D6.1
Case-based Feedback Adaptation – v1

Dementia Ambient Care: Multi-Sensing Monitoring for Intelligent Remote Management and Decision Support

Dem@Care - FP7-288199

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Abstract (for dissemination)	This report presents the specifications and information requirements that must be fulfilled in order to determine the appropriate feedback for the different situations in which the Dem@Care system will be used. It also investigates the means by which this feedback should be communicated to the user. Mathematical tools for modeling activities including context-prediction, behavioural analysis, and activity recognition are reviewed, as input for further work. The mathematical model will help provide appropriate feedback only when necessary and will be used to generate alarms, reminders, and instructions. Feedback will be given mostly through visual means (lights, pictures, and text) and audio cues will be used bring attention to system-initiated feedback. Voice prompts will be used to facilitate forward navigation in user interfaces. Navigation for PwD will be based on *prioritized tasks*. that mirror real-life activities.

Version Log

Version	Date	Change	Author
V0.1	29 Aug 2012	Initial draft – Document Structure	DCU Eamonn Newman
V0.2	12 Oct 2012	Addition of interaction events and alerts	DCU Joanna McHugh
V0.3		Addition of Mathematical models	LTU Chris Nugent
V0.35		Feedback and notifications added to use-case scenarios	LTU Josef Hallberg
V0.4	9 Nov 2012	Added Section 2.2 – Adaptation mechanisms	LTU Chris Nugent
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v0.9	20 Nov 2012	Clarifications in the Executive Summary and Introduction chapters. Further addressing reviewer's comments.	LTU Johan E. Bengtsson
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Executive Summary

This report contains specifications and requirements for determining the kind of feedback appropriate for each situation and how it should be communicated to Persons with Dementia, carers and clinicians.

Chapter 2 describes rules for a first feedback decision model, intended to specify when and how feedback should be delivered that is generated by the semantic interpretation component of the system. The chapter also gives an overview of possible mathematical modelling tools for later elaborating the decision model. Any additional models needed to detect contextual parameters for adapting user interfaces will be expressed using the ontologies described in D5.1 Semantic Knowledge Structures and Representation.

Chapter 3 lists the feedback events where adaptation of the user interface will be needed and analyzes which notifications and queries each is going to need from the semantic interpretation component of the system. It also describes initial assumptions about how each feedback should be communicated.

Chapter 4 describes the Case-based Feedback services to be provided by Dem@Care, via four user interface components and one coordinating *Feedback Engine* component.

Key specification decisions have been to provide navigation between *prioritized and stackable tasks* that can be started and stopped by either the user or the system, and the use of HTML5-based view layers for user interface components.

Further work will be needed to identify which tasks are higher priority than others, based on the ontology described in D5.1 Semantic Knowledge Structures and Representation, where the tasks are known as *Activities*. It remains to determine whether further contextual parameters will be needed to adapt the user interfaces to the current situation. The Dem@Care ontology will need minor updates to support what is described in this deliverable (to be documented in D5.2 Multi-Parametric Behaviour Interpretation v1) and it needs to be determined if the semantic interpretation module of the system should aim to also detect higher-level non-behaviour contextual parameters for user interface adaption.

Abbreviations and Acronyms

PwD	Person with Dementia
FTA	Fault Tree Analysis
AAL	Ambient Assisted Living
ER	Evidential Reasoning
DS Theory	Dempster-Shafer Theory
TL	Temporal Logic
HMM	Hidden Markov Model
(PO)MDP	(Partially Observable) Markov Decision Process

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1 Introduction

1.1 Work Package 6 Client-side Interaction

The objective of WP6 Client-side Interaction is to "provide people with dementia and clinicians with the information and feedback necessary to for the remote management and treatment of dementia. To this end, WP6 creates user interfaces for persons with dementia (PwDs), their carers and clinicians.

The development of client-side interaction components is guided by needs and acceptability factors identified by WP2 Requirements and Impact, and it relies heavily on information sources from WP4 Situational Analysis of Daily Activities and WP5 Medical Ambient Intelligence. The client-side interaction components will be delivered to WP7 System Integration. Further refinement of the client-side interaction components rely on the formative evaluations as part of the piloting phases. The all-important activity recognition logic will rely on the semantic interpretation component of the system, however, some user interface level activities may be inferred directly.

1.2 Task 6.1 Case-based Feedback Adaptation

T6.1 will deliver tested software modules for WP7 to integrate into the overall Dem@Care system. The report *Case-based Feedback Adaptions* will be delivered in two versions, a public version in October 2012 and a non-public version in August 2014. Incremental updates to the software module are expected until November 2014.

A decision model will be developed based on outcomes of WP4 Situational Analysis of Daily Activities and WP5 Medical Ambient Intelligence, that will provide context-prediction, behavioural analysis, and activity recognition. This mathematical model will help provide appropriate feedback only when necessary and in suitable formats.

Feedback will be given mostly through visual means (lights, pictures, and text). Audio cues, which consist of simple sounds, may be used to draw attention to information. Voice prompts will be used to facilitate forward navigation.

In addition to **warnings** and **reminders** the person with dementia will also be encouraged to perform **cognitive exercises**, such as reminiscing over recent activities, and to review the day by looking at the daily activities supported by pictures. These pictures will have been collected by the environment or a mobile camera worn by the person with dementia.

1.3 Purpose of this report

This report will inform the development of case-based feedback components in the first Dem@Care prototype. It contains specifications and requirements for determining the kind of feedback appropriate for each situation and how it should be communicated, and describes rules for a first feedback decision model.

The report also gives an overview of possible mathematical modelling tools for elaborating the decision model in D5.2 Multi-Parametric Behaviour Interpretation v1 or D6.3 Case-based Feedback Adaption v2.

2 Decision Model

The decision model for feedback adaption will help provide appropriate feedback only when necessary and will be used to generate alarms, reminders, instructions. Feedback will be given mostly through visual means (lights, pictures, and text) but voice prompts will be used judiciously to guide navigation and audio cues will be used to draw attention to information.

The input to the decision model is mainly Activities recognised by the semantic interpretation component of the system (see D5.1 Semantic Knowledge Structures and Representation), however user interaction activities may be inferred directly. The decision model will also be based on a model of prioritised Tasks (in D5.1 denoted Activities), where different task types are seen as having different importance to the user, for example Sleeping is seen as more important than "give Eating feedback", if the two activities occur at the same time. The activity priorities should be personalized and possibly also dynamic in nature.

This initial description of the decision model proposes basic rules for when and how to give feedback to PwD, carers and clinicians. A mathematical model with more elaborate rules will be described in D6.3 Case-based Feedback Adaptation v2, based on D4.2 Activities Monitoring & Lifelogging and D5.2 Multi-Parametric Behaviour Interpretation v1. Therefore, feedback intended to stimulate doing cognitive exercises is not addressed, and the use of mathematical models for context-prediction, behavioural analysis, and activity recognition are not analyzed in this deliverable.

However, in the following section a brief literature review on these subjects are given as reference material for prototyping case-based feedback adaptations in the first Dem@Care prototype.

2.1 Mathematical Models - Literature Review

In the development of systems which offer support within the realms of ambient assisted living (AAL), formalised models and analysis techniques have been considered as appropriate choices from the perspective of making developments amenable based on a systematic approach (Parente, 2011). The Dem@Care system will share some properties and requirements with AAL systems. In this Section we consider the following techniques: fault trees, evidential reasoning, temporal logic, hidden Markov models and partially observable Markov models. In addition to the providing the technical details of how each model works, each approach will be considered from the perspective of their specific usage in the target domain within Dem@Care through presentation of a series of case studies. The Case Studies are purely illustrative for each of the presented scenarios, and are not necessarily representative of the types of scenarios to be supported for client-side interaction in Dem@Care. Requirements for necessary queries and notifications derived from the Dem@Care use cases are presented in Section 3.

Fault Tree Analysis

Fault tree Analysis (FTA) is a well-known and widely used technique for the evaluation of dependability in safety-critical systems (Vesely et al., 1981). The underlying concept of FTA relates to the detection and modeling of the relations among basic factors that may lead to an undesirable outcome (also known as a hazard) of the system. Within the realms of Dem@Care a fault could be the delivery of a reminder when the PwD is in a different room from the reminding device. The core of the abstraction of FTA is the Fault Tree (FT). A FT has the ability to graphically represent combinations of faults/events that will result in the occurrence of an undesired event. Faults can be events that are associated with component hardware failures, human errors, software errors, or any other form of errors, or in the context of Dem@Care undesirable situations for the PwD for example missing a reminder or form of automated support provision (Vesely et al. 2002).

A FT is constructed based on a top-down approach. At the top of the tree is the undesired event, for example missing a reminder, which is labeled the top event (TE). Following this, the series of events and sub-events which may lead to the TE is presented. These events are then further decomposed until the basic events (also called primary events or leaf events) are identified.

The relationship between the events in the tree are usually modeled through use of simple logic gates such as AND, OR and NAND. Extensions, which support temporal dependencies and can prioritise the processing of events, are also possible. Due to their simplicity and efficiency, FTs have been widely used to: represent the hierarchical relationships among component-level causal factors that can yield an undesired system-level outcome (Malhotra and Trivedi 1994); evaluate the threats and vulnerabilities of software (Herzog and Shahmehri 2001); analyse urban flooding (Ten Veldhuis et al. 2009); perform requirements analysis of intrusion detection systems (Helmer et al. 2002) and model socio technical probabilistic risk in health (Marx and Slonim 2003).

Scenario[1]

For the purposes of considering the operation of a FT and the types of information it can process, let us consider the scenario of monitoring a PwD in her/his home during the night. This will involve the usage, in this scenario, of a personal health monitoring system to detect increases in vital signs, such as heart rate and temperature in addition to an activity monitor. Wireless Sensor Networks will be used to provide information relating to where the PwD is within the home and which objects they may have interacted with in addition to the provision of environmental conditions such as temperature.

Consider the specific scenario where the health of a patient is monitored by two main factors: their heart rate and their body activity. The heart rate is provided by a personal health monitoring system made up of three devices: a heart rate monitor, a pulse oxymeter and a sphygmomanometer. During the design of the FT, based on prior experience of working with these devices in addition to their ability to provide a direct or indirect measurement of heart rate their reliability is set to 0.8, 0.7 and 0.6, respectively. Activity levels are measured in the scenario by two devices: a body-worn accelerometer strapped to the upper thigh and a motion detector.

[1] Within this Section the scenarios have been selected based on the data they generate and the desired outcome. This facilitates an analysis of the techniques being discussed. Dem@Care client-side interaction scenarios are presented in Section 3.

Based on these devices, the FT can be modeled as presented in Figure 1. Within the FT, the leaf events are the sensing devices from the personal health monitor and the activity monitor. Using the example FT as presented in Fig. 1 the health status of the patient is considered to be normal provided there is information being received within range from either the personal health monitor or the activity monitor as represented by the use of the OR gate, g2, within the FT. More specifically, the information about heart rate should be provided by at least two out of the three devices (2/3 voting gate, g0); for the body activity a measurement is required from both the accelerometer and the motion detector hence the use of the AND gate, g1.

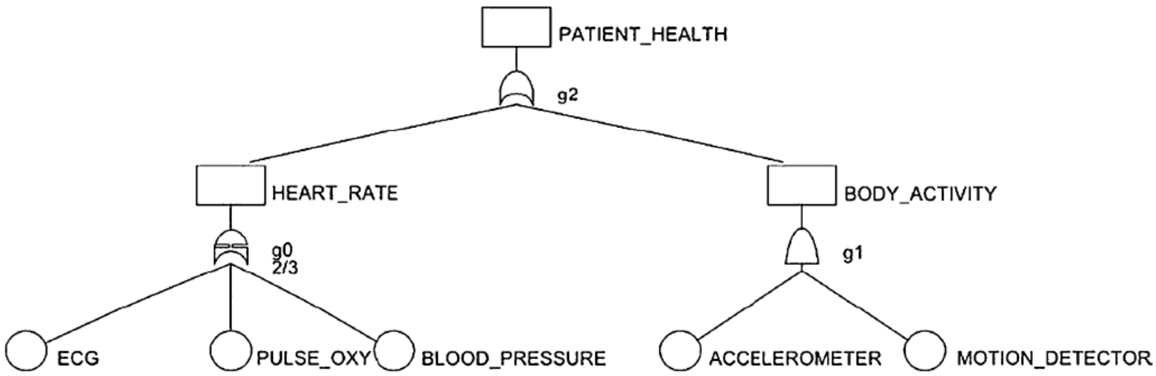

Figure 1: Fault Tree for monitoring health status and activity levels

Analysis of Technique

FTs are generally considered to be less expressive than other modeling techniques, however, they present other advantages that can be considered valuable:

- FTA is a well-known methodology that has been used in many research and industrial domains.
- A FT can be used to pre-compute possible effects of changing the type or the design of the system architecture.
- For a non-technical user for example a healthcare professional or carer, a FT is easy to understand.

Evidential Reasoning

Evidential Reasoning (ER) is based around a body of instance-based techniques (Dempster 1968; Shafer 1976). These techniques can be used to analyse the impact of evidence, which may stem from a variety of sources, upon a given set of hypotheses. The Dempster-Shafer (DS) theory (Dempster 1968; Shafer 1976) is central to the process of ER. DS can be used to manage instances where data is complex, heterogeneous and unreliable. Within Dem@Care the client-side interaction information will be gleaned from different sources and may have to accommodate for uncertainty. DS theory is a generalisation of probability theory and provides a more powerful and flexible management approach of uncertainty than basic probabilistic approaches.

Within DS theory a mass function is used to represent the distribution of belief over the space of hypotheses referred to as the frame of discernment. Belief can be assigned to a singleton or sets of sources. The relationship among the sources of data is generally represented by joint-belief functions rather than conditional-belief functions. This choice has the advantage of enabling a faster computation and is still rich enough to describe a variety of relations among sources of evidence. ER has been successfully used to solve a variety of information management problems; environmental impact assessment (Wang et al. 2006), business decision making (Srivastava and Mock 2002), and medical diagnosis (Jones et al. 2002).

Scenario[2]

Bob is a PwD who has a tendency to become agitated at certain times throughout the day. Bob's carer receives information related to Bob remotely, given that he lives alone. Based on this information the carer is required to infer if Bob is in good health or if his level of agitations have increased and he requires some form of support or if perhaps a visit should be made to his house. The measure of health status can be depicted by three levels: L0 (low risk), L1 (medium risk) and L2 (high risk).

At 8 a.m., Bob speaks with his carer via phone and says that following an examination by his doctor, the doctor found him to be in good health. Within the next hour, technology installed within Bob's house alerts his carer that Bob is in the living room and is either watching TV or is on the phone. At 10 a.m., motion sensors within Bob's house detect that Bob is engaging in a series of repetitive actions which are indicative that his level of agitation are increasing. A message is sent to the carer's mobile phone warning them of this situation. At this point in time the carer must therefore make a decision whether or not to intervene. A further piece of evidence that can be taken into account is that the level of health status for Bob has never reached L2 and in the past has only once reached L1.

Using ER, the analysis is made up by two steps: firstly to establish the relations between the sources of evidence and secondly to analyse the impact of the evidence. In the first step the frames of discernment can be identified. There are two different frames: health status (described by three risk levels) and Activities (sleeping, watching TV, using phone).

Health := {L0, L1, L2}

Activities := {Sleeping, Watching_TV, Using_Phone}

The compatibility networks presented in Figure 2 depicts all the possible relations that may exist within the given scenario between the two different frames of discernment. In this case it can be used to describe how the activities of sleeping, watching TV and using the telephone can be related with the differing levels of health status. When considering different frames of discernment it is necessary to consider which are the relationships between them and how they can be interconnected within a scenario.

[2] This scenario has been presented to provide an overview of the types of information and problems to be solved using ER. Dem@Care client-side interaction scenarios are presented in Section 3.

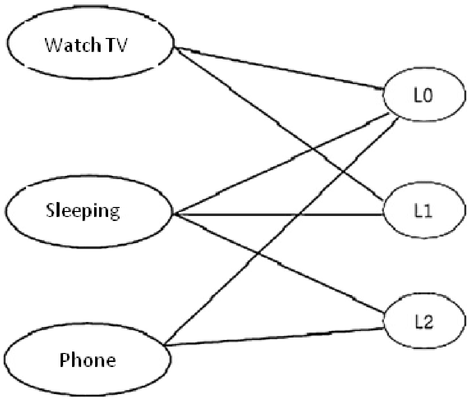

Figure 2: Evidential Reasoning - compatibility relations

A transition graph can be used to describe the dependencies within the same frame of discernment with respect to time. Figure 3 depicts how the health status levels evolve over 1 h between two subsequent observations.

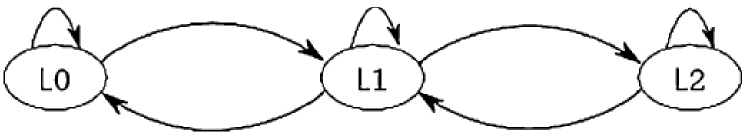

Figure 3: Evidential Reasoning - transition graph for health status levels

In the second stage of the ER process, calculations are performed to identify how each piece of evidence impacts on one frame of discernment and can therefore be represented with mass functions. The opinion of the doctor impacts directly on the frame of health status levels. If, for example, we consider that we can absolutely trust their judgement when they say that Bob is in good health, we can assess a level of confidence for L0 to be equal to 1:

Doctor → m(L0)=1.

Consideration of the activities that are being undertaken can be related to the activities frame. If these are automatically measured within the home and their classification is not always entirely accurate due to unreliable sensor measurements then this level of uncertainty should be taken into consideration. For example, the accuracy of watching TV can be assigned with a confidence of 0.2 and the confidence of using the telephone with a confidence of 0.8:

Activity → m(Watching_TV)=0.2, m(Telephone)=0.8

The information provided by the motion sensors impacts upon the frame health status levels. If information is received indicating that the level of agitation has reached a certain level, this information can be used to assign a confidence level of 0.4 to a low-risk health status level and 0.6 to the higher health status levels (which exploits the possibility of Dempster-Shafer theory to assess confidence to a set of hypothesis). In a similar manner, the past medical history can be evaluated:

Motion Sensors →m(L0)=0.4, m(L1,L2)=0.6, History → m(L0)=0.8, m(L1,L2)=0.2

The complete evidential network is presented in Figure 4. This can be used to assess the impact of the evidence upon the overall hypothesis. The basic operations used to estimate the mass function of each node are: fusion, which determines the consensus from several bodies of evidence; translation, which determines the impact of a body of evidence upon elements of a related frame of discernment and projection, which determines the impact of bodies of evidence at some future (or past) point in time.

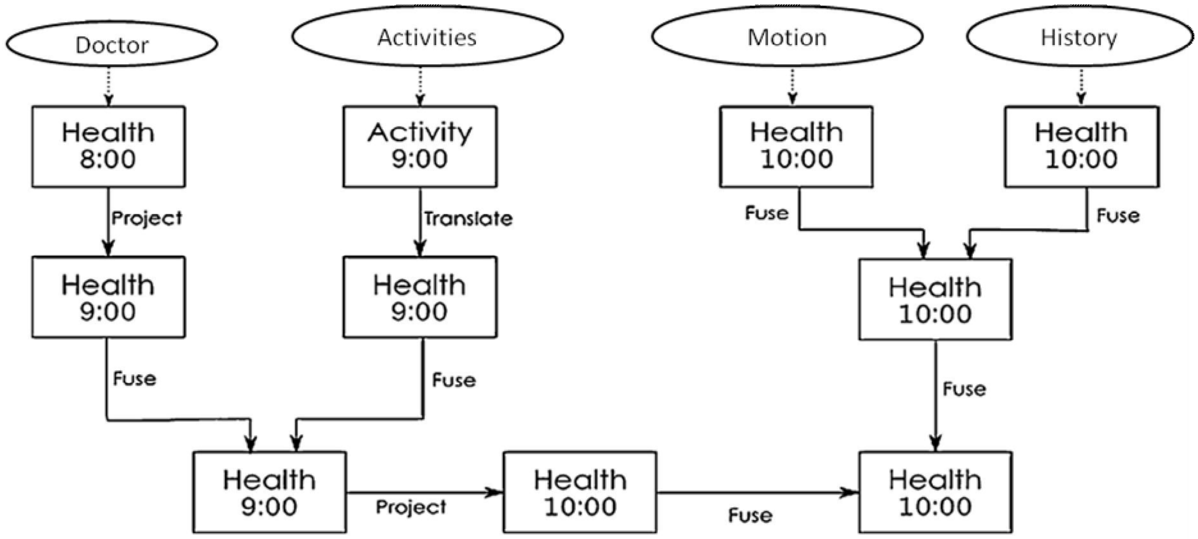

Figure 4: Evidential Reasoning - analysis graph

For example, it is possible to project the information provided by the doctor over time using the network that shows the possible evolution of health status levels over time. After an hour from L0 it is possible to move to L1 or remain in L0. Based on this movement the new mass function is represented as:

$M_{health\_status@9.00}(L0,L1)=1$

Taking into account the information provided by the detection of activities and according to the compatibility relationships, if the PwD is watching TV at 9.00 this is quite a normal activity; however, if he is sleeping at this time it may be considered abnormal behaviour. Through the use of the translate operator it is possible to calculate the health status:

$M_{health\_status@9.00}(L0)=0.2$, $M_{health\_status@9.00}(L1)=0.7$, $M_{health\_status@9.00}(L2)=0.1$

To combine the information from two different frames it is necessary to use the fusion operator. A similar approach can be adopted to process the information at the other nodes of the network and subsequently estimate the mass function of the last one (Health@10:00) that will describe the confidence associated to each health level at 10 a.m.

Analysis of Technique

The most advantageous feature of ER is its ability to deal with uncertain and heterogeneous sources of data. In addition, the inference process can be represented by a graph that can be considered as easy to interpret, from a non-technical perspective. Through this approach it can be possible to provide an explanation of the end result provided. Extensions to the ER approach exist which allow analysis of the impact of individual pieces of evidence on the overall end result to be calculated. This is a key characteristic not always supported in other techniques that are based on a hidden computation method that is not always graphically viewable (for example HMM or Bayesian Networks). Although time can be accommodated to a certain extent, this is considered as one of the weaker features of the ER approach.

Temporal Logic

Temporal Logic (TL) relates to the use of any logic language that supports temporal reasoning (Emerson 1990). Different concepts of time lead to different instances of temporal logic. For example, in Linear Temporal Logic (LTL) it is possible to describe a process with infinite states on a single time line (Emerson 1990). In terms of TL it is possible to identify a sequence of the possible steps which may be involved within a process. This is subsequently referred to as a *path*. Based on the definition of the path it is then possible to stipulate a rule which is referred to as the path formula. The path formula is a combination of atomic propositions on the steps through usage of Boolean connectors and temporal operators. For example, consider the following expression using the Until (U_t) operator:

$$\gamma_1 \ U_t \ \gamma_2$$

This can be interpreted as meaning the action γ_1 must occur within a specified time interval *t.* Following this, the action γ_2 must occur. Further examples of temporal operators are presented in Table 1.

Table 1: Examples of temporal logic semantics

Temporal operator	Semantics
Y Φ	It is true if Φ is true in the previous state
Hτ Φ	It is true if for all time τ, Φ is true
Oτ Φ	It is true if Φ is true within a time τ

$\psi\ S\tau\ \Phi$	It is true if ψ is true since Φ, within a time τ

Scenario[3]

Consider the scenario of a PwD using a form of assistive technology to support them with their daily activities. Central to the usage of such a system is the definition of the rules that the system should follow in terms of monitoring and providing support to the PwD. The rule must describe, in an easy way, the activity that the PwD will be requested to perform. An automated system can subsequently use the rule to detect the behaviour of the user, understand if the user is performing it correctly and if required offer prompts for assistance.

Consider the definition of a rule that explains how a PwD must take their medication:

The medication must be taken within 2 hours after getting out of bed. Within this period the patient must also ensure that they have had something to eat, prior to taking the medication.

To address this scenario using TL the first step is to identify the most basic components within the rule that cannot be simplified any further. These are referred to as the atomic prepositions. Considering the medication management scenario, the atomic prepositions are the following:

- "Get out of bed"
- "Eat Something"
- "Take the medication"

Using logical and temporal operators, composite concepts can be expressed. For example, the composite concept "eat something prior to taking the medication" can be expressed via the following rule:

"Eat something" AND "Take the medication" = "Eat something prior to taking the medication"

The following is an example of how a process can be represented introducing the notion of time. In this instance the entire process should be completed within 120 minutes of the PwD waking up.

("Get out of bed" U "Eat and take medication")$_{\text{120 minutes}}$

Figure 5 depicts the visualisation of the rule.

[3] This scenario has been presented to provide an overview of the types of information and problems to be solved using TL. Dem@Care client-side interaction scenarios are presented in Section 3.

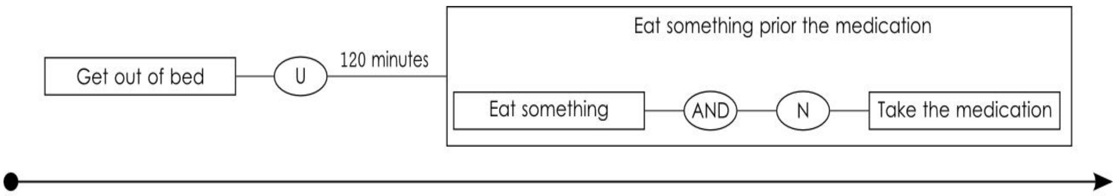

Figure 5: Temporal Logic - Medication management scenario

Analysis of technique

One of the main advantages of using TL is the solid theoretical logic background upon which the technique has been established. Through the use of the temporal operators and logic prepositions the language is capable of expressing a variety of situations. To a certain extent these rules both in the TL logic form and if expressed visually can be understood by non-technical users. In addition, it is possible to convert the rules into a machine running format.

One of the main disadvantages of the approach is the requirement on domain knowledge in the specification of the rules.

Hidden Markov Models

In terms of modelling, the *state* of a system is considered to represent a clear, identifiable configuration of the system along with its components (Parente et al., 2011). Consider for example a binary output from an information management system with two states namely on and off. A modelling technique which is capable of encoding the state of a system will produce what is referred to as a stateful model.

If the system is dynamic, the state can change over a period of time. Consider the previous example of a binary sensor attached to a door. If the door is opened, closed and then opened again the state of the sensor will change from on to off and then back to on. This evolution of the sequence of states is referred to as a process. If a process has the Markov property (i.e. the future state depends only on the present state and not on the past history) it is referred to as a Markov Process (Norris, 1998). Markov models are used to model a system, whose state is directly observable and whose evolution follows a Markov Process. If the state can't be directly acquired and must be inferred by a set of observations, an extension to the model, referred to as the Hidden Markov Model (HMM), is used (Rabiner and Juang 1986).

Scenario[4]

Consider the scenario of a PwD living within a sensorised home. Within the home it is possible to detect, through the use of embedded binary sensor technology, activities such as using the toilet, sleeping, showering, to name but a few. It is possible to use one Markov Model for each activity. Each state in the model can be used to represent the activation of a sensor and hence a certain sequence of senor events can be used to describe the activity.

[4] This scenario has been presented to provide an overview of the types of information and problems to be solved using HMM. Dem@Care client-side interaction scenarios are presented in Section 3.

Once the model is created, the probability is computed for each sequence of sensor activations. To handle the temporal information and use it to distinguish between overlapping activities each state is annotated with a distribution that represents the likely start time and duration of each sub-activity. The matching of this distribution with the values reported by the observation also contributes to the final calculation of probability.

From the sensor network within the PwD's home in this example, it is not possible to directly monitor what is happening in the house. It is therefore necessary to infer the activity from the low level data provided by the sensors. For this reason the use of HMMs are suggested where the activity is the underlying "hidden state" of the system and the samples are the "observations". This approach has been used in (Van Kasteren et al. 2008). Figure 6 presents the details of how the data can be split into time slices. For each time slice, the activity y_t must be inferred by the binary vector x_t that represents the observation.

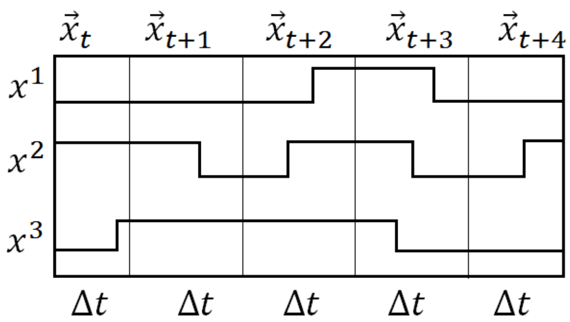

Figure 6: Hidden-Markov Model - time-slicing of sensor activations

Iin Figure 7, the sequence of activities (y) is related with the sequence of observations (x) within the HMM. This representation enables the model to consider each time slice in relation to the previous one and the following one, and hence exploits the temporal dependencies of the samples being considered.

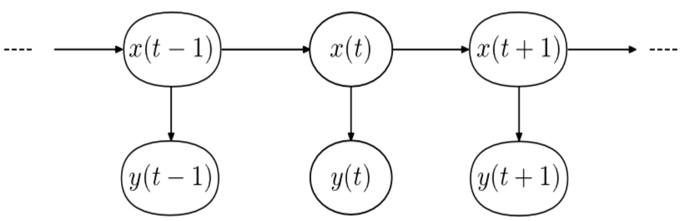

Figure 7: Hidden-Markov Model - activities (y) and observations (x)

Analysis of technique

A strength of HMMs is that temporal reasoning is inherently supported. In addition, it also has the ability to support multiple activities.

The main disadvantage of the approach is the high computational costs during training. Furthermore, as the model increases in complexity its distance increase from natural language and graphical representation. This can cause issues when dealing with non-technical users and trying to maintain and update the model.

Partially Observable Markov Decision Process

In instances when it is required to model a system whose processes are partly random a Markov Decision Process (MDP) can be used. With a MDP a finite number of states are used with each one being used to represent a certain configuration of the process being modelled. At each time the decision-maker chooses an action among those available in the current state. Following this action the system moves into another state with a certain probability and the decision maker receives a reward calculated by a function that takes in account the start state, the end state and the chosen action.

In the instance of a Partially Observed Markov Decision Process (POMDP) the underlying state of the system cannot be directly observed but must be inferred based on local observations and assumptions (Monahan 1982).

Scenario[5]

Consider an assistive support tool for a PwD with the following core requirements:

- recognize the action that the PwD is performing.
- analyse in real time the performance of the PwD in completing the action.
- prompt the PwD to reach their goal in relation to completing the action.

Consider as an illustrative example the activity of preparing pasta. This is a complex activity that involves a number of objects within the kitchen environment. In addition the activity itself may be undertaken in a number of different ways. The basic steps of the activity can be presented as follows:

The user must fill a pot with water and put it on a hot cooker. Following this the person must wait for the water to boil and then add salt and pasta, stir the pasta and finally strain it when the cooking time has been reached.

Establishing the model comprises the definition of four sets of variables: *state variables*, *actions* and *dynamics*, *rewards*, *observations*.

The *state variables* are used to describe the environment and its physical conditions. In the current scenario we can define the following:

- UL - user location sink/cooker/away *
- SW - sink water on/off
- CS - cooker switch on/off

[5] This scenario has been presented to provide an overview of the types of information and problems to be solved using POMDP. Use Cases for WP6 are presented in Section 3.

- WB - water boiling yes/no
- WI - water inside the pot yes/no
- PI - pasta inside the pot yes/no *
- SI - salt inside the pot yes/no *

The possibility of using the variables marked with an asterisk depends mostly on what type of observations are available. The activity status variables describe the various steps of the activity. Also other types of state variables such as system variables (i.e. the history of actions taken by the system to help the user) and user variables (i.e. estimate the response of user to promptings) can be used. The *actions* detail the manner in which the system can interact with the PwD for example the provision of an audio prompt to boil the water. The *dynamics* describe how the state variables stochastically evolve due to the actions chosen by the system and the actions effectively performed by the user. The *rewards* are the heuristics used to evaluate the improvements in the process given by each prompting. Finally, the *observations* are the data acquired by the sensors. Based on these observations it is possible to evaluate the state variables and subsequently derive the actual state of the system.

Analysis of technique

The use of POMDPs within the domain of AAL has achieved high levels of accuracy in terms of their performance in activity recognition scenarios. Perhaps their most advantageous feature is their ability to incorporate both the actions of the user and the actions of the system within the same framework.

The main drawback of the technique can be viewed as being, similar to HMMs, the high computational cost of the training period. This can have a knock on effect in relation to the scalability of the model given that every time a variable is to be added or deleted that describes the process or modifies the steps of the process; the training stage must be entirely repeated. These are, however, only drawbacks related to the training process. Once the model is generated it is viewed as being computationally costless.

2.2 Model Adaptation and Updates

Section 2.1 has presented an overview of a range of mathematical models that can be used for the purposes of activity recognition, however, the client-side interaction components are not expected to include activity recognition functionality (except for simple inferences from user interface actions by the user). Instead, the semantic interpretation component of the system is expected to recognize both user behaviour and other contextual parameters.

Coupled with the process of activity recognition is the notion of a User Profile, Behavioural Analysis and Adaption that can be used to both initialise and update the settings of client-side interaction components. In the first instance the model should be specific to allow a User Profile to be used to ensure that personalised service delivery is possible. In the second instance an adaptation component is required to update the User Profile as behaviour changes occur. Alternatively, user preferences may change and as such updates to the framework should also be possible. Figure 8 presents an overview of the entire process.

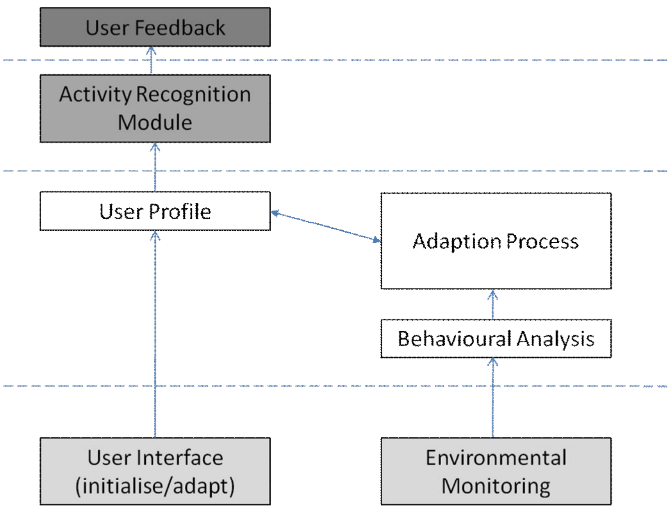

Figure 8 Architectural concepts for adaptation and change[6].

The following provides an overview of each of the components:

Activity Recognition Module: as presented in Section 2.1, the activity recognition module is responsible for the processing of the information related to the events within the environment and how these are subsequently processed to provide the most relevant feedback to the PwD within their environment. It contains a *Semantic Interpretation* component that maintains a view of the state of the person with dementia and the surrounding environment, using the ontology specified in D5.1 Semantic Knowledge Structures and Representation.

User feedback: the user feedback module is responsible for taking the output from the activity recognition module and providing the most appropriate form of feedback to the PwD. This is part of the *Patient Interface* (see annex). This may be in relation to the modality of the feedback from a text, image, video or voice perspective or it may involve a more elaborate context aware component which can be used to detect where the PwD is and what is their current activity and subsequently decide, for example, to delay to delivery of automated support or to select, based on the range of available mediums, the device through which feedback and support will be provided.

User Profile: the user profile is necessary to store the personalised information related to each user of the system, for fast adaption and personalization in the user interfaces. The details to be stored will be related to the rules within the activity recognition system. For example, if repetitive motions of a certain behaviour are known the frequency of these repetitions could be stored. Alternatively times when medication is to be taken or the possibility of leaving the bed during the night-time to use the bathroom could also be recorded. The use of such a profile provides a number of benefits. Primarily it supports the personalisation of the activity recognition process. Secondly, it addresses the cold start issue

[6] In D5.1 Semantic Knowledge Structures and Representation, "Behavioural Analysis" is described as being part of the Semantic Interpretation component.

where the activity recognition model can be preloaded with values. Thirdly and finally it supports flexibility within the system allowing the user profile to be adapted or changed depending on the user's preferences or behavioural changes. The User Profile could be part of the DemCare Ontology described in D5.1 Semantic Knowledge Structures and Representation.

Adaptation process: within this component of the system the information stored within the user profile can be both accessed and updated. If any behavioural changes recorded through the *behavioural analysis* module are noted then the appropriate updates can be made to the user profile. For example, if it is noted that the PwD has started to sleep longer in the mornings due to seasonal changes, then the user profile can be updated to reflect that the typical time to leave the bed in the morning is going to be later. Profile updates will require a form of human verification to ensure that only valid changes are registered. The PwD habits and behavioural changes will be described in D5.2 Multi-Parametric Behaviour Interpretation v1, and the rules for adapting the client-side interaction components based on that will be described in D6.3 Case-based Feedback Adaptation v2.

User Interface: a module will be provided to allow key stakeholders the ability to both initially populate the user profile and secondly to retrieve the profile, view its contents and make any changes required.

3 Required System Services for Feedback

This chapter describes the services to be provided by the *Feedback Engine* component that will manage case-based feedback to PwD, carers and clinicians. However, it starts by describing the query and notification services that are required from the Dem@Care system to enable the Feedback Engine to function.

It is based on the Dem@Care use cases and the scenarios described in D2.2 Functional Requirements & Scenarios v1. The modality and type of notifications, as well as the target user and the environment in which the notification is relevant, are specified in accordance to those functional specifications.

An analysis of the Use Cases and Scenarios was carried out in order to identify the environmental and physiological events that would have an impact on the case-based feedback process. This chapter describes the notable queries and notifications derived from this analysis.

Please note that each sections contains illustrations of the use cases followed by specifications of the required notifications.

3.1 Sleep notifications

In this scenario, we wish to monitor the PwD while they are in bed and sleeping. The system interface must act in an appropriate manner for each state that the PwD may be in (i.e. preparing for bed, sleeping, waking normally, waking abnormally).

The notifications are derived directly from the use cases for the @Home scenario. Each use case and its resultant required notification are illustrated below;

Use Case Sleep 1000: Monitoring night-time sleep (Figure 8)

- In Home and Nursing Home
- No notifications

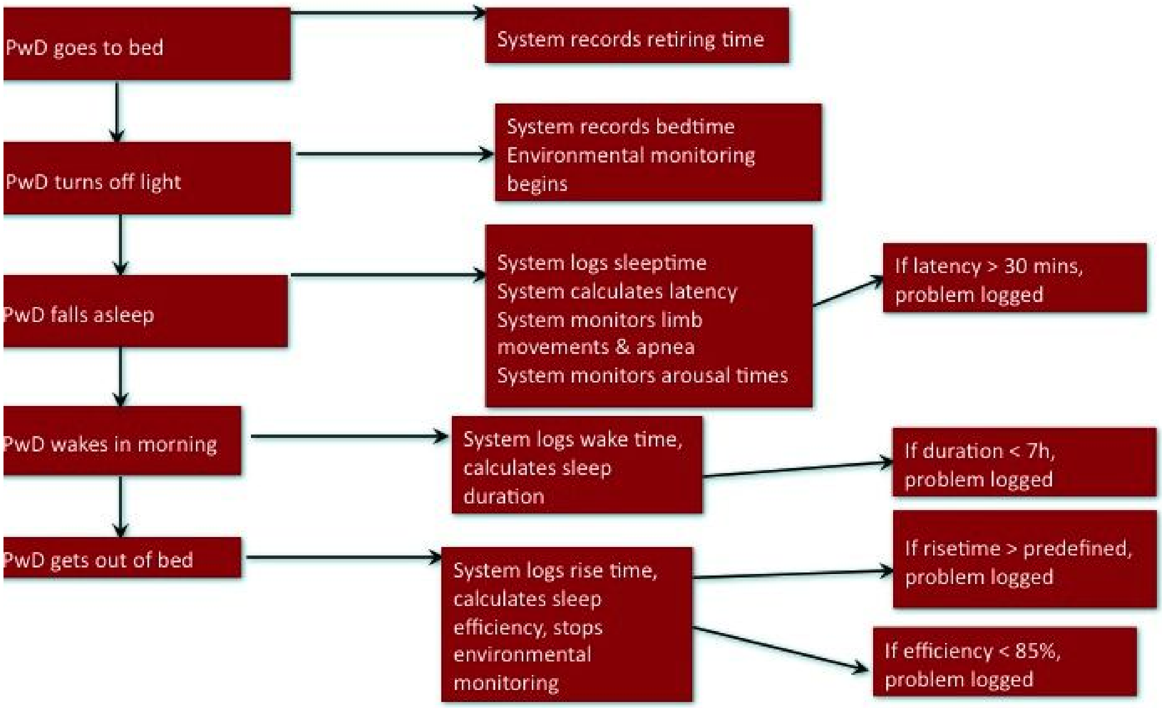

Figure 8: Use Case Sleep 1000 - Monitoring night-time sleep

Use Case Sleep 1000-1: dealing with awakenings (Figure 9)

- Notification: Notifying carer and clinician of disturbances in the sleep patterns of the PwD
    - In Home and Nursing Home
    - Visualization of results, messages, alerts
        - Comment: Information available upon request from carer or clinician
- Notification: At night - Notifying the PwD (and the carer) that it is night and inform the PwD if the PwD has difficulties to sleep again
    - In Nursing Home
    - Audio content
        - Comment: Functional requirements specify that the carer should be notified. However, such notification is likely only to be needed when additional "problems" arise which may cause the PwD to need assistance.

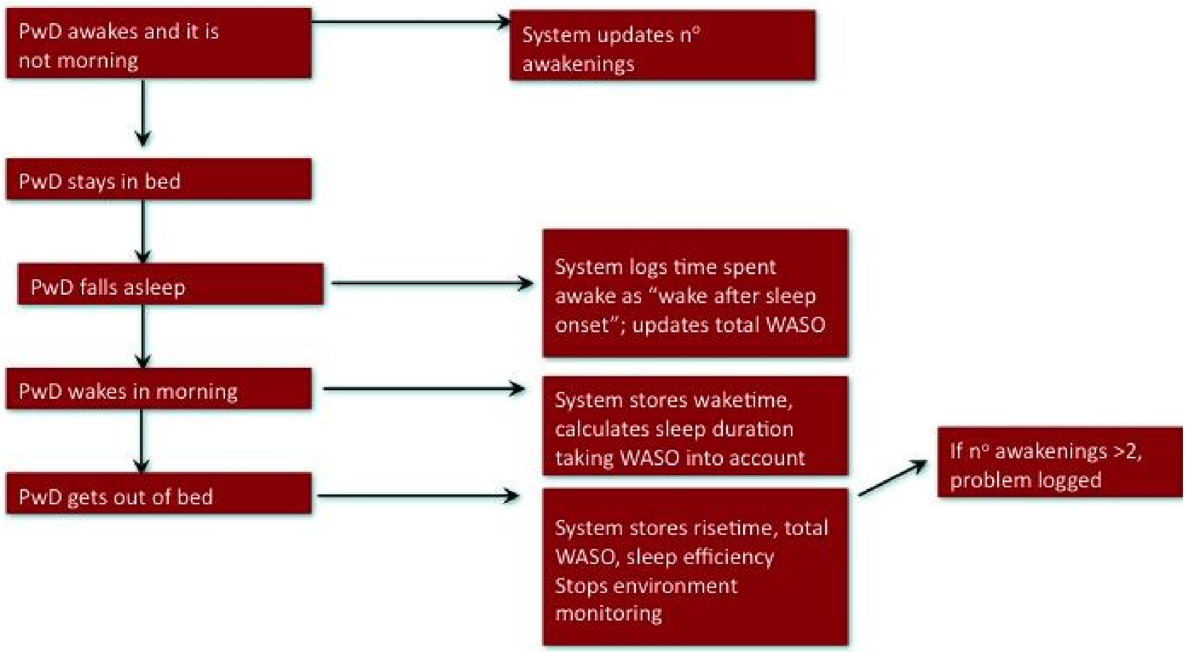

Figure 9: Use Case Sleep 1000-1 - dealing with awakenings

Use Case Sleep 1000-1-1: Dealing with bed exits (Figure 10)

- Notification: Notifying the carer whether the PwD is sleeping, and if not if some non-night activity is going on
    - In Nursing Home
    - Audiovisual content
- (Not in functional requirements - Notification: Alert the PwD and encourage the PwD to return to bed)
    - (Not in functional requirements so no indication to where it is going to be used, Home, Nursing Home, or both)
    - Audiovisual content

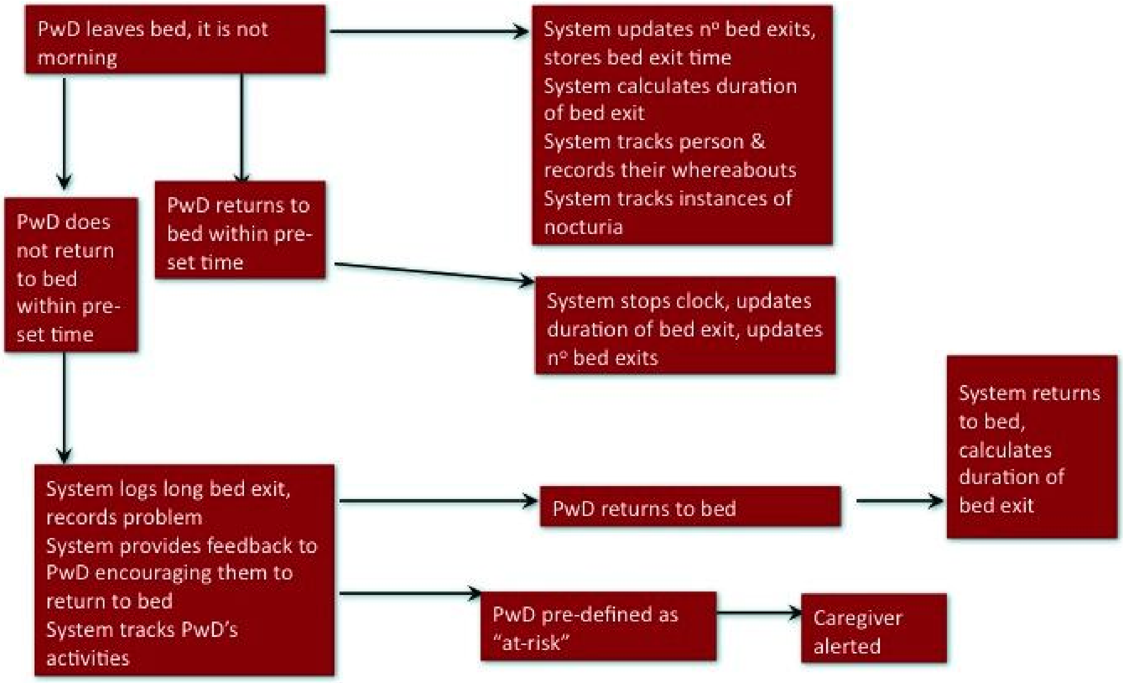

Figure 10: Use Case Sleep 1000-1-1 - Dealing with bed exits

Use Case Sleep 1000-1-1-3: Dealing with insomnia onset (Figure 11)

- (Not in functional requirements so no indication to where it is going to be used, Home, Nursing Home, or both)
- No notifications

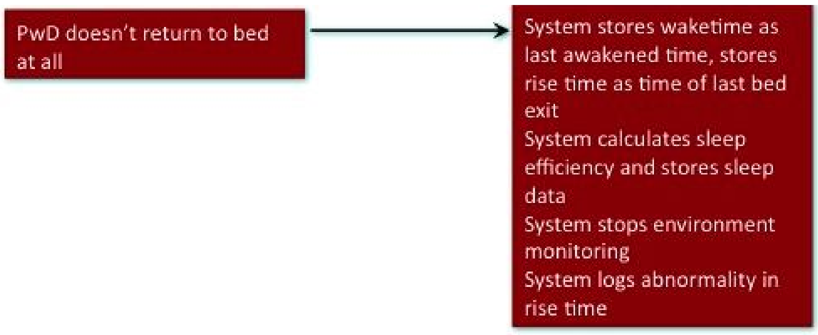

Figure 11: Use Case Sleep 1000-1-1-3 - dealing with insomnia onset

Use Case Sleep 1000-1-2: Difficulty falling asleep (Figure 12)

- (Not in functional requirements so no indication to where it is going to be used, Home, Nursing Home, or both)
- No notifications

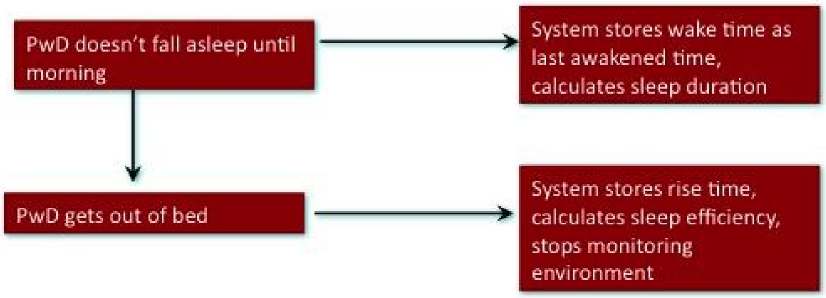

Figure 12: Use Case Sleep 1000-1-2 - Difficulty falling asleep

Use Case Sleep 2000: Search reasons for abnormal sleep (Figure 13)

- (Not in functional requirements so no indication to where it is going to be used, Home, Nursing Home, or both)
- Notification: Notifying the PwD of abnormal sleep
    - Visual feedback

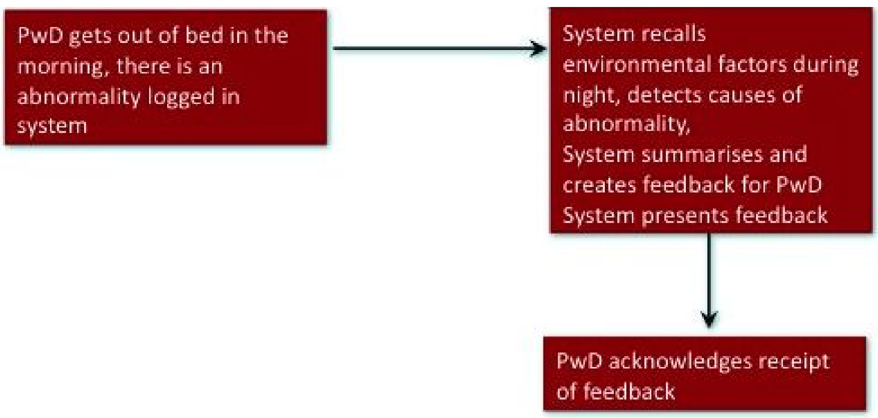

Figure 13: Use Case Sleep 2000 - Search reason for abnormal sleep

Use Case Sleep 3000: Clinician Feedback (Figure 14)

- Notification: Notifying the Clinician (and carer) about sleep patterns
    - In Home and Nursing Home
    - Visualization of results, messages, alerts.
- Notification: Educating the Carer and the PwD about the effects of medication and their side effects to sleep
    - In Home and Nursing Home
    - Audiovisual content
- Notification: Recommendations to the PwD and the carer for improving the sleep quality of the PwD according to his/her profile and preferences
    - In Home and Nursing Home
    - Audiovisual content

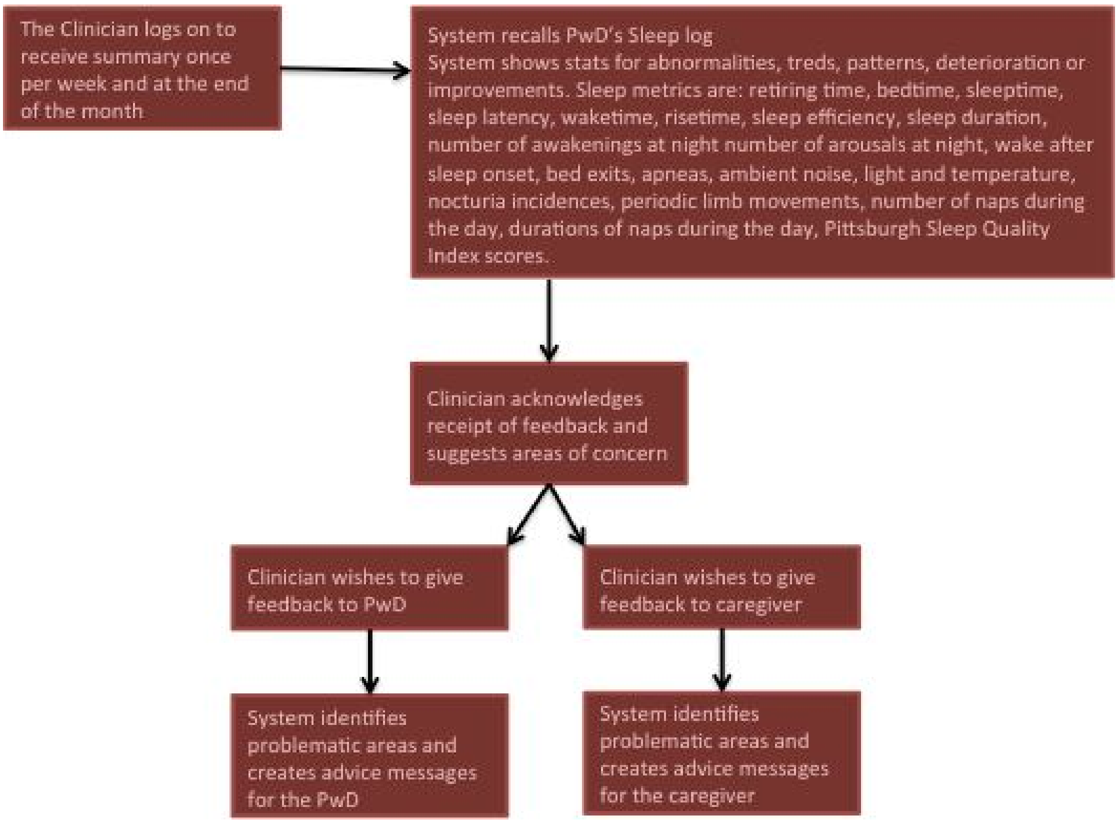

Figure 14: Use Case Sleep 3000 - Clinician Feedback

Use Case Sleep 4000: PwD Feedback (Figure 15)

- Notification: Motivate the PwD to improve sleep
    - In Home and Nursing Home
    - Messages, visualization of positive progress
- Notification: Recommendations to the PwD and the carer for improving the sleep quality of the PwD according to his/her profile and preferences
    - In Home and Nursing Home
    - Audiovisual content

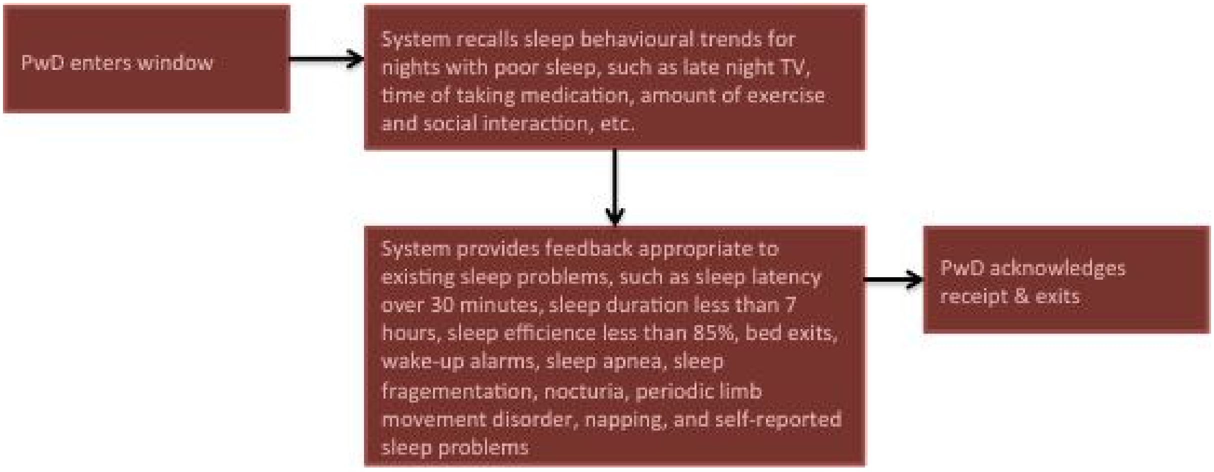

Figure 15: Use Case Sleep 4000 - PwD feedback

Use Case Sleep 5000: Present Sleep Questionnaire (Figure 16)

- Notification: monthly reminder to the PwD to fill in the questionnaire
    - (Not in functional requirements so no indication to where it is going to be used, Home, Nursing Home, or both)

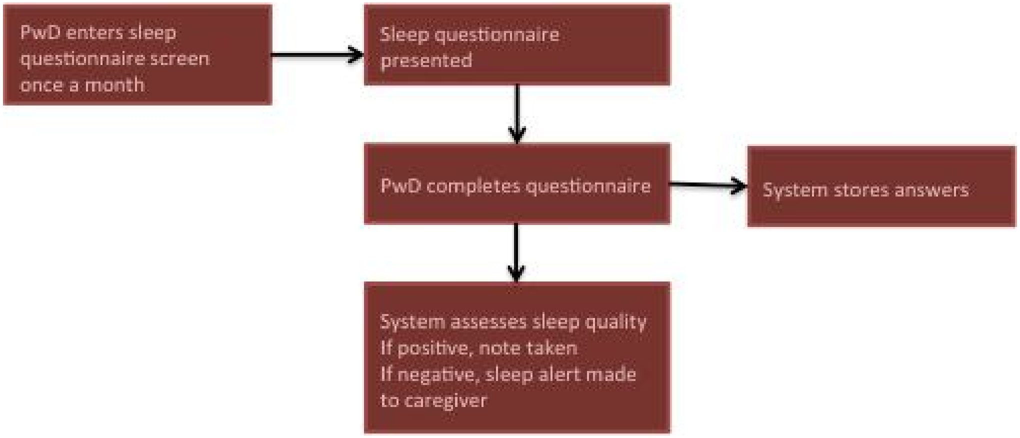

Figure 16: Use Case Sleep 5000 - Present Sleep Questionnaire

Use Case Sleep 6000: Monitoring daytime sleep (Figure 17)

- Notification: Motivate the PwD to improve sleep
    - Messages, visualization of positive progress
    - In Home and Nursing Home

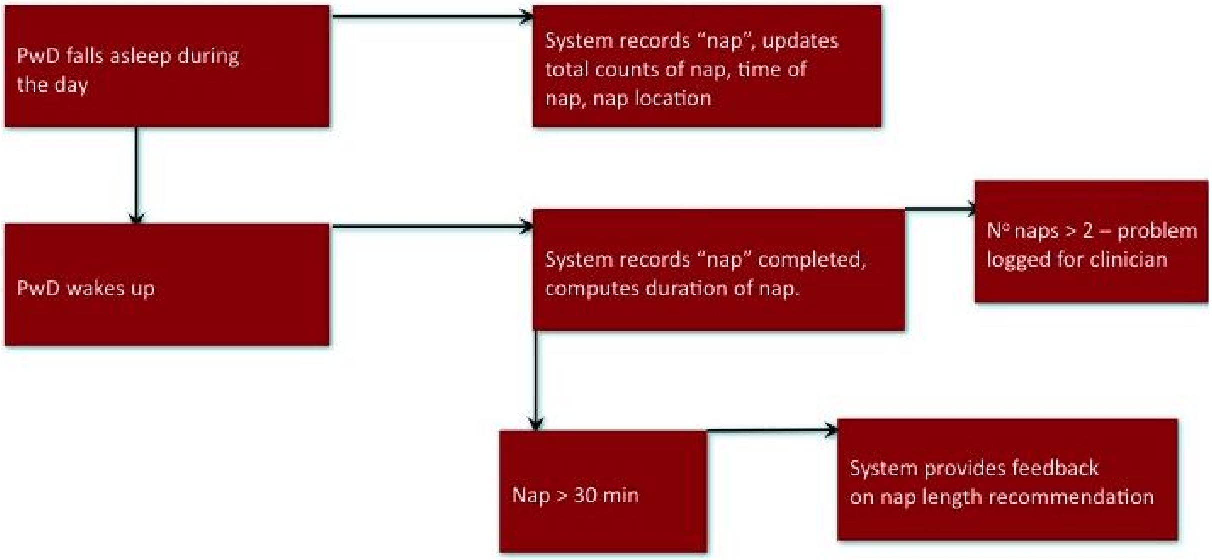

Figure 17: Use Case Sleep 6000: Monitoring daytime sleep

3.2 Social Interaction notifications

In this scenario, we wish to monitor the PwD while they are socialising, both on the telephone and person-to-person. The system must be able to recognise a social interaction and record relevant details about the behaviour of the PwD, the success of their interactions, and their conversational partner.

The notifications are derived directly from the use cases for the @Home scenario. Each use case and its resultant required notification are illustrated below;

Use Case Social Interaction 1000: face-to-face social contact (Figure 18)

- In Home and Nursing home
- No notifications

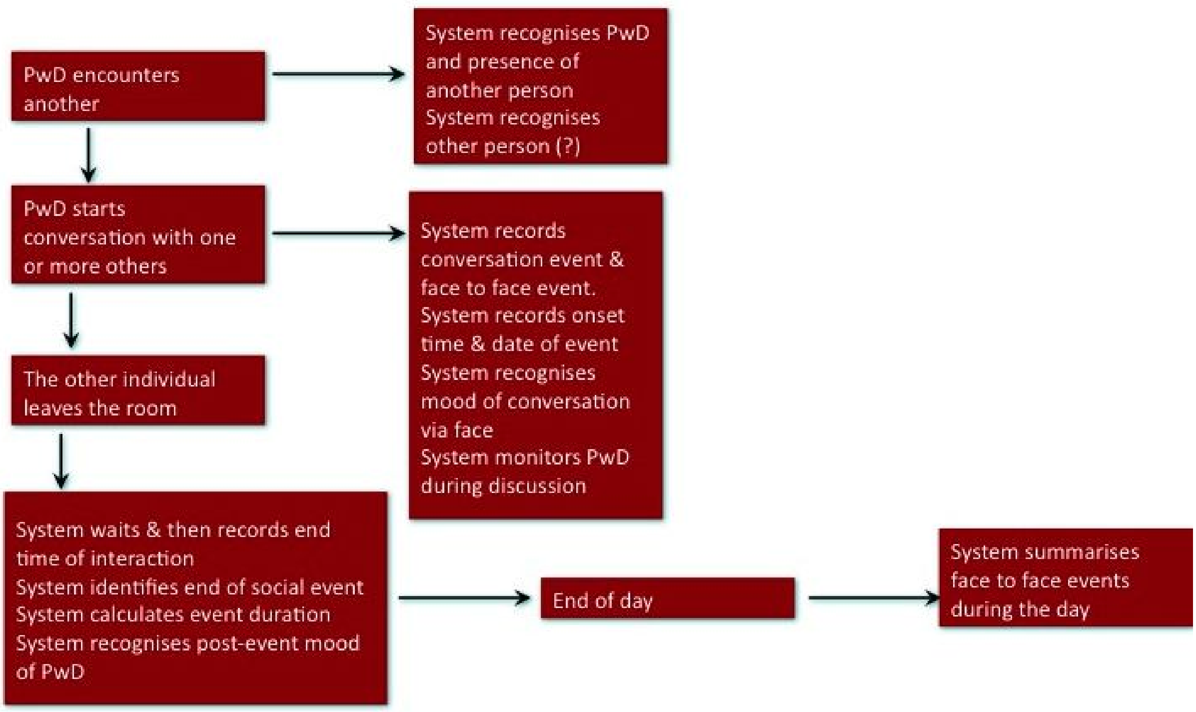

Figure 18: Use Case Social Interaction 1000 - Face-to-face contact

Use Case Social Interaction 1001: PwD receives a phone call (Figure 19)

- Notification: Inform the PwD about incoming call
  - In Home and Nursing Home
  - Alert, Audiovisual content

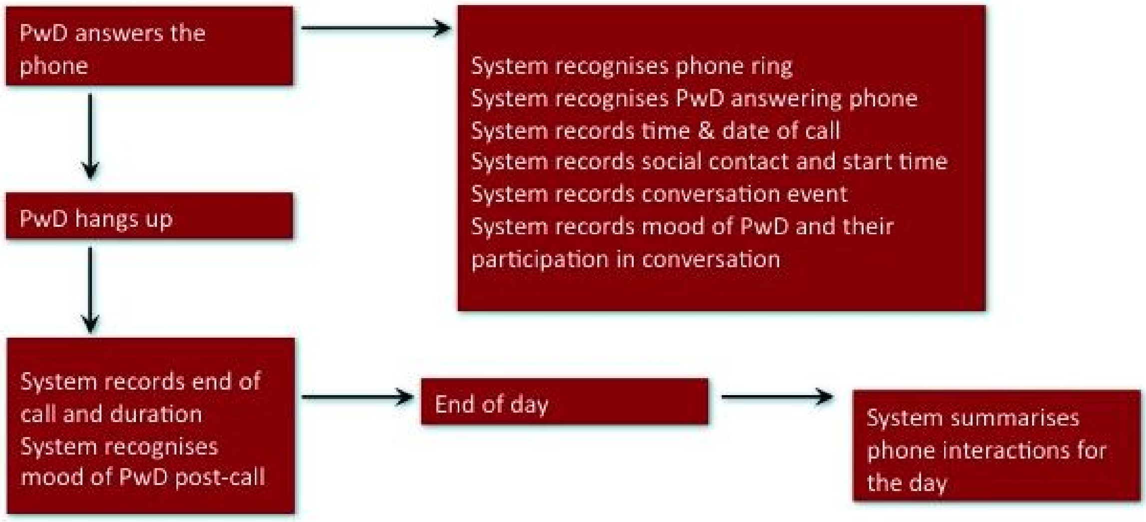

Figure 19: Use Case Social Interaction 1001 - PwD receives a phone call

Use Case Social Interaction 1002: PwD initiates a phone call (Figure 20)

- In Home and Nursing Home
- No notifications

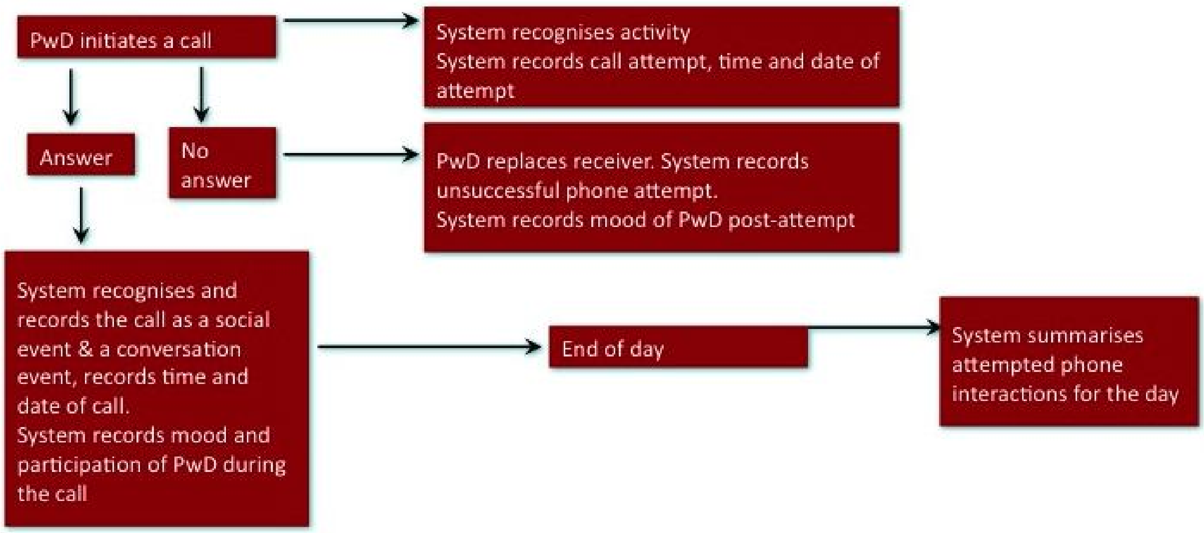

Figure 20: Use Case Social Interaction 1002: PwD initiates a phone call

Use Case Social Interaction 1000-1: Insufficient number of face-to-face events (Figure 21)

- In Home and Nursing Home
- Notification: alert caregiver of abnormality
    - (Not in functional requirements)

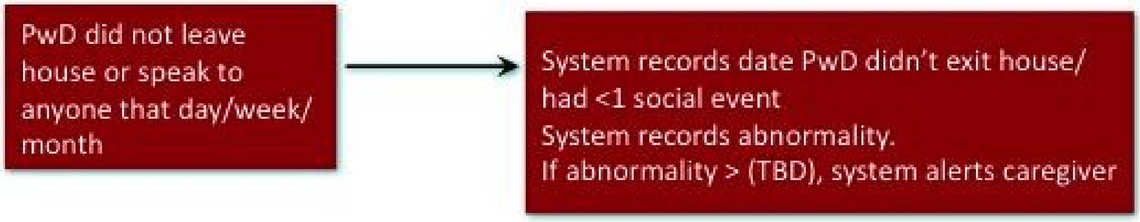

Figure 21: Use Case Social Interaction 1000-1: Too few face-to-face events

Use Case Social Interaction 1002-1: Insufficient number of phone events (Figure 22)

- In Home and Nursing Home
- Notification: alert caregiver of abnormality
    - (Not in functional requirements)

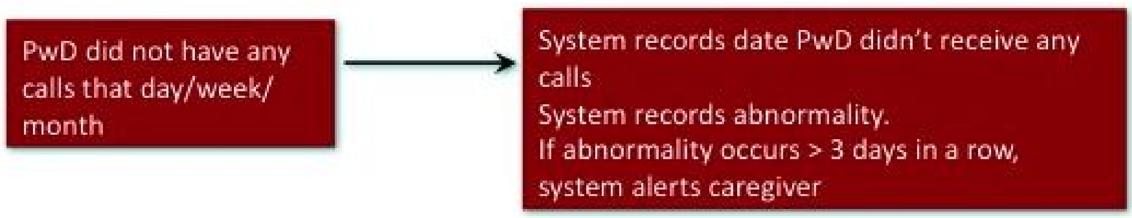

Figure 22: Use Case Social Interaction 1002-1 - Too few phone events

Use Case Social Interaction 1003-1: Insufficient number of phone calls initiated (Figure 23)

- In Home and Nursing Home
- Notification: alert caregiver of abnormality
    - (Not in functional requirements)
- Notification: Remind the PwD to make calls to people he/she uses to

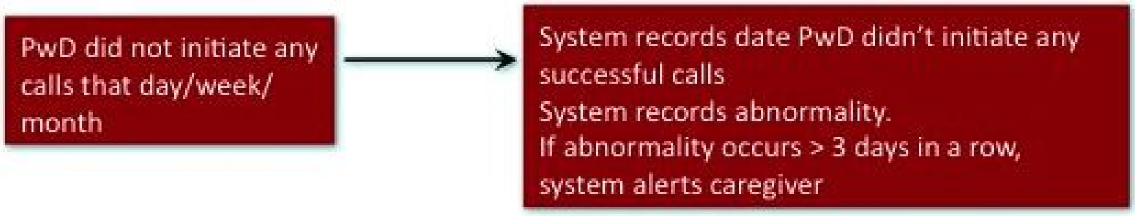

Figure 23: Use Case Social Interaction 1003-1 - Too few phone calls initiated

Use Case Social Interaction 1001-2: Insufficient number of conversations (Figure 24)

- In Home and Nursing Home
- Notification: alert caregiver of abnormality
    - (Not in functional requirements)

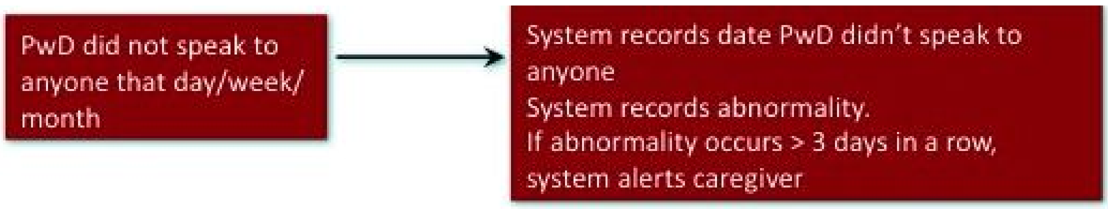

Figure 24: Use Case Social Interaction 1001-2 - Too few of conversations

Use Case Social Interaction 2000: Feedback to clinician (Figure 25)

- In Home and Nursing Home
- Notification: Educate the PwD and the carer about the effects of social contact to dementia
- Notification: Recommend the PwD and the carer for ways to social contact for the PwD, according to his/her preferences and condition
- Notification: Inform the carer about negative trends in social contact
- Notification: Motivate the PwD to socialise

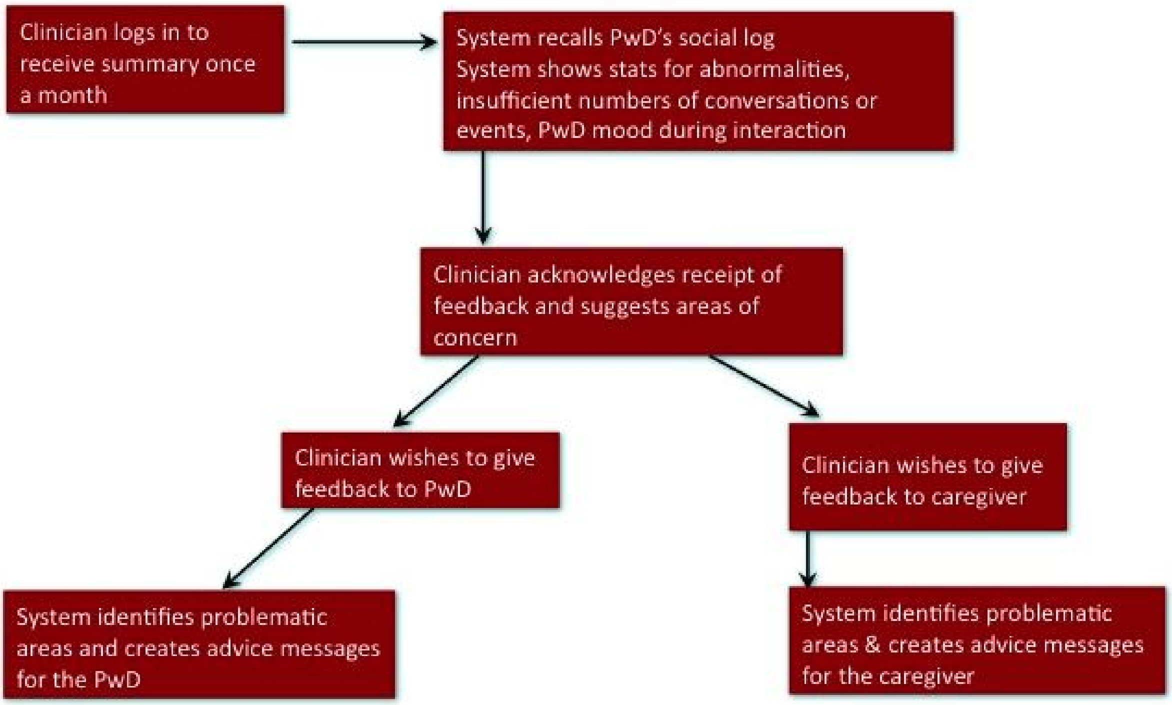

Figure 25: Use Case Social Interaction 2000 - Feedback to clinician

3.3 Exercise notifications

In this scenario, we wish to monitor the PwD while they are engaged in physical activity, both inside and outside of the home.

The notifications are derived directly from the use cases for the @Home scenario. Each use case and its resultant required notification are illustrated below;

Use Case Exercise 1000: Monitoring physical activity at home (Figure 26)

- In Lab, Home, and Nursing Home
- Notification: Reward/Motivate the PwD with positive trends in physical activity/exercise
    - In Home and Nursing Home
    - Audiovisual content
- Remind the PwD about the exercise sessions in the morning and 30 minute before starting
    - In Home and Nursing Home
    - Reminder, audiovisual content
- Guide the PwD to perform the exercise
    - In Home and Nursing Home
    - Exercise guidance, Audiovisual content, simulated presence

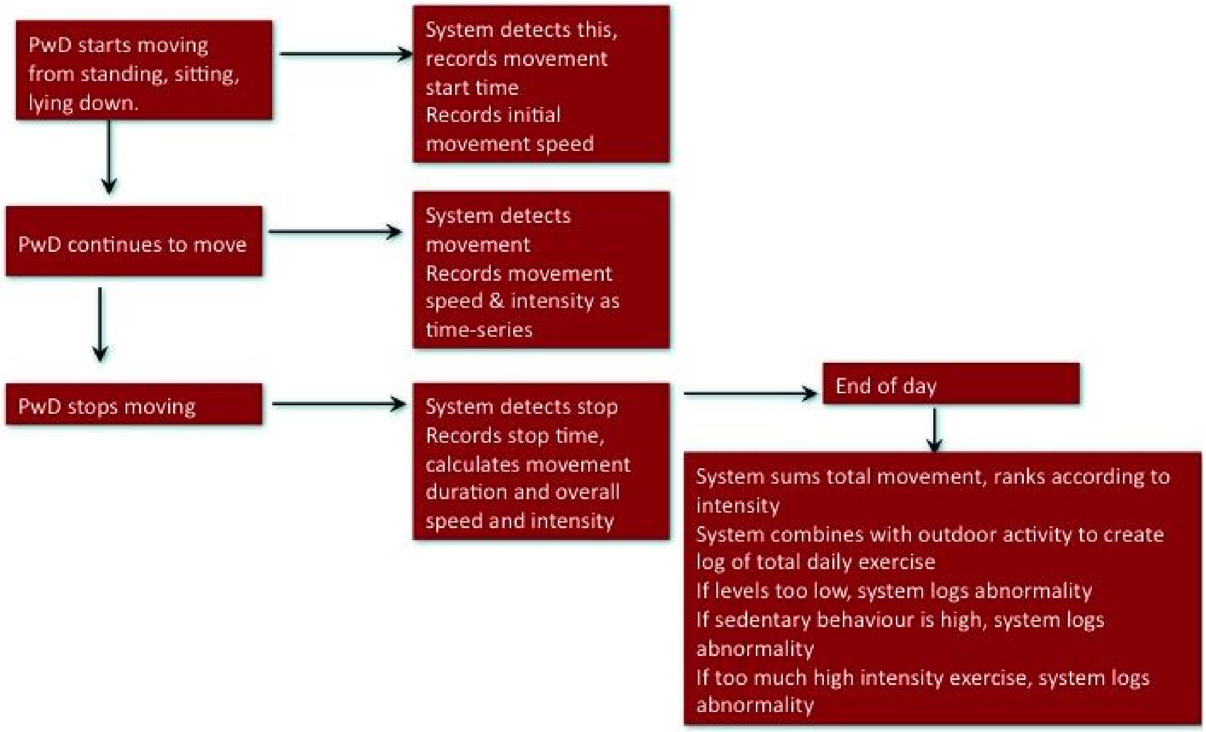

Figure 26: Use Case Exercise 1000: Monitoring physical activity at home

Use Case Exercise 3000: Monitoring outdoor physical activity (Figure 27)

- In Lab, Home, and Nursing Home
- Notification: Reward/Motivate the PwD with positive trends in physical activity/exercise
    - In Home and Nursing Home
    - Audiovisual content
- Remind the PwD about the exercise sessions in the morning and 30 minute before starting
    - In Home and Nursing Home
    - Reminder, audiovisual content
- Guide the PwD to perform the exercise
    - In Home and Nursing Home
    - Exercise guidance, Audiovisual content, simulated presence

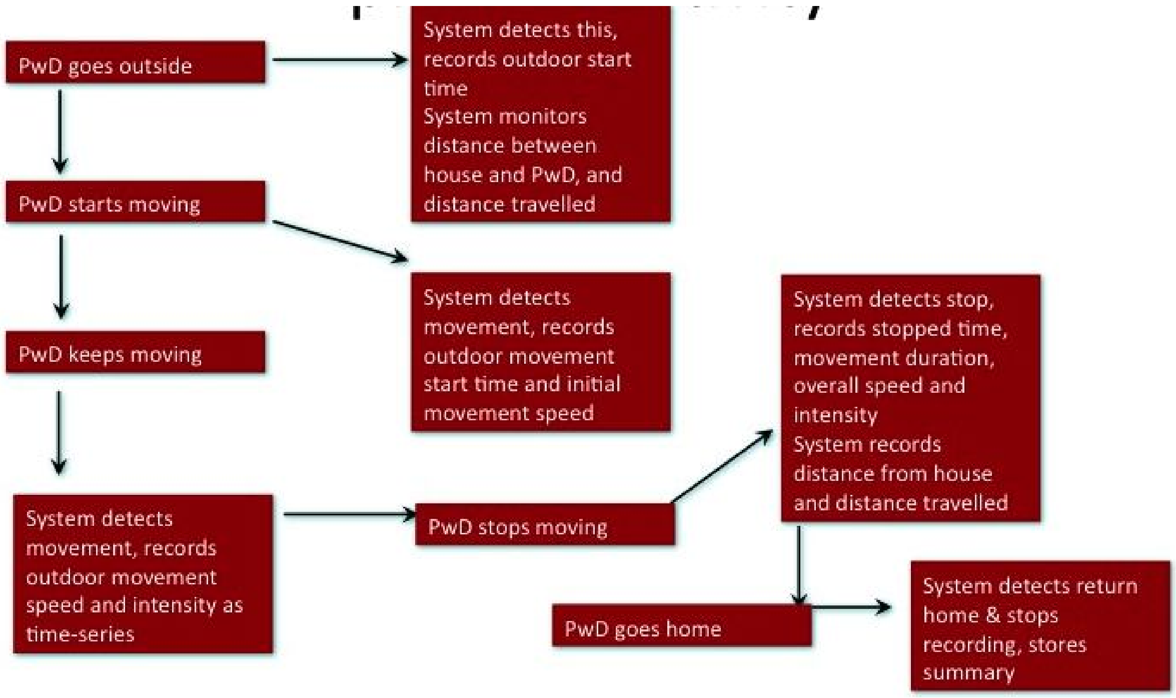

Figure 27: Use Case Exercise 3000: Monitoring outdoor physical activity

3.4 Activities of Daily Living notifications

In this scenario, we wish to monitor the PwD while they are engaged in activities of daily living around the house, particularly as applied to eating behaviours.

The notifications are derived directly from the use cases for the @Home scenario. Each use case and its resultant required notification are illustrated below;

Use Case Eating 1000: Monitor eating (Figure 28)

- In Home and Nursing home
- Notification: Notify the carer when PwD starts to have meals in different places in the house
- Notification: Notify the carer when the PwD starts to have different eating habits
- Notification: Notify the Carer when the PwD starts to have difficulties with using cutlery correctly

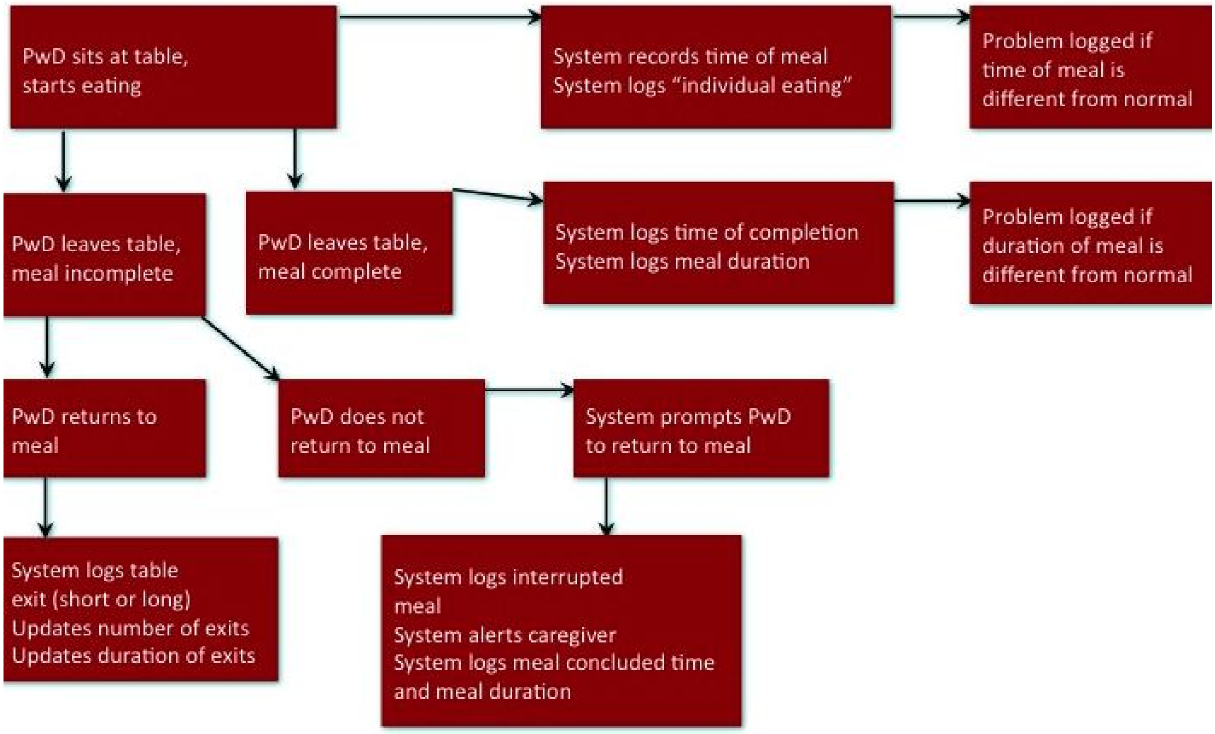

Figure 28: Use Case Eating 1000 - Monitoring Eating

Use Case Eating 1000-2: Patient has not eaten after a certain time (Figure 29)

- Notification: Notify the carer when the PwD has missed a meal
    - In Home and Nursing Home

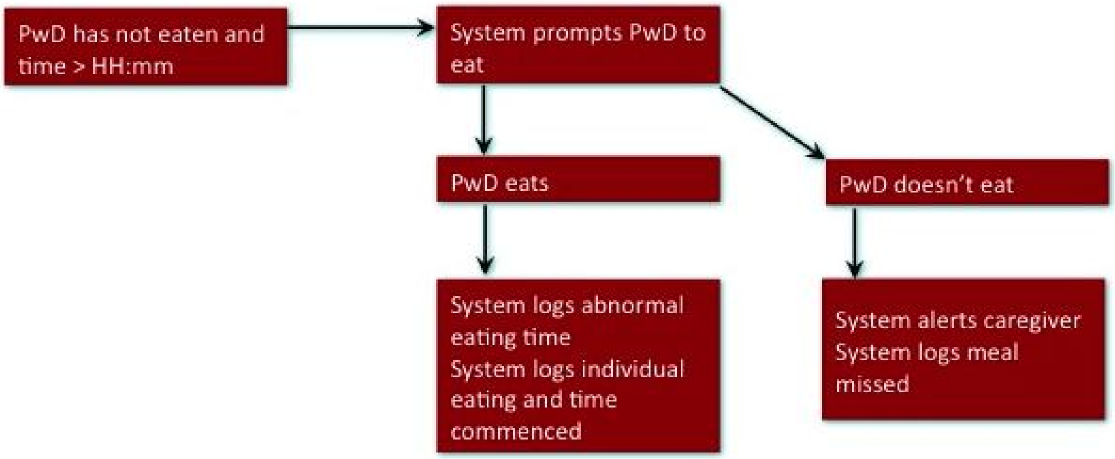

Figure 29: Use Case Eating 1000-2: Has not eaten after a certain time

Use Case Eating 2000: Monitoring meal preparations (Figure 30)

- In Home and Nursing Home
- Notification: Alert the PwD of open fridge
    - (Not in functional requirements)
- Notification: Remind the PwD to tidy
    - (Not in functional requirements)

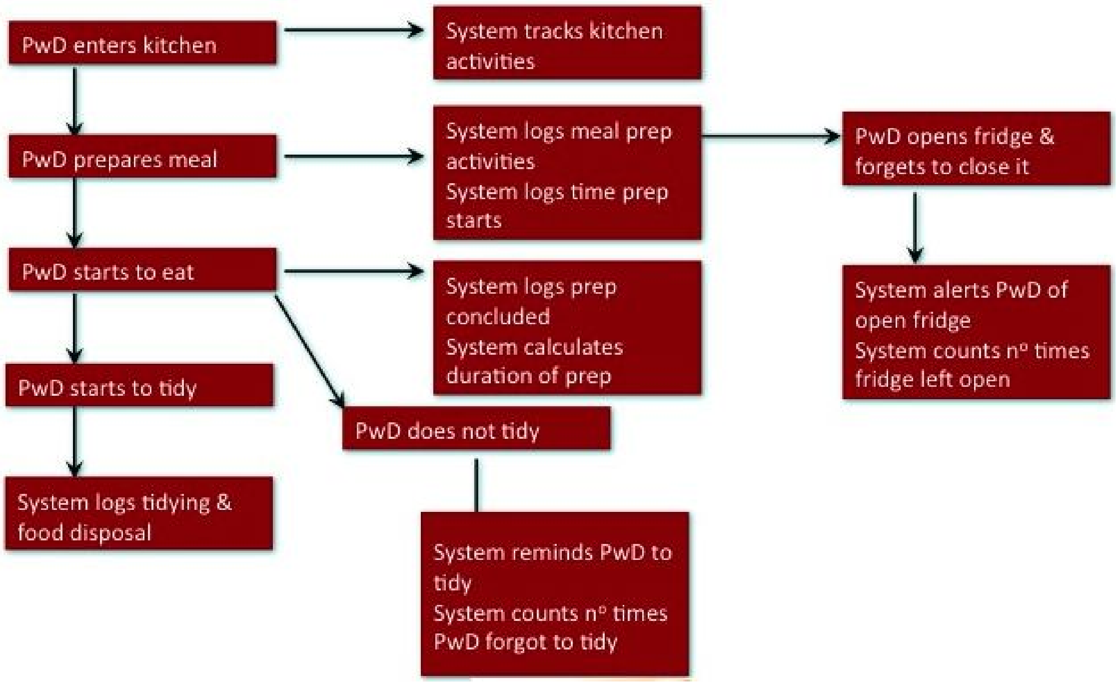

Figure 30: Use Case Eating 2000: Monitoring meal preparation

Use Case Eating 3000: Feedback to the clinician (Figure 31)

- Notification: Inform the carer and the clinician when the PwD has an accident in the kitchen with the use of devices
    - In Home
- Notification: Inform the clinician about eating and meal preparation habits and problems
    - (Not in functional requirements)

Figure 31: Use Case Eating 3000 - Feedback to the clinician

Use Case Eating 4000: Feedback to the caregiver (Figure 32)

- Notification: Inform the carer and the clinician when the PwD has an accident in the kitchen with the use of devices
    - In Home
- Notification: Notify the carer about recommendations to the PwD for meals according to his/her preferences and past meals
    - In Home
- Notification: Inform the Carer (and PwD) about the need for shopping
    - In Home
- Notification: Inform the caregiver about PwD eating advice
    - (not in functional requirements)

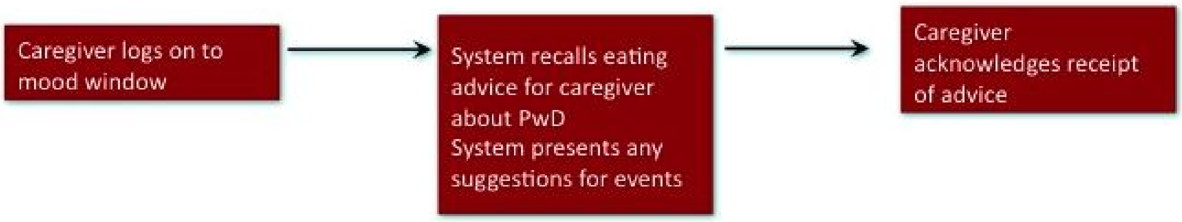

Figure 32: Use Case Eating 4000 - Feedback to the caregiver

Use Case Eating 5000: Eating out (Figure 33)

- In Home
- Notification: present the PwD with an Eating Out questionnaire
    - (Not in functional requirements)

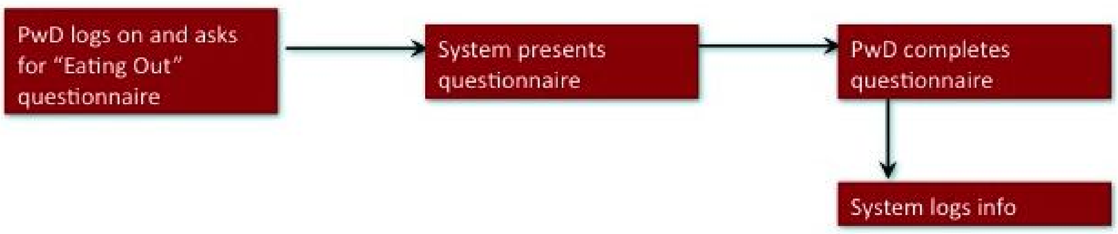

Figure 33: Use Case Eating 5000 - Eating out

3.5 Mood notifications

The measurement of mood is not performed online, nor indeed with sensors of any type, so there is no low-level physiological or environmental data that provides any indicators of mood.

All mood information is collected by questionnaire that is presented to the user once a week. This will be scheduled explicitly for presentation to the PwD. Reminders may be required if survey is postponed.

The notifications are derived directly from the use cases for the @Home scenario. Each use case and its resultant required notification are illustrated below;

Use Case Mood 1000: Present Mood Questionnaire (Figure 34)

- In Home and Nursing Home
- Notification: remind the user to take the mood questionnaire once per week
    - (not in functional requirements)
- Notification: Inform the carer and the clinician about the detection of negative mood trends

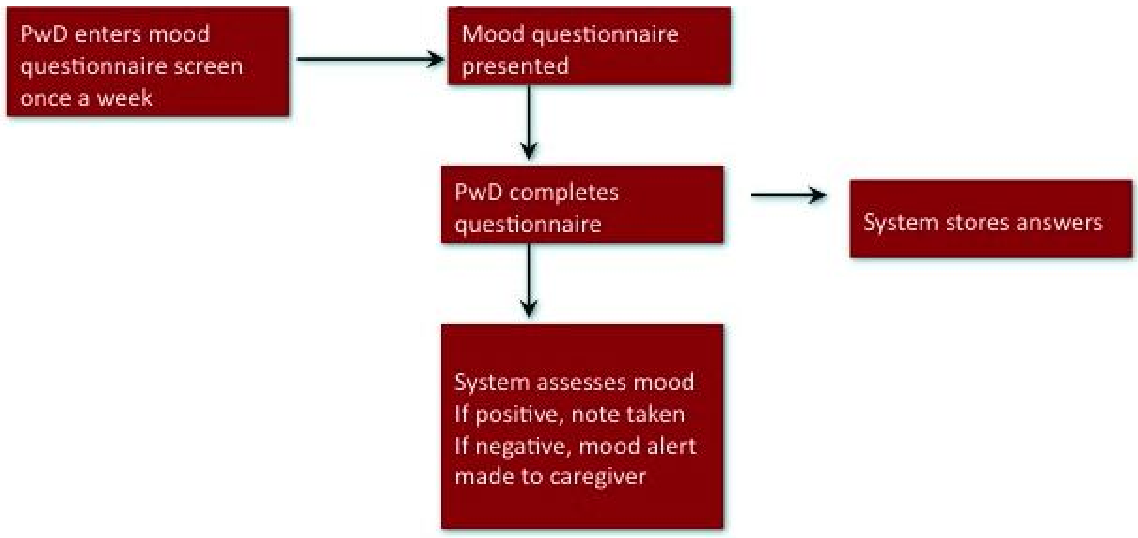

Figure 34: Use Case Mood 1000 - Present Mood Questionnaire

Use Case Mood 2000: Feedback to the clinician (Figure 35)

- In Home and Nursing Home
- Notification: notify the clinician about PwD's mood and related behaviours, abnormalities and problematic moods
  - (not in functional requirements)

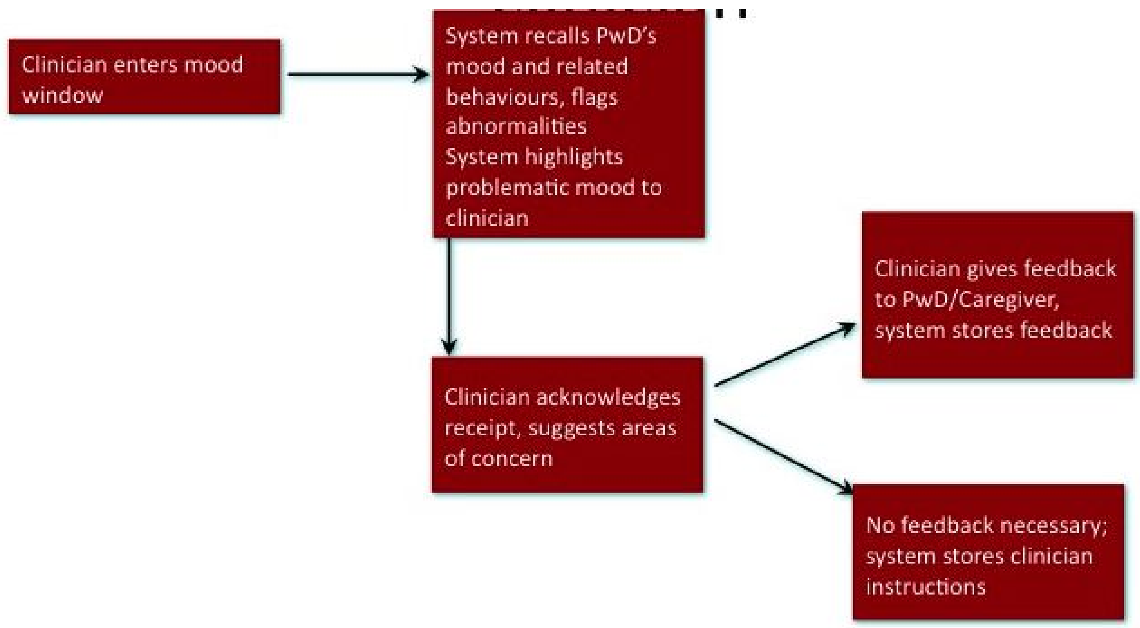

Figure 35: Use Case Mood 2000 - Feedback to the clinician

Use Case Mood 2000-1: Clinician gives PwD feedback (Figure 36)

- In Home and Nursing Home
- Notification: Educate the PwD about the effects of medication incompliance to behaviour and mood
- Notification: Educate the PwD about the parameters that affect mood

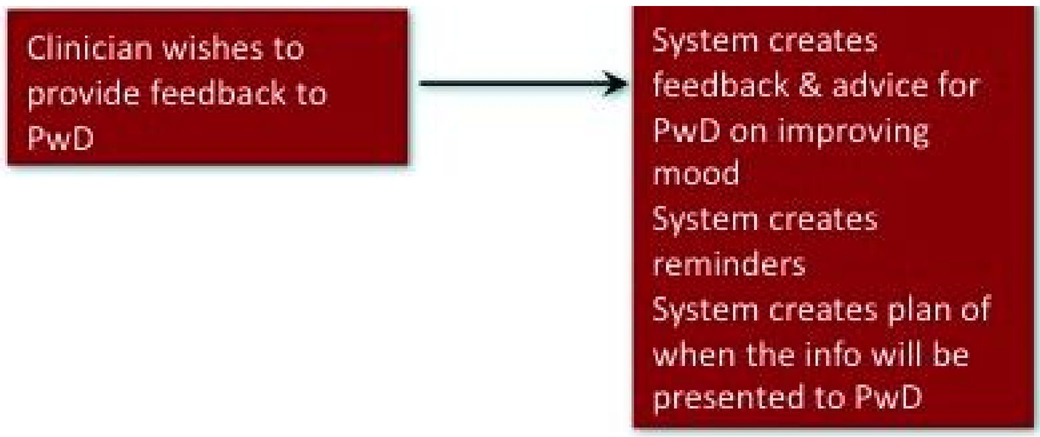

Figure 36: Use Case Mood 2000-1 - Clinician gives feedback to PwD

Use Case Mood 2000-2: Clinician gives caregiver feedback (Figure 37)

- In Home and Nursing Home
- Notification: Educate the caregiver about the effects of medication incompliance to behaviour and mood
- Notification: Educate the caregiver about the parameters that affect mood
- Notification: Inform the carer about identified factors for agitation, aggression, nervous behaviour

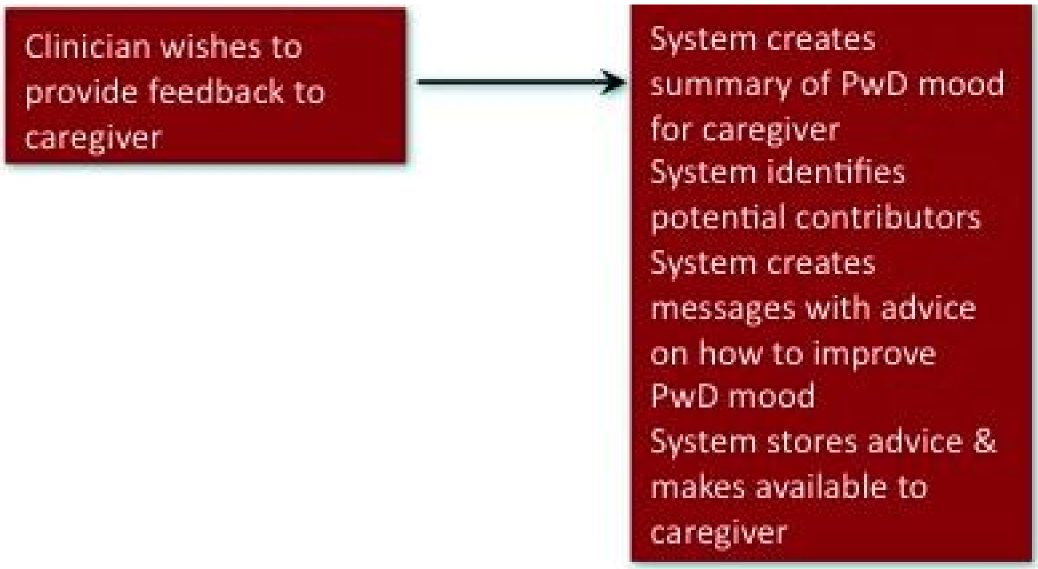

Figure 37: Use Case Mood 2000-2 - Clinician gives feedback to caregiver

Use Case Mood 3000: PwD receives feedback (Figure 38)

- In Home and Nursing Home
- Notification: Educate the PwD about the effects of medication incompliance to behaviour and mood
- Notification: Educate the PwD about the parameters that affect mood

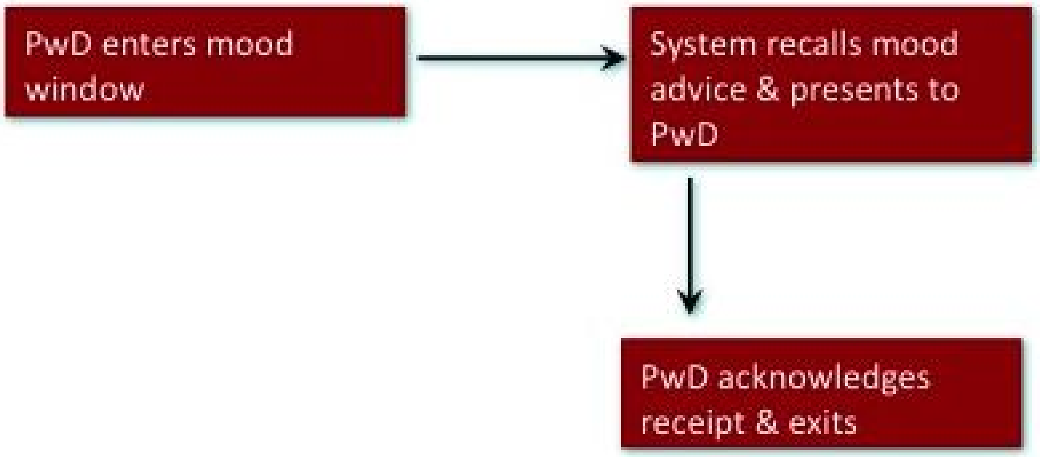

Figure 38: Use Case Mood 3000 - PwD receives feedback

Use Case Mood 4000: Caregiver receives feedback (Figure 39)

- In Home and Nursing Home
- Notification: Educate the caregiver about the effects of medication incompliance to behaviour and mood
- Notification: Educate the caregiver about the parameters that affect mood
- Notification: Inform the carer about identified factors for agitation, aggression, nervous behaviour

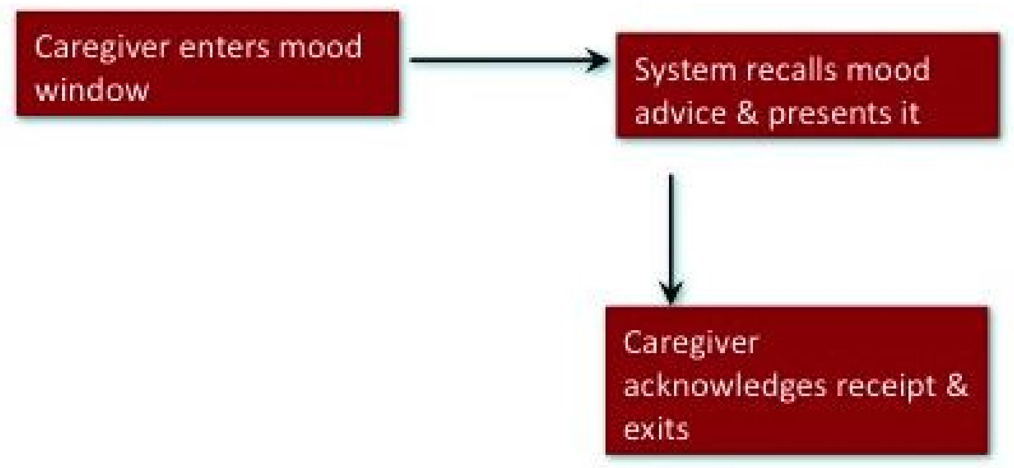

Figure 39: Use Case Mood 4000 - Caregiver receives feedback

3.6 Mathematical Models for Scenarios

This section explores mathematical models for supporting the activity recognition that is required for case-based feedback adaption. The actual algorithms and mathematical models to be used in the Dem@Care system will be described in deliverables 4.2 Activities Monitoring & Lifelogging v1 and D5.2 Multi-Parametric Behaviour Interpretation v1. The purpose is to illustrate possible ways of approaching this important area.

As shown in Chapter 2, there are a number of different mathematical models available for use. In this section, we identify how the mathematical models presented may be applied in the scenarios described earlier in this chapter.

Fault trees can be used for analysis of system errors and failures and to recognise other undesirable situations. This can be used in a number of the use-cases discussed above, where the sensing devices, for example, can trigger that particular events have happened, such as if the PwD has suffered a fall, or their house-door has been left open.

Hidden Markov Models (HMMs) and Partially Observable HMMs (POHMMs) will be used where the user is engaged in an activity that consists of a sequence of separate tasks. The HMM will be used to track the user's progress through the activity, and ensure that none of the tasks are missed, or done out of order.

Furthermore, HMMs can be used where it is necessary to interrupt the PwD while they are engaged in an activity. The HMM can be used to record the current state of the activity (i.e., the currently-running task in the sequence) and also to identify the transitions between the tasks, in order to identify an interruption point that will be minimally disruptive.

For example, a PwD may be engaged in a task such as preparing food when an incoming phone call occurs. The HMM mathematical model could allow the system to identify that the user has just completed preparing the vegetables, but not yet started to cook them. In this case, the HMM can allow the call to be connected to the PwD. When the conversation is finished, the PwD may receive a reminder (if necessary) to begin cooking the vegetables, as this is the next stage in their food preparation activity.

If the PwD was already cooking vegetables when the incoming call occurred, then the HMM may identify that this task should not be interrupted by phone calls and so the call would be sent to voicemail explaining that the PwD is busy, and a message can be left for the the PwD to receive when the cooking task is completed.

Certain classes of scenarios may not require any complex modelling at all and can then be handled by simpler mechanisms. For example, normal feedback sent by the system (e.g., weekly or monthly records of exercise or diet) could be handled by a simple queuing mechanism. This can be augmented with priority queues and labelling for more urgent feedback.

Emergency notifications to carers and clinicians would be handled separately from the ordinary notifications. Here we could use Fault Tree Analysis to provide quick, robust generation of responses to undesirable situations (e.g., physiological sensors report that the PwD is undergoing a medical emergency). Also this can be dealt with using priority queues.

4 Provided Case-based Feedback Services

This chapter gives an overview how the intended client-side interaction services for PwD, carers and clinicians. Detailed component specifications are in Appendix A. Note that similar descriptions are also available in the project-internal D7.1 System Architecture. There will be public deliverables documenting the evaluation of these prototypes after testing with users.

The system GUI shall consist of four interfaces addressing the groups of system users:

- Family Interface – mainly for PwD, but also for use by family
- Carer Interface – feedback to informal carers or care staff
- Clinician Interface - assessment data for the clinician
- Administrator Interface – administration of users, services and data

The concrete user interfaces will be specified and implemented within a co-design process, which is suitable for a research project. The full GUI specification for system prototype V1 is a work in progress and will be progressively documented in the project-internal deliverables, D6.2 Closed Loop for People with Dementia v1 and D6.4 Closed Loop for Clinicians v1.

The navigational graph shows the possible transitions between screens.

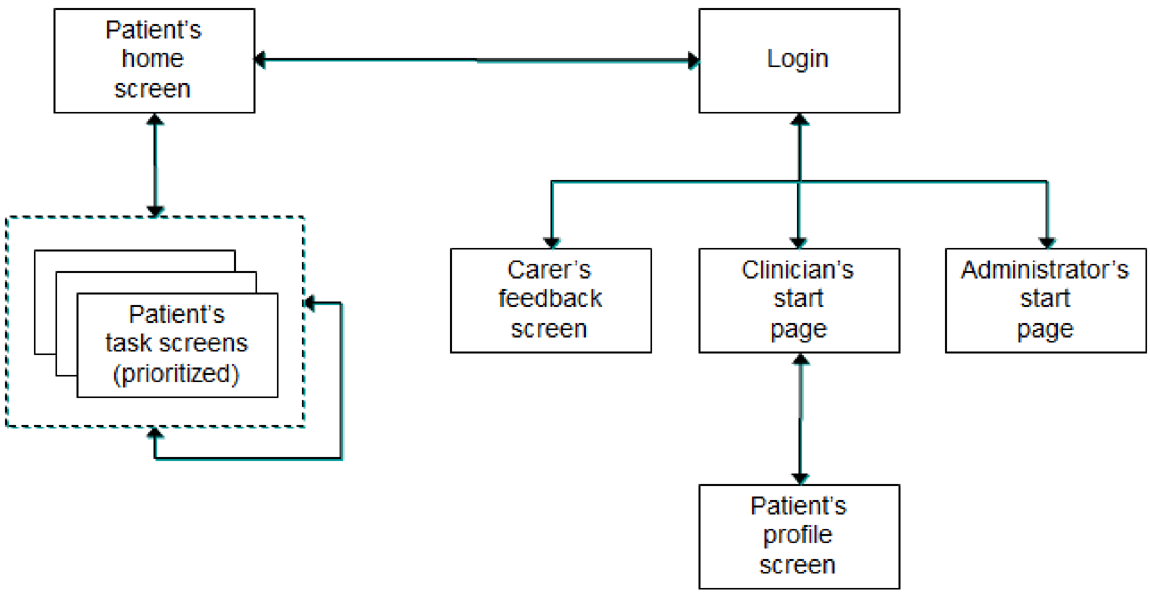

Figure 40: GUI Screen Transition Graph

Carers, Clinicians and Administrators are expected to access the Dem@Care system from a variety of devices, including general-purpose computers. For them, navigation starts at the Login screen.

In devices intended for the Person with Dementia, the navigation will start at the Patient's Home Screen, showing a personalized set of icons for manually activating Tasks (for example accessing the agenda, calling the carer etc). Navigation to Tasks may also be initiated by the Dem@Care system (for example scheduled feedback and questionnaires, alarms etc), but only if the new Task has higher priority than the current ongoing Task (onscreen task, or detected real life tasks of the PwD). When a Task finishes (by explicit PwD action or by the system), then any ongoing lower-priority Task becomes visible.

The PwD can immediately go to the Patient's Home Screen from any Task screen, and Tasks normally has an expiration time after which they are automatically finished (closed) by the system.

By using an invisible special procedure (details to be determined), Carers or visiting Clinicians or Administrators can go to the Login screen from the Patient's Home screen. When they logout (manually or after a set timeout), the user interface returns to the Patient's Home screen.

5 Conclusions

This report describes how Case-based Feedback Adaptations will work in Dem@Care.

Possible mathematical models for activity recognition has been analyzed as basis for further work in WP4 Situational Analysis of Daily Activities and WP5 Medical Ambient Intelligence. Fault Tree Analysis, and Hidden Markov Models are recommended.

Feedback services to be provided have been described, both user interface components and a orchestration component *Feedback Engine*. Detailed component architectural requirements have been described.

Important architectural decisions include the use of HTML5 for View layers of user interfaces and a navigation model for PwD based on prioritized tasks that can be either

- real-life tasks that the system detects and tries to mirror with supporting feedback to the PwD.
- Dem@Care tasks initiated by the PwD, for example to call someone.
- System-initiated tasks intended as interventions to make the PwD start some activity.

In all cases, the goal of the system is that the current task shown in the Patient Interface will mirror the real-life task that is either going on, or should be going on.

Further work will be needed to identify which tasks are higher priority than others, based on the ontology described in D5.1 Semantic Knowledge Structures and Representation, where the tasks are called *activities*.

The descriptions in this document will be updated based on experiences from prototyping case-based feedback, and from testing with users.

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A Appendix – Component Specifications

This appendix describes functional and non-functional requirements on the main client-side interaction components. The concrete user interface screens will be described in following project-internal deliverables.

A.1.1 Component: Family/Patient Interface

Functional scope
This interface will be used by the person with dementia for receiving feedback based on indicators derived from sensors, or entered manually by clinicians or carers. *In a later version, this component will be expanded to also give easy access to the life story and life log, and instrumental support to the entire family in Remembering, Social Contacts, Safety and Daily Activities.* Patient Interface includes: • Patient's home screen with a small and personalized set of tasks that the PwD can initiate, such as looking at past feedback and alerts, looking at the agenda of upcoming activities or the picture diary of past activities, making calls or sending messages, etc. • Patient's feedback screens: the system will initiate feedback tasks at specified time intervals (for example daily, weekly or monthly) or when indicator thresholds for behaviour or dementia symptoms are exceeded. The feedback can be delayed if the PwD is already involved in a task with higher priority (detected or initiated by the PwD in the home screen). • Patient's alert screens: the system can initiate full-screen messaging tasks, either on a scheduled basis (for example a reminder to prepare a lunch), or based on detected unfavourable conditions (for example an alert if the user wakes up not at the right time, or if a door is left open), or explicitly (the clinician or carer can send immediate alerts to the PwD). • *Later: A sleep mode full-screen task can be initiated by the system, either scheduled for a certain time in the evening, or after detecting that the PwD has gone to bed to sleep.* • *Later: A visitor mode full-screen task can be initiated either by the system (when detecting visitors at the door), or by the PwD (button on the Home Screen).*

Inputs

System input to start and stop prioritised tasks. PwD input to start and stop prioritised tasks (task buttons, confirming by tapping the screen, going back to the home screen etc). Login input cannot be used for PwD, authentication must be automatic.

Outputs
Showing full-screen tasks, such as feedback, reminders, messages, alerts, diary.

Preconditions
There must be informed consent from the PwD that the interface tries to mirror ongoing real-life tasks, and sometimes tries to change them. The Patient Interface device must have been associated with a specific PwD, thorugh a special procedure. Carers and Clinicians must be authorized to initiate tasks for the PwD.

Effects
The Patient Interface will help the PwD, relatives and clinicians to discover unfavourable patterns in behaviour and dementia symptoms, suggesting simple changes that make life easier to manage and avoids further cognitive decline.

User’s involvement
The PwD should normally acknowledge tasks that are started by the system (message from clinician/carer, reminder, alert). The PwD should also use the Patient Interface to facilitate activities in daily life (remembering, social contacts, activities of daily living).

Required Resources
The Patient Interface will consist of software (assumption HTML5 code) loaded into a touch screen device (computer or pad). The device will be connected to the rest of the Dem@Care system, via Internet or via private networking.

Required system interfaces
Patient Interface needs to communicate with a FeedbackEngine component, to inform it when the PwD starts and stops tasks (so that multi-device installations can work in a coordinated manner). This communication will be jQuery based.

Provided system interfaces
Patient Interface will provide interfaces for starting and stopping prioritized tasks from its installed repertoir. This system interface will likely be based on HTML5 Server-Sent Events, http://dev.w3.org/html5/eventsource/

Other requirements and features
The Patient Interface must be extremely easy to use, with single-button or zero-button operation for most things. The complexity of each screen must be kept low and focusing on the task at hand. The design must be inclusive, so that people with vision, hearing or haptic decline can also use it. The Patient Interface needs transparent but yet secure authentication of PwD, because explicit login procedures will not work for PwD, and the system handles sensitive personally identifiable data that must be protected from unauthorized access. The simplistic approach of storing a machine password in the device is not sufficient. Transparent biometric alternatives such as face or voice verification should be explored.

A.1.2 Component: Carer Interface

Functional scope
This interface will give feedback to the carer about the PwD's situation. Two types of feedback can be displayed: regular feedback for non-urgent information (for example: feedback of the patient social activities), and alerts for emergency (for example: the patient fell down). The interface also allows the carer to start tasks for the PwD at a set future time, typically by sending reminders to the Patient interface. The carer can only start tasks for which there is informed consent in advance by the PwD. Finally, the Carer Interface gives limited rights to access and modify the profile of the PwD, which task buttons to have available on the home screen in the Patient Interface, and specific settings for those.

Inputs
Carer login information – or the same transparent authentication as is used in the Patient Interface. Carer confirming and navigating past feedback, or starting new tasks for the PwD (for example reminders, messages, sleep mode).

Outputs
Viewing feedback about the PwD's situation.

Preconditions
The carer must be a registered user in the system. There must be informed consent from the PwD on which types of feedback the carer can receive, and what types of tasks that the carer can start and stop tasks in the Patient Interface.

Effects
The Carer Interface gives respite and relief to relatives, so that they are not as tied to the home, instead relying on the Carer Interface to help them discover problems, and set reminders for things that must be done while they are away. For professional staff in nursing

homes, the Carer Interface saves time in that it facilitates checks that otherwise would have to be carried out manually, for example checking that the PwD is in bed and sleeping.

User's involvement
The carer should explicitly log in in order to use the Carer Interface, however transparent biometric authentication will be explored too. The carer should normally acknowledge the reception of the feedback. The carer can use Carers Interface to start and stop tasks in the Patient Interface (depending on informed consent and authorization), in order to assist the PwD without always having to be present.

Required Resources
Any device with a web browser can be used. Touch screen smartphones are recommended in order to really allow relatives to leave the home, and to fit in a pocket for nursing home staff (this is important).

Required system interfaces
Patient Interface needs to communicate with a FeedbackEngine component, to be able to start and stop tasks in the Patient Interface(s). This communication will be jQuery based.

Provided system interfaces
Carer Interface will provide interfaces for receiving feedback about the situation and symptoms of the PwD. Although the user interface may have a different style from the Patient Interface, the same mechanisms for starting and stopping prioritized tasks could be used for the Carer Interface. This system interface will likely be based on HTML5 Server-Sent Events, http://dev.w3.org/html5/eventsource/

Other requirements and features
The Carer Interface must be easy to use. The design must be inclusive, so that people with vision, hearing or haptic decline can also use it.

A.1.3 Component: Clinician Interface

Functional scope

This component helps the clinician assess the cognitive status of the patient, and to assess long-term trends in behaviour and symptoms. The interface also allows the clinician to modify the patient's profile, and to schedule periodic reminders that start tasks for the PwD, for example positive feedback, cognitive training or reminiscence therapy with a relative.

For use in diagnostic rooms (@Lab), the Clinician Interface summarizes an assessment session following a pre-defined activity and observation protocol.

Inputs

The clinician's login information. Selecting the PwD to focus on. The clinician makes modification of service settings or schedules periodic ICT-based therapeutic tasks for the patient, including feedback, reminders, reminiscence therapy, assessment sessions.

Outputs

Viewing the patient's patterns in behaviour and dementia symptoms. Schedules for ICT-based dementia therapies.

Starting and stopping diagnostic assessment sessions.

Preconditions

The clinician must be a registered user in the system.
There must be informed consent from the PwD to use the system, and what ICT-based therapies that should be used.

Effects

The Clinician Interface gives the clinician objective assessment data to complement his personal observations and judgement about the PwD. This saves time and might improve diagnostics.

User's involvement
The clinician should type a username and a password to log to the interface, or use an access card. The clinician should have full control over the patient profile (viewing, modifying and deleting). The clinician can start tasks for the patient, including feedback, reminders, scheduled cognitive therapies or assessment sessions.

Required Resources
Any device with a web browser can be used. We expect it to be the normal computer used by the clinician.

Required system interfaces
Clinican Interface needs to communicate with a FeedbackEngine component, to be able to start and stop tasks in the Patient Interface(s). This communication will be jQuery based.

Provided system interfaces
The Clinician Interface component will provide no system interfaces.

Other requirements and features
Dem@Care must integrate into the normal workflow of the clinician. This means that all interaction should occur on the initiative of the clinician, or any workflow engine already in use at the clinic. It also means that we cannot mandate special types of computers, and that different user interface styles (skins) should be provided to match the existing work environment.

A.1.4 Component: Administrator Interface

Functional scope
This component gives the administrator full control over Dem@care users. This includes changing the access rights, creating, deleting or modifying users, and also accessing detailed personal data in emergency situations.

Inputs
The administrator login information. Information about the system usage status of all PwD.

Outputs
Viewing the users of Dem@care system with their profile information and authorizations.

Preconditions
The administrator must be registered as such with the system.

Effects
The Administrator Interface enables management of users, including activation, modification and deletion of user profiles. It helps monitor the usage level of the system, quickly identifying problems with devices, Internet access or lack of use. It also allows important access to detailed personal information in emergency situations.

User's involvement
The administrator should type a username and a password to log to the interface. The administrator can create new users and modify the rights of existing users

Required Resources

Any device with a web browser can be used. Different skins for touch-based and non touchbased devices should be created.

Required system interfaces
There needs to be a Profile Server somewhere.

Provided system interfaces
The Administrator Interface component should provide a system interface for receiving alerts about problems with devices, connectivity or low usage. Normally, the administrator would register a mobile phone or email address for this purpose, but it should also be possible to receive them on-screen. This system interface will likely be based on HTML5 Server-Sent Events, http://dev.w3.org/html5/eventsource/

Other requirements and features
-

A.1.5 Component: Feedback Engine

Functional scope
This component handles the control flow among the Dem@care user interfaces (patient, carer, clinician and administrator) and the Dem@care system. The aim is to maintain a model of the interaction situation of the PwD (which priortized tasks are active, on-screen and in real life), and to decide on when and how to initiate new tasks for the PwD. Explicit requests from carers anc clinicians to start tasks are also handled, and the PwD responses to system-initiated tasks are logged, for pattern detection in WP5. Tasks are prioritised, so that an ongoing higher-priority task (such as sleeping) does not get interrupted by a lower-priority task (such as a reminder to take a walk). Instead the lower-priority task gets queued until its *expire time* ends. Expired system-initiated tasks gets logged and summarized since they are indicators of the system not being optimally set up.

Inputs
Tasks requests from the Carer Interface and Clinician Interface (to be sent to the Patient Interfaces). Notifications (or periodic queries) from WP5 about the Semantic Interpretation of the PwD state from the ontology (for sending to the Carer Interface and Clinician Interface based on periodic schedules and thresholds). *Notifications from the WP5 Semantic Interpretation module when certain ontology-based criteria are fulfilled). Note: this is an assumption that needs to be verified.* Requests to access the patient profile in the database (to be sent to the clinician interface). Requests to create/modify users' rights from the administrator interface (to be sent to the Dem@care database). Feedbacks about the patient state from the patient interface (to be sent to the database). Requests to log in from all interfaces (to be sent to the database). Permission to use the Dem@care system from the database (to be sent to the right interface based on the user).

Outputs
Task start and stop requests to Patient Interfaces. Queries to the WP5 Semantic Interpretation Module.

Logged device use data to the WP5 Semantic Interpretation Module.

Preconditions
The PwD and the carers must have been activated in the system (via the Administrator Interface). The WP5 Semantic Interpretation module must have been calibrated to accurately detect what real life task is currently ongoing for the PwD. The profile of the PwD must have been personalized.

Effects
The Feedback Engine enables the GUI components to start and stop tasks at suitable moments.

User's involvement
There is no user involvement, the feedback engine should work automatically based on pre-defined rules

Required Resources
A server is required, with the Feedback Engine software component installed. It is assumed to be built integrated into the Qt toolkit, that supports several frameworks and programming languages.

Required system interfaces
FeedbackEngine needs the start/stop task system interface of Patient Interface. The Clinician Interface and Administrator Interface may have similar interfaces for receiving alerts.

Provided system interfaces
The FeedbackEngine provides an XML-based notification interface for the WP5 Semantic

Interpretation component. It provides task start/stop notification interfaces also for Patient Interfaces.

Other requirements and features
Feedback Engine needs to rely on the latest know-how about behavioural and psychological symptoms of Dementia (BPSD). Therefore the rules for when and how to give feedback to PwD and carers must be easy to change.