CogWatch – Cognitive Rehabilitation of Apraxia and Action Disorganisation Syndrome

D2.3.1 Report on networks I

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EXECUTIVE SUMMARY

This deliverable aims at defining CogWatch general architecture and the developing software algorithms for the analysis, evaluation and presentation of the rehabilitation sessions execution. Moreover, this deliverable aims at defining the communication and security protocols implemented in the project. The definition of the algorithms and protocols are been defined starting from the deliverable D2.1 Report on system specification whose objectives were the analysis of system specifications and the definition of the architecture.

In a general point of view, networks are been defined as the developed algorithms and implemented protocols for the comprehensive CogWatch system. The purpose of the report is to provide a technical overview of these algorithm and protocols, which are classified depending on the function they provide.

CogWatch system is composed by two main subsystems, the Client Subsystem, corresponding to the patient side used to perform rehabilitation sessions, and the Server Subsystem, in charge of monitoring patient performance and progress. The overall CogWatch architecture is defined, including a general schema and a particular description of the defined sub-systems through block diagrams, and a description of every implemented function.

The developed algorithms are based on the data received by the monitoring devices described in the D2.2.1 Report on devices I and are focused on the deployment of the first prototype of CogWatch system. More detailed and general information will be presented in the D2.3.2 Report on networks II.

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REVISION HISTORY

Revision no.	Date of Issue	Author(s)	Brief Description of Change
v0	14/09/2012	UPM	Table of Contents
v1	17/09/2012	UPM	Section 3 (Fusion Module, Information Handler, Scheduler, Post processing module & Statistics)
v2	01/10/2012	UPM	Section 1 and section2
v3	18/10/2012	UPM, UoB - EECE	Integration of ROAMIN, LST and UOB-EECE in section 3
v4	28/10/2012	UPM	Section 4
Final Draft	09/11/2012	UPM	Section 5 and 6. Final revision
Final Draft	12/11/201	UPM, UoB - EECE	Final Draft ready for Peer Review
Final Draft	03/11/201	UPM, UoB - EECE	Peer Review received
Final	03/11/201	UPM	Revision of the deliverable and improvement according to the Peer Review.

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Abbreviation
AADS	Apraxia and Action Disorganisation Syndrome
AM	Account Manager
CCS	CogWatch Client sub-system
CHS	CogWatch HealthCare sub-system
CSS	CogWatch Server sub-system
CWS	CogWatch WebPortal sub-system
HIH	HEALTHCARE Information Handler
LAN	Local Area Network
LIN	LOG-IN Module
MAN	Metropolitan Area Network
PAN	Personal Area Network
UR	User Repository
VTE	Virtual Task Execution
WCM	Web Portal Communicator Module
WIH	Web Portal Information Handler
WLAN	Wireless Local Area Network
WPA	Web Portal Algorithm

1. INTRODUCTION

This deliverable is focused on the description of the developing software modules in the CogWatch system, together with the description of the communication, security and network specification. This deliverable is focused on the first prototype of CogWatch system. More detailed information will be presented in the D2.3.2 Report on networks II.

This deliverable aims at describing the general architecture of the Cogwatch system, with a particular attention to the developing software modules, the interoperability between different modules, the communication protocols, the network specification and the implemented security protocol and procedures.

CogWatch requires the development of ad hoc algorithms, able to identify and predict the errors made during the task execution. For this reason, dedicated modules are been implemented in order to analyse the data coming through different devices, described in the deliverable D2.2.1 Report on devices I.

The report is divided in five main sections, which describes the overall algorithms and protocols used in the developing of the first prototype of the CogWatch system. Section 2 describes the general architecture of the CogWatch system, including an overall description of the sub-systems, the communication and security protocols that composed the comprehensive system.

Section 3 describes the CogWatch Client sub-system (CCS), with a particular attention to the developed modules and algorithms of the first prototype. In the CCS, data are collected using the devices described in the D2.2.1 Report on devices I.

Section 4 discusses the CogWatch Server sub-system (CSS). It is composed by two different modules, the CogWatch HealthCare sub-system (CHS) and the CogWatch WebPortal sub-system (CWS). The CHS is the sub-system in charge of communicate with the CCS and receive from it data and statistics of rehabilitation sessions. The CHS would be installed in a healthcare centre and it should be able to manage also data coming from external resources. The CWS is the sub-system in charge of presenting to the healthcare personnel the data and statistics about the patients and about the rehabilitation session. It should be installed in an external and unique server.

Section 5 describes the communication and security protocols used to assure the personal data and the secure transfer of information between the different sub-systems of the CogWatch system.

Finally, section 6, will present the conclusion of the deliverable and will introduce the future steps that will be describes in D2.3.2 Report on networks II.

2. GENERAL ARCHITECTURE

The overall architecture of the CogWatch system is illustrated in Figure 1. CogWatch system aims at developing improved methodologies at home for rehabilitation of apraxia and action disorganization syndrome of patients, consequences of stroke.

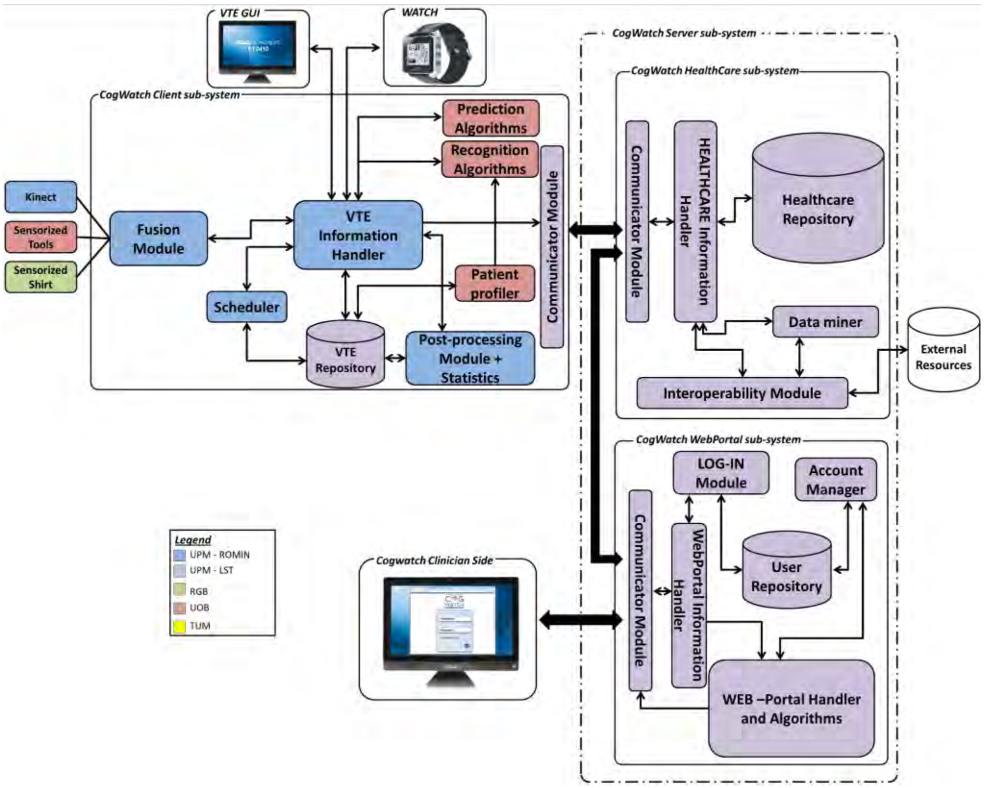

Figure 1 - Cogwatch general architecture

The CogWatch System is composed by two main subsystems, ***the CogWatch Client sub-system*** (CCS) and the ***CogWatch Server sub-system*** (CSS).

The CCS will be located at the patients" home, and will be used for collection and analysis of the data acquired during the rehabilitation sessions scheduled by the health professionals.

The CSS subsystem is the remote point of the system architecture that manages all patient information from all active CCS and presents the results of the rehabilitation sessions to the healthcare personnel. It is composed by the CogWatch HealthCare sub-system (CHS) and the CogWatch Web Portal sub-system (CWS). The CHS is the sub-system in charge of receives and store data of the rehabilitation sessions. The CHS would be installed in a healthcare centre and it should be able to manage data coming from external resources. The CWS is the sub-system in charge of presenting to the healthcare personnel the data and statistics about the patients and about the rehabilitation session. It should be installed in an external and unique server. It is a web based portal, accessible by the healthcare or administration personnel from any location. They will be able to access information from several remote sources from any computer with an available internet connection.

3. COGWATCH CLIENT SUB-SYSTEM

The **CCS** is defined as the *home-based* subsystem used to acquire and process the data acquired using the CogWatch devices.

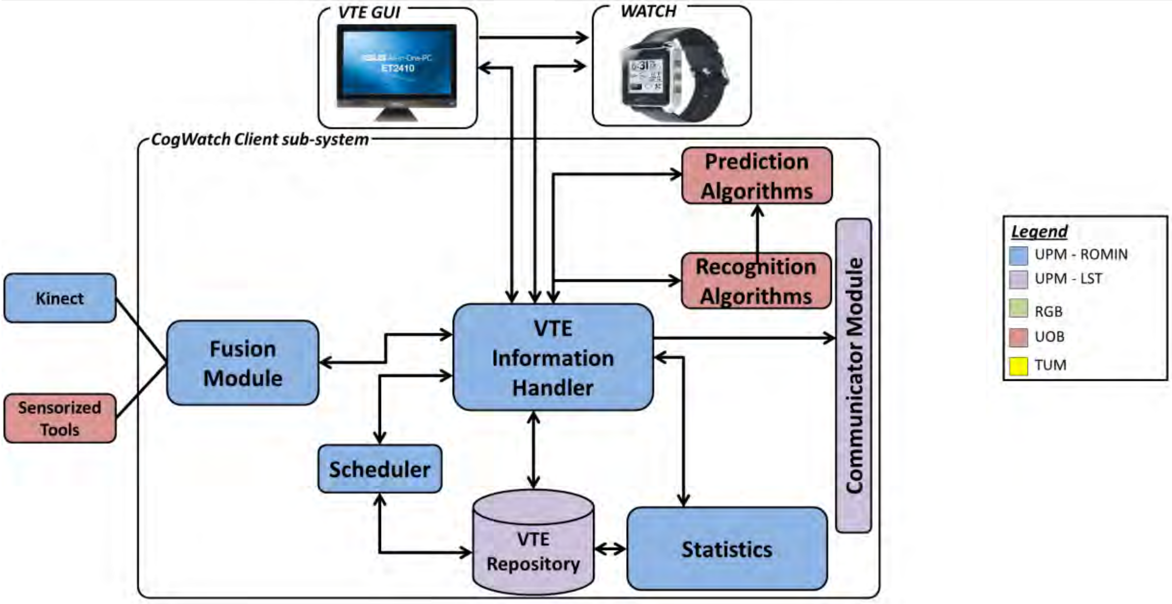

Figure 2 - Cogwatch Client Sub-System architecture of first prototype

For the first prototype the CSS will be composed by a smart watch, sensorized objects, a Virtual Task Execution (VTE) module and a Kinect. The VTE is an *"All In One computer*", that allows tactile interaction. Those devices are been described in the *D2.2.1 Report on devices I*.

In order to process data coming from the different CogWatch devices, several algorithms are developed and installed in the VTE in order to assess the patient performance when carrying out one or several tasks defined for the CogWatch system. In this case, since the architecture is oriented to the first prototype of the system, the defined task will be just the tea making. Each AADS patient using CogWatch system will have a CSS version installed at home.

Figure 2 presents a description of the architecture designed of the CSS for the first prototype and in particular it is composed by the following modules:

- **Fusion module:** This module is in charge of the synchronization and fusion of different kind of data coming from the monitoring devices (i.e.: in this prototype Kinect and Sensorized tools);
- **Scheduler:** This module is in charge of the rehabilitation sessions scheduling;
- **VTE Information Handler:** It is the core module of the client sub-system. It is in charge of handling all the information and triggers other modules when an event is detected.
- **Statistics:** This module is in charge of the generation of statistics based on relevant data obtained from rehabilitation sessions;

- **VTE Repository:** This is the repository where the information related to the patient will be stored (personal information, medical data, treatment information and raw signals acquired during the rehabilitation sessions);
- **Prediction Algorithms:** This is the task model. It takes the outputs of the Recognition Algorithm (sub-task labels) and parses these against a model of the task. When errors are detected it outputs codes to identify the error, the type of error, and the cue that should be given to the participant
- **Recognition Algorithms:** This module takes the outputs from the sensorized objects and detects when particular actions in the task have been performed. It is the module in charge of the detection and classification of errors during the rehabilitation scheduled sessions;
- **Communication Module:** This module is responsible of the communication with the **CSS**. Security protocols are also implemented in this module.

Hereinafter, a detailed description of the CSS software modules is provided.

3.1 Fusion Module

This module acts as the channel between the devices which data is obtained from (Kinect and sensorized objects) and the VTE Information Handler (ANNEX I include an example about the output format file of the Fusion Module).

For the sensor data fusion of the different sensor types, there must be some objective or query to be answered for which knowing the values of all the sensors in combination will allow the question to be answered.

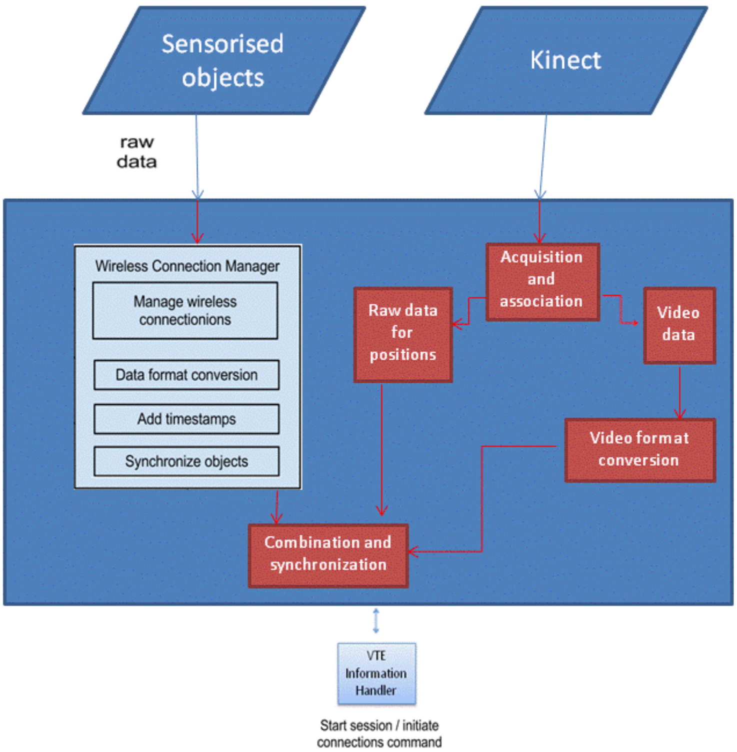

Figure 3 - Fusion module diagram.

Sensor data fusion may require the temporal relationship of the sensors to be known to a good certainty. With enough sensors located across an area, it becomes possible to infer the spatial/temporal dependence of a variable if the process is ergodic. Sensor data fusion can provide means to identify information that would not be possible with any single sensor, if the phenomenon is sufficiently large. To achieve all of these goals, different processes or stages are implemented in the fusion module.

As seen in Figure 3, the inputs of the module are:

- The information provided by the accelerometers and force sensors from the sensorized objects.
- The hands positions and video streaming from Kinect.

The module outlines several stages or processes for data fusion:

- Acquisition and association: this first level aims at acquiring the data from Kinect and classifying it by separating the raw data (hands positions) from especially, the video streaming for a parallel and different analysis.
- Video format conversion: this stage is focused on the conversion of the video format obtained from Kinect. The thing is that Kinect records the scenario environment using a specific format which can only be read by using a specific program from Kinect Studio. So, this stage transforms that specific format into a common one.
- Wireless connection manager: meanwhile, this stage is only focused on obtaining the data from the sensorized objects by managing the Bluetooth communications, processing and synchronizing their own information.
- Combination and synchronization: finally, all the information already processed is combining and synchronizing in this level. So, that sensors data is combined into a specific file to ensure reliability and accuracy.

As shown in the figure, the VTE Information Handler, besides reading the information provided by the fusion module, acts as a trigger in order to communicate with the wireless objects.

So, the module will deliver as outputs a file with the corresponding data from hands positions, accelerations and forces well structured, and a task video in a common and easy to read format. The thing is that data fusion is a multi-layered process of refining the sensor inputs, first by collecting the raw data and video, then processing that data, and finally structuring and reorganizing the info for delivery.

3.2 VTE Information Handler

It is the core module of the client sub-system. It is in charge of handling all the information and trigger a dedicated module when an articular event is detected.

This module is one of the three with access permission to the VTE Repository. For this reason it will be the mask between other modules that want to communicate with the local data bases. While this module is activated the Scheduler and the Statistic module will be disabled.

The Information Handler is in charge of avoiding the system to collapse by giving more priority to processes that leave pending of information other modules, locking them.

The general function of the Information Handler is to select in dependence of priority tables what are the most important inputs and outputs. See Figure 4.

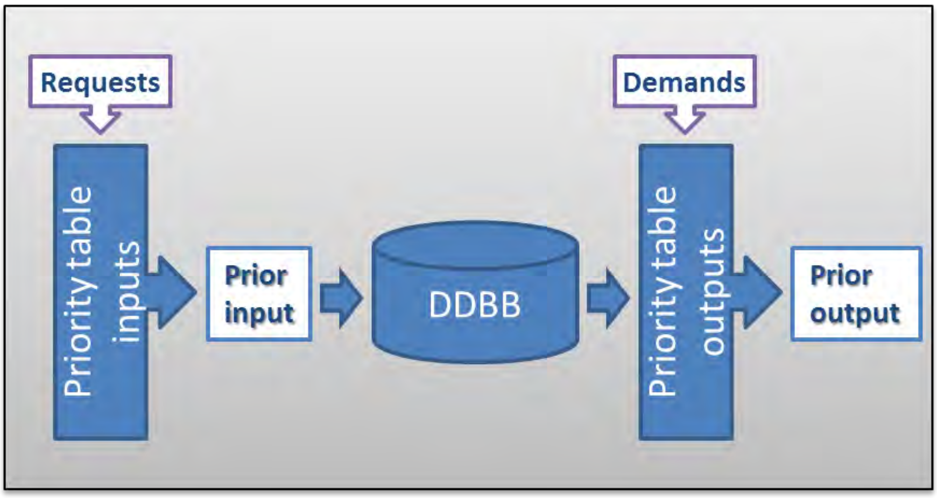

Figure 4 - Information Handler diagram.

The interactions between the modules are supervised by the Information Handler.

Fusion Module interacts with the data base only in case that the session is finished and the video and the text with the information form Kinect and sensorized objects is stored. The main interaction of Fusion module is between this module and the Recognition Algorithm. The Information Handler links the current array of data from Fusion Module and sends it to the Recognition Algorithms module. At the same time the Information Handler saves in a temporal text file every array that receives during the session. Another interactions of the Fusion Module, is the activation and idle of the sensors when start/stop buttons of the VTE GUI are pressed.

Recognition Algorithms module, must start their work with the session and consequently end with it. The recognition will be subjected to the data incoming from Fusion Module.

The Prediction Algorithms module is in charge of giving the errors codify and send them to the Information Handler. That information is the principal component for the cueing system of The VTE GUI and if a fatal error or danger for the patient is detected system will immediately actuate. Also errors are stored at the errors register on the VTE Repository. In order to save resources the Prediction Module will be ignored during the patient assistance request explained in D.2.2.1.

The VTE GUI module needs from the VTE Repository multiple graphic resources and, for this reason, the interaction between VTE GUI and the VTE Repository will be a common process. Furthermore, it will be necessary for this module to acquire the cueing for the current error with higher priority than other callings to the VTE Repository. At last, the interaction with the Scheduler module will be reflected in the warning of a new session and the access to the calendar for task planning.

The following table, Table 1, resumes the messages that this module handles.

Module	Information shared between both modules	Module
Fusion Module	Save video at the end of session	VTE Repository
	Save Kinect hands positions/sensorised objects data	
Prediction Algorithms	Save errors in the error table	
VTE GUI	Save/delete task in calendar	
	graphic resources: images	
	graphic resources: simulations	
	graphic resources: audible messages	
	graphic resources: text messages	
	Languages: application strings	
	Cueing for current error	
	Activation: Start button pressed	Prediction Algorithms
	Send error to the current error array of VTE GUI	
	Patient assistance request	
	Activation: Start button pressed	Recognition Algorithms
	End of session: Stopt button pressed	
	Activation: Start button pressed	Fusion Module
	End of session: Save data	
	Warn of new session	Scheduler
Fusion Module	Send sensor´s data for analisys	Recognition Algorithms

Priority
Highest
High
Medium
Low
lowest

Table 1 - Interactions supervised by Information Handler module.

Notice that the inherent priorities of the messages are codified by the colour hierarchy, but, the priorities of the errors, are intrinsic codified.

3.3 Scheduler

It is the module in charge of the scheduling management. It will launch a new rehabilitation session and save the details of a new scheduled session in the DDBB (VTE repository).

This Module will always be working while the system is in idle mode. The Scheduler will be checking continuously the following upcoming task in the time table while the system is idle. The time table will be set by the VTE-GUI module and the Web portal and will include date, time and type of task. The Scheduler is one of the three modules that can access to the local data base and also communicates with the VTE Information Handler.

See Table 2 with Input/output information below:

Input from…	**Data format**	**Output to…**	**Data format**
VTE Information Handler **VTE Repository**	Date and task of a new session	VTE Information Handler VTE Repository	Trigger Query to the DDBB table

Table 2 - Input/output table for the Scheduler module.

The following diagram explains how the module works. See Figure 5.

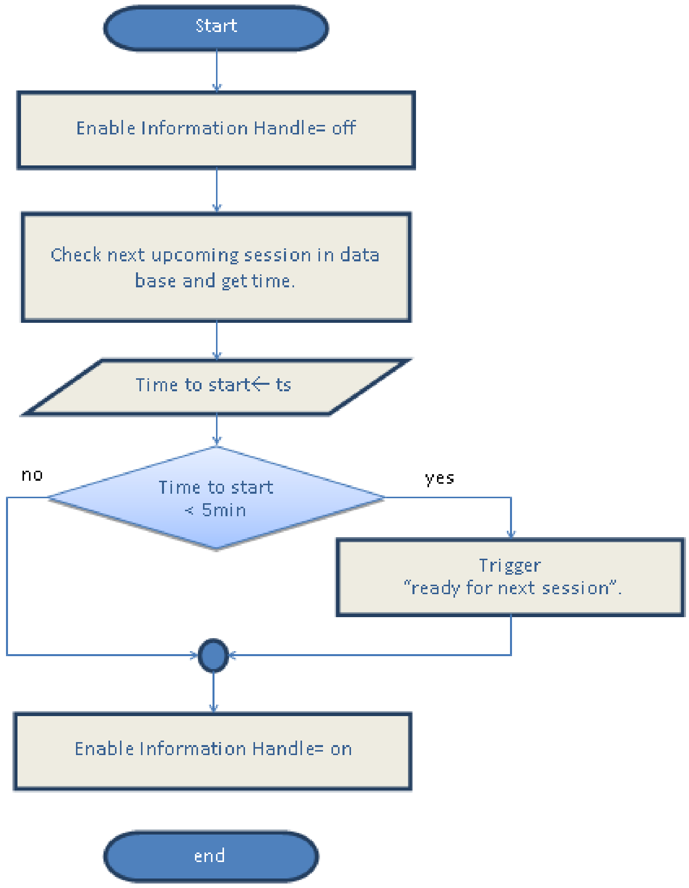

Figure 5 - Scheduler diagram.

First the system is activated by the Information Handle module that will specify if it´s a trigger checking that will take place by different methods.

The first action that the system does is disabling Information Handle module and the Statistics module for avoiding collision in the access to shared resources of the VTE Repository.

The trigger checking is called periodically while no CogWatch session is activated. This method is in charge of comparing the current time with the next soonest upcoming task. If the next task is programmed to take place in the following 5 minutes the method will return a trigger request to the Information Handle and will enable that module. Then the Handle Information module will start the task assistance and disable the Scheduler module.

The output trigger will activate a watch vibration, will trigger the data acquisition and will display in the VTE monitor a message to inform the patient that the next rehabilitation session is ready.

The clinician is the only responsible for programming the sessions.

3.4 VTE Repository

The ***VTE Repository*** is to manage generic but essential information about the users of the CogWatch System and the data coming from the scheduled rehabilitation sessions. This repository is allocated in the VTE and it is used to store patient information together with the raw data acquired by the sensors, the results of the processed data and the session"s statistics of each user.

In particular, the VTE Repository includes:

- Personal information about the patient (Name, Surname, Address, CogWatch ID, Address, ...);
- Medical data;
- Treatment information;
- Raw signals acquired during the rehabilitation sessions;
- Results of the rehabilitation sessions (as results of the recognition algorithms)
- Statistics;
- Caregiver and emergency services contact information;
- CogWatch service data (i.e.: healthcare centre and professionals assigned);
- Scheduled rehabilitation sessions.

3.5 Prediction Algorithms

3.5.1 Action prediction in the first CogWatch prototype

Action prediction in the first CogWatch prototype is the responsibility of the Task Model (TM). The inputs to the TM are the sub-goal labels that are output from the automatic action recognition (AAR) system. These sub-goals correspond to the second level of the task making tree from D1.1 “Report on scenarios”. The outputs from the TM are “cue prompts” that are passed to the VTE Information Handler in the event that the participant makes an error, or an indication that the task has been completed successfully.

Options for the TM and the AAR systems were discussed in detail in D3.1 “Report on action recognition techniques” and the rationale was given for the choices of the TM and AAR system for the first prototype. These components are described in detail in D3.3.1 “Report on predictive models 1”. Only a brief overview is given here.

3.5.2 The Task Model

As explained in D3.1, the TM in CogWatch prototype 1 is based on a Markov Decision Process (MDP). The states of the MDP correspond to sequences of sub-goals that can be extended to a complete, successful instantiation of the tea making task. Associated with each state are a set of potential state transitions, corresponding to sub-goals which are valid extensions of that state. For example, if the current state corresponds to [“fill kettle”, “boil water”, “add water to cup”] then potential transitions would be to the states corresponding to:

- [“fill kettle”, “boil water”, “add water to cup”, “add teabag to cup”]
- [“fill kettle”, “boil water”, “add water to cup”, “add sugar to cup”]
- [“fill kettle”, “boil water”, “add water to cup”, “add milk to cup”]

When a sub-goal is output from the AAR system it is evaluated against these transitions. If it corresponds to a valid extension of the current state, then the appropriate transition is taken and the system moves into the corresponding new state. In addition to the sub-goal label, the AAR system outputs timing information, indicating the start and end times of the sub-goal. This information is used to update the information in a “history vector” in the current state and this vector is passed to the new state. In this way, in addition to the sequence of completed sub-goals that constitute the state, the system also has access to information about the time taken to complete each sub-task, the total time taken to reach the new state, and any costs that have been incurred.

If the sub-goal that is output from the AAR is not a valid extension of the current state, or the cost function exceeds a given value (for example, because of the delay in completing the next sub-goal) then the system remains in the current state and a cue prompt is passed to the VTE Information Handler (Figure 2). The data structure of the cue is a vector containing the ID of the the cue that should be sent to the subject, its priority (Fatal, non-Fatal…or Level_1, Level_2…), its number (CA#1, CA#2…), and the next legal action predicted by the algorithm, if applicable.

The error types and the corresponding cues have been agreed with psychologists at TUM and UOB-Psychology. An example of the Error Table for the tea making task with milk and sugar is included in appendix II.

3.5.3 Coping with uncertainty

One issue with this type of TM is that it is not well equipped to accommodate errors in the output of the AAR system. If the system is in state s_1 then in a conventional MDP the probability P (s_2 | s_1, A) of moving to state s_2 depends on s_1 and the sub-goal A that has been executed. In practice, A is unknown and the TM must make do with a, the output the AAR system when sub-goal A was performed by the participant. This requires an extension of a MDP called a Partially Observable MDP.

The use of POMDPs is discussed in more detail in deliverable D3.3.1 “Report on predictive models 1”. However, from the perspective of the VTE Information Handler, the inputs to and outputs from the TM are the same as for a MDP.

3.6 Recognition Algorithms

3.6.1 Automatic activity recognition (AAR)

Options for the AAR system were discussed in detail in D3.1 “Report on action recognition techniques” and the rationale was given for the choices of the AAR system for the first prototype. The AAR system is described in detail in the M12 deliverable D3.3.1 “Report on predictive models 1”. Only a brief overview is given here.

The inputs to the AAR system are the outputs of the Fusion Module (Figure 2). The Fusion Module synchronises the outputs from the instrumented devices (for example, the instrumented coasters) attached to the objects involved in the task, with hand-position data detected by Kinect. It collates all of this data into a single feature vector, at a typically frame rate of 200 Hz. The outputs from the AAR system are sub-goals corresponding to the second level of the tea making task tree from D1.1 “Report on scenarios”. These are passed to the TM.

3.6.2 Hidden Markov Model (HMM) based sub-goal detection

The arguments for using an HMM-based activity recognition system in the first CogWatch prototype were presented in D.3.1 “Report on action recognition techniques”.

Prior to the start of the project it was intended that the first prototype would exploit an existing real-time HMM-based speech recognition system. However, there are fundamental differences between speech recognition and activity recognition. For example, in the former it can be assumed that the signal corresponds to a well-ordered sequence of words, but this is not necessarily the case in activity recognition, where sub-goals can overlap or co-occur. In a simple speech recognition system, all valid word sequences are compiled into a single integrated grammar network. Recognition is then the process of finding the route through this network that achieves the most probable match with the acoustic data.

To accommodate the partially-ordered structure of sub-goals, the CogWatch AAR is being implemented as a set of parallel, HMM-based sub-goal detectors (this was described in D3.1). The input to a sub-goal detector is the sub- vector from the Fusion Module corresponding to sensors associated with the objects that are relevant to the sub-goal. For example, the system responsible for detecting the “pour milk into mug” sub-goal requires sensor data from the instrumented coasters attached to the milk-jug and the mug, plus the Kinect hand-coordinate data. The detector includes the relevant sub-goal model (in this case a HMM of the “pour milk into mug” sub-goal) and a “background” model to accommodate any activity involving the jug and mug which is not the “pouring” sub-goal (for example „toying“ with the jug, the jug at rest). The sub-goal detector continuously compares the input sequence with the “sub-goal” and “background” models and the sub-goal is detected when its model has a higher probability than the background model.

3.6.3 Preliminary experiments on sub-goal detection

Preliminary experiments have been conducted using the outputs of a prototype instrumented coaster attached to a jug, to detect the “pour” sub-goal. These experiments are described in detail in deliverable D3.3.1 “Report on predictive models 1”. In summary, a detection accuracy of 70% has been achieved for the “pour” sub-goal. It is hoped that this represents a lower-bound on performance, for the following reasons:

- The experiment was conducted using only sensor data from a single instrumented coaster attached to a jug. In the first prototype it is envisaged that the input to the "pour" sub-goal detector will also include data from the instrumented coaster attached to the „receiving" mug plus hand coordinate data from Kinect,

- The „background" data in the training and test sets corresponds to a range of „non-pouring" movements of the jug, which are probably more extreme than those that would occur naturally in actual trials.

The experiments have highlighted problems with the sensor data which will require further investigation. For example, the three Force Sensitive Resistors (FSRs) attached to the coaster return consistent values when the jug is raised and not resting on the work surface, but variable values when it is at rest on a surface. In the current experiments this was resolved using a simple thresholding technique. However, a more sophisticated approach is needed if the coaster is to detect changes in the weight of an object, due, for example, to the addition of milk to a mug. These issues are discussed in detail in D.3.3.1.

3.6.4 Implementation of the AAR

The AAR is being implemented in C#. It uses the standard format for HMMs and recognition networks (wordnets) from Cambridge University Engineering Department"s HMM Toolkit (HTK). Consequently, components developed and tested offline using HTK can be incorporated immediately into the CogWatch AAR.

3.7 Post-processing Module +Statistics

This module is in charge of the generation of statistics based on relevant data obtained from the VTE Repository. Currently, the data thought to generate statistics is composed by:

- Type of errors.
- Type of cues.
- Current state in which errors occurs. (Time, subtask)

So, the information presented above is the input to this module, of course, besides the period of time in which the patient commits errors.

As shown in the Figure, the module reads the corresponding data from the VTE Repository and several graphics are represented in order to show the information in a very clear, attractive and easy to understand way to the clinicians and/or people in charge of analyzing the rehabilitation sessions. See Figure 6 - Statistics module diagram.Figure 6.

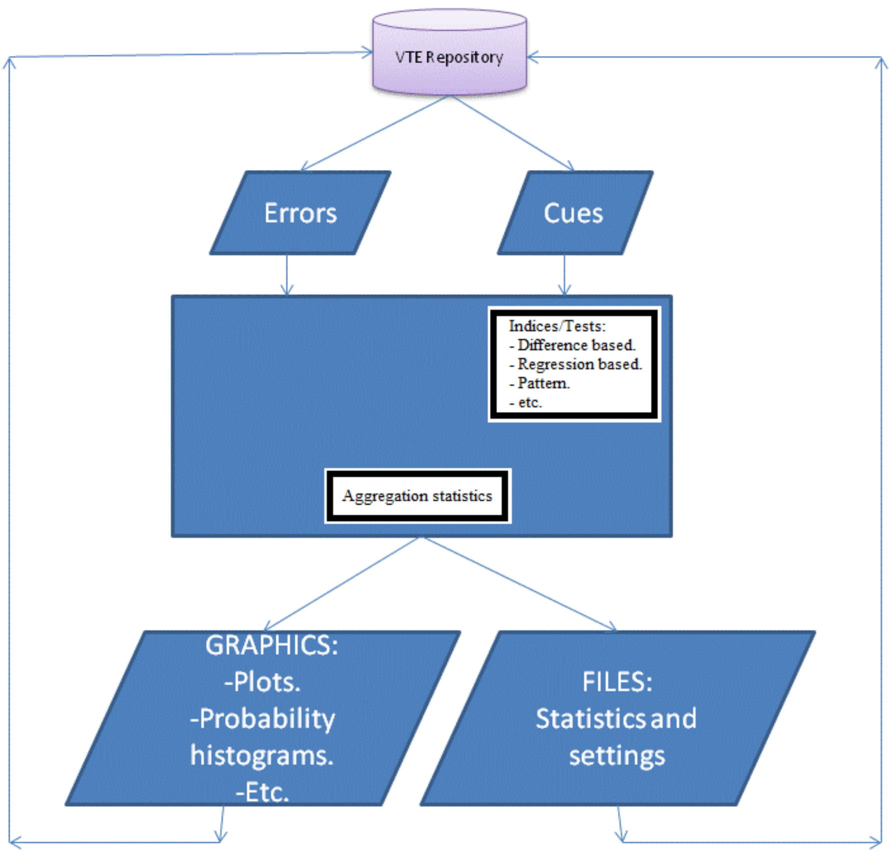

Figure 6 - Statistics module diagram.

It is important to mention that for future prototypes this module will be modified and extended. One of the new implementations will be the post-processing of the video data obtained from Kinect using avataring taking into account the data protection law.

3.8 Communicator Module

The ***Communicator Module*** is responsible to establish and transfer the information between the ***CCS*** and the ***CSS***. In this particular case the Communicator Module located in the VTE will exchange the information with the ***CHS*** sub module of the ***CSS***.

The expected data from the ***CCS*** are the results and statistics of the performed rehabilitation sessions while, for the expected data from the ***CHS***, these concern new scheduled sessions of the rehabilitation session. The communication between the two components is bidirectional and it is independent of the channel‟s nature as well as the protocols used in the low levels of the network stack.

Finally, in order to handle large amount of data and avoid high traffic situations, the ***Communicator Module*** compression algorithms are used to limit the size of the data exchanged. Moreover, an encryption mechanism is implemented in order to secure the channel from malicious attacks using both symmetric and asymmetric encryption.

In order to establish this kind of connection between the communicators, two objects have been created, one for the ***CCS*** and one for the ***CHS*** respectively. The architecture of the ***Communicator Module*** is presented in Figure 7 :

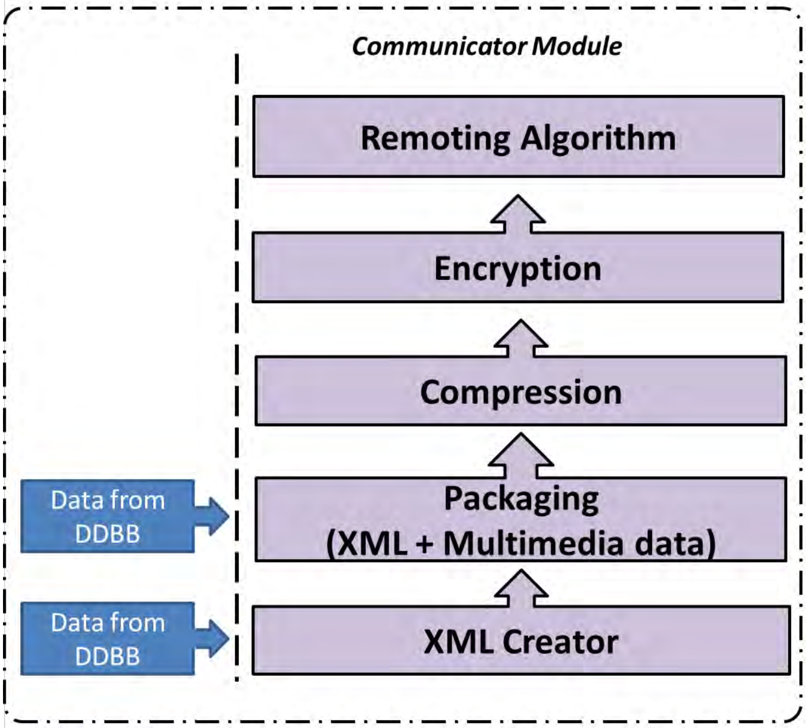

Figure 7 - Communicator Module of CCS

When the ***CCS*** wants to update data from the ***CHS***, it calls the objects of the ***CHS*** unit. Similarly, when the ***CHS*** wants to update data from the ***CCS*** it calls the ***CCS*** object. The Https Channel class is the preferable class to be used for the communication channel, as it provides support for wire-level protection using Secure Sockets Layer (SSL) and authentication using Integrated Windows Authentication or Kerberos, more details about security and protocols are described in section 5.

4. COGWATCH SERVER SUB-SYSTEM

The ***CogWatch Server sub-system (CSS)*** is dedicated to the storage and visualization process of all patient data and rehabilitation sessions statistics. It is designed to assist the clinician in the follow-up of the patient rehabilitation of AADS.

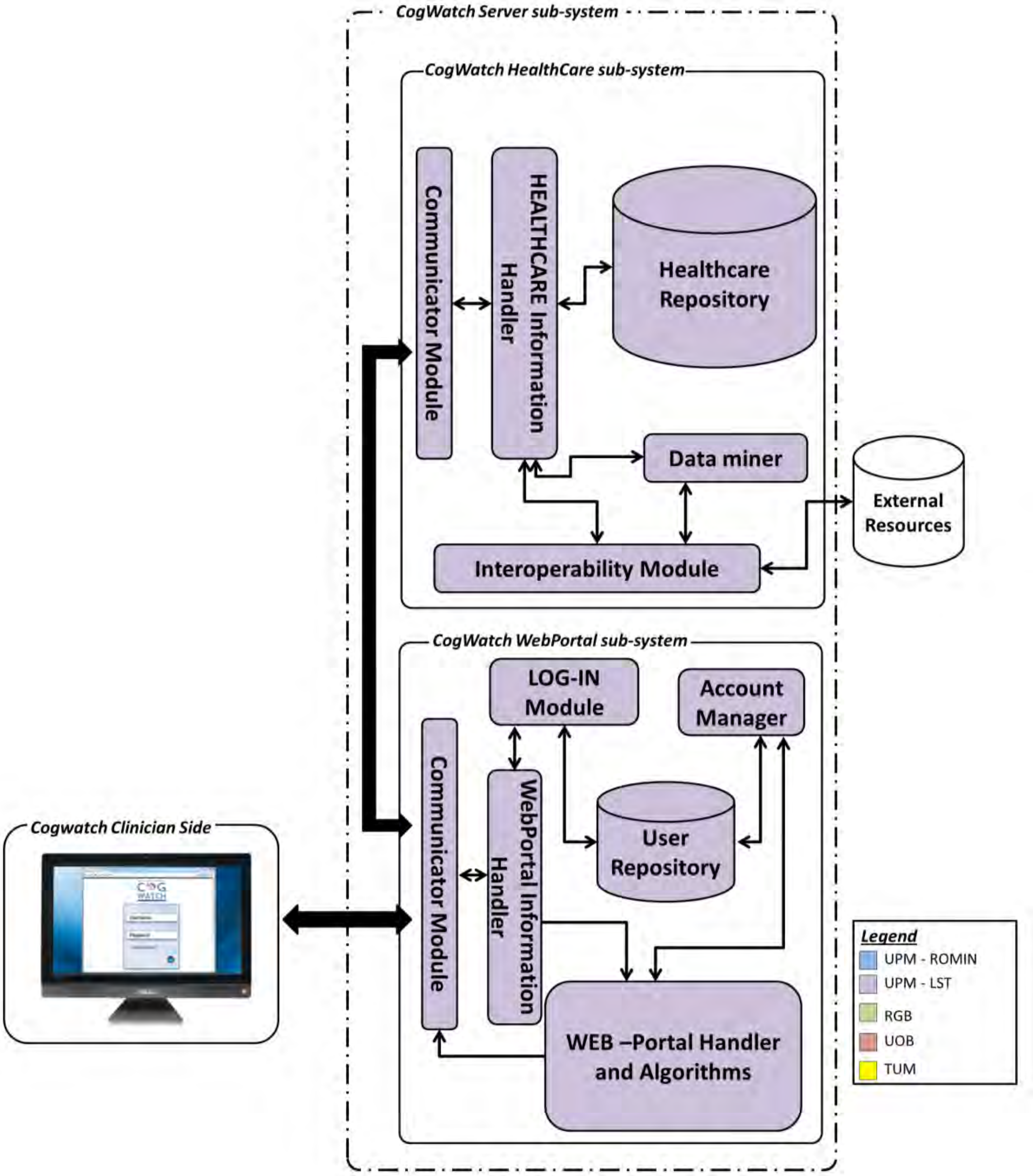

Figure 8 - Cogwatch Server Sub-System architecture

As shown in Figure 8, the ***CSS*** is composed by two different modules, the ***CogWatch HealthCare sub-system (CHS)*** and the ***CogWatch WebPortal sub-system (CWS)***. Detailed information about the ***CHS*** and ***CWS*** are presented in the following sections.

4.1 CogWatch HealthCare sub-system

The ***CHS*** is defined as the remote healthcare server, in charge of communicate with the ***CCS*** and receive from it data and statistics of rehabilitation sessions. The Healthcare ***CHS*** is dedicated to the storage of the medical and personal information of the patient"s assigned to each Healthcare center. Moreover it will contain the results and the statistics of the rehabilitation sessions performed. In the theoretical deployment of the CogWatch system, every Healthcare center, belonging to the CogWatch network, will be provided with the Healthcare Server and it will be adapted to the every healthcare particular system. However in order to avoid the difficulties and restrictions that might be derived from the installation of new software in a healthcare center, a virtual machine will be created for each participant healthcare center of the CogWatch trials. Every Virtual machine will be work as an independent server simulating the feature and characteristics of an independent server.

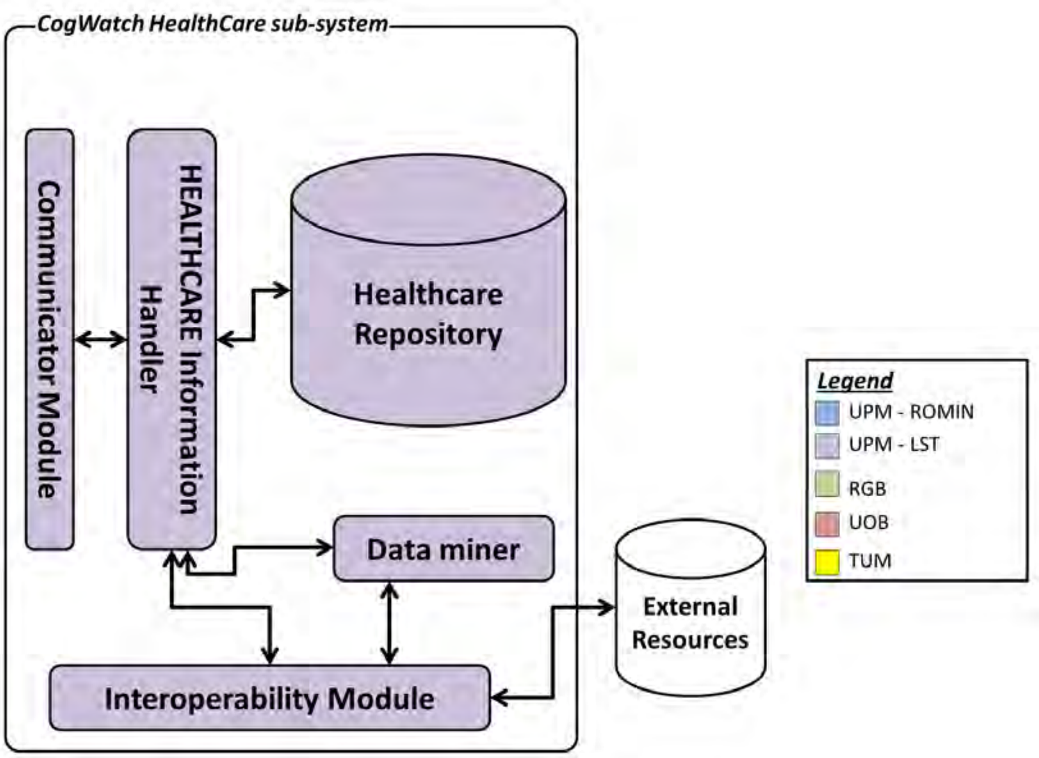

Figure 9 - CogWatch HealthCare sub-system

As shown in Figure 9, the ***CHS*** is composed by:

- **Communicator Module:** This module is responsible of the communication with the **CSS** and **CWP**. Security protocols are also implemented in this module
- **HEALTHCARE Information Handler:** It is the core module of the HealthCare sub-system. It is in charge of handling all the information and triggers other modules when a specific event is detected.
- **Healthcare Repository:** This is the repository where the information related to the patient will be stored, together with the statistics of the rehabilitation sessions. Only data belonging to the patients assigned to the specific healthcare center are stored in this repository.

- **Data Miner:** Generic and customizable algorithms able to face future problems of the system. **<u>It will not be deployed for the first prototype.</u>**
- **Interoperability Module**: This module is in charge of guarantees interoperability with existing and already in use external resources, at the healthcare center. **<u>It will not be deployed for the first prototype.</u>**

Hereinafter, a detailed description of the **CHS** software modules is provided.

4.1.1 <u>Communicator Module</u>

The ***Communicator Module*** is responsible to establish and transfer the information with the communicator module located in the ***CCS*** and in the **CWS**. The communication between the communicators is bidirectional and it is independent of the channel‟s nature as well as the protocols used in the low levels of the network stack. Moreover, an encryption mechanism is implemented in all communicator modules, in order to secure the channel from malicious attacks using both symmetric and asymmetric encryption.

Hereinafter, a detailed description of communication is provided defining different scenarios:

a) CCS → CHS:

This scenario defines the communication between a **CCS** and the associated **CHS**. Once a rehabilitation session is completed, the results are been saved in the ***VTE Repository***. Once the channel is been open by the ***Remoting Algorithms*** of both subsystems, data are transferred to the connected **CHS**. The expected data from the ***CCS*** are the results and statistics of the performed rehabilitation sessions. Once the transmission is completed, the channel is closed and data are been stored in the **CHS** repository following the flow chart described in Figure 10.

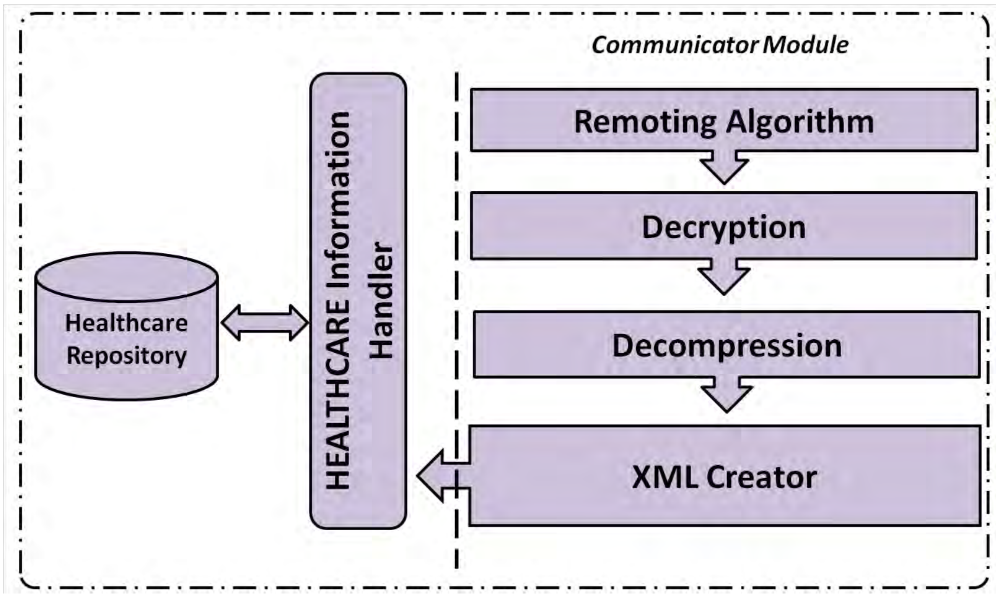

Figure 10 - Communication diagram for incoming messages

b) CHS → CCS:

This scenario represents the communication between the ***CCS*** and the ***CHS***. One a rehabilitation session is scheduled in a remote way (see D.2.2.1 for more details), the system is in charge to update the VTE repository sending the information about it.

As showed in Figure 11, once the sessions is scheduled and information are saved into the ***Healthcare Repository***, the Healthcare Information Handler is in charge to retrieve those data from the repository and pass the information to the ***Communicator Module***. It will create the XML file, compress and encrypt it and sent it to the associated **CCS**. This functionality will be not implemented for the first prototype of the CogWatch system.

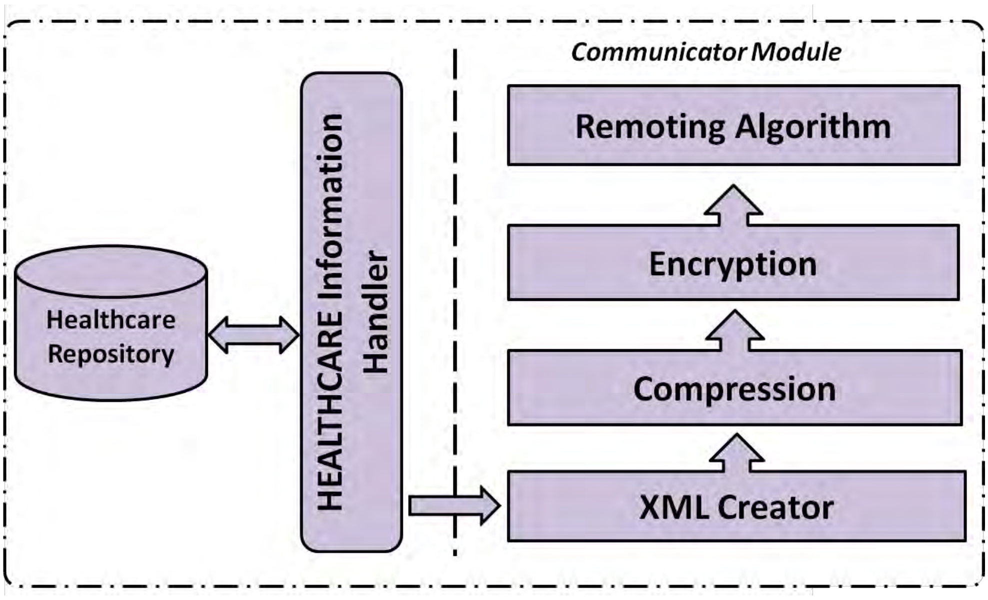

Figure 11 - Communication diagram for outgoing messages

c) CWS → CHS:

The Communication between the **CWS** and the **CHS** is needed in order to retrieve data from data from the Healthcare Repository and show them in the clinician side. When the clinician select the option view and the session statistic to analyse, the Communication module located in the will create the query message and will send it to the assigned CHS. Roles and permission will be also managed by the **CWS** modules. The CHS Communicator Module starts to process the message as soon as it receives it as shown in the overall workflow diagram for the incoming message (Figure 10).

d) CHS → CWS:

The communication between the **CHS** and the **CWS** is started when the CHS receive a data request query. Once the Message is correctly decrypted and decompressed, as show in Figure 10, the ***Healthcare Information Handle*** is the module in charge of retrieve the information from the Healthcare repository create the response and send it to the ***Communicator module*** of the CHS. As show in Figure 11, the outgoing message will be created starting from the information retrieve from the database and send to the CWS

4.1.2 HEALTHCARE Information Handler

The HEALTHCARE Information Handler (HIH) is the core module of the HealthCare sub-system. It is in charge of handling all the information and triggers other modules when a specific event is detected.

The HIH is the module in charge of centralizes the activities of the CHS, controlling the data flow and avoiding the collapse of the subsystem. The HIH is developed in a modular way, allowing future implementation and introduction of new modules in the CHS.

During the first prototype the HIH is designed to manage the data flow between the Communicator Module and the HealthCare Repository. In particular, when the result of a new rehabilitation session is received, the HIH is the module in charge of save the data to the HealthCare Repository identifying the correct table. In the other hand, when the CWS send a request to the CHS, the HIH is in charge of retrieve the data from the repository and pass them to the Communicator module for the communication procedure.

4.1.3 Healthcare Repository

The aim of the ***Healthcare Repository*** is to store information about all the users of the CogWatch System assigned to the Healthcare center (both clinicians and patients). The ***Healthcare Repository*** ***will not be linked*** to any other form of ***Electronic Patient Record*** and will only include data from the CogWatch system. This repository is allocated in every ***CHS*** and it is accessible only through the ***Healthcare Information handler***.

In particular, this repository includes:

a) In case of **Patient**:

- Personal information about the users (Name, Surname, Address, CogWatch ID, Address, ...);
- Medical information (including treatment and rehabilitation);
- Results of the rehabilitation sessions
- Statistics (according to the statistics generated in the ***CCS***);
- Scheduled rehabilitation sessions.

b) In case of **Clinician**:

- Personal information about the users (Name, Surname, Address, CogWatch ID, Address, ...);
- Assigned patients;
- Scheduled rehabilitation sessions

In order to avoid large amount of data, only processed data will be stored in the ***Healthcare Repository***.

4.1.4 Data miner

The Data Miner module functionality is not defined for the first prototype of the CogWatch system. The idea is to have remote algorithms able to face future problems and analyse data in the server side of the system, if necessary (e.g.: an Alarm Manager) . As the functionality of the Data Miner is very specific and not directly evident to the final system users, it required in-depth discussions with clinicians to reveal the usefulness of this module during the functional specifications phase. The data miner functionality concentrates at exploiting the available information in the **CHS** to produce ad hoc and customizable algorithms for the evaluation and analysis of the results of the patients‟ rehabilitation sessions (i.e.: algorithms that can make associations among various conditions or algorithms for the analysis of the evolution of the therapy among different patients).

4.1.5 Interoperability Module

CogWatch system is an integrated care system that aims at supporting clinicians for the cognitive rehabilitation of patients affected by Apraxia and Action Disorganization Syndrome. CogWatch pilots will be hosted by healthcare centers offering different facilities for electronic health record management within Clinical information systems. Within this context, we can envision that at least fundamental information should be exchanged by the CHS with external Clinical information and legacy systems and that this exchange should conform to the HL7 standard. The main types of exchanged information between the CHS and other CISs can be the following (if available and with the direction of the information flow as seen from the CHU):

1. General patient information (demographic data): *inbound/outbound*

2. Patient anamnesis (previous diseases and corresponding treatments/medications): i*nbound*

3. Reports on patient pathology and evolution: *outbound*

4. Medication types and schedules related to CogWatch: *outbound*

Additional types of medical information to be exchanged will be considered at a later stage depending also on the attainable knowledge about the external Clinical information and legacy systems available at CogWatch pilot sites.

This module will not be implemented for the first prototype of the CogWatch System and its development is strictly linked with the pilot site policy.

4.2 CogWatch WebPortal sub-system

The ***Web Portal Sub-system*** is dedicated to the allocation of the medical web portal and the account information repository. This will be an independent and unique server. During the development of the CogWatch system the Web Portal Sub-system will be installed at UPM in Madrid, Spain. The Web Portal Sub-system will contain a Communicator Module, a Log-in Module, an Account Manage, the WEB-Portal handler and Algorithms and the User‟s repository.

Both the inputs (from the Healthcare sub-system) and outputs (to the CogWatch medical side) of the Web-portal Sub-system will be HTTP and HTTPS request-responses.

The ***CWS*** is the sub-system in charge of presenting to the healthcare personnel the data and statistics about the patients and about the rehabilitation session. It will be installed in an external and unique server.

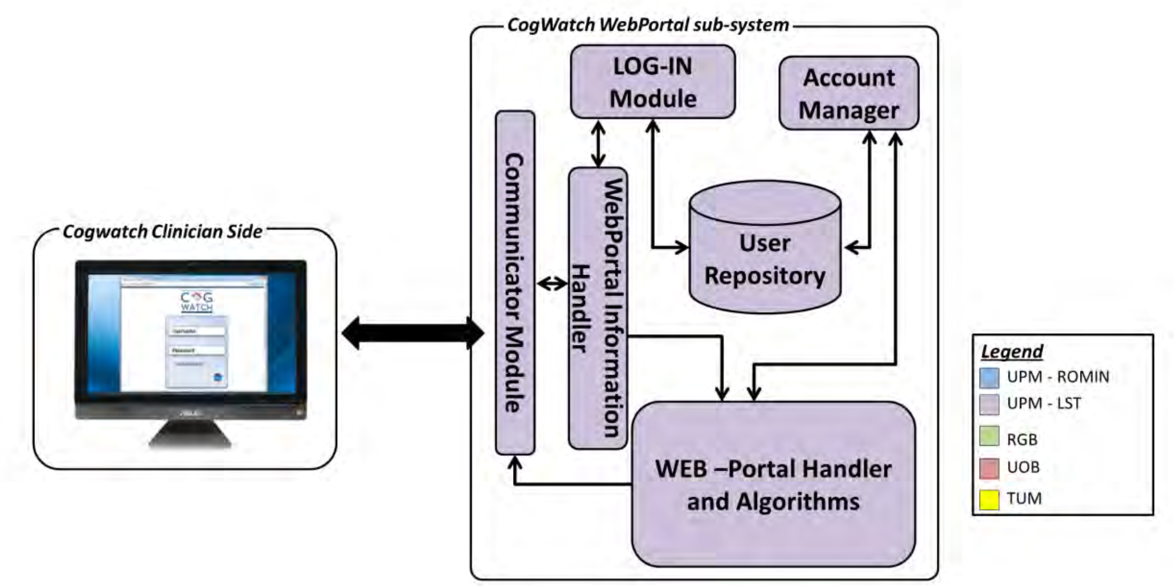

Figure 12 - CogWatch WebPortal sub-system

As shown in Figure 12, the ***CWS*** is composed by:

- ***Account Manager***: is the module used to administer user accounts for users.
- ***LOG-IN Module:*** is the module that allows secured, role-based, multi-device access to the system data and for the definition/modification of the access authorization to the patient data, as described by relevant legislation on patient data ownership.
- ***User Repository: it*** contains the user access information, authorization information and user action logs.
- ***Communicator Module:*** This module supports the multi-directional communication between all CogWatch subsystems.
- ***WebPortal Information Handler***: it is the module in charge of the information management exchange between different sub-modules and to encapsulate the

centralized system‟s logic and ensure all users initiated or system initiated actions are performed smoothly, and the User Repository, in which all data are recorded.

- ***WEB-Portal Handler and Algorithms***: it will be the module that contains all algorithms of the web portal and it will manage the data in order to return the correct information to the user.

4.2.1 Communicator Module

The ***Communicator Module*** is responsible to establish and supports the multi-directional communication with the communicator module located in the CHS. The communication between the communicators is bidirectional and it is independent of the channel‟s nature as well as the protocols used in the low levels of the network stack. Moreover, an encryption mechanism is implemented in all communicator modules, in order to secure the channel from malicious attacks using both symmetric and asymmetric encryption.

The communication between the CWS and the CHS is needed in order to retrieve data from data from the Healthcare Repository and show them in the clinician side. Both subsystems are communicated using a XML encrypted message with results (***CCS*** → ***CHS***) or data query (***CHS*** → ***CCS***) of the information request by the users of the ***WebPortal***. More details about the defined scenarios are presented in 4.1.1.

4.2.2 LOG-IN Module

The ***LOG-IN Module*** is the module in charge of allows secured, role-based, multi-device access to the ***WebPortal*** and for the definition and modification of the access authorization to the patient data, as described by relevant legislation on patient data ownership. This module accesses the User Repository, in order to retrieve users‟ access and authorization information.

Figure 13 - Log-in window of the CogWatch Web Portal

The purpose of the ***LOG-IN Module*** is to provide a secure mechanism by deploying the traditional security measures (access control, authorization) for the CogWatch system. In the initial access window or page (Figure 13), the user can log into the System, introducing the provided username and password, and it will automatically redirect to the appropriate page, according to his role.

The role type of the user disallows users to access information without permission, for instance an administrator cannot access critical information about patients or rehabilitation sessions. More information about the roles and permissions of the users are given in **Error! Reference source not found.**.

If there is an attempt to access a page without the required log-in information, the user is redirected to the initial log-in page. The initial access page can be also used to recover the access credentials, in case of users will lose them (see **Error! Reference source not found.**).

4.2.3 WebPortal Information Handler

The Web Portal Information Handler (WIH) is the module in charge of the management of the information exchange between different sub-modules and to encapsulate the centralized system‟s logic. The functionalities of this module are based on the same ideas of the Information handlers described in previous sections (3.2 and 4.1.2). The interaction between the WIH and the others modules of the CWS are described in Table 3

Module	Action	Description
WCM	INPUT	The WIH is called by the WCM when information to be showed in the web portal is received from the CHS. The WCM is in charge of trigger the correct sub-module.
WCM	OUTPUT	The WCM is triggered by the WIH when is necessary to show new data to the clinicians. The WIH will pass the query information to the WCM.
LIN	INPUT	During the Log-In procedure, the WIH is called by the LIN in order to trigger the algorithm in charge of the username-password verification. In this case the WIH is also in charge of retrieve data from the UR
LIN	OUTPUT	The WIH will pass the result of the username-password verification to the LIN in order to allow (or not) users to get in to the system
AM	INPUT-OUTPUT	In this case the WIH is the module in charge of the communication between the AM and the UR. Data are been retrieved, saved or modified into the UR according to the AM functionality (see 4.2.5).
WPA	INPUT	The WPA will call the WIH once a new request of data is needed, in order to show it to the users. The WIH is the module in charge of the communication between the WPA and the WCM or the UR.
WPA	OUTPUT	Once a data request is finalized, the WIH will trigger the WPA and will pass to it the requested information. Thanks to this procedure the WPA will be able to show the results to the end user.
UR	INPUT-	The WIH is the only module allowed to create, modify or change tables in

OUTPUT	the UR, as well as data stored in them.

Table 3 - Interaction between WIH and other modules

4.2.4 <u>User Repository</u>

The User Repository of the CWS contains the information related to the patient are stored in order to allow the log-in procedure and to define the connection with the CHS.

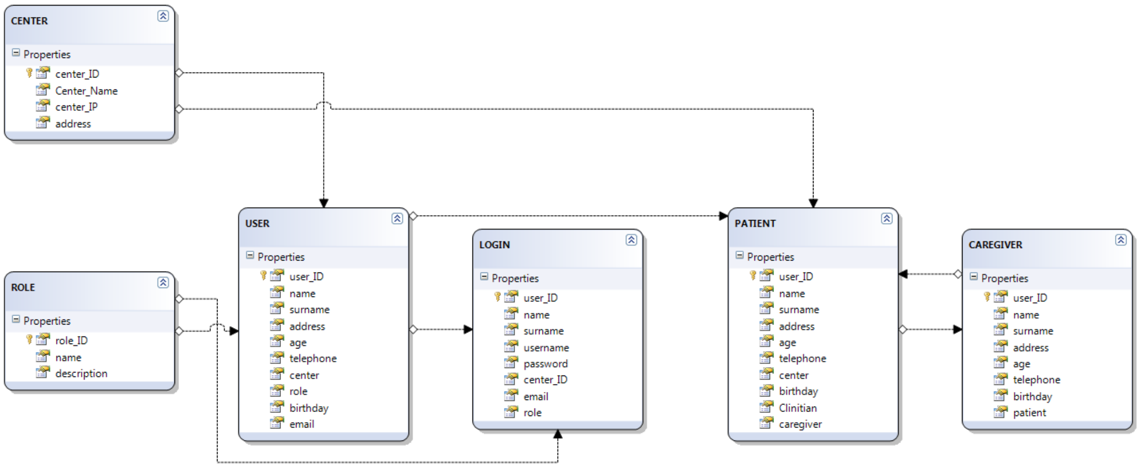

Figure 14 - Preliminary version of the User Repository

Figure 14 shows the preliminary version of the User Repository and in particular:

- **CENTER:** This table contains the information about the different centers (UPM, UoB and TUM) of the 3 different pilot sites o the CogWatch project.
- **ROLE:** This table identifies a unique ID for the users of the system, as described in **Error! Reference source not found.**.
- **USER:** In this table are saved the CogWatch registered user"s data. This information is used by the CWS for the personal set up of the web portal and for the permission procedures.
- **LOGIN:** This table contains the log in information of the registered users. Sensible data as username and password will be coded and encrypted to ensure the security of the system.
- **PATIENT:** This table contains the general information of the patients registered in the CogWatch systems as well as the information about the assigned clinician and caregiver.
- **CAREGIVER:** In this table, general information of the caregiver is saved.

The presented repository will be implemented in the first prototype. Further development and improvement will be discussed in future deliverables.

4.2.5 Account Manager

Account Manager is the module in charge of creates, delete and maintain user accounts for the CogWatch Web Portal. The following actions are the core functionalities of the module:

- Create an account and specify its roles and permission;
- Modify an account information;
- Delete an account.

The principle user of this module is the system administrator, although some limited functionalities (e.g. password change) are also accessed by other users. The system administrator uses the module to create a system account with specific role and permission (see **Error! Reference source not found.** for more details).

Figure 15 show an example of how the account manager can be used for the register protocol. The first step of the protocol (1) is the registration request from a user that can be done filling the on-line form (***not in first prototype***) or sending an e-mail with personal data to the ***Web System Administrator***. Once data are been confirmed with the associated Healthcare center (2), the Administrator will introduce and confirm data of the web For creating the patient profile, including the permissions and roles associated to the user (3). When data are introduced into the system, the Account Manager is the module in charge of generates automatically the user profile associating a username and a password (4). A register confirmation, together with the generated log-in information, will be send to the user to confirm the registration (5). In order to improve security level, the system will require to the user to change the password in the first access to the system (6).

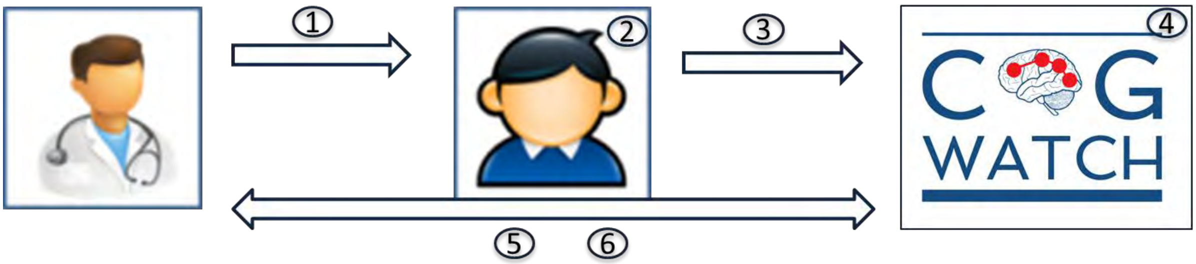

Figure 15 - Account Manager register protocol

4.2.6 WEB –Portal Algorithms

The WEB-Portals Algorithms module (WPA) is in charge of the visualization of the data retrieved from the CHS. Algorithms will be also used for future implementation. It will be the module that contains all algorithms of the web portal and it will manage the data in order to return the correct information to the user. This module received the information from the WIH (usually a XML file) and it is in charge of automatically creating the Web page according to the user‟s requests. In order to get it, information and data processed by other modules are needed, in order to show the information in the correct way.

The first page create by the WPA is the log in window (Figure 13). Once the log-in procedure is finalized and the session key is created, the WPA will be able to create the pages according to the user profile and permissions (**Error! Reference source not found.**) and according to their requests.

Appendix IV shows some examples of the automatically created pages.

5. NETWORK AND COMMUNICATION

5.1 Communication technologies and standards

Communication technologies are important issues to take in account during the development of a personal health system like the CogWatch. It is important to identify the different environment and the components involved in the system before the definition of the communication technologies. Each environment, or sub-system, needs a different implementation of the communication protocol that depends on the characteristics and the features.

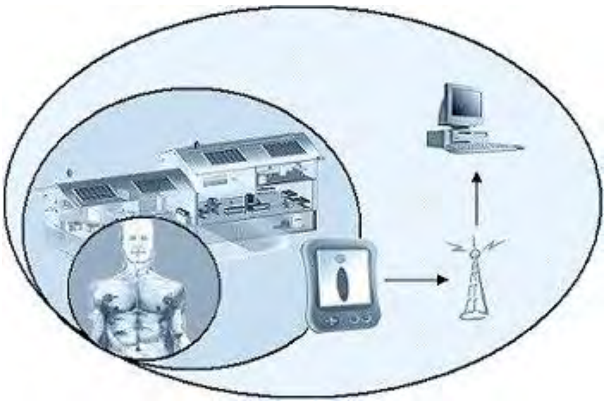

Figure 16 – Different environment in GogWatch

In CogWatch, two different areas are defined, the CCS and the CSS, in which multiple communication standards are used. Hear in after, a detailed comparison, analysis and identification of most suitable existing communication technologies and standards will be elaborated, according to the CogWatch system architecture and functional specifications, as show in Figure 16.

Figure 17 shows the network types including the most well-known technologies.

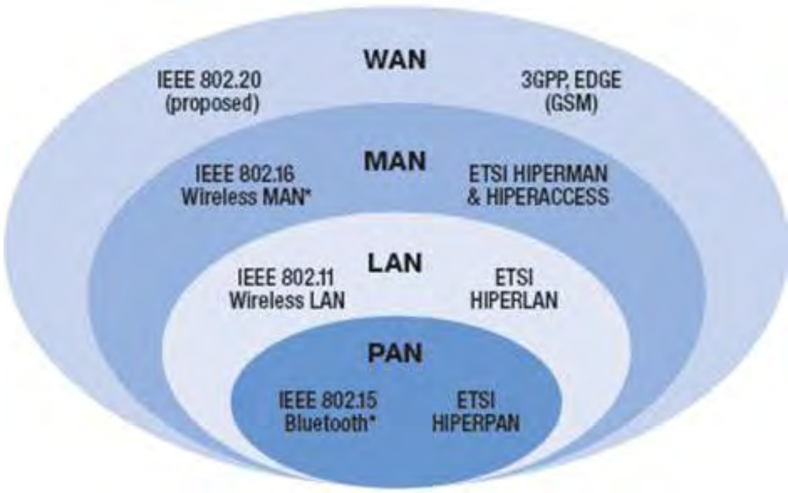

Figure 17 – Global wireless standards

A **Personal Area Network** (PAN) is a data network used for communication among devices close to one person. PAN is usually wireless and used for communication among the personal devices themselves or for connecting to a higher level network and the Internet. A wireless personal area network (WPAN) is a PAN carried over wireless network technologies such as IrDA, Bluetooth, Wireless USB, Z-Wave, ZigBee. The reach of a PAN varies from a few centimeters to a few meters. A PAN may also be carried over wired computer buses such as USB and FireWire.

In the CogWatch project, a PAN is created in the CCS in order to allow the data transmission between the sensors and the VTE. **Bluetooth** standard is the communication technology adopted in the CCS. Bluetooth was selected because it provides a way to connect and exchange information between different devices via a secure, globally unlicensed short-range radio frequency. Bluetooth is a radio standard and communications protocol primarily designed for low power consumption, with a short range (power class dependent: 1 metre, 10 metres, 100 metres) based around low-cost transceiver microchips in each device.

A **Local Area Network** (LAN) or **Wireless Local Area Network** (WLAN) is communication data network used to link two or more computers. It uses radio communication to accomplish the same functionality that a wired LAN has. WLAN utilizes spread-spectrum technology based on radio waves to enable communication between devices in a limited area, also known as the basic service set. This gives users the mobility to move around within a broad coverage area and still be connected to the network. This technology is used in the CCS in order to get the access to internet for the communication protocols between CCS and CSS.

A **Metropolitan Area Network** (MAN) is a computer network that cover up to several kilometers, typically a large campus or a city. A MAN usually interconnects a number of local area networks (LANs) using a high-capacity backbone technology, such as fiber-optical links, and provides up-link services to wide area networks (or WAN) and the Internet.

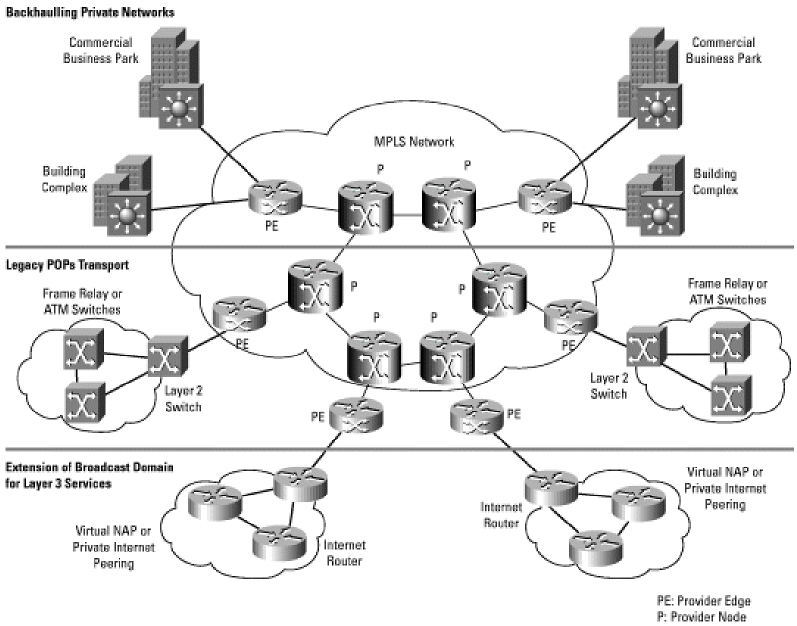

Figure 18 - Example of Metropolitan Area Network

A **Wide Area Network** (WAN) is a data network covering a broad geographical area. WANs are based on the connection of LANs, allowing users in one location to communicate with users in other locations. Typically, a WAN consists of a number of interconnected switching nodes. These connections are made using leased lines and circuit-switched and packet-switched methods. The most presently used WAN is the Internet network. Other examples are 3G and mobile WiMAX networks, which are Wireless WANs. The WANs often have much smaller data rates than LANs (consider, for example, the Internet and Ethernet). WAN in used In CogWatch project for the internet base User interface and for the communication between the different sub-modules.

5.2 Security and Privacy layer

Security and privacy aspects are important issues to be managed during the definition, development and deployment of every ICT system. Since CogWatch system will deal with the transfer storage and analysis of patient‟s data, efficient and secure communication protocols are needed in order to preserve the privacy of the users. The first focused is to ensure the data transmission between CogWatch sub-systems (CPS, CHS and CWS).During the design and development of the first prototype of the system, different issues are considered, and in particular:

- Physical security
- Database and web security
- Access controls
- User authentication
- Data encryption/decryption
- Secure transmission of information

In many case standard protocols are used, even if specific procedures are designed ad hoc for the project. The system provides a secure environment for the storage, access and transmission of information while maintaining the capability to process the acquired data. In the following sections, both the issues of security and privacy in CogWatch system are addressed focusing in the ways to ensure the protection of patient‟s data.

5.2.1 Security

Security is one of the main issues that need to be taken into account during the design and development phases of the whole system. The following paragraphs aim to describe the main methods related to application and system protection.

In CogWatch multiple aspects of security are been considered and implemented, including:

- User authentication
- User permissions and roles
- Data encryption/decription
- Transmission security
- Password recovery process

5.2.1.1 User authentication

Authentication is the method used to identify a user, machine or application and verifying this identity. At the network security, ensures that the origin of a message or electronic document is correctly identified, with an assurance that the identity is not false.

In computer networks and web technologies, authentication is usually done through the use of usernames and passwords. Cross-check data between the username and password is guarantee that the user is authentic. The weakness in such system for transactions that are significant is that passwords can often be stolen, accidentally revealed, or forgotten. A remedy for these weaknesses is the use of digital certificates.

A digital certificate is an electronic document that that uses a digital signature to bind a public key with an identity. The certificate can be used to verify that a public key belongs to an individual. It is issued by a certification authority (CA) and contains the user"s name, a serial number, expiration dates, a copy of the certificate holder's public key (used for encrypting messages and digital signatures), and the digital signature of the certificate issuing authority so that a recipient can verify that the certificate is real. Some digital certificates conform to a standard, X.509, actually an ITU Recommendation.

During the first prototype of the CSS, only a cross-check data between username and password will be implemented, considering that the system will be used in a supervised environment with a restricted number of users. The module on charge of the Authentication is the LOG-IN module described in 4.2.2.

5.2.1.2 User Permission and roles

Once identified and authenticated, the users get a list of permissions that allow them to access specific information and function of the system. A new user is created and is associated with a specific profile (4.2.5), in order to define a set of access rights for each type of user. Examples of access rights are inserting, deleting, updating, and viewing data. Database-specific access rights may be used in conjunction with application specific access rights for controlling the availability of functions to users that may, ultimately, access the system.

In CogWatch project 4 different users" profiles are defined:

- **Administrator**: is the person in charge of maintain and operate the Cogwatch system and network. The Administrator of the system is not allowed to view personal data of the patients and the results of the rehabilitation session. In the first prototype the role of the administrator is to create the users accounts monitor the users" account and verify the identity of them.
- **Clinician**: clinician is defined as the healthcare provider working in a clinic or in a hospital. Usually is identified as the medical doctor that takes in care a specific patient.
- **Therapist**: in the CogWatch system the therapist is defined as the person in charge of the rehabilitation session with AADS patients.
- **Caregiver**: The caregiver is defined as a relative of a friend that helps the patient with his or her activities of daily living.

Table 4 describes the roles and the specific permission of the different users of the Cogwatch system in the first prototype. Roles are defined and assigned by the Account manager, while the permission are assigned before the user authentication by the log-in module. Combining the information, the system is capable to offer to the users only the assigned task and protect the personal data of the patient.

	Administrator	Clinician	Therapist	Caregiver
Create user profile	Yes	No	No	No
Visualize patient personal data	No	Yes	Yes	Yes
Visualize Patients treatment	No	Yes	Yes	Yes
Visualize patient sessions statistics	No	Yes	Yes	No
Add/modify session	No	Yes	Yes	No
Associate Patient/Clinician	Yes	No	No	No
Create Patient Profile	Yes	No	No	No
Modify Patient personal data	No	No	No	Yes

Table 4 - Roles and permission in CogWatch

5.2.1.3 Data Encryption and secure transmittion

Public networks such as the Internet do not provide a means of secure communication between entities. Communication over such networks is susceptible to being read or even modified by unauthorized third parties. Encryption algorithms are needed when sensitive personal data are transferred between different WEB applications. Data need to be encrypted before the transmission and decrypted once are received on the remote application. CogWatch system need to address the issue of data transmission since the monitoring data are obtained in the CPS and transmitted to the CHS and CWS.

Cryptography helps protect data from being viewed provides ways to detect whether data has been modified, and helps provide a secure means of communication over otherwise no secure channels. For example, data can be encrypted by using a cryptographic algorithm, transmitted in an encrypted state, and later decrypted by the intended party. If a third party intercepts the encrypted data, it will be difficult to decipher.

CogWatch is developed in the .NET Framework, and in this case the classes used for develop the encryption is included in the ***System.Security.Cryptography*** namespace. In particular The ***System.Security.Cryptography*** namespace provides cryptographic services, including secure encoding and decoding of data, as well as many other operations, such as hashing, random number generation, and message authentication. This functionality is included in the communicators modules (3.8, 4.1.1 and 4.2.1) of the CogWatch system.

The fisrt protptype of the CogWatch system will be developed in order to work with Hypertext Transfer Protocol (HTTP) standard protocol for the data transmission. The security in the transmission is ensured by the small scale number of the users in the first trial and by the intranet connection. Future implementation of the CogWatch will implement the Hypertext Transfer Protocol Secure (**HTTPS**). HTTPS provides authentication of the web site and associated web server that one is communicating with, which protects against different attacks as the example of the **man-in-the-middle**.

One of the security protocol developed for the CogWatch system is defined as the IP filtering. During the first prototype of the system, a draft version of the IP filtering protocol for the connection will be implemented. The IP filtering allows the communication and transmission of data only between the IP addresses listed in a white list, avoiding the connection of other users. Only the Administrator can access and modify the list of allowed IP addresses. The Communicator modules (3.8, 4.1.1, and 4.2.1) are in charge of the cross-checking

5.2.2 Privacy and confidentiality

The CogWatch System is based on internet and electronic data collection. It will provide easier access to the health information of the patients and more information about the rehabilitation session of the AADS patients will be available in an electronic format. This information will be stored in a secured way through the method described in the previous section, but other methods are needed in order to protect the user privacy and confidentiality.

In the technological part, all data stored in the CogWatch database are anonymous. Internal algorithms are implemented in order to cross the data and presented to the assigned clinician the personal data of the patients. In this case, only statistic data (age and gender) will be available for the scientific community, and the patient will appear in the rehabilitation session results files only with the ID.

The privacy and confidentiality of the patients involved in the development of the Cogwatch system is one of the most important issues to be managed during the project. During the first prototype the technological measures are complemented with the personal commitment of partners involved in the development of the project. Future prototypes of the CogWatch will implement more innovative and technological based solution, such as the avataring and the video anonimisation.

6. CONCLUSIONS

CogWatch system aims at develop an ***AADS*** rehabilitation system based on highly instrumented objects and tools that are parts of the everyday environment of the patients. Using ad hoc algorithms, the sensorized objects can be used to monitor the behaviour and the progress of the rehabilitation therapy, as well as help ***AADS*** patients giving them real time feedbacks to carry out activities of daily living in an efficient way.

This deliverable is focused on the description of the general architecture of the whole system and each sub-system, in order to better understand the way users will interact with them and to show the solution proposed, with particular attention to the software modules in the communication, security and network specification. This deliverable is focused on the first prototype of CogWatch system.

CogWatch system is composed by two main subsystems: the ***CogWatch Client Subsystem*** and the ***Cogwatch Server subsystem***. The general architecture of the system is described in Section 2.

Section 3 describes the architecture and the software modules of the ***CogWatch Client Subsystem*** with a particular attention to the algorithms developed for the first prototype and the ideas for the future development.

Section 4 is dedicated to the description of the architecture of the ***CogWatch Server sub-system***. It is the sub-module dedicated to the storage and visualization process of all patient data and rehabilitation sessions statistics. It is designed to assist the clinician in the follow-up of the patient rehabilitation of AADS. The ***CogWatch Server sub-system*** is composed by the ***CogWatch Healthcare Subsystem***, dedicated to the storage of the medical and personal information of the patient"s assigned to each Healthcare center, and the ***CogWatch WebPortal Subsystem***, in charge of presenting to the healthcare personnel the data and statistics about the patients and about the rehabilitation session.

Section 5 describes the communication technologies, the security protocols and the privacy policy adopted in the system to assure the personal data and the secure transfer of information between the different sub-systems of ***CogWatch***.

The described architectures, technologies, protocols and software modules are based on the first version of the prototype of the system. All the functionalities of the first prototype of the system will be evaluated during the first evaluation phase and reported in the appropriate deliverables. For the future development of the system, new functionalities will be introduced, improving the system according to the results of the evaluation phases.

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APPENDICES

Appendix I: File Format example of the Fusion Module.

The following Table represent an example of the file format produced by the Fusion Module. Data from the devices are synchronised and aligned in order to allow the correct data analysis. First column define the timestamp (in ms) every 2 ms. Next six columns contains the tri-axial coordinates(x, y and z) of the position of the left (LH) and right (RH) hands given by the KINEC. Other columns identify the tri-axis accelerometer and the force of the sensorized objects (MUG, KEATTLE and SUGAR).

Time(ms)	pos_x LH	pos_y LH	pos_z LH	pos_x RH	pos_y RH	pos_z RH	acc_x MUG	acc_y MUG	acc_z MUG	F1 MUG	F2 MUG	F3 MUG	acc_x KETTLE	acc_y KETTLE	acc_z KETTLE	F1 KETTLE	F2 KETTLE	F3 KETTLE	acc_x SUGAR	acc_y SUGAR	acc_z SUGAR	F1 SUGAR	F2 SUGAR	F3 SUGAR
2	-0,114564709	-0,148990348	1,688334227	0,239531428	-0,115568712	1,655633807	2022	2022	2489	1201	864	924	2030	2002	2460	607	506	434	2032	2001	2461	607	506	434
4	-0,114257246	-0,149263889	1,688414335	0,240617961	-0,114660941	1,657744884	2022	2022	2489	1201	864	924	2030	2002	2460	607	506	434	2032	2001	2461	607	506	434
6	-0,114257246	-0,149263889	1,688414335	0,240617961	-0,114660941	1,657744884	2022	2022	2489	1201	864	924	2030	2002	2460	607	506	434	2032	2001	2461	607	506	434
8	-0,114257246	-0,149263889	1,688414335	0,240617961	-0,114660941	1,657744884	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
10	-0,114011042	-0,149579391	1,688881159	0,241297618	-0,114158325	1,658951044	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
12	-0,114011042	-0,149579391	1,688881159	0,241297618	-0,114158325	1,658951044	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
14	-0,146535307	-0,109118514	1,74360323	0,297080129	-0,102745533	1,726766229	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
16	-0,146535307	-0,109118514	1,74360323	0,297080129	-0,102745533	1,726766229	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
18	-0,149438515	-0,113981575	1,734197021	0,297949225	-0,102009147	1,728093743	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
20	-0,149438515	-0,113981575	1,734197021	0,297949225	-0,102009147	1,728093743	2022	2022	2489	1201	864	924	2030	2001	2462	608	506	433	2028	2002	2461	607	506	433
22	-0,115573749	-0,15083921	1,691690445	0,297821581	-0,102891162	1,729355812	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
24	-0,115573749	-0,15083921	1,691690445	0,297821581	-0,102891162	1,729355812	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
26	-0,115299545	-0,151204973	1,692844272	0,297619253	-0,103328668	1,728611231	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
28	-0,115299545	-0,151204973	1,692844272	0,297619253	-0,103328668	1,728611231	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
30	-0,120951958	-0,150411814	1,699248195	0,297896773	-0,102961153	1,729145765	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
32	-0,120951958	-0,150411814	1,699248195	0,297896773	-0,102961153	1,729145765	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
34	-0,120309338	-0,148753107	1,701341867	0,298001081	-0,10002391	1,731135607	2022	2022	2489	1201	864	924	2027	2002	2461	607	506	434	2028	2002	2459	607	506	434
36	-0,120309338	-0,148753107	1,701341867	0,298001081	-0,10002391	1,731135607	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
38	-0,152777076	-0,119918935	1,73330152	0,298283219	-0,100155152	1,731088281	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
40	-0,152777076	-0,119918935	1,73330152	0,298283219	-0,100155152	1,731088281	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
42	-0,151277363	-0,12017937	1,727137566	0,297928214	-0,100288041	1,730980039	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
44	-0,151277363	-0,12017937	1,727137566	0,297928214	-0,100288041	1,730980039	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
46	-0,151277363	-0,12017937	1,727137566	0,297928214	-0,100288041	1,730980039	2022	2022	2489	1201	864	924	2030	2006	2462	608	507	434	2033	2005	2465	607	507	433
48	-0,144725353	-0,125880823	1,711202979	0,298499644	-0,100794382	1,731322646	2022	2022	2489	1201	864	924	2021	2023	2488	1198	862	921	2022	2023	2487	1198	863	921
50	-0,144725353	-0,125880823	1,711202979	0,298499644	-0,100794382	1,731322646	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
52	-0,132978007	-0,12985234	1,690320134	0,298446655	-0,100907654	1,731159091	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
54	-0,132978007	-0,12985234	1,690320134	0,298446655	-0,100907654	1,731159091	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
56	-0,114359625	-0,143914044	1,684223294	0,298093796	-0,100904964	1,731380105	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
58	-0,114359625	-0,143914044	1,684223294	0,298093796	-0,100904964	1,731380105	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
60	-0,113884106	-0,143741086	1,688278198	0,298450232	-0,101325847	1,731082797	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
62	-0,113884106	-0,143741086	1,688278198	0,298450232	-0,101325847	1,731082797	2022	2022	2489	1201	864	924	2029	2003	2461	608	507	433	2029	2003	2462	609	507	433
64	-0,113936648	-0,144212216	1,688798904	0,297397554	-0,101002105	1,73049593	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
66	-0,113936648	-0,144212216	1,688798904	0,297397554	-0,101002105	1,73049593	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
68	-0,113936648	-0,144212216	1,688798904	0,297397554	-0,101002105	1,73049593	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
70	-0,113941349	-0,144114822	1,688742995	0,297130615	-0,100711502	1,730548739	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
72	-0,113941349	-0,144114822	1,688742995	0,297130615	-0,100711502	1,730548739	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
74	-0,113337584	-0,14516592	1,690562725	0,296772063	-0,103899121	1,72873044	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
76	-0,113337584	-0,14516592	1,690562725	0,296772063	-0,103899121	1,72873044	2022	2022	2489	1201	864	924	2032	2005	2463	606	510	431	2032	2006	2459	606	510	431
78	-0,14726007	-0,105106674	1,739080906	0,296471328	-0,103878252	1,728479981	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
80	-0,14726007	-0,105106674	1,739080906	0,296471328	-0,103878252	1,728479981	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
82	-0,14742671	-0,112338156	1,730805635	0,296320319	-0,103860959	1,728307962	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
84	-0,14742671	-0,112338156	1,730805635	0,296320319	-0,103860959	1,728307962	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
86	-0,112959512	-0,149184793	1,683522224	0,296282589	-0,103851199	1,72824502	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
88	-0,112959512	-0,149184793	1,683522224	0,296282589	-0,103851199	1,72824502	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
90	-0,112959512	-0,149184793	1,683522224	0,296282589	-0,103851199	1,72824502	2022	2022	2489	1201	864	924	2028	2002	2461	608	505	434	2029	2004	2462	608	505	435
92	-0,112475313	-0,143597692	1,688311219	0,296129197	-0,103688568	1,728149176	2022	2022	2489	1201	864	924	2028	2003	2460	608	506	433	2029	2005	2463	609	506	434
94	-0,112475313	-0,143597692	1,688311219	0,296129197	-0,103688568	1,728149176	2022	2022	2489	1201	864	924	2028	2003	2460	608	506	433	2029	2005	2463	609	506	434
96	-0,112317652	-0,143155947	1,687841177	0,296108156	-0,103861518	1,727598667	2022	2022	2489	1201	864	924	2028	2003	2460	608	506	433	2029	2005	2463	609	506	434
98	-0,112317652	-0,143155947	1,687841177	0,296108156	-0,103861518	1,727598667	2022	2022	2489	1201	864	924	2028	2003	2460	608	506	433	2029	2005	2463	609	506	434
100	-0,147298366	-0,112370729	1,734747052	0,296121269	-0,103529863	1,727687001	2022	2022	2489	1201	864	924	2028	2003	2460	608	506	433	2029	2005	2463	609	506	434

Appendix II: Resumed tables of the Input and output in the CCS.

Module/System	Sub-Module/Sub-System	Description	Responsible Partne	Others Partners involv	Programming Language	Input from	Input Format	Output to	Output Format
CogWatch Client Subsystem	Fusion Module	It is the module in charge of collecting input raw signals, sincronizing them and performing the first processing and analysis. **(To be completed by UPM - ROMIN)**	UPM-ROMIN	UoB - EECE, RGB		Kinect Sensorised Tools Wearable t-shirt VTE Information Handler		VTE Information Handler	
	VTE Information Handler	It is the core module of the client sub-system. It is in charge of handling all the information and trigger a dedicated module when a articular event is detected. **(To be completed by UPM - ROMIN)**	UPM-ROMIN	-					
	Scheduler	It is the module in charge of the scheduling management. It will launch a new rehabilitation session and save the details of a new scheduled session in the DDBB (VTE repository) **(To be completed by UPM - ROMIN)**	UPM-ROMIN	UPM-LST					
	VTE Repository	It is the local database containing all the patient data, together with the raw data acquired by the sensors, the results of the sessions.	UPM-LST	UPM-ROMIN, UoB - EECE, RGB	MySql	All modules	Query from other modules	All modules	Query from other modules
	Prediction Algorithms	This is the task model. It takes the outputs of the Recognition Algorithm (sub-task labels) and parses these against a model of the task. When errors are detected it outputs codes to identify the error, the type of error, and the cue that should be given to the participant.	UoB - EECE	UPM-ROMIN, TUM	Python				
	Recognition Algorithms	This module takes the outputs from the sensorized objects and detects when particular actions in the task have been performed. In prototype 1 the outputs of the recogniser are at the second level of the tea-making task tree, i.e. Put water into cup, put teabag into cup, pour milk into cup....	UoB - EECE	UPM-ROMIN, TUM	C#				
	Patient profiler	It is the module in charge of defining the patient profile. It will emulate the "clinitian" experience comparing the possible errors and the patient preferences. **(To be completed by UoB - EECE)**	UoB - EECE	UPM-ROMIN, UoB - Psy, TUM,					
	Post-processing Module + Statistics	It is the module in charge of the post processing of the data acquired. It will generate statistics, video post-processing… **(To be completed by UPM - ROMIN)**	UPM-ROMIN	UoB - EECE, UPM-LST, UoB - Psy, TUM					
	Communicator Module	It is the module in charge of sending the results of a session to the dedicated healthcare center. It will implement the security layer (encryption) and the communication protocol	UPM-LST	UPM-ROMIN	C#	VTE Information Handler	XML with results of the session; Video of the session; Other information.	CogWatch HealthCare Sub	Encrypted file

Appendix III: Error Table Example

ID	Unique identifier of the error
NAME	Name of the error
TYPE	Type of error. E.g.: omission, sequence… (see table TYPE)
OBJECT	Object affected by the error. E.G.: cup, spoon… (see table OBJECT)
TASK	Task affected by the error. (see table ERROR)
DESCRIPTION	Description of the error
PRIORITY	Priority following table PRIORITY
WAIT PERIOD	Wait period between one subtask an the next (see table WAIT PERIOD)
CUE ACTION	Cue action to be implemented by the VTE
AUDITORY MESSAGE	Auditory Message to be provided by the VTE
TEXT MESSAGE	Text Message to be provided by the VTE
PICTURE/SIMULATION	Picture or simulation to be provided by the VTE

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)	DESCRIPTION
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING + SUGAR + MILK	N/A	Fail to initiate movement before begining of the task
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is not in the cup yet.
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is in the cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING + SUGAR + MILK	Add water into cup	Fill the cup with water more than 2 times (can be separated by other action)
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING + SUGAR + MILK	Put the tea bag into the cup	If participant does not put the tea bag in the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING + SUGAR + MILK	N/A	If participant does not remove the tea bag from the cup
E0007	Fail to add sugar	OMISSION	SUGAR CONTAINER	TEA MAKING + SUGAR + MILK	Add sugar into the cup	If participant does not add sugar in the cup
E0008	Fail to add milk	OMISSION	JUG OF MILK	TEA MAKING + SUGAR + MILK	Add milk into the cup	If participant does not add milk in the cup
E0009	Heat water > 1	PERSEVERATION	KETTLE	TEA MAKING + SUGAR + MILK	Heat water	Water is heated more than once
E0010	Adding tea bag>1	PERSEVERATION	TEA BAG	TEA MAKING + SUGAR + MILK	Put the tea bag into the cup	More than one tea bag is placed in the cup
E0011	Pause in movement	PERPLEXITY	N/A	TEA MAKING + SUGAR + MILK	N/A	Fail to initiate movement in a sequence (>30s pause in the movement)
E0012	Not heating water	OMISSION	KETTLE	TEA MAKING + SUGAR + MILK	Heat water	Fail to heat up the water (switch on the kettle)
E0013	Not adding water to the cup	OMISSION	CUP	TEA MAKING + SUGAR + MILK	Add water into cup	Water is not added to the cup
E0014	Adding again sugar when distracted	PERSEVERATION	SUGAR CONTAINER	TEA MAKING + SUGAR + MILK	Add sugar into the cup	Sugar is added to the cup again after some other activity in the meantime
E0015	Adding again milk when distracted	PERSEVERATION	JUG OF MILK	TEA MAKING + SUGAR + MILK	Add milk into the cup	Milk is added to the cup again after some other activity in the meantime
E0016	Special cue, error after error *	NOT ATTENDING TO CUES	N/A	TEA MAKING + SUGAR + MILK	N/A	Participant commits two or more errors in a row, without attending to cues, does not try to fix the errors

* after cue 1 system resets to the next step after the last correct action

ID	PRIORITY	WAIT#1 (1st_error_cue)	WAIT#2 (2nd error cue)	CUE ACTION #1	CUE ACTION #2	CUE ACTION #3	CUE ACTION #4
E0001	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak
E0002	Level 1: Error occurred, but is recoverable.	5 s	5 s	Vib1	Image+Verb	Sim75+Verb	Verb+Textbreak
E0003	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Aud	Verb+Textbreak	
E0004	Level 4: Error occurred, resulting in a fatal error that also causes harm to the user	5 s	5 s	Vib2	Vib+Aud	Image+Verb	Verb+Textbreak
E0005	Level 1: Error occurred, but is recoverable.	20 s	15 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak
E0006	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak
E0007	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Verb+Textbreak
E0008	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Sim75+Verb
E0009	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Aud	Nextstep+Text	Verb+Textbreak
E0010	Level 1: Error occurred, but is recoverable.	10 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak
E0011	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak
E0012	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Sim 100	sim75+Verb	Verb+Textbreak
E0013	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak
E0014	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Vib2	Aud	Verb+Textbreak	
E0015	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	10 s	Vib2	Aud	Verb+Textbreak	
E0016	Level 1: Error occurred, but is recoverable.	15 s	10 s	Aud	Verb+Textbreak		

ID	If effective next step	AUDITORY MESSAGE	TEXT MESSAGE	SIMULATION/PICTURE
E0001	N/A	CA 1 'Please touch the screen if you wish to see the next step', CA 'You are making a tea without milk or sugar', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0002	Pour the water in a kettle	CA2 'You need to heat water before you add it to the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle lid being opened
E0003	Pour the water in a kettle	CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again', CA3 'Let's take a break and try again in 5 minutes'		Kettle lid being opened
E0004	Wait until tea is ready	CA 2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'	CA 4 'Let's take a break and try again in 5 minutes'	Full cup
E0005	Tilt the kettle until cup is full	CA 2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the cup
E0006	Pick cup in order to take a sip	CA 2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the rubbish
E0007	Pick cup in order to take a sip	CA 1 'You are making tea with milk and sugar. Add sugar to the cup', CA3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Putting sugar into the cup
E0008	Pick cup in order to take a sip	CA 1 'You are making tea with milk and sugar. Add milk to the cup', CA3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Putting milk into the cup
E0009	Pour the water in the cup	CA 2 'The water is heated, pour the water in the cup', 'Water is ready, put the water in the cup'	CA 4 'Let's take a break and try again in 5 minutes'	Pour water in the cup
E0010	Wait for the water to boil	CA 2 'Only one tea bag is needed in the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Remove uneccessary tea bag from the cup
E0011	N/A	CA 1 'Please touch the screen if you wish to see the next step', CA2 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0012	Tilt the kettle until cup is full	CA 2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle button switched on
E0013	N/A	CA 2 'Pour water into the cup from the kettle', CA 3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	NA
E0014	N/A	CA 2 ' You have already added sugar to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		NA
E0015	N/A	CA 2 ' You have already added milk to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		Next step
E0016	N/A	CA 1 ' You are making mistakes, attend to the system'	CA 2 'Let's take a break and try again in 5 minutes'	Next step

Error Type Table

ID	NAME
TE001	OMISSION
TE002	SEQUENCE
TE003	ADDITION
TE004	PERSEVERATION
TE005	TOYING
TE006	PERPLEXITY
TE007	ANTICIPATION
TE008	OBJECT SUBSTITUTION
TE009	EXECUTION
TE010	NOT ATTENDING TO CUES
TE011	QUALITY

Object Table

ID	DESCRIPTION
O01	KETTLE
O02	TEA BAG
O03	CUP
O04	JUG WITH WATER
O05	JUG OF MILK
O06	SUGAR CONTAINER
O07	SPOON
O08	N/A

Appendix IV

Resumed tables of the Input and output in the CSS.

The ***CogWatch Server sub-system (CSS)*** is dedicated to the storage and visualization process of all patient data and rehabilitation sessions statistics. It is designed to assist the clinician in the follow-up of the patient rehabilitation of AADS.
*This subsystem **will be developed in a beta version** for the first prototype of the Cogwatch System. Further improvement both in the developmente of the algorithms and in the structure should be implemented for future prototypes.

Module/System	Sub-Module/Sub-System	Description	Responsible Partner	Programming Language	Input from	Input Format	Output to	Output Format
CogWatch Healtcare Subsystem (CHS)	**HEALTHCARE Information Handler**	It is the core module of the HealthCare sub-system. It is in charge of handling all the information and triggers other modules when a specific event is detected.	UPM-LST	C#	HEALTHCARE Repository + Data Miner + Interoperability Manager + Communicator Module	Query from others modules	HEALTHCARE Repository + Data Miner + Interoperability Manager + Communicator	Results of operational funciotn of the module. + Trigger calls
	HEALTHCARE Repository	This is the repository where the information related to the patient will be stored, together with the statistics of the rehabilitation sessions. Only data belonging to the patients assigned to the specific healthcare center are stored in this repository.	UPM-LST	Microsoft SQL / MySQL	HEALTHCARE Information Handler	Queries from HEALTHCARE Information Handler	HEALTHCARE Information Handler	Queries to HEALTHCARE Information Handler
	Data Miner	Generic and customizable algorithms able to face future problems of the system. It will not be deployed for the first prototype. ***This module will not be developed for the first prototype of the Cogwatch System**	UPM-LST	C#	Interoperability Manager + HEALTHCARE Information Handler	Query from others modules	Interoperability Manager + HEALTHCARE Information Handler	Results of operational funciotn of the module. ***to be defined**
	Interoperability Manager	This module is in charge of guarantees interoperability with existing and already in use external resources, at the healthcare center. It will not be deployed for the first prototype. ***This module will not be developed for the first prototype of the Cogwatch System**	UPM-LST	C#	HEALTHCARE Information Handler + Data Miner + External Resources	Query from others modules	HEALTHCARE Information Handler + Data Miner + External Resources	Results of operational funciotn of the module. ***to be defined**
	Communicator Module	This module is responsible of the communication with the CCS and CWP. Security protocols are also implemented in this module.	UPM-LST	C#	HEALTHCARE Information Handler + CCS and CWS Communicator modules	XML with results of the session; Video of the sessio; Other information.	HEALTHCARE Information Handler + CCS and CWS Communicator modules	XML with new scheduled sessions; Other information.

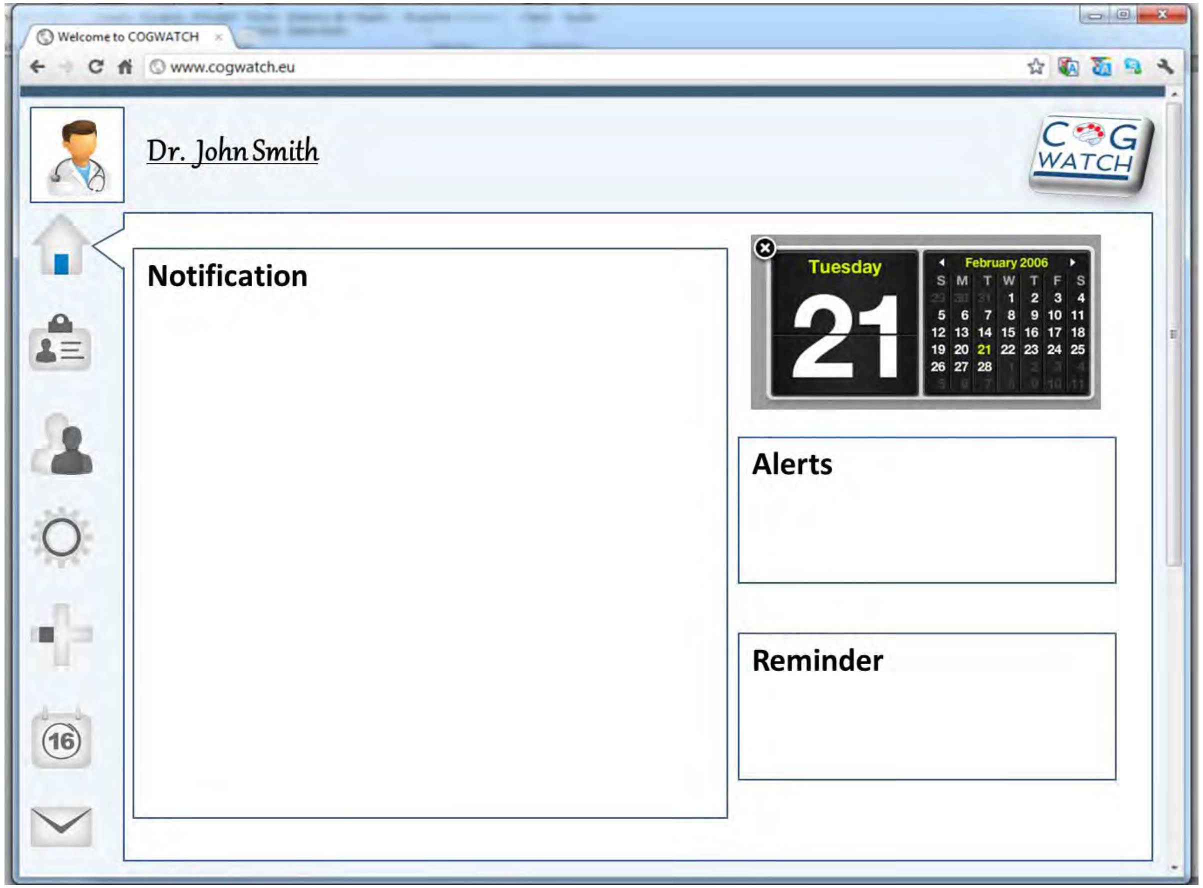
The ***CogWatch Healtcare Subsystem CHS*** is defined as the remote healthcare server, in charge of communicate with the ***CCS*** and receive from it data and statistics of rehabilitation sessions. The Healthcare ***CHS*** is dedicated to the storage of the medical and personal information of the patient"s assigned to each Healthcare center. Moreover it will contain the results and the statistics of the rehabilitation sessions performed.

Module/System	Sub-Module/Sub-System	Description	Responsible Partner	Programming Language	Input from	Input Format	Output to	Output Format
CogWatch WebPortal Subsystem (CWS)	**WebPortal Information Handler**	It is the core module of the CogWatch sub-system. It is in charge of handling all the information and triggers other modules when a specific event is detected.	UPM-LST	C#	LOG-IN Module + Communicator Module + Communicator Module	Query from others modules for trigger the alghorithms	LOG-IN Module + Communicator Module + Web-Portal	Results of operational funciotn of the module
	User Repository	This is the repository where the information related to the patient will be stored in order to define the connection with the CHS.	UPM-LST	Microsoft SQL	Account Manager + LOG-IN Module	Query from others modules	Account Manager + LOG-IN Module	Query to others modules
	LOG-IN Module	This is the module in charge of allow the users to log into the System. With the correctly provided user name and password the user is directed either to the administration or user window	UPM-LST	C#	User Repository + WebPortal	Query from others modules	User Repository + WebPortal	Results of operational funciotn of the module
	Account Manager	The Account Manager module is responsible to create/deactivate and maintain user accounts for the centralized system. The following actions are the core functionalities of the module: - DEFINE ROLES - DEFINE REGISTER PROTOCOL	UPM-LST	C#	User Repository + Web-Portal Handler and Algorithms	Query from others modules	User Repository + Web-Portal Handler and Algorithms	Results of operational funciotn of the module
	Communicator Module	This module is responsible of the communication with the CHS. Security protocols are also implemented in this module.	UPM-LST	C#	WebPortal Information Handler + Web-Portal Handler and Algorithms +	XML with results of the session; Other information.	WebPortal Information Handler + Web-Portal Handler and	Query and XML for information exchanging; Other informations.
	Web-Portal Handler and Algorithms	It is the module in charge of the visualization of the data retrieved from the CHS. Algorithms will be also used for future implementation.	UPM-LST	C#, ASP, .NET, CSS, HTML	Account Manager + WebPortal	Query from others modules	Communicator Mo	Query to be send to the CHS

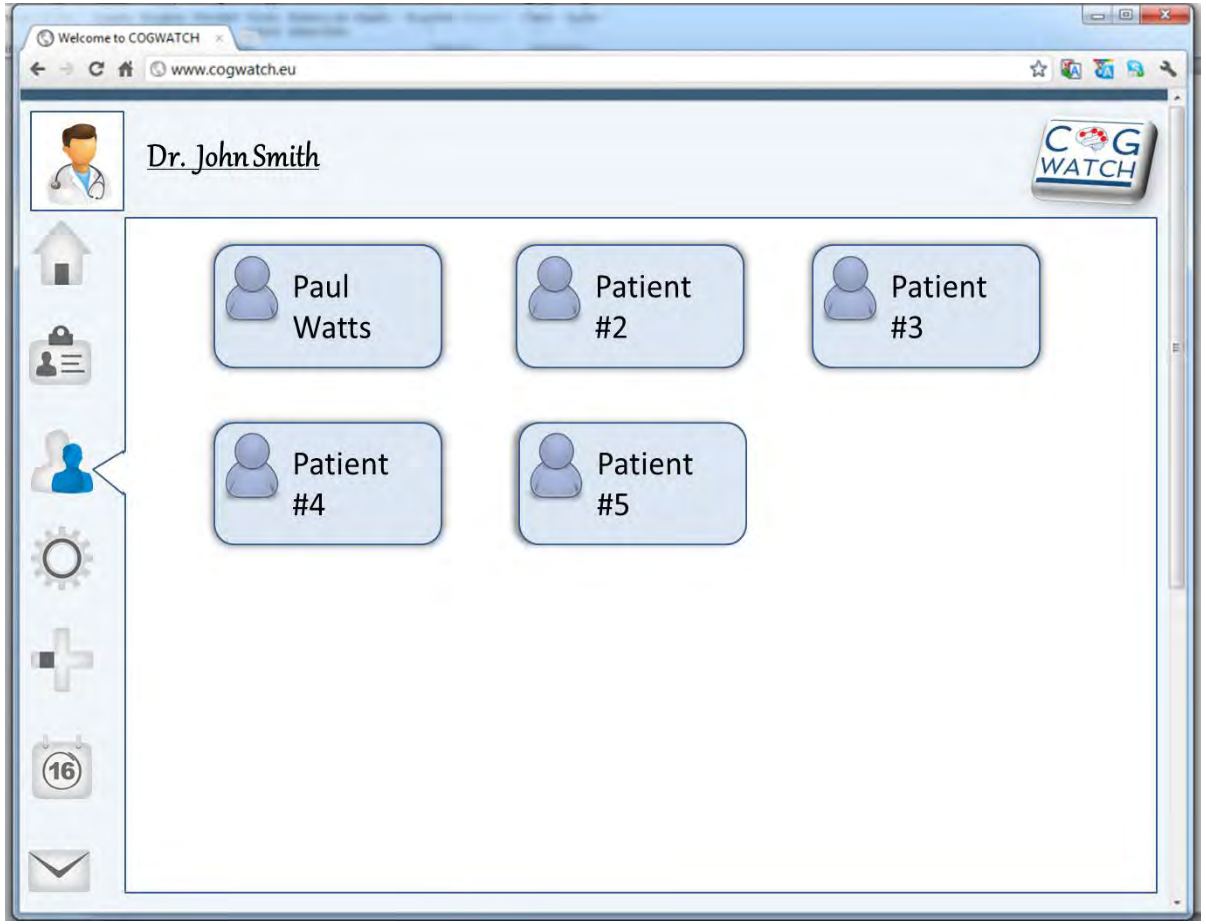
The ***CogWatch WebPortal Subsystem*** **CWS** is the sub-system in charge of presenting to the healthcare personnel the data and statistics about the patients and about the rehabilitation session. It will be installed in an external and unique server.

Appendix V: Web portal examples

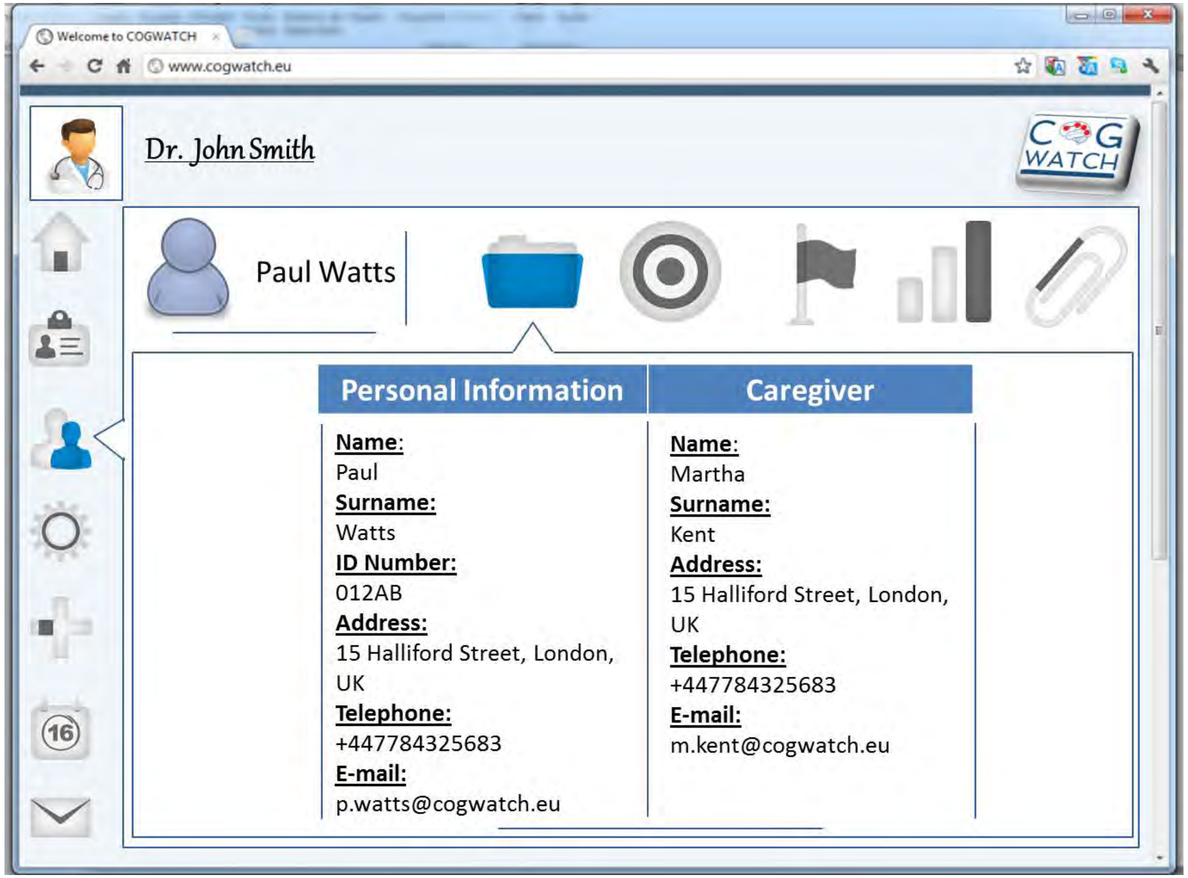
Cogwatch Portal Home Page



CogWatch patients screen.



CogWatch patient personal information and clinician data.



CogWatch rehabilitation sessions.