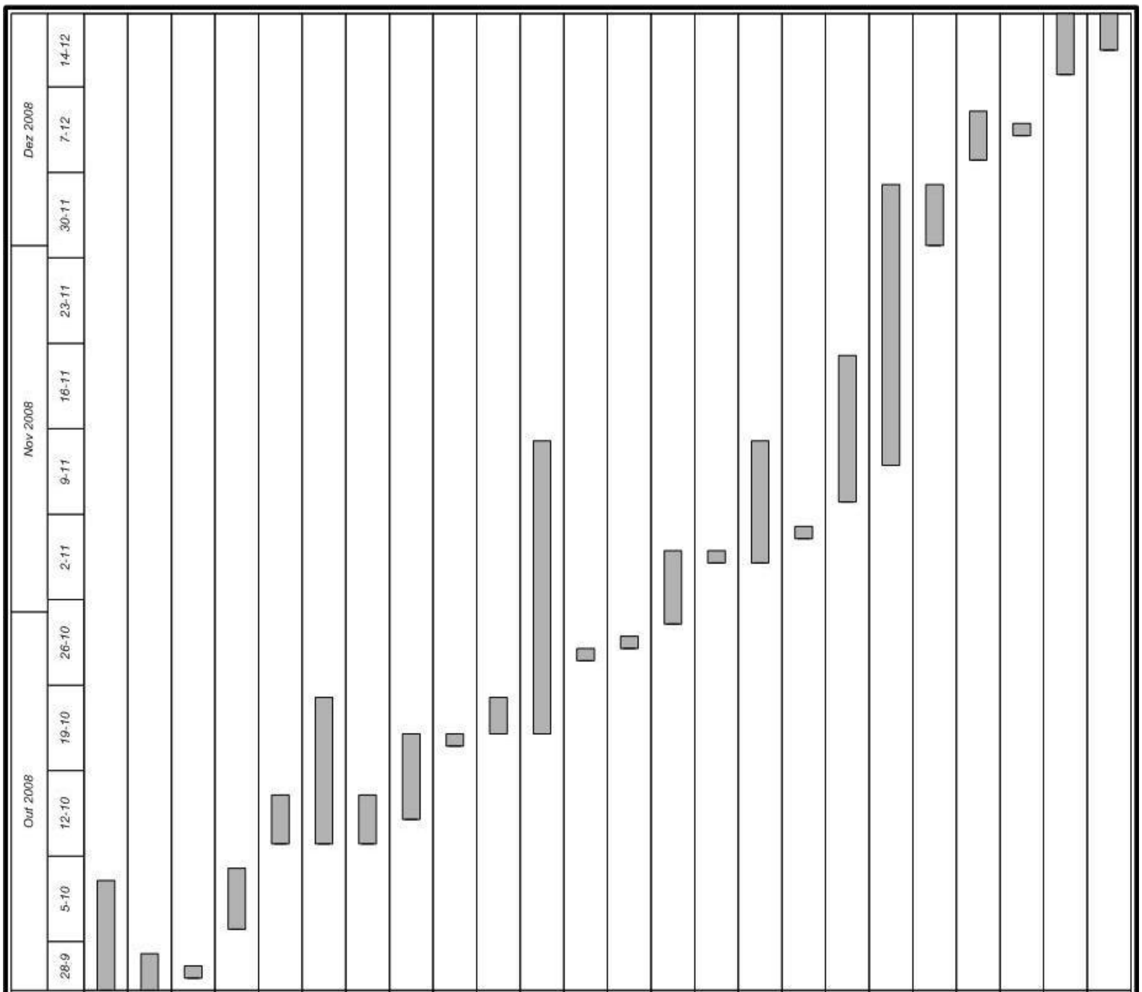

Table IV - Scheduling for the Second Semester (Part 1)

ID	Task Name	Start	Finish	Duration
1	Continuation of the Development of a C# Program to program the Wiimote's features	07-01-2009	16-01-2009	3d
2	Bluetooth Protocol Study	13-01-2009	16-01-2009	4d
3	HID protocol Study	13-01-2009	16-01-2009	4d
4	Study of Articles on position detection with accelermeter	19-01-2009	23-01-2009	1w
5	1st Intercalarly Presentation Poster development and revision	27-01-2009	04-02-2009	1w 2d
6	Study of fall detectors algorithms	02-02-2009	06-02-2009	1w
7	Study of algorithms to detect DRA activities	05-02-2009	11-02-2009	1w
8	Matlab Tutorial	05-02-2009	19-02-2009	2w 1d
9	1st Intercalarly Presentation	18-02-2009	18-02-2009	1d
10	Project Division	03-03-2009	03-03-2009	1d
11	Real-Time Graph Study	02-03-2009	04-03-2009	3d
12	Real-Time Graph Development	09-03-2009	12-03-2009	4d
13	Meeting with Engineer Lara Osório	12-03-2009	12-03-2009	1d
14	Interruption	13-03-2009	17-03-2009	3d
15	Specification's Document	17-03-2009	27-03-2009	1w 4d
16	XML Study - Introduction	18-03-2009	24-03-2009	1w
17	Primitive definition of information to appear on the Windows Application	27-03-2009	01-04-2009	4d
18	Meeting with Eng. Soraia Rocha and Eng. Rafael Simões	02-04-2009	02-04-2009	1d
19	Flowchart development	03-04-2009	03-04-2009	1d
20	Windows Application development – First development	06-04-2009	15-04-2009	1w 3d
21	Presentation	15-04-2009	15-04-2009	1d
22	Meeting with Eng. Soraia Rocha and Eng. Rafael Simões	16-04-2009	16-04-2009	1d
23	Encontro Nacional de Estudantes de Engenharia Biomédica	16-04-2009	17-04-2009	2d
24	Windows Application development – improvements and multi-session	20-04-2009	28-04-2009	1w 2d

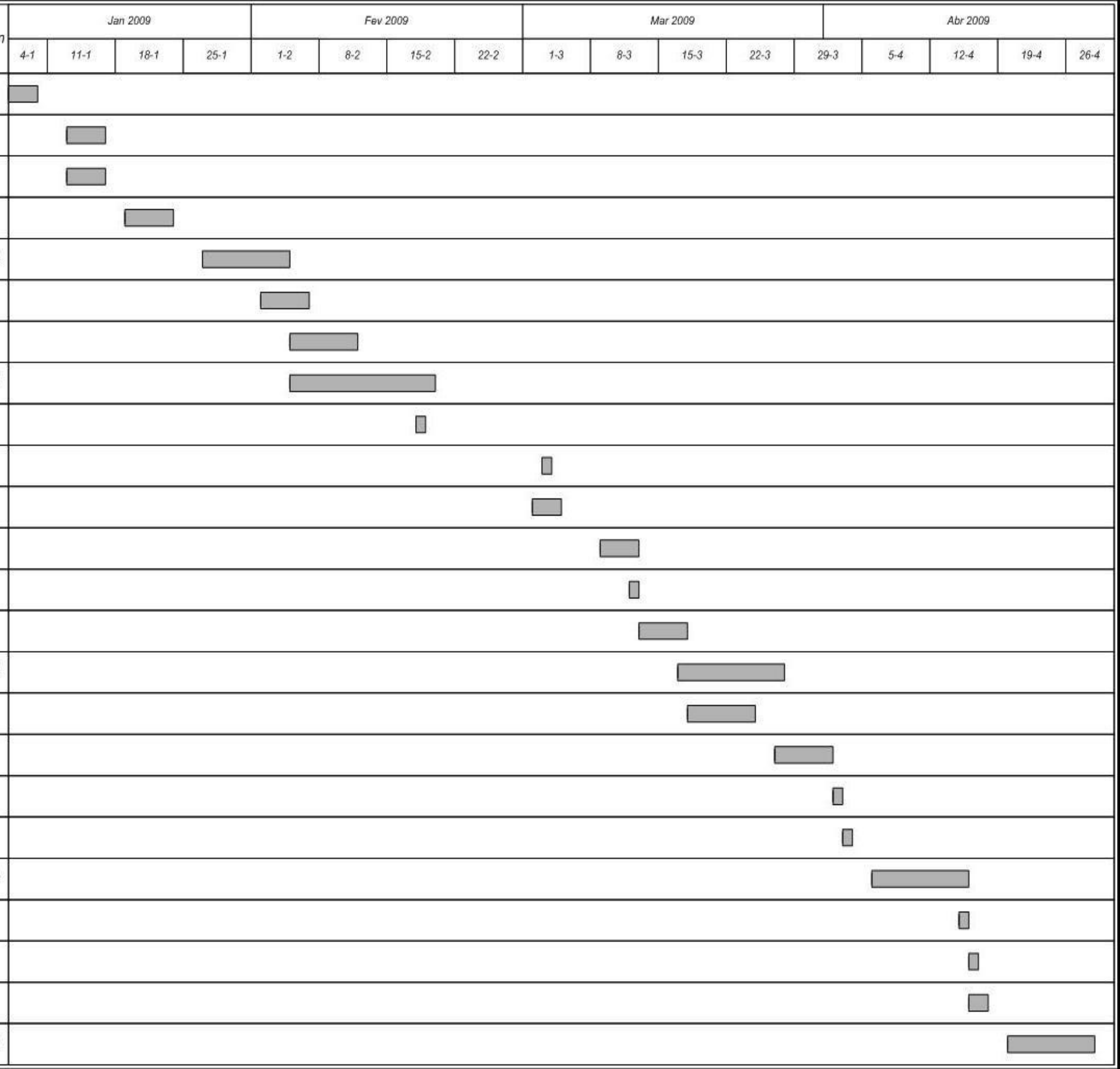

Table V - Scheduling For the Second Semester (Part 2)

ID	Task Name	Start	Finish	Duration	Mai 2009				Jun 2009				Jul 2009					Ago 2009			
					3-5	10-5	17-5	24-5	31-5	7-6	14-6	21-6	28-6	5-7	12-7	19-7	26-7	2-8	9-8	16-8	23-8
1	Windows Application development – Validations and Report	04-05-2009	15-05-2009	2w																	
2	Windows Application development – Multi-Session Validation and database development	18-05-2009	29-05-2009	2w																	
3	Windows Application development – Multi-language and bugs fix	01-06-2009	04-06-2009	4d																	
4	Windows Application development – Validations and Patient's history development	05-06-2009	10-06-2009	4d																	
5	Organization of thesis Bibliography	18-06-2009	19-06-2009	2d																	
6	Complementation of the division parts of the project	22-06-2009	03-07-2009	2w																	
7	Windows Application development – Fix Bugs	22-06-2009	09-07-2009	2w 4d																	
8	User Guide documentation	29-06-2009	30-06-2009	2d																	
9	Write thesis	24-06-2009	07-08-2009	6w 3d																	
10	AAL Safe executable Solution	17-07-2009	17-07-2009	1d																	

3. Related Works

In this chapter, the objective is to understand the current state-of-the-art in the area of Elderly care and what are the strongest and weakest points of each system found to be related with the project. So, it will be analyzed the fall-related projects developed until the moment and what motivated the students to build this solution. A brief description and specific features of some products available in the market will be made since understanding their key functionalities and characteristics can help understand some of the choices made in the project.

3.1 Ambient Assisted Living

Ambient Assisted Living is a joint research and development program existing due to the collaboration of 23 Countries including Portugal, which main objective is to collect funds to enhance the quality of life of the elderly individuals and strengthen the industrial base in Europe using Information and Communication Technologies (ICT) (3).

Figure 2 – 23 AAL partners (3).

The motivation of this funding activity is the increasingly number of older people in Europe, causing a demographic change and a prompted active research in technology solutions for automated functional and health status monitoring and assistance to measure individuals' health status. This new developments have in mind the improvement and extension of the quality time that ageing persons have in their homes. They must support monitoring health status and be aware of functional capability of older people, enhancing the security and stimulating social contact as well as serving as a way to communicate with health care providers in case of risk (3).

In fact, a study made in 2006 estimates that in 2050 the ratio's old-age dependency, i.e., the population below working age divided by the population of working age will double leading to a substantial upward pressure on economic growth, since the number of working people will drop to half (4). Although in Portugal this situation is not as pronounced since presently and according to the Portuguese Institute of Statistics (INE) for each old individual there exists about 4 working people. This number will more than likely tend to decrease over the years increasing the number of elderly and decreasing the number of young people.

The impact of the demographic changing scheduled for the upcoming years has already brought some changes in the present political legislation. An increase in the age at which workers retire was set in many European countries as a way to diminish the pressure on the economy, increasing the tax income and delaying the payments of retirement pensions (5).

3.1.1 CURRENT ALL PROJECTS

AAL Joint Programme has funded different researching and testing projects in the different participant states. In this section will be introduced a brief overview if what is being done in a few AAL partner states.

3.1.1.1 CAALYX

CAALYX, Complete Ambient Assisted Living Experiment, is a two-year project developed with partnership of Spain, Portugal, Germany, Italy, UK and Ireland and funded by the European Commission (EC) under the Sixth Framework Programme (FP6) (6). The project aims at the improvement and extension of the autonomy and self-confidence in the senior's age group by developing a wearable device not only capable of measuring vital signs, but also detecting falls, location and reporting an occurrence.

This funding project considers three main areas of development (6), as can be seen in Figure 3:

- **Roaming Monitoring System**: its purpose is to monitor vital signs, falls during the user's daily life and communicate his/hers location to the Central Care Service in case of emergency.

- **Home Monitoring System**: has the purpose to broaden the number of monitoring devices and sensor in the home environment and integrate home automation equipment in the system. Its main intention is to integrate video communication and VoIP (Voice over IP) allowing communication between the user and his/hers relatives, as well as remote monitoring and service-provision (teleshopping or periodic consultation with doctor or personal caretaker).

- **Central Care Service and Monitoring System**: Is the Center where the alerts are received. The caretaker evaluates the urgency of the alerts and whether or not to call the emergency service (112) (seen in Figure 3). Case it is communicated, the geographic position and data will be provided to the emergency service. In addition to this service, the center provides also video communication with the home environment to attend the elderly demands and reminder alarms.

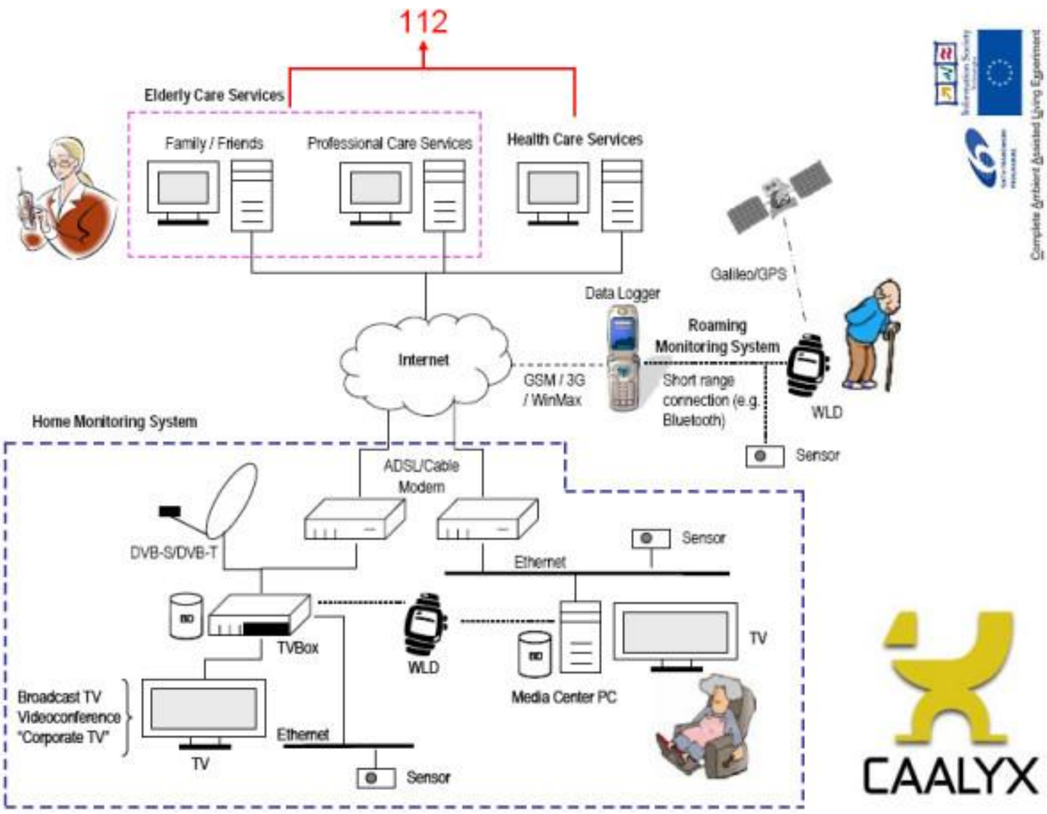

Figure 3 - Diagram showing the main components of CAALYX (6)

At the time that this document is being written, this project is still under development.

3.1.1.2 NetCarity

The Netcarity project is currently being developed with a partnership between the European Commission and the University of Tuebingen and Pavia, the Czech Technical University and technology firms such as IBM, MR&D and Siemens. The project is developing an ambient technology system that aims at seniors to maintain their own well-being, independence, safety and health at home community.

The Netcarity infrastructure is built around a smart gateway which has the purpose of collecting data measured from multiply distributed devices placed in the elderly home and external data source. By using existing protocols like wi-fi or

GSM, the system is not limited and can interface with other available systems. The Gateway processes the data and selects the most appropriate information according to the user currently using the Netcarity System and the entity that wants the report (family friends, shopping services or hospital family doctor) (7).

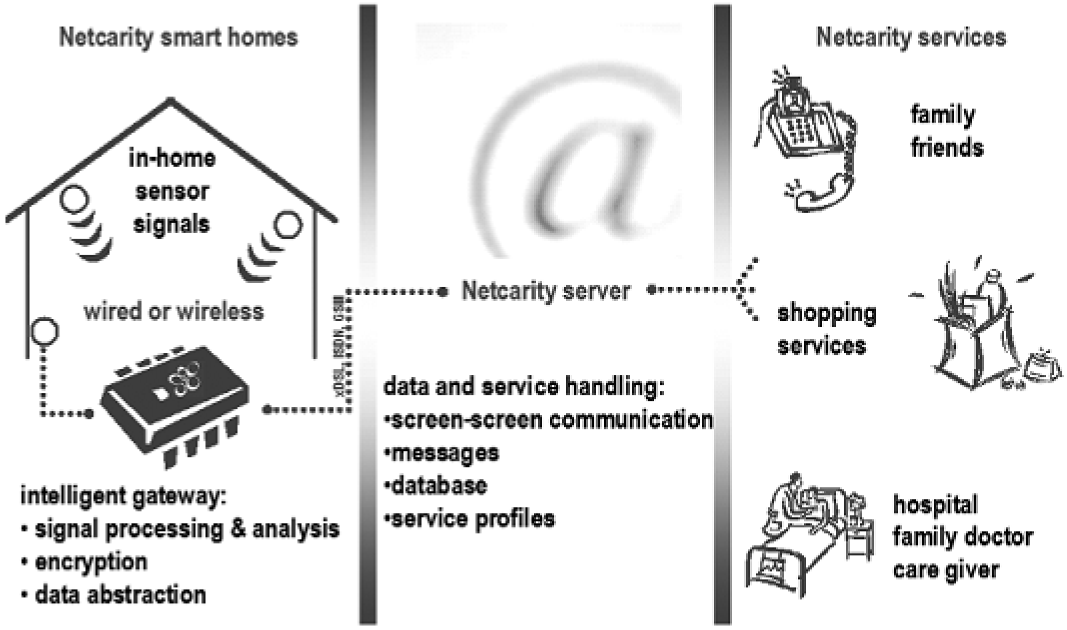

Figure 4 – Netcary Infrastructure (7)

The system that Netcarity is developing is being tested in different locations so that the project benefits from flexibility and customization features from different demographic groups.

3.2 Background problem

Falls and its related injuries have a variety of definitions and may be precipitated by intrinsic or extrinsic factors. Intrinsic factors have a physiologic cause; on the other hand the extrinsic ones occur due to the environment or other exposures (8). According to Tinetti, Speechley, and Ginter (8), a fall is defined as "an event which results in a person coming to rest unintentionally on the ground or lower level, not as a result of a major intrinsic event (such as a stroke) or overwhelming hazard." Generally, a fall is described as "the failure of a planned action to be completed as intended" (i.e., error of execution) or "the use of a wrong plan to achieve an aim" (i.e., error of planning) (8).

Falls are the leading cause of injuries in the increasingly older adult population. In Portugal, 40 to 60% of individuals over 65 years have experienced at least one fall, and this is the most important cause of mortality accidents after 75 years as seen in Figure 5. Moreover, 20% of these persons are found an hour or more after the fall (9). Fear of falling may induce some lifestyle changes like isolation, reduced mobility or increasingly dependency.

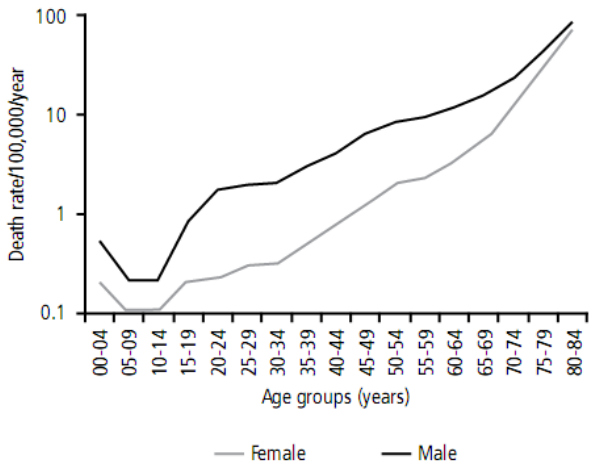

Figure 5 –Mortality rate due to accidental fall by gender and age group in the European Union (26)

Fall related sequels are expensive. Non-fatal falls represent between $16 billion to $19 billion of the annual costs, as for fall related deaths the number ascends to $170 billion (8). Therefore, fall detector devices have been an important research area since the 90's decade.

Associated with a DRA detector the concept of a safety device, as it is the fall detector, would be improved since an activity monitoring device assists in determine if a fall was injurious or not, from seeing the position that the user stayed after the fall.

Apart from that, regular activity can prevent the requirement for health care treatments or assist as an important adjuvant to medical treatment. Older individuals who have remained active throughout their existence preserve much of their physical strength as well as their endurance (10). Elderly with health issues and physical limitations require the practice of exercise programs or at least live a life with few sedentary activities such as lying and sitting too much. Furthermore, there is scientific evidence (10) that regular physical activity has powerful positive effects on both psychological and physical well-being. So, a device capable of monitoring the daily life of an old individual would assist the physician responsible in determine if the patient's lifestyle is helping or hindering his treatment, assist on prescribing adjustable exercises if needed and may aid in the prevention of lifestyle-related diseases such as obesity, diabetes and cardiovascular condition.

3.3 State of art

Fall detection and prevention equipment require a great amount of reliability. Given that the devices are subject to false positives, reliability is not as abundant as desired and its effectiveness depends of the rapid response of caregivers and their availability (11).

3.3.1 iLife

iLife is an easy-to-use, battery operated medical alert service designed to provide the elderly conditions to live alone in their homes. It's composed by a wireless sensor that is worn in the user's body and its main purpose is to detect falls using not only accelerometer data but also activity monitoring, like abnormal body movements or extended periods of inactivity. This device will automatically alert a responsible party when either a fall or an abnormal period of no motion/inactivity occurs (12). Also, help can be summoned manually, pressing the blue button seen in Figure 6.

Figure 6- iLife™ Fall Detector Sensor (12)

The iLife™ Fall Detection Sensor is a multi-vector motion analysis platform deriving two-axis inertial acceleration data as well as the static acceleration (gravity) vector. This sensor's technical details can be seen in Table VI.

Table VI - Technical Details of iLife™ Fall Detection sensor

Physical Properties	2.25" wide, 2.75" high, and 0.57" thick
	2 ounces total weight
Sample rate	16 or 256 per second
Power Source	Lithium "button cell" CR2477 battery
Battery Life	3 to 6 months based on end-user level of activity
Inactivity Selection(s)	OFF, 30, 60, 90 and 120 minutes
Other features	Water resistant, supervised automatic low battery reporting
	LED for visual confirmation of activation
	433.92 MHz, 900 MHz and other operating frequencies available

3.3.2 *Falls Management Solution*

A Falls Management Solution is an accelerometer and sensing based product created to ease the independent life of vulnerable people and to reduce the level of injury sustained. It is available as a pendant or a home unit and the main purpose is to easily summon help whenever it's required. The product is constituted by an array of non intrusive telecare sensors like a fall detector, a bed/chair Occupancy Sensor, a PIR (movement detector) and a pull cord (13).

The fall detector is the ultimate sensor of reliability. Operates on an 869 MHz European Social Alarm radio frequency and uses a two-stage detection process to identify a fall. Firstly, the sensor detects both impact and angle and emits a buzzing noise to alert the user that it is about to raise an alarm if he/she is not in the vertical position so the user can cancel it if necessary.

The bed occupancy sensor is used at night time. It is an unobtrusive pad that is placed under the mattress and has the purpose of detecting if the user leaves the bed and automatically turns on the bedside light in order to minimize the risk of falling. Can be programmed to send an alarm if the user exceeds the time to return to bed. Can also be used on chairs and wheelchairs (13).

A PIR detector, i.e. a Passive Infra Red detector, detects movement or monitors activity in a pre-defined area. Being part of a fall detector, it is programmed to raise an alarm if it senses no movement in a room for a prolonged period of time.

A Pull Cord as the name tells is a cord that the user can pull whenever the he falls and is not using neither the personal radio trigger nor a fall detector. Is normally suited for the bedrooms.

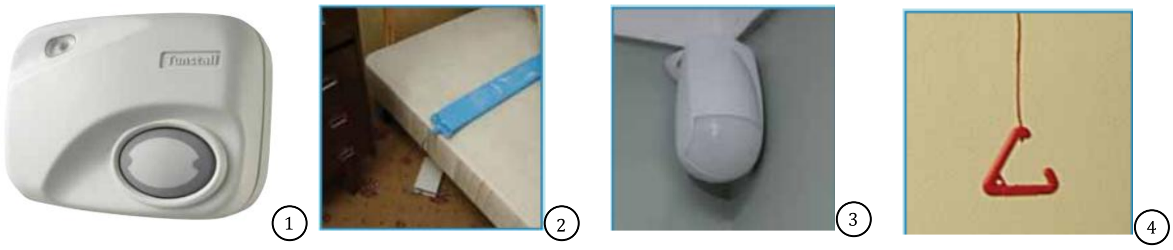

Figure 7- Telecare Sensors (13)

Legend: 1- Fall detector; 2 – Bed Occupancy sensor; 3- PIR; 4 – Pull Cord

Once the sensors detect a potential problem an alarm is fired and a call is automatically made to a 24 hour monitoring centre, and the user can communicate and both parts decide the appropriate measure to be taken.

The system assures reliability using a Class 1 radio receiver that enables service providers to respond rapidly to client's changing needs. It is flexible, since it could be manually programmed by each user and has an automatic low battery warning ensuring an optimum operation. The fall detector's technical details can be seen in Table VII.

Table VII - Fall Management Solution Technical Details

Physical Properties	75 mm wide, 53 high, and 28mm thick 75 g total weight
Power Source	2 Lithium 6V cells
Battery Life	6 months
Radio Transmitter	869,2 MHz
Radio Range	Up to 50 meters

3.3.3 *HALO MONITORING*

myHalo is a Personal Monitoring and Alarm System developed to deliver an innovative solution that help seniors maximize their independence, lower healthcare costs, and allow them to remain at home longer. The solution uses wireless sensor technology connected through a secure web page that has the purpose of informing the user's family of the aged person's health status. This system besides a fall detector also features an algorithm to distinguish between DRA. myHalo is a proactive system that automatically informs the suitable responsible if a problem arises. The solution employs wearable sensors to automatically detect falls as well as vital signs (14).

Figure 8 – Chest Strap Transmitter (14)

In Figure 9, a detailed description of myHalo system is displayed. The user is given a myHalo chest strap (seen in Figure 8) which is a waterproof system designed to provide comfort to the user. This device has tiny sensors that detect the user's orientation and motion with three degrees of freedom. It is constantly monitoring the measurement data searching for patterns indicative of fall occurrence. If a fall is detected, the solution sends a wireless message to a Health Server (F9.3) via the user's Home Gateway (F9.2). The message is then transmitted to a professional call center and designated caregivers (F9.4).

Figure 9 - myHalo's working stages (14)

myHalo System monitors beside falls, also heart rate and heart rate variability, skin temperature, spent calories, sleep and awake patterns. This sensor's technical details can be seen in Table VIII.

Table VIII - myHalo Technical Details

Frequencies	2400 - 2483.5 MHz
Power Output	1mW max
Heart accuracy	± 4 bpm, under steady heart conditions
Users	Multi-user accommodation
Data rate	250 kbs max burst
Battery	Lithium Polymer
Battery life rating	1 year

3.4 *AAL* Safe System Overview

The systems mentioned above have several similarities to the system developed by the project's students as can be seen in Table IX. The students purpose was to accomplish several of the existing features in these systems and overtop their limitations, bearing in mind the specifications for the system (using a Wiimote device) and the nature of the project.

Table IX - Features of the studied Systems

Functionalities	iLife	Falls Management Solution	myHalo	*AAL* Safe
Wireless nature	✓	✓	✓	✓
Portability	✓	✓	✓	✓
Wearable design	✓	✓	✓	X
Battery powered	✓	✓	✓	✓
Continuous Monitoring	✓	✓	✓	✓
Activities Monitoring	✓	✓	✓	✓
Process acquired data	✓	X	✓	✓
Change Settings	X	✓	✓	✓
Cancel alarm	X	✓	X	✓
Manual activation for help	✓	X	✓	X
Caregivers summoning	✓	✓	✓	X
Information Accessing	X	X	✓	✓
PC required	X	X	X	✓
Patient Management Database	X	✓	✓	✓

Due to the wireless nature of the systems described above, portability is an advantage acquired. *AAL* Safe is no exception, however while the other systems have a wireless range of about a 100 meters, due to the use of a Wiimote the developed system has a range of 10 meters. This subject is further developed in the next chapter. Portability improves the mobility and the comfort of the patient providing them a life with no limitations around the house. A disadvantage of a wireless system is its low security, since everyone on the device's range can access the data transmitted and also it is battery powered needing constant care for the power input. Nevertheless, given that the project is a proof concept no solution is given to this issue but in the future an encryption system has to be added.

In order to fully achieve the portability feature, the device must also have a wearable design. Unlike the other system studied, which mainly the fall detector is a device to wear in the neck as pendant or in the chest with a strip, the *AAL* Safe fall detector is a Wiimote. The Wiimote is not a wearable device so to speak, so in order to avoid reading errors that may be embedded in the acceleration of a device handling from the neck, to be near the mass center of the patient's body and to give a more comfortable outlook for the device, the students opted to place the Wiimote (as a fall detector) in the patient's back, near the coccyx.

As an inclusion in the AAL concept, *AAL* Safe was developed having in mind the improvement of the elderly life while living at home and extending this situation as further as possible. This way, as an expansion of the concept and thinking of this system as a product, other finality was found: to make the aim of the system a nursery house where the users would be the patients and a responsible person nominated by the host would monitor the sessions and look for alarming situations. This could be achieved since the system handles multisession and continuous monitoring. This comes as a great advantage to the *AAL* System since the majority of the products in this area of expertise only aim to a house environmental product, limiting its scope and monitoring continuously one patient at a time.

In *AAL* Safe, a fall is detected when the acceleration data received from the Wiimote reaches a threshold determined by the algorithm developed. Unlike the other systems that sent an alarm if after a fall the device is in a horizontal position, this system raises an alarm if for a period of 5 seconds the device suffers no movement. This is due to the concept that the person wearing the device may not fall in a horizontal pavement and as so, the system avoids false positives.

The majority of the systems previously described send an alarm to a caregiver or a family individual in case a risky situation occurs; this is done by email, text message or even a call. However, since *AAL* Safe is thought to be used in a Nursery environment and the patients will be constantly monitored by a responsible person, the system does not require a sending module to send an alarm notification.

In case the alarm situation turns to be not as injurious as may be thought or even a false alarm, the receivers could get concerned with no need and respond to an emergency neglecting the real ones. So in order to avoid this situation *AAL* Safe has a cancel button that can be configured and pressed when such a situation occurs. On the other hand, some of the other devices present a manual help button called “Panic Button” that summons help of a caregiver if needed. The *AAL* Safe system presently lacks of this option, since the scope of the product is a Nursery House the patients have constant care, however to improve and complete the system’s features and since the Wiimote as innumerous buttons, a panic button can be programmed in near future.

The *AAL* Safe system is completed with an output visualization interface that provides the responsible person or the patient the monitored data in real-time and the alarms raised. After a monitoring session has taken place the user must be given an option to visualize the patient’s session-related data. myHalo™ and “Fall Management Solutions” systems are also fulfilled by this interface option, having a web application that can be accessed both by the family individual but also by the Centre responsible for the systems.

Furthermore, *AAL* Safe’s solution is capable of storing the patient’s details as well as the data regarding the monitorizations. The data stored can be managed by the user and can be visualized either in the Interface, or in a report that may be generated to store the progressive history of the patient and thus to take measures if is noted that the patient does not have an active life (the DRA activities are reported as statistics) or a grand number of alarms have been raised lately.

In conclusion, AAL Safe should be a dynamic and useful solution, providing the product target a user oriented solution that receives measurement data and provides the user a reliable and efficient system.

4. REQUIREMENTS ANALYSIS

In the launch of the present project it was given to the students a Nintendo Wii's remote and was solicited to them to exploit its appliance to the biomedical field and if could be inserted in the concept of Ambient Assisted Living. Throughout the first semester the students explored the AAL concept and possible ideas that could implement the Wiimote's accelerometer. After a market analysis and taking on account the features of the device the students decided to program the Wiimote in order to monitor an elderly daily life and detect both risk situations, as it is a fall, as well as DRA activities. After settling on the idea, the next step was to decide the main functions that the solution must provide. The solution consists on a system that must offer the visualization of the measured data and monitorization of the patient in real time. Also, it should allow the firing of alarms set off within the supervision and data management (both patients and session details) with creation of session reports.

In order to improve the concept of the project, the students studied the elderly needs, their difficulties and above all the already existing products in the market to revise what should be adapted or improved.

The global design of the solution can be divided into two categories: Signal processing which is responsible for collecting acceleration data from the patient and for the classification of a fall and DRA and Data Management which is the system responsible of handling all the information managed on the solution. Having on account the people target of the solution, it was opted to design a user-friendly solution which could be managed by its scope of use. In the following pages, a brief description of the system will be made.

4.1 SOFTWARE ANALYSIS

The Windows Application where the graphical interface is located was developed in CSharp language on NET Framework 3.5 SP1 using several freeware libraries including the *WiimoteLib*. As for the Wimote signal processing algorithm it was under the responsibility of Ricardo Amaro and was developed in MATLAB language and its libraries used on NET Framework 3.5 SP1.

4.1.1 CSHARP LANGUAGE

CSharp (C#) is a language developed by Microsoft with the intention of being a simple, modern, general-purpose and type-safe programming language. It is an upgrade from the C family languages and it is supported by .NET Frameworks' Common Language Runtime (15).

As a multi-paradigm programming language, C# language is both object and component-oriented. C# provides language constructs to directly support events, methods and properties, which have attributes that provide declarative information about the components and integrate their own information. This characteristic makes C# one of the most natural languages in the creation and use of software components (16).

C# has embedded a set of characteristics, such as garbage collection, exception handling and type-safe, which assist in the construction of durable and robust applications. Furthermore, it has a unified type system. This means that all C# types besides inheriting from a single root object type, they also share a set of common operations, and values of any type can be stored, transported and operated upon a consistent manner. Also, since C# supports both user-defined reference types and values type, it allows a dynamic allocation of objects and lightweight structures (16).

C# language profits from the existence of innumerous libraries, many of them open sourced, which ease the creation of a new program and behave the way the developer wants it to. The student took advantage of a few API sources available on-line such has *WiimoteLib*, *Zedgraph* or even *iTextSharp*.

In short, the student opted to use C# as the preferable language of the project due mainly to its capability to support many libraries, particularly the

WiimoteLib which was the foundation of the project since it could communicate and acquire data from the Wiimote.

4.1.2 Complementary Software

Besides the use of Microsoft Visual Studio 2008 which was the main tool for the development of *AAL* Safe Software, other software programs were used by the student as an aim to achieve the final stage of the project.

Table X - Software Requirements

Software	Usage
Microsoft Office	Documentation
PDF reader (Adobe Acrobat Reader or Foxit PDF Reader)	Visualize reports
Matlab	Algorithm development
Microsoft Visual Studio 2008	Windows Interface development

4.2 Acquisition Solution

This project's acquisition module is constituted by a Nintendo's Wii remote control which has, among other sensors, an accelerometer that senses motion from the patient and is placed in its back, just above the user's coccyx. The device communicates with the PC via Bluetooth and the data is displayed in real time.

4.2.1 Nintendo Wii Remote

The Nintendo Wii is a game console created by Nintendo and launched in the market in September 2006. Due to its revolutionary allure and extreme popularity, Nintendo has since tried to keep hardware information leakage to a minimum. The attempt has failed though, given that a group of individuals have reverse engineered the Wii hardware and its technical details are well known at the moment (17).

The Wiimote is an exceptionally versatile device that uses a combination of built-in accelerometers with 3 degrees of freedom and infrared (IR) cameras that can collect LEDS' light placed within a Sensor Bar (in the console), and sense its position in 3D space via triangulation. The Wii controller connects to host, console or PC, via wireless Bluetooth technology, transmitting acceleration data and IR camera pixel coordinates at 100 Hz (18). Besides these components, this device is completed with rumble feature, a speaker and an external extension connector for other input devices, not relevant to the present document.

Figure 10 – Nintendo's Wii Remote view from different angles (15)

4.2.1.1 Why a Wiimote?

First of all, it must be said that the use of a Nintendo Wii Remote Control was a challenge proposed by ISA. At the time that this document is being written, the Wiimote has incited much curiosity on account of its low-cost value, versatility and attractiveness. Due to light weight and small structure, many corporations have been studying its application on several areas. So, the students studied its application to the Biomedical field.

4.2.1.2 Wiimote's Technical Specification

ACCELEROMETER

The wiimote has the ability to sense motion due to an accelerometer ADXL330, fabricated by ANALOGS, placed towards the front within the device. The ADXL330 is a small, thin, low power, complete 3-axis accelerometer that measures acceleration with a minimum full-scale range of ±3 g and a sensibility of 10%. Also, measures the static acceleration of gravity in tilt-sensing applications and acceleration resulting from motion, shock or vibration (19). The Nintendo Wiimote is supported by springs built out of silicon, and it is the force exerted on these springs that the sensor can measure the acceleration of the device (20). The voltage reading in the accelerometer is proportional to the acceleration of the tiny mass.

In case the Wiimote is motionless, the device reports the gravitational force of the internal mass, i.e. 1g (9,81 m/s^2), if the device is in free fall the report reads a vertical force of approximately 0. The Wii controller is calibrated during manufacturing and its values are stored in the device's flash RAM (21).

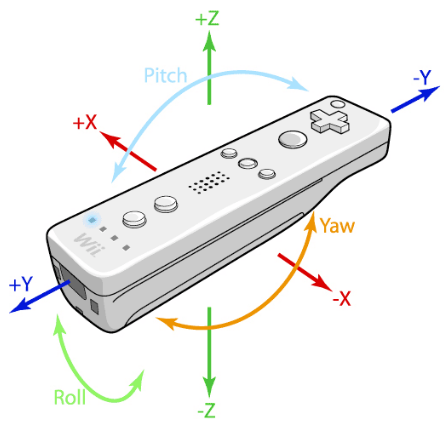

Figure 11 – Three Degrees of Freedom of Wiimote

Features of the ADXL330 accelerometer can be seen the following table.

Table XI - ADXL330 Accelerometer Features

Features
3 axis sensing
180 μA at VS = 1.8 V (typical) power operation
1.8 V to 3.6 V single-supply operation
10,000 g shock survival
Excellent temperature stability

BLUETOOTH COMMUNICATION

The Wiimote transmits and receives data via Bluetooth using a on-board Broadcom 2042 Bluetooth driver chip which is a Class 2 Bluetooth, i.e. its maximum permitted power is 2,5 mW and has a range of approximately 10 meters. This class supports entirely Human Interface Device (HID) protocol which is directly based on the USB HID and as so, the device will appear as a common standard input device to any Bluetooth host not needing any authentication or encryption features (21) (20).

The HID standard allows devices to be self-describing, using a HID descriptor block which consists of an enumeration of reports implicit to the device. Wiimote uses the Service Discovery Protocol (SDP) and reports its HID descriptor block when queried to the host. Reports are like network ports assigned to a particular device and are unidirectional. Only the length of the data is returned, in bytes (21).

The Service Discovery Protocol (SDP) enables the application to discover which services are available and their characteristics allowing the connection between the devices. When queried with SDP, the Wiimote reports back the following information:

Table XII - Unique Values sent by Wii Remote(13)

Attribute	Data
Name	Nintendo RVL-CNT-01
Vendor ID	0x057e
Product ID	0x0306

These values received by Bluetooth are unique to the Wiimote allowing its automatic identification. In Table XIII can be visualized the reports that the Wiimote uses and its description.

Table XIII - Report Sent to Wiimote (13)

Report ID	Size	Function
0x10	1	Unknown
0x11	1	Player LEDs
0x12	2	Data Reporting Mode
0x14	1	Speaker Enable
0x15	1	Status Information Request
0x16	21	Write Data
0x17	2	Read Data

OTHER FEATURES

The remaining features of the Nintendo Wii remote control can be visualized in Table XIV.

Table XIV - Wiimote Features

Feature	Description
Buttons	There are 12 buttons: • 4 arranged in directional pad • the rest spread on the Wiimote
IR camera	Placed in front of the Wiimote
LEDs	There are 4 LEDs: • placed in the bottom edge • indicates discoverable mode by blinking • show battery level
Rumble	Small motor attached to an off-center weight
Speaker	Low quality, used for short sound
Memory	Contains a 16 KiB EEPROM chip
Power Source	Uses to AA batteries, allowing powering for about 60 hours if used alone and about 25 if using both accelerometer and pointing functionality

4.2.2 ACQUISITION MODULE

The acquisition Module is the element of the present solutions that will allow continuous monitoring of the patient's acceleration as well as permit constant communication between the host and the Nintendo Wii remote and its features. The main purpose of this module is to receive the measurement data from the device and display it in real-time.

When the Acquisition Module obtains a start receiving command, it should verify if the device chosen to do the monitoring is available and in case it is, it should collect all the measurement data and the device's state. The communication between the host and the Wiimote is made using one of many Wiimote APIs available, the *WiimoteLib* using the device from a .NET application.

4.2.2.1 Wiimote API

As mentioned above, the launch of the Nintendo Wii Remote has brought a large amount of interest from a group of individuals to analyze different ways to exploit the device. As a result, a vast selection of Wiimote's Applications Programming Interfaces (APIs) is available as freeware on the Web. A Wiimote API is a device driver that is responsible for connecting the host to the Wiimote via Bluetooth, using Bluetooth HID standard and be able to control the Wiimote has well as receive its data.

For the present project it was selected the Wiimote API that could provide the following features:

- License available and free of charges;
- Clean, simple and efficient codebase that could easily be used;
- Implementation in VS2008;
- Access to most (preferably all) of Wiimote features;
- Access to multiple Wiimotes simultaneously.

Having all this features in account, it was chosen the *WiimoteLib*. The library was developed by Brian Peek and other associates with the intent of using a Nintendo Wii Remote (Wiimote) and extension controllers from a .NET application (22).

In order to connect the Wiimote to the host several steps must be taken:

- Start the Bluetooth option and search for available Wiimote devices;
- Press both 1 and 2 button and hold until the connection is done;
- Wiimotes are listed as Nintendo RVL-CNT-01, if no device appear with this name the process should be started over;
- Press the Wiimote from the list and conclude the connection.

In annex, it can be seen a resume of the basic commands used in the project to interact the wiimote to the host, Annex - Basic Commands used in WiimoteLib.

The library currently accesses to a limited number of report types that the Wiimote is able to send (22). Specifically, those reports are:

- Buttons data;
- Buttons and accelerometer data;
- Button, accelerometer and IR data;
- Button and extension data;
- Button, accelerometer and extension data;
- Button, accelerometer, extension and IR data.

At the moment of the present document the speaker feature is not available.

4.3 Data Management Module

The Data Management Module is the core of the solution, and as so is responsible for managing the interaction and fluxes between the different subjacent modules, Database, Windows Application, Processing Data and ReportGeneration each one of them with different requisites. It manages all the data provided both from the patients registered in the system and the data regarding their monitorizations.

Firstly, the patient's details are registered in the Windows Application and subsequently stored in the database. The solution consists on a system that must provide on a first hand a real-time visualization of the processed data (Processing Data Module) and its alarms and daily routine which are also stored in the system and attached to the patient monitored. The information gathered must be then stored and could be displayed on a report.

In the next section, a detailed description will be made of the main requisites to be implemented in the *AAL* Safe software system. In annex the flow of the Data Management is described, Annex - Data Management Dependencies.

4.3.1 DATABASE

A Database is an entity responsible for structured data storage, with a low-redundancy and must provide a fast way of saving and retrieving information. The database must be connected to the Windows Application. Concerning this connection, the main tasks related to this module are:

- Save and edit information of patients registered in the system;
- Save all the data related to a Monitorization session.

4.3.2 WINDOWS APPLICATION

The Windows Application is the interface in which the user may access the functions available in the system and should be divided into three submenus, an area where the registration ought to be made, other where the patients processed data and the alarms and DRA monitoring should be visualized and finally an area where the Wiimote will be configured.

The system must be improved with a flow of information between the subjacent modules in which the Windows Application Module will have a major role since is responsible to give the instructions to the system to manage the data. Also, it should supply useful information, such as patients registered in the system and Monitorization sessions details, among others.

Finally, since it should be a user-friendly interface, it ought to be implemented help buttons which may help the user to exploit the system, as well as exception handlers.

The main requisites of the Windows Application are:

- Add, edit and delete Patient;
- Visualize patient's details;
- Initiate and store new Monitorization session;
- Real-time monitoring;

- Visualize alarms set off during session;
- Visualize Monitorization details: Initiation and conclusion, Duration of each DRA in percentage, true fall alarm, fake fall count and energy expenditure of the patient during Monitorization;
- Configure the communication device in different options: button and rumble time;
- Help guide;
- User-friendly Interface, easy and simple to use;
- Create Reports with information regarding Monitorization Sessions.

4.3.3 Data Processing

As already mentioned, the Windows Application main concern is to visualize data in real-time as well as observe an alarm setting off. In order to achieve this goal, an algorithm must be developed aiming the processing of the acquired data in order to detect accurate falls as well as distinguish different DRA.

The algorithm must achieve the following points:

- Real-time monitoring;
- Fall detection;
- Real-time distinction between DRA;
- Alarm set;
- Energy expenditure during Monitorization session;

4.3.4 ReportGeneration

Reports can be generated in the Windows Application and is the output of the Monitorization sessions. The data displayed in the report is unchangeable. Furthermore, this module must be capable of exporting reports into a PDF format.

The main requisites of this module are:

- Display useful information concerning the Monitorization session selected;
- Create a PDF document which can be printed if needed.

5. SYSTEM ARCHITECTURE

The following chapter will consist on a description of the characteristics of the components within the Solution System considering the human interaction with the referred System. The Solution *AAL* Safe System is constituted by two components, Personal Computer (PC) and a Nintendo Wii Remote, which corresponds to the Acquisition Module, and a BT connection. The Wiimote acquires the data and send it via BT to the PC. The PC incorporates the Data Management Module (Visualization Module, Processing Data Module, Database (DB) and the ReportGeneration Module).

This chapter will be subdivided into two subcategories, the Physical Architecture and the Logical Architecture.

5.1 PHYSICAL ARCHITECTURE

AAL Safe physical architecture comprehends the interaction between the patients with a PC through a Wiimote. In Figure 12 can be seen a physical structure of a possible product made from this system. Fleeing from the ALL concept and entering more in an eldercare model, this system could be used as a monitoring system in a Nursing Home.

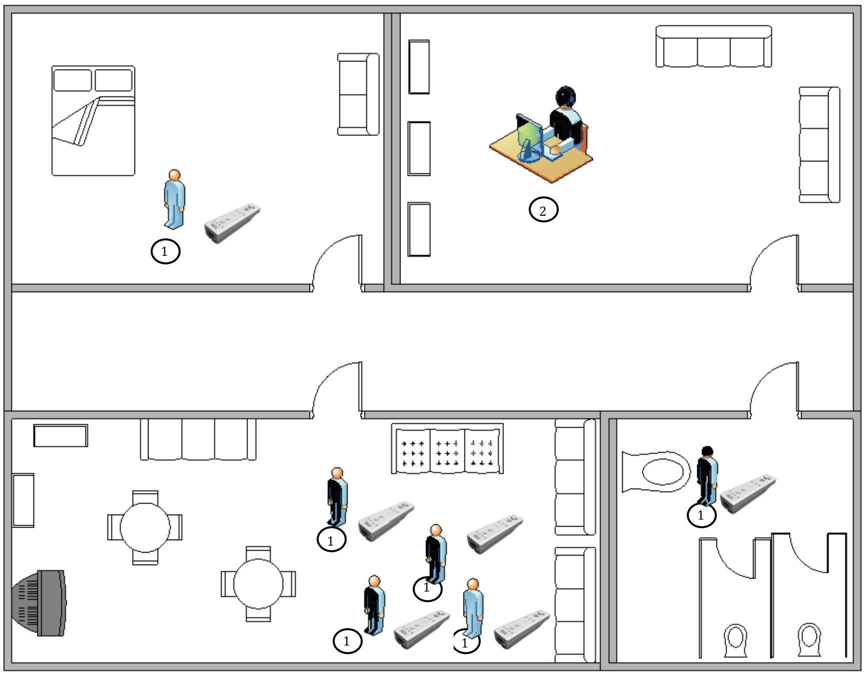

Figure 12 – Physical Scheme of *AAL* Safe

Legend: 1- Acquisition Module; 2 –Person responsible for monitorization sessions

The acquisition module is attached to the patient [F12.1] and is placed on the patient's back in a horizontal position, near the sacrum in order to achieve more accurate data since the device has not an appropriate size for its function. It must be connected to the Processing host (PC). The data is sent to the PC where a responsible person [F12.2] will monitor the DRA and falls of the patient. Take note that the acquisition module must be within 10 meters from the processing host.

Due to the nature of the present project, it was chosen the simplest application interface solution, a Windows Application. This solution is installed on the users' computer, meaning that the application will be much richer and more responsive than the web application, also having a higher performance. However, comparing to the web application it lacks mobility, ease of access and configuration maintenance.

The database module consists on Visual Studio Datasets, i.e., a virtual relational database having for that matter, relationships between tables. Datasets are objects that contain data tables where data is temporarily stored when using the application (23). The Windows Application is then provided of a local in-memory cache to work with and it can be accessed even if the application and its database are disconnected. The dataset maintains information about changes to its data so the database is updated when reconnected. The relational view of the data is represented in XML (24). XML provides easy communication between the dataset and the Windows Application. The database module is connected to the Windows Interface and is used in the creation of Reports.

The wireless communication between the Wiimote and the PC is made by Bluetooth, which is the communication supported by the device.

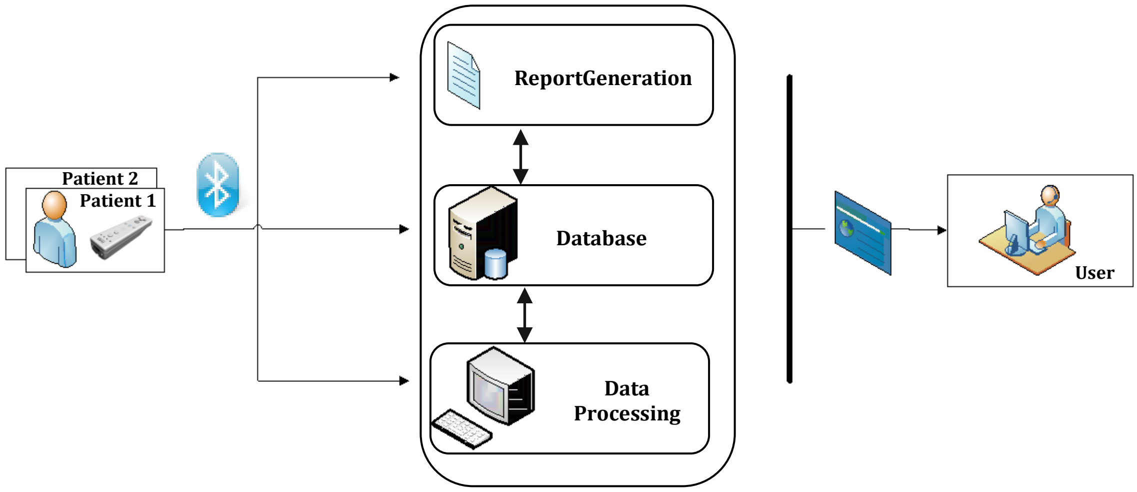

Figure 13 – Physical Architecture

5.2 Logical Architecture

AAL Safe is based on a multi-tier architecture, a structure in which the presentation, the application processing and the data management are logically separated processes. This architecture has the advantage of allowing any of the three tiers to be independently upgraded or replaced. As seen in Figure 14, the Presentation Tier consists on the Windows Application, a user interface, the Logic Tier handles the data management and processes the algorithm, and the data is stored on the database on the Data Tier.

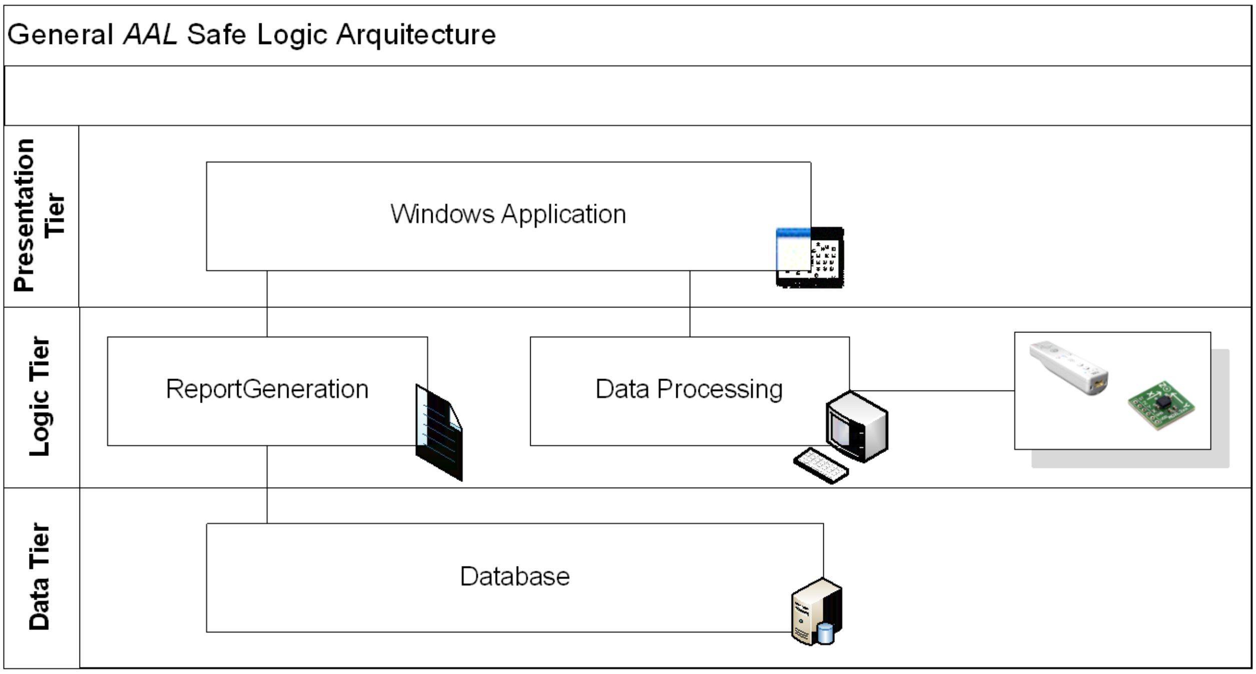

Figure 14 – *AAL* Safe's General Logical Structure

The Presentation Tier of the acquisition process begins when the Windows Application is started on the computer's host. Firstly, the user searches for available Nintendo Wiimote devices in the area and then the Windows Application is used. The details from the patient are routed to the Database. The presentation tier is responsible to give the instructions to the system to interact the different subjacent modules.

In the Logic Tier, the device chosen is connected and starts routing the acceleration data to the user interface where it is processed by the fall and DRA algorithm in the Processing Data module. The statistics concerning the processed data and presented in the Windows Application are then routed to the database. The ReportGeneration module can be accessed in the Windows Application, in two different areas. When accessed the ReportGeneration module generates a PDF format report. Both reports display data stored in the Data Tier, the database.

Shortening, the Data Tier is responsible for storing data regarding the two tiers above and it sends information to the ReportGeneration module when requested, as can be seen in Figure 15.

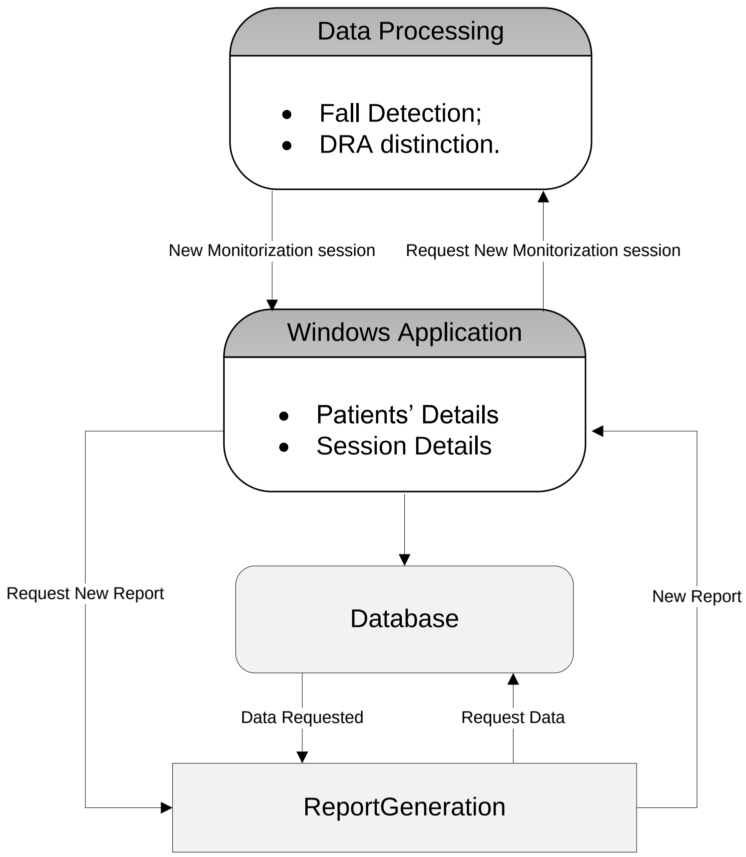

Figure 15 – Logical Architecture

6. Software Development

6.1 Database Design

The database design was made during the development of the software, considering the data needed to be stored regarding the Windows Application demands. As mentioned before, the Database module consists on Visual Studio Datasets. The structure of a DataSet is similar to that of a relational database since it exposes a hierarchical object model of tables, rows, columns, constraints, and relationships.

The main features saved in the Data Tier are related to the patient, their register in the system and their sessions and related alarms. So, the behavior of the database can be divided into two main modules, the patients and information related to the monitorization session. Both of these modules are composed by several entities as seen in Table XV.

Table XV – Entities of *AAL* Safe's database

Patients	Patients	Patients registers details
Patients	AnglePatient	Angle related to each patient and used in the Processing Data Module
Monitorization Sessions	MonitSession	Information concerning monitorization sessions
Monitorization Sessions	Alarms	Alarms set off in monitorization sessions
Monitorization Sessions	DailyRoutines	Routines performed by the patient in monitorization sessions

ENTITIES RELATIONSHIPS

The relationships between the database entities of the *AAL* Safe solution can be summarized as an interaction between the patient monitored and the monitorization sessions. A patient has associated none, one or several monitorization sessions. A monitorization session has one and only one patient associated, however can have none, one or several alarms or dailyRoutines associated. An extension of the specification of the AAL Safe system database is available in Annex – Database Specification.

6.2 INTERFACE DEVELOPMENT

The development of the Windows Application had many aspects in consideration and the most important was the recipient of the project: the elderly. So, in order to achieve a user-friendly application the student tried to put the solution as simple as possible, an intuitive organization of the application and appealing visualization. An introduction on the use of the *AAL* Safe solution and its main functions can be consulted in the Annex – User Guide.

6.2.1 AAL SAFE APPLICATION

In order to achieve all the main requisites for this Windows Application which are User-friendly, easy and simple to use Interface, a fixed menu was used with the purpose of providing a fast and efficient way of consulting the different sections being redirected when pressing the menu. In Figure 16 can be seen the menu at the disposal of the user: "Patients Area" [1], "Monitorization Area" [2] and "Settings Area" [3]. The click event directs the user to the different sections. The menu section remains the same in every section, the main window [4] is the only one that changes according to the preference of the user.

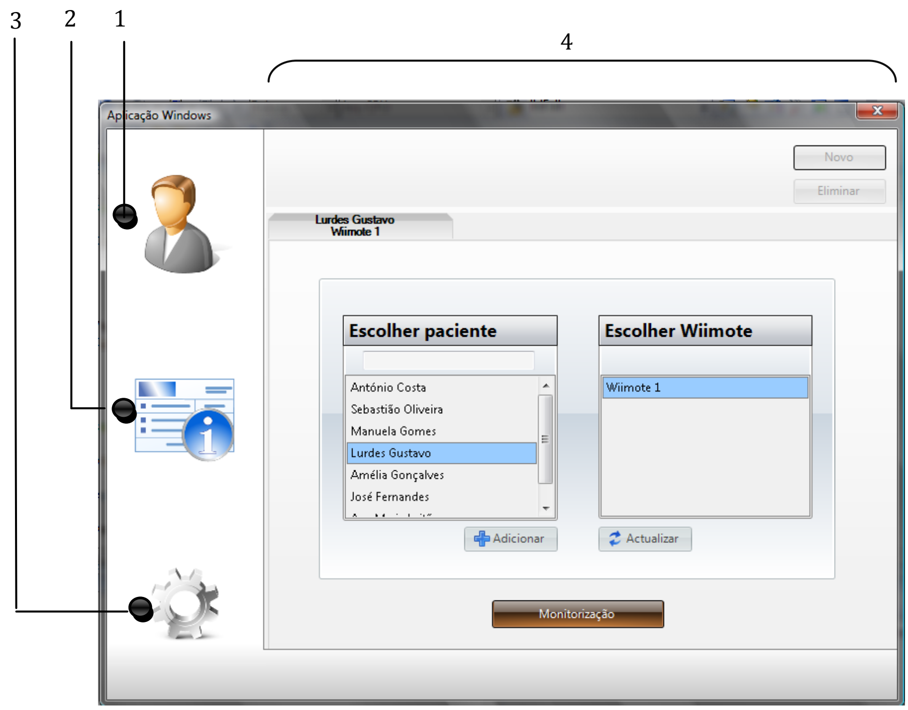

Figure 16 – Main Organization of *AAL* Safe

Legend: 1, 2, 3 – Menu; 4 – Main Window

6.2.1.1 PATIENTS AREA

In this area, the user can register patients to the system adding all their information (name, sex, birthday and transition angle). Furthermore, he has at his disposal all the other patient's details registered in the system. These details can be edited or deleted.

In addition, on this area the user can access to any patient's history as long as it was not deleted from the system. The patient's history is a request to the database and includes the visualization of all details concerning a monitorization session.

DATE FORMAT

Considering the scope of the system, it had to be taken some choices in order to make the interface more intuitive for the elderly. So, instead of using what is normally used in a Windows Application as a date selection tool, the DateTimePicker (available on the VS2008), the student opted to use three lists where the user can manually insert the year, month and day of the birthday date in a more perceptive way.

6.2.1.2 MONITORIZATION AREA

This area allows the visualization of the acceleration data in real-time, shown in Figure 17, after being treated by a processing algorithm.

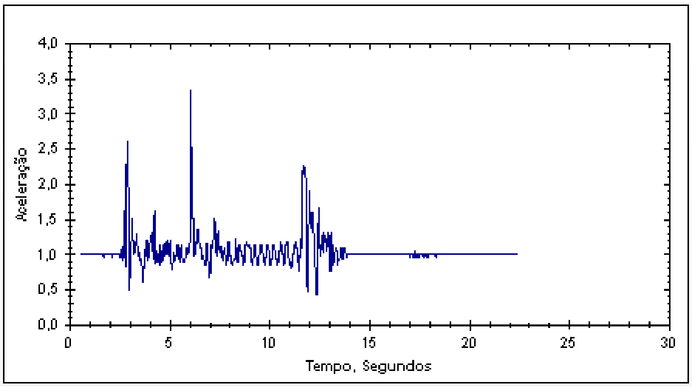

Figure 17 – Processed data in Application's chart

During the session is displayed the different patient's DRA activities, sit, stand, lay, and a visual and sound alarm when a fall occurs.

After the conclusion of the session, the user can visualize all the session's details, including the percentage of time spent on each DRA activities and the number of falls or fake falls (situations that fire the alarm and not being an actual fall, the patient presses a button to cancel the fall alarm) and other statistics.

MULTISESSIONS

This system supports multisession monitorizations, which allow the monitorization of different patients with different devices in a multi-tab way. When a fall occurs in any tab, a visual warning appears in the top of the Interface, accompanied by a sound alarm and the tab where the fallen patient was being monitored emerge on the Windows Application. Thus, the system gives two warnings visual and sound, to ensure that the alarm is checked and the patient receives the attention he needs.

The system has a control which disables the user to monitor a patient that is already being monitored as well as to use a device that is being used in other monitorization. To begin a monitorization, the patient and the device are selected from a list, which only displays the entities not used.

As long as there are available monitoring devices and the host's computer has the minimum requirements (RAM and processing unit capability), the system can monitor different patients at the same time.

6.2.1.3 SETTINGS AREA

This is the area where the user can access the configurations available for the devices used. The user can modify the button to be pressed when a fake fall occurs and the time that the device will vibrate between fire an alarm and stipulating that the fall was real (if the button was not pressed). Also it is available the device's battery durability. Furthermore, the user can access to a test zone, where it can be verified if the alterations were made successfully.

6.2.1.4 MULTI-LANGUAGE

The *AAL* Safe system was completed with a multi-language option providing the system a more global feature. The system currently supports both Portuguese

(Portugal) and English (United States of America) languages, however these features can be extended to another languages. The Portuguese language was chosen for the obvious reason, since this project was developed in Portugal. As for the English language, it was chosen the language from United States of America since it is a global language.

On the base of this feature is a concept known as globalization, which allows an application to behave correctly according to the culture defined on the operating system. The defined culture determines the display mode that the numbers, date format, negative numbers format, etc, appears on screen (25). Usually for every culture supported by the application, resources must be created. Given that the *AAL* Safe supports two languages, it has two resource files for each culture available, the “pt-PT” and the “en-US”. For each string needed on the system, it was added a dictionary pair name-value. The name must be equal in each resource file and the value is changed according to the defined culture.

6.2.1.5 INFO

The main requirement of the user interface is to provide the host with a clean, interactive and intuitive application. So, in order to achieve this requirement and besides building a visual attractive application, the student bear in mind that some aspects may not be as intuitive, so a couple of info buttons were displayed where the user might have some doubts. Furthermore, the info functionality may fire a message box informing the user when an exception occurs.

The system is completed with preventive error messages that avoid adding an inconsistent name. The user is prohibited from adding names including numbers or characters which do not include A to Z letters and punctuation. When this occurs the “Add” button becomes disabled. Otherwise, and as long as there is a consistent name on the message box, the button is enabled.

6.2.2 *FLOW CHART*

Following will be presented a flowchart of the use of *AAL* Safe System. First of all is needed for the Wii remote control to be well placed in the patient's back, near the coccyx in a horizontal position as seen in Figure 18. Furthermore, the Bluetooth connection between the device and the host's computer must be established.

Figure 18 – Position of the Wii in *AAL* Safe Solution

The process is initiated in the Monitorization Area where the patient is submitted to a Monitorization session.

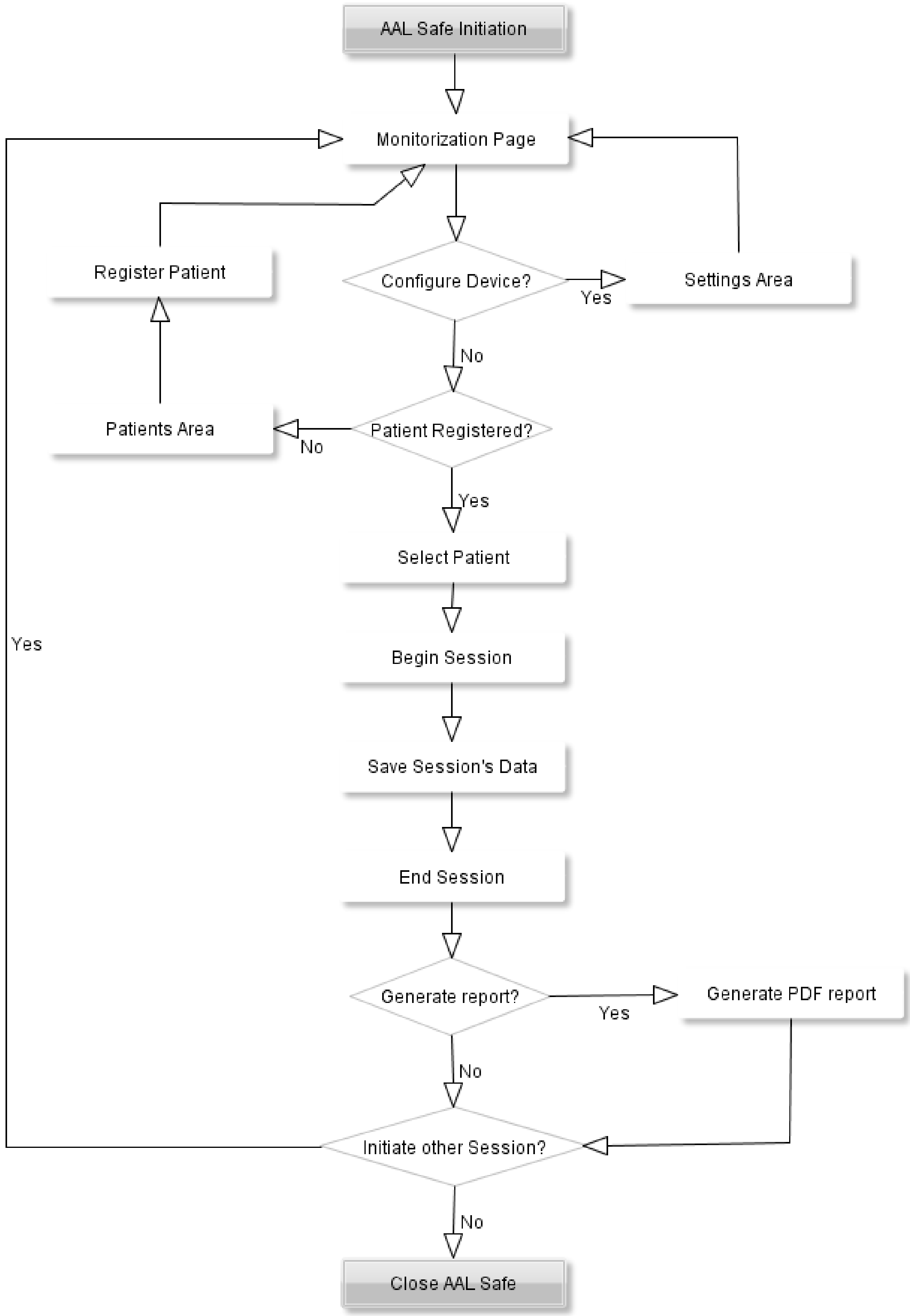

Figure 19 – New Session Flowchart

6.3 Processing data

The Processing Data Module is based on an algorithm developed by Ricardo Amaro. The acceleration data from the Wii remote control is gathered and sent to the PC via Bluetooth, and the data is processed using the functions of the *WiimoteLib* mentioned in Annex – Basic Commands used in WiimoteLib –and Matlab tools.

The transition angle added when the patient is registered in the Patient's Area is unique to each patient of the system. This angle is used in the Processing Data Module and is related to the angle that each person does with the recto angle when sited. To make the algorithm more accurate, it was made an option in the Interface to select the angle favorable for each person. The default angle is 10º; however it can vary between 5º and 15º which is uncommon.

The algorithm was then implemented on the Windows Application Solution and the data visualized in the Monitorization Area.

6.4 ReportGeneration

The ReportGeneration module was implemented as a way to improve the project and the knowledge of the student since it was not a pre-requisite for an experimental project. The report acts as a gather of essential information collected during the Monitorization sessions. The implementation stage was developed in VS2008 using a freeware library available online, *iTextSharp*.

This module is immutable, i.e. the information displayed on the report is not chosen by the user. After a supervision session or during a visualization of the patient's history, a button "Generate Report", is displayed on the windows and if pressed the report is automatically generated. An example of a report can be seen in annex – Report Example.

The contents that a report displays are divided in four tables. The first one is a logo of the host entity of the project, ISA, and acts as the report header.

Secondly, the main information of the patient supervised, name, sex, birthday and transition angle is displayed. The footer presents the address and telephone number of the host entity. The main information is presented in the "Statistics" table that presents:

- Monitorization Date – Date that the supervising session took place ;
- Monitorization Beginning – Time of the beginning of the supervising session;
- Laying duration – Duration that the patient spent in the laying position during the supervising session, in percentage;
- Sitting Duration - Duration that the patient spent in the sitting position during the supervising session, in percentage;
- Standing Duration - Duration that the patient spent in the standing position during the supervising session, in percentage;
- Undefined Duration – Duration of the time that the DRA activities algorithm could not discern the activity made during the supervising session, in percentage;
- Transitions Duration – Duration that the patient spent transiting between activities, in percentage;
- Energy expenditure – Amount of energy spent by the patient during the supervising session, in W/Kg;
- Number of falls – number of real falls;
- Number of fake falls – number of supposed falls cancelled by the patient;
- Monitorization Ending - Time of the beginning of the supervising session.

7. TESTS

Software testing is an essential part of the system development lifecycle. The test plan is a part of the project's documentation. The objectives and functional requirements of a software application are delimited and bounded by the project plan (26) (27). The test phase is made to provide confidence in the system, identify areas of weakness and mainly to prove that the system is both usable and operable.

In annex a test documentation is provided (Annex – Tests) which is designed to create test cases to qualify the application for functional fit, system stability, usability, security and performance (27).

8. Conclusion

The *AAL* Safe solution was developed through the academic year of 2008/2009 as a project of the final year of the master's degree in Biomedical Engineering. The final aiming of the project was to exploit the versatile and economical device, known as Wii remote control and turn it into a reliable fall detector, one of the major concerns of the Ambient Assisted Living concept. For that matter, the students have studied new programming languages and signals from the tri-axial accelerometer placed within the Wiimote and determined patterns to distinguish DRA from falls and build an Interface solution. Particularly, the student had to build a solution to provide the patient information and real-time monitoring in an interactive and user-friendly way.

Globally, the general goals of the system have been achieved. The final solution comprehends a Windows Application that provides the user with a real-time multi-monitorization platform, building reports related to Monitorization sessions, visualization of patients' details and Wiimote manual configuration. The Windows Application is completed with the algorithm developed by Ricardo Amaro, and collectively they make a system capable of detect a fall, distinguish DRA activities and set visual and sound alarms, and data management and real-time monitoring.

As for the scope of the project, initially it was thought that the solution should be applied in a house environment, and only a single person would be monitored. However, throughout the development of the project it was decided that since the system was able to monitor more than one device at a time, that it should be implemented in a hospitality facility like a Nursery Home. This feature provides the system with an advantageous attribute in comparison with other Solutions available in the market. As a system that can have a multisession option, the *AAL* Safe solution is ideal to be used in a multi-human environment. The patients can be monitored and its data will all be delivered to a single Interface where a responsible person will assist de Monitorization sessions and provided the required care when needed.

It must be understood that the Wiimote is not an indicated device for the purpose of detecting a fall; it was used as a way to take advantage of a new technology and test the capacity of the students to apply this device to a present concern. As a way to make this solution closer to reality to Wiimote device should be replaced by a more capable and suitable device that could be more comfortable for the patient to wear.

8.1 FUTURE WORK

In the next section are provided some suggestions on how to continue improving the project in a present and future scenario.

GENERAL ARCHITECTURE

An essential development to integrate the system would be to replace the Wii remote control with a more suitable hardware. Thus, the acquisition module would be replaced with a user-friendly adapter which should have an accelerometer and a single button. The accelerometer to be used could be the ADXL330, the same used within the Wiimote, which as the test may confirm is suitable to identify and distinguish both a fall and different DRA activities. The button should be used to cancel a situation where a fall is not considered hazardous.

Secondly, the adapter should also be implemented with a class 1 Bluetooth in order to extend the range of the device to 100 meters. As mentioned in a previous chapter, Chapter 3 – Related Works, with the purpose of making the system securer an encrypted login should be implemented to prevent a foreign user to visualize a patient's details.

In a subsequent step, a suitable Datacenter should be implemented since for the purposes of the present project a primitive database was built. The new Datacenter would allow a more adapted installation of the system in a new host and would provide a more flexible data structure. The communication between the Datacenter and the Data Management Module should be implemented.

SOFTWARE

Some improvements can be made in the user's interface in order to ensure a more capable solution.

- Regarding the alarms visualization, it should be completed with a text message or email service to inform responsible people of a hazardous situation;
- The alarm should only be turned off when checked;
- The Datacenter should be responsible for handling the information regarding the alarms sent;
- As for the report, more information concerning the details of the session should be added such as a note of the frequency of falls that the patient has suffer in the past Monitorization sessions or if the patient spends too much laying or sitting down time;
- The solution should be completed with a login system in order to protect the privacy of the patients since this system was built regarding a multi-session system and as so many patients will be registered.

8.2 Final Appreciation

As the number of elderly individuals continues to increase over time so would increase the families concerns from them living alone at their homes. So it was the students aim to, while being evaluated to use a Wiimote, built a development of an economical solution to cease this problem.

The development of this project, in spite of confusing in the early stages, was very gratifying in personal and technical terms. Personally, being incorporated in a global technology company has made me understand the environment and be able to face the future ahead of me. Also, the process of developing the project was very enriching since it enabled me to improve my knowledge and acquire and face for the first time a code writing environment.

In short, I may say that I am pleased to contribute for the development of an experimental project that could be improved and turned into a product easing the life of many senior people and to have worked within a multidisciplinary team.

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10. ANNEXES

10.1 DATABASE SPECIFICATION (DETACHED)

10.2 USER GUIDE (DETACHED)

10.3 TESTS (DETACHED)

10.4 REPORT EXAMPLE

Nome:	**Joaquim Abrantes**
Sexo:	**Masculino**
Data de Nascimento:	**28-06-1933**
Ângulo de transição	**10**

Estatísticas

Ínicio da Monitorização	**05-09-2009 04:29:13**
Tempo Deitado	**61,06 %**
Tempo sentado	**9,73 %**
Tempo de pé	**13,27 %**
Tempo de Transições	**10,62 %**
Tempo de Movimentos Indefinidos	**5,31 %**
Energia Dispendida	**1162,78**
Nº de Quedas	**1**
Nº de Quedas Falsas	**1**
Fim da Monitorização	**05-09-2009 04:30:11**

ISA Portugal
Estádio Cidade de Coimbra, 92
3030-320 Coimbra
Telf: 239 791090

10.5 BASIC COMMANDS USED IN WIIMOTELIB

In Table XVI, it can be seen a resume of the basic commands used in the project to interact the wiimote to the host.

Table XVI - Basic Programming Commands used in *WiimoteLib.*

Command	**Description**
Wiimote wm= new Wiimote()	Creates new Wiimote instance
wm.Connect()	Connect the Wiimote to the host
wm.Disconnect()	Disconnect the Wiimote from the host
wm.WiimoteState	Interact with the features of the device and reports its state
wm.SetReportType	Set report type to return all data from the Wiimote
WiimoteCollection wc = new WiimoteCollection();	Wiimote class that gathers all the Wiimotes connected in a list
wc.FindAllWiimotes	Find all Wiimotes connected via Bluetooth

10.6 DATA MANAGEMENT DEPENDENCIES

TABLE XVII - List of Requirements – Software and their Dependencies

	Description	Dependencies
Database	R1 - Save and edit information of users registered in the system;	-
	R2 - Save all the data related to a Monitorization Sessions.	-
Windows Application	R3 - Add, edit and delete User;	R1
	R4 - Visualize user's details;	R1
	R5 - Initiate and store new Monitoring Session;	-
	R6 - Real-time monitoring;	R13
	R7 - Visualize alarms during session;	-
	R8 - Visualize Monitorization details;	R13; R2
	R9 -Configure the Communication device in different options;	-
	R10 - Help guide;	-
	R11 - User-friendly Interface, easy and simple to use;	-
		-
	R12 - Create Monitorization Reports.	R19; R20
Data Processing	R13 - Receive measurement data from WiimoteLib;	-
	R14 - Real-time monitoring;	R13
	R15 - Fall detection	R13
	R16 - Real-time distinction between DRA;	R13
	R17 - Alarm set off;	R13
	R18 - Calories spent during Session;	R13
ReportGeneration	R19 - Display useful information concerning the Session selected;	R1; R2
	R20 - Create a PDF document which can be printed if needed.	R19