AAL PROGRAMME	**PersonAAL**	

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Responsible Unit: **CNR, ISTI, HIIS Laboratory**

Contributors: **PLUX**

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Executive Summary

Current technology offers devices and applications to detect a wide range of environmental and user-related parameters. Monitoring such parameters allows us to build knowledge about the context around the elderly.
However, tools able to integrate in real time data coming from all the potential sensors are missing, as well as tools for analyzing such data and acting consequently when certain conditions are met.
It is fundamental that data analysis, both for short term (alerts) and long term (behavioural) purposes, can be performed taking into account the specificities of the context where the system is used. In order to fit the particular needs, requirements and routines/tasks of the considered user, it is required that the rules for triggering adaptations and alerts be customizable according to the elderly's habits. In the same way, the approach to behaviour analysis should be customizable based on the local uses. For instance, different people may have different habits on the time they get up or go to sleep (even at a more general level differences exist in the number and time of meals between various countries, due to traditions, weather, hours of light, etc.). To this aim, the architectural characteristics of the monitoring approach should be clearly defined in order to show how our solution is able to support the requirements identified in the project.

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1 INTRODUCTION

The increase of the average age of European citizens, mainly characterised by higher life expectancies and decreasing birth rates, is a current matter of concern as in the next future there will be the need of providing adequate and sustainable support to an increasing number of people who are more subject to develop health diseases. PersonAAL aims to address the challenge of making active and healthy ageing a reality by keeping older people healthy, fulfilled and independent in their home for as long as possible.

To this aim PersonAAL proposes a technological solution to support both formal and informal caretakers in monitoring the elderly behaviour and promptly acting upon any specific need of the elderly in a personalised manner. Monitoring can be beneficial at various levels: in the short-time it allows to raise alarms as soon as the elderly behaves unexpectedly, such as when they open the entrance door in the middle of the night; the long-time monitoring is instead aimed to make assessments on relevant deviations from the expected pattern, such as changes in level of physical activity. The prerequisites for such functionalities are a robust, flexible and extensible data gathering support, able to collect and exploit data coming from a variety of sources, typically sensors deployed in the environment or worn by the elderly.

However, we are aware that gathering and mining user contextual information poses some critical concerns in relation to privacy and potential inappropriate exploitation of such information. In PersonAAL, we will aim to preserve elderly's privacy according to existing data protection regulations (e.g. anonymisation, protection of data in secure places). In Section 3.1 we will better detail how we plan to address such ethical issues in our Project.

This deliverable describes the main aspects of the monitoring platform and introduces the behaviour analysis approach. It assumes some knowledge of the PersonAAL architecture (see D1.1.a – Architecture Specification (Initial)]

This document is structured as follows: after the Introduction (Section 1), Section 2 is dedicated to the monitoring support, i.e. monitoring of contextual parameters and handling of the associated data; Section 3 describes how behaviour analysis is carried out by specifying an expected behaviour and checking for possible deviations in the elderly's actual behaviour derived from monitored data. Lastly some conclusions and indications for future work are provided.

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2 CONTEXTUAL MONITORING

2.1 Infrastructure for monitoring contextual parameters

The monitoring of the contextual parameters is provided by the Context Manager. The main objectives of this subsystem are detecting the current values of a wide range of variables (related to user, environment, technology, etc.) and informing other architectural modules about relevant changes in such values. The Context Manager provides all the functionalities to collect, store, modify and retrieve data (see the simplified architectural diagram in Figure 1). It is composed of a context server and a set of context delegates. The context server contains all the functionalities for storing and analyzing data in a centralized manner, while the context delegates are distributed in the user device(s) or in the environment.

A context delegate is a software devoted module to get data from a sensor (a real one or 'virtual' one, i.e. an external software service able to gather some data, such as weather forecast service), elaborate them and send them to the context server.

A context delegate can consist of:

- A small standalone app, deployed on the user smartphone, that connects to an embedded sensing device (e.g. the accelerometer, the light sensor, the GPS module, etc.), acquires the raw data, processes it and sends the resulting features to the context server;
- A software, deployed in any device, that acquires data from an external service (which can be considered a 'virtual' sensor) and sends them to the context server;
- A web page functionality (for example implemented by an added script), that monitors the user interaction performance (speed, wrong clicks, etc.) and informs the context server periodically, so that possible deterioration in the user's physical and/or cognitive capabilities can be detected;

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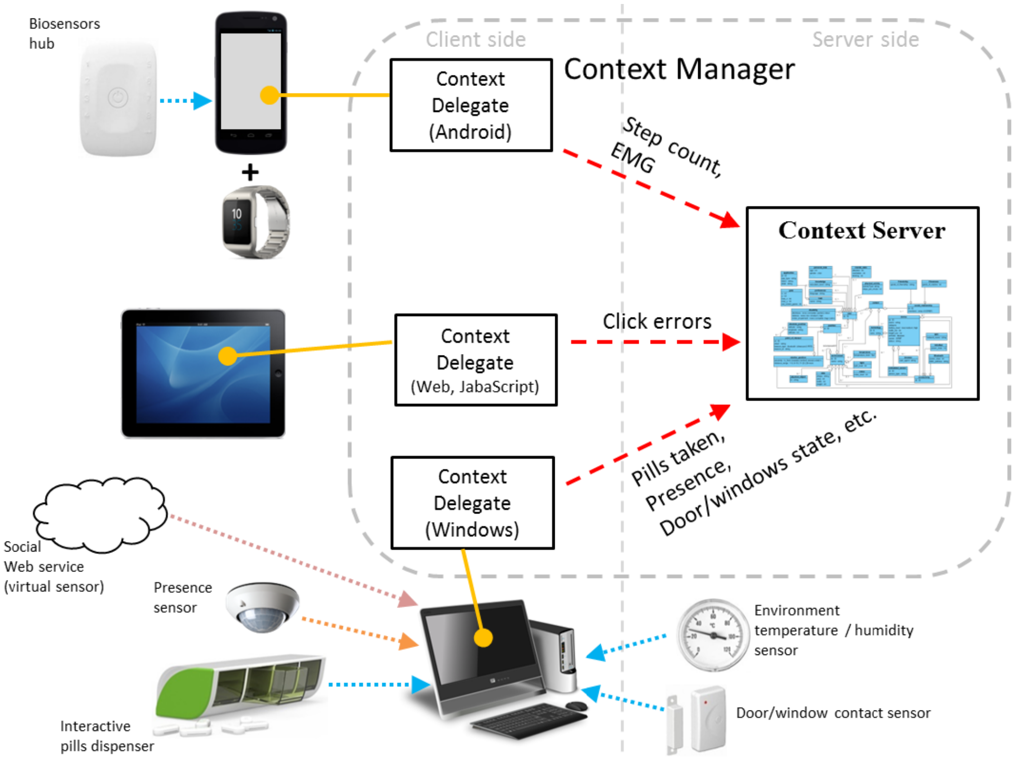

Figure 1 – General architecture of the Context Manager.

2.2 Data collection and organisation

The context delegate implemented on Android will have the objective of collecting, processing and sending to the context server the data acquired from the biosensors. These biosensors will allow the acquisition of muscle activity, heart activity, arousal state, motion, light intensity and body temperature. In order to gather these signals it will be used a versatile, easy-to-use, low-cost and scalable platform the BITalino. This includes a wide range of sensors that allow the real-time acquisition of several biosignals. The sensors that enable these measurements are:

- Muscle activity – Muscle activation is triggered by bioelectrical signals of very low amplitude sent from motor control neurons on our brain to the muscle fibers. Electromyography (EMG) enables the translation of these electrical signals into numerical values, enabling them to be used in a wide array of applications. This sensor is especially designed for surface EMG, and works both with pre-gelled and most types of dry electrodes. The bipolar configuration is ideal for low-noise data acquisition. This sensor enables applications such as physical rehabilitation, posture correction, muscle reflex assessment, among others.
- Heart activity - Heartbeats are triggered by bioelectrical signals of very low amplitude generated by a special set of cells in the heart (the SA node). Electrocardiography (ECG)

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enables the translation of these electrical signals into numerical values, enabling them to be used in a wide array of applications. This sensor allows data acquisition not only at the chest (“on-the-person”), but also at the hand palms (“off-the-person”), and works both with pre-gelled and most types of dry electrodes. The bipolar configuration is ideal for low noise data acquisition. This sensor enables the diagnose of abnormal cardiac rhythms and conduction patterns based on variations in the duration, amplitude and morphology of the ECG waves. It also allows the extraction of heart rate and heart rate variability.

- Arousal state – Sweat glands secretion is a process that allows our body to regulate its temperature, but it is also associated the sympathetic nervous system activity. Whenever we become aroused (e.g. nervous) or relaxed, that state is partially translated into the sweat production or inhibition at the glands on our hands palms and feet. This changes the resistance of our skin; Electrodermal Activity (EDA) monitoring enables the translation of these resistance changes into numerical values, allowing its use in a wide array of applications. Typical applications include emotional mapping and stress/relaxation biofeedback.
- Motion – Motion produces accelerations that can be translated into numerical values. The Accelerometer (ACC) has a limited bandwidth, especially designed to acquire data from kinematic and biomechanical events. The analog output of each axis can be accessed individually, extending its potential use. Typical applications include posture detection, range of motion estimation, step counting, actigraphy, fall detection, vibration analysis and shock detection. Typical applications include activity monitoring, fall detection, posture assessment among others.
- Light intensity – Light sensors are typically used for ambient light measurement. However, a common need when working with biosignals is the synchronization of the recorded data with specific light sources (e.g. a computer screen for visual evoked potentials). If applied to the computer screen, the light sensor can be used to detect chromatic changes in the stimuli, hence providing a synchronization source. The light sensor can also be useful for optical synchronization with third-party devices (provided that such device can trigger an LED), in applications where it is important to have electrical decoupling between devices.
- Temperature – The temperature (TMP) sensor has been especially selected for targeting the measurement of body or environmental temperature. Its small form factor enables easy application on the any surface. Typical applications include peripheral temperature data acquisition.

The BITalino platform streams raw data from these sensors wirelessly to the context delegate that is running on the smartphone. This platform is able to stream data via Bluetooth Classic or via Bluetooth Low Energy, however due to the possible number of sensors required and consequently the large amount of streamed data Bluetooth Classic stands out as the most suitable technology.
The context delegate will use an Android API that implements all the basic methods and callbacks for initiating a connection, starting an acquisition, receiving the raw signal stream, actuating on the device, stopping the acquisition and disconnecting.

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Data coming from external sources such as sensors, is collected by the context server. Data collection can exploit various channels, the main one being RESTful Web services. The advantage of the RESTful approach is the possibility of addressing resources through a URI, which reflects the path of the involved resource in the data store of the context server. For instance, in order to update the physical activity of user Bob (with userid "bob"), it is sufficient to perform a POST to the following address:

https://{base URL}/user/bob/physicalActivity,

where base URL is the URL of the context server and the POST content is the JSON description of the attributes to be modified on the Physical Activity entity (e.g., "activity type" or "steps per minute").
The main requirement to access RESTful Web services is the use of the HTTP protocol. HTTP is supported by libraries on many programming languages, making it possible to easily develop RESTful context delegates in Java, C#, etc. A context delegate, devoted for instance to monitor the user Web activity, can also be embedded into a Web page; this is possible by implementing a JavaScript procedure that makes AJAX calls to the context server. Since the context server implements CORS (Cross-Origin Resource Sharing), it can accept requests coming from Web pages hosted in external servers.
Other interfacing channels to the context server are also available, such as the HTTP (non-RESTful), where an entity can be created/updated through a HTTP POST to the base URL of the Context Manager containing a particular XML message specifying the new entity data. This low level approach is powerful since it gives access to all the parameters of the entity, such as the time to live threshold, but requires the knowledge of the entity unique identifier (which is instead transparent when relying on the RESTful interface).
A low level TCP mechanism to exchange messages with the Context Manager is also available.

Incoming data is organized by the context server into a set of interconnected objects, each containing one or more attributes. The object classes and the relationships between them are expressed in a context model, which is defined in a XML schema. The context model is domain-specific, i.e. it results from a specialization process aimed to make the model more suitable for the specific application domain (in our case, ambient-assisted living).

2.3 Data retrieval

Data can be retrieved from the context server in two main manners, i.e. synchronously and asynchronously.

- Synchronous retrievals are made on explicit request by a module external to the context manager. An example is a request made by a module devoted to adapt an interface to the user preferences (which are considered to be part of the context of use), that queries the context server for the "Preferences" entity of the user;
- Asynchronous notifications are automatically sent by the context server to modules that have previously subscribed for a particular state or for changing one or more parameters. A subscription can specify conditions on an arbitrary number of parameters (e.g., notify when the entrance door is opened between 23:00 and 06:00). The

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advantage of the asynchronous approach is that the subscriber module is not required to continuously query the context server for the current values of the involved parameters, nor it has to check if the conditions are verified.

The Context Manager can format response data in XML or JSON. The former mode provides data in a structured way (i.e. easily readable by humans and thus particularly useful when debugging). The latter mode provides a compact format which is bandwidth-efficient at runtime.

2.3.1 Queries and synchronous retrievals

Synchronous retrievals are blocking operations, where the module in need of data keeps blocked while waiting for the response. Synchronous retrievals are necessary when the requester promptly needs some information which is supposed to be already available and which is not expected to change frequently. An example is an engine that, when the application is run, queries for the current user coordinates in order to adjust the clock to the local time zone.
The typical way to synchronously retrieve data from the Context Manager is the RESTful one, i.e. making a HTTP GET to the URI of the entity to query:

https://{base URL}/user/mary/Preferences,

which will provide the current state for the Preferences sub-entity of the entity of user 'mary' as response.
In the same way as updates, queries can be made via HTTP too: an XML command can be posted to the base URL, specifying the identifier of the entity to query.

2.3.2 Subscriptions and asynchronous notifications

The technique of subscription-notification is convenient when one or more of the following situations occur:

- It is not known if the requested information is (or when it will be) available;
- The requested information can change unexpectedly anytime;
- There is the need to check conditions involving multiple parameters.

Asynchronous notifications are enabled by a previous subscription, where the requester declares which kind of event it is interested in.
The following code is an example of a XML message that a requester module, e.g. an adaptation engine, may send to the Context Manager (see 1 in Figure 2) to subscribe for specific noise increase events.

```
<op>subscribe_event</op>
<subscriber_address>http://grimilde.isti.cnr.it/AdaptationEngine/ae_http</subscriber_addres>
<event>
```

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```
        <simple_event event_name="_high_noise " xPath="/user/environment/@noise"/>
</event>
<condition operator="gt">
        <entityReference xPath="/user/bob/environment/@noise"/>
        <constant value="85" type="int"/>
</condition>
```

It was predetermined that a context delegate running on the user smartphone continuously sends updates on the detected noise level to the Context Manager (2).

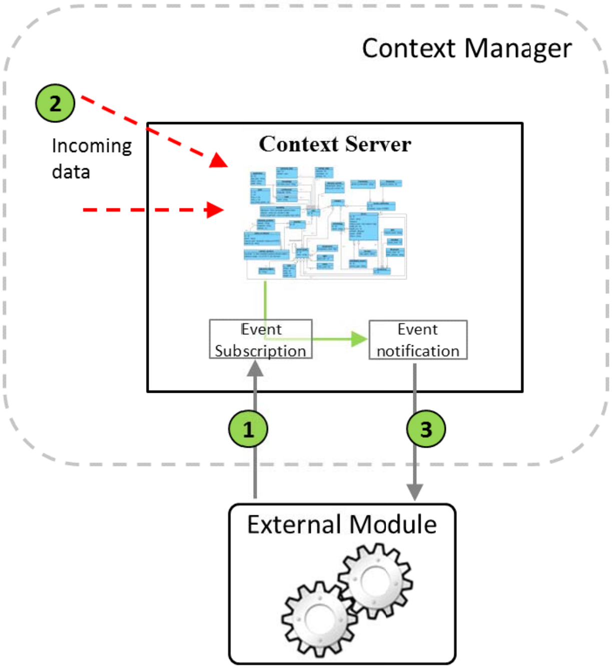

Figure 2 – Integration between the Context Manager and a generic external module relying on the subscription-notification mechanism.

When the Context Manager determines that the current noise value exceeds the thresholds of 85 (dB), it immediately notifies the subscriber module by sending a JSON message via POST to the specified address (3). The following is an example of JSON notification:

```
{"events" : [{
        "name": "_high_noise",
        "verified" : "true",
        "ref" : "/user/bob/environment/@noise",
        "value" : "92"
        }]
```

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}

It is worth noting that a notification is also sent to the subscriber when the condition is not satisfied anymore, i.e. when the noise level drops below the threshold (in this case, the “verified” flag is “false”:


```
{"events" : [{
        "name": "_high_noise",
        "verified" : "false",
        "ref" : "/user/bob/environment/@noise",
        "value" : "70"
        }]
}
```


If no conditions are specified for the event, then it is assumed that the subscriber is interested in being notified about any change of the parameter value.

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3 BEHAVIOUR ANALYSIS

3.1 Ethical Issues

The PersonAAL platform will collect data for the purpose of customising the services and of providing the users with relevant information about their health-related state/progress. We are aware that continuous monitoring of elderly's daily life and activities could generate ethical issues/doubts. To this regard, in PersonAAL, we will aim to a privacy-aware platform that will preserve privacy according to existing data protection regulations (e.g. anonymisation of personal data, protection of data both at data storage and at communication level).
Informed consent will be requested and gathered from the users of PersonAAL, so that they will be fully aware of the goals of the Project and the type of data being recorded. Data collected will be treated anonymously in the development of any reporting and users' information will be kept strictly confidential and not shared with third parties. The collected data will be encrypted and saved on secured servers, guaranteeing access only to authorised persons. Furthermore, we will also implementation the 'minimal disclosure' principle, whereby each actor in the information chains will have solely access to the data needed to deliver the intended service.

3.2 Objectives of the behaviour analysis

The behaviour analysis is devoted to the detection of patterns in a dataset that do not conform to the expected behaviour. The aim is to identify possible anomalous situations, such as deviations in elderly's behaviour/routines (which may indicate initial signs of decline).
Our approach is based on the comparison between the actual behaviour of the elderly with an expected one.
The actual behaviour is derived from the analysis of data gathered and made available by the Context Manager. The analysis is aimed to infer/recognise the actual user activities. To this aim, various types of activities are considered, in a AAL scenario the ones that are typically considered are Activities of Daily Life or ADLs, which are grouped into (Ni et al., 2015):

- *Basic ADLs*: personal self-care activities, such as eating, drinking, sleeping, toileting, bathing and dressing.
- *Instrumented ADLs*: activities not strictly necessary but that let an individual live independently in a community. Examples of instrumental ADLs are: using a telephone, housekeeping, preparing food and taking a medication.
- *Ambulatory activities*: related to specific motions or postures, such as walking or doing physical exercise.

The expected behaviour is built with the collaboration of caretakers, who have an intimate knowledge of routines, tasks, and needs of their beloved ones. In the next subsection we will discuss how we plan to model such expected behaviour.

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3.3 Specifying the expected behaviour

In order to define the activities done by the user, a task model can be used. Task models indicate the logical activities that should be supported in order to reach users' goals (they are typically used when designing interactive applications). In (Serral et al., 2014) there is a tool-supported methodology to facilitate the creation of AAL systems through the use of executable task models. In our case, we plan to use task models to describe the elderly's **expected** behaviour (in terms of e.g. specific tasks/activities to carry out, typical daily routines followed, particular requirements and needs the elderly can have, which could be connected with their current health state or disability/disease the user can suffer from). The task model is then provided as input to the Behaviour Analyzer module which compares its data with information (gathered by the Context Manager) describing the **actual** behaviour of the user.

The task model should be created with the collaboration of caregivers (or even the elderly themselves), who have an intimate knowledge of the needs of their care beneficiaries. In order to specify task models, we plan to use a notation developed at CNR-ISTI, the ConcurTaskTrees (CTT) notation (Paternò, 2000) which allows to focus on the various activities modelled in a hierarchical manner. This is a widely used notation, which has also been considered for standardization in W3C (https://www.w3.org/TR/task-models/).

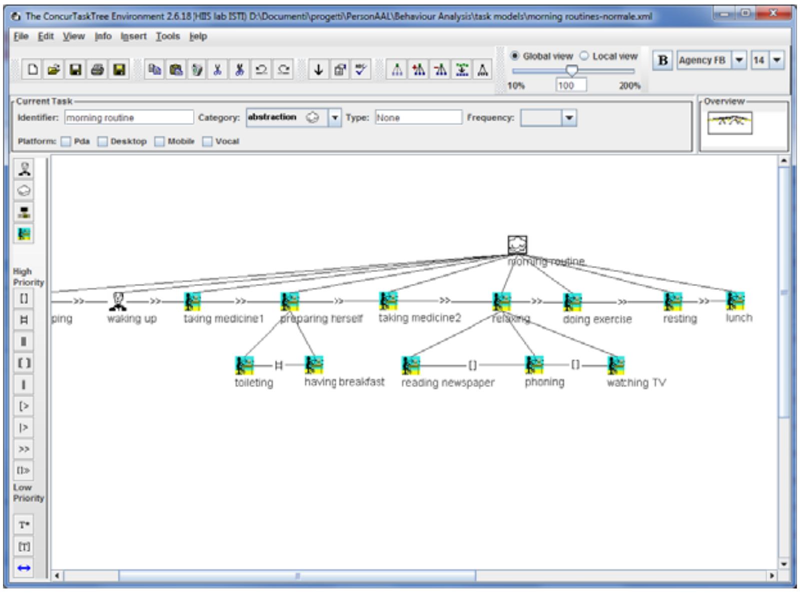

Figure 3 – ConcurTaskTree Environment (CTTE), the editor for task trees.

A graphical syntax allows designers to specify the relationships between activities (temporal operators) which are (we name just the most used ones):

- Choice []
- Order Independence |=|

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- Interleaving |||
- Disabling [>
- Enabling >>
- Suspend/Resume |>
- Iteration *

In order to specify task models a dedicated tool can be used, allowing to specify the tasks, their expected order, their frequency, etc. In particular, ConcurTaskTrees Environment (CTTE) (Mori et al., 2002), publicly available at http://giove.isti.cnr.it/ctte.html is the tool supporting the interactive creation and interactive simulation of task trees (see Figure 3).

The proposed method consists on developing the task model of the application considered and then compare it to the actual path followed by the user to identify deviations/shifts associated with tasks. The follow-up analysis may reveal the distance of the shift, its criticality, and may help to identify possible remedies/actions to take.

Examples of abnormal behaviours in a AAL scenario could be the following ones:

- Prescribed medicine is not taken in due time;
- A non-prescribed medicine is taken;
- Elderly sleeps at unusual time (e.g. after breakfast);
- Elderly goes to sleep without having dinner;
- Elderly has lunch at unusual time (e.g. 4 p.m.);
- Elderly wandering at unusual time (e.g. in the middle of the night);
- Elderly still or not responding for an unreasonably long time and/or in an unexpected location or situation, or after detecting a fall;
- Abnormal sleep patterns (e.g. sleep less/oversleep);
- Abnormal activity patterns (e.g. no physical exercise or exercise less than usual);
- Elderly opens the fridge at breakfast time, picks the milk, then mistakenly puts the milk box in the non-refrigerated food cabinet and closes its door.

An example of a task model describing the expected morning activities of an elderly is depicted in Figure 4. In particular, the task model visualised in Figure 4 describes the morning routine of a user. The elderly, wakes up after having slept (see the ">>" Enabling operator), then should take medicine1 (before breakfast) and then can alternatively do one of these two activities: i)doing firstly some toileting and then having breakfast; ii) or inversely first having breakfast and then got to the toilet. The order independence of these two possible paths is represented by the |=| operator between '*toileting*' and '*having breakfast*' tasks. Afterwards, the user should perform task medicine 2 (which is expected to be taken after breakfast), and only then can relax. This step involves one of the following activities (see the [] Choice operator): read a newspaper, phone to some friend/relative watch TV. Then, the morning routine foresees that the elderly will do some exercise, then have some rest. Finally, having lunch ends the elderly's morning routine.

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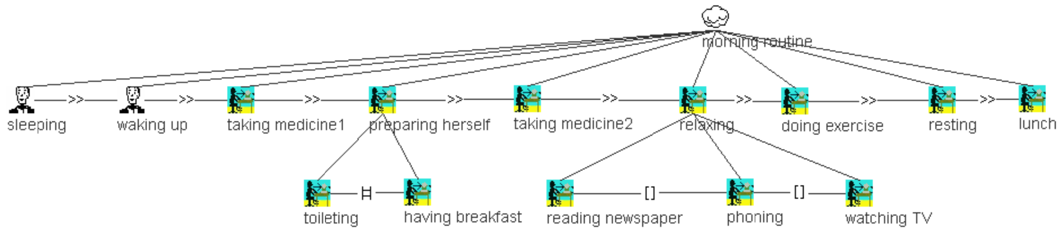

Figure 4 – Example task tree representing the expected typical morning routine of an elderly

With respect to the 'expected behaviour' shown in Figure 4, we can identify a number of possible examples of 'abnormal' task sequences/paths. In particular, in the following list, we named each anomalous path also trying to classify its criticality (potentially critical, uncritical). In addition, in bold we highlighted the specific sub-paths of elementary tasks which were incorrectly performed:

1. *Medicine1 taken after breakfast (potentially critical):* Sleeping → waking up → **toileting** → **having breakfast** → **taking medicine1** → taking medicine2 → relaxing → doing exercise → resting → lunch (*critical*)
   In this case the anomalous deviation is the fact that medicine1 is taken *after* breakfast, whereas the task model in Figure 4 specifies that medicine1 should be taken *before* breakfast. The deviation has been judged critical as it involves the prescribed manner of taking a medicine (e.g. having breakfast can affect medicine's intake).

2. *Toileting before taking medicine1 (uncritical)*: Sleeping → waking up → **toileting** → **taking medicine1** → having breakfast → taking medicine2 → relaxing → doing exercise → resting → lunch
   In this case the deviation consists of doing toileting before taking medicine1. This path represents a 'deviation' just because it does not comply with the behaviour described in the task model. However, it does not seem to represent a critical deviation since each of the two involved activities do not have any impact on the other one.

3. *Medicine2 taken before breakfast (potentially critical):* Sleeping → waking up → taking medicine1 → toileting → **taking medicine2** → **having breakfast** → relaxing → doing exercise → resting → lunch
   This case is similar to case 1. The only difference is that now the deviation involves medicine 2 (expected to be taken after breakfast)

4. *Unexpected sleep activity and no exercise (potentially critical*): Sleeping → waking up → taking medicine1 → preparing herself → taking medicine2 → **sleeping** → lunch
   In this case the deviation consists of the elderly's sleeping during the morning, which could be a sign of some diseases of tiredness.

5. *Wrong medicine taken (potentially critical):* Sleeping → waking up → **taking medicine3** → preparing herself → taking medicine2 → relaxing → doing exercise → resting → lunch

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In this case the elderly unexpectedly takes a wrong medicine: this is an unexpected event that does not necessarily have critical implications (for instance, when the patient intentionally takes an over-the-counter drug, or when the medicine does not interfere with his/her medical prescriptions).

3.4 Possible Task-related Anomalies in Elderly Behaviour

As already mentioned, an anomalous situation is characterized by a difference between the observed/actual situation (derived from sensing the current user context) and the expected one (described in a task model). As mentioned before, the identified deviation could be characterized by different degrees of severity and could be the sign of various situations: the beginning of an unhealthy habit of the elderly, the insurgence of an illness, or even a serious physical/mental decline. The monitoring is thus useful to highlight trends as well as for giving recommendations to the elderly, sending them health-related reminders, etc.

When considering tasks, several aspects can be affected by anomalies. By means of using the CTT task model notation (with some further improvements/additions), we can identify for instance the following types of deviations:

- *Unusually long inactivity* (the elderly has fallen or has lost consciousness);
- *Unusually short activity* (the lunch was too quick);
- *Unusual presence* (the elderly is sitting in the living room at late night);
- *Unusually frequent activities* (too many visits to the toilet);
- *Violations of action order relationship constraint* (eating after instead than before medicine intake).

In particular, in order to provide a systematic manner to assess the various types of deviations that can affect a task, we have identified the following ones, identified by some keywords:

- **None**. The task has not been performed or has been performed without producing any result. This deviation is decomposed into:
    - o **No input**. Lack of initial information necessary to perform a task;
    - o **No performance.** The task has not been performed;
    - o **No output.** The task has been performed but its results are lost;
- **Other than**. The tasks considered have been performed differently from what the designer intended in in the task model. This deviation is decomposed into:
    - o **Less.** It can be further decomposed into *less input*, *less performance*, *less output* according to the cause of the deviation;
    - o **More**. It can be further decomposed into *more input*, *more performance*, *more output* according to the cause of the deviation;
    - o **Different**. It can be further decomposed into *different input*, *different performance*, *different output* according to the cause of the deviation;
- **Ill-timed**. The tasks considered have been performed at the wrong time. This deviation is decomposed into:
    - o **Time**. It can be further decomposed into *too early* and *too late* according to when the activity occurs (respectively earlier/later than when was planned);

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- o **Duration.** It can be further decomposed into *too long* and *too short* according to the duration of the activity;
- **Ill-located**. The tasks considered have been performed at the wrong place.

3.5 Identifying Deviations in Elderly's Expected Behaviour

Figure 5 shows an overview of the integrated architecture consisting of the Context Manager and the module for behaviour analysis. At configuration/personalization time, a task model of the expected elderly's behaviour is built and is indicated as a circled '1' in Figure 4. The task model is converted into a set of events/conditions that can be managed by the context manager. In general tasks correspond to specific activities that have to be performed to reach some user's goal. Thus, the corresponding events can be associated with tasks when e.g. specific actions are performed by the user (e.g. the user enters in a room). The corresponding events are used to specify subscriptions (2) in the Context Server. The event subscriptions specify the subscriber and the notification target, and are saved in the Context Server, which continuously gets data from external sources (i.e. from sensors/services through context delegates). When one or more events are verified, the notifications are sent to the module in charge of comparing the expected and actual behaviour (4). The module performs a check between the expected list of events extracted by the module named "Task model to Events converter" and the events actually detected by the Context Server. The analysis output, appropriately rendered, is then displayed to the caretaker. To implement this module we will consider previous experience in tools for usability evaluation (Paganelli and Paternò, 2003) in which it was developed automatic support for comparing logs of user interactions with the expected dynamic user behaviour described in the task model to identify possible usability problems.

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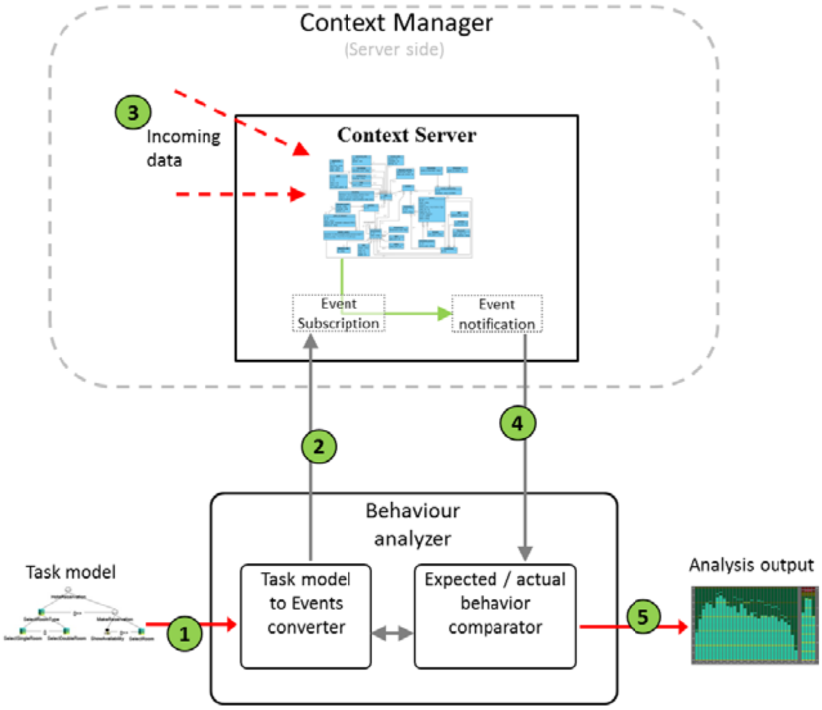

Figure 5 – Architecture of the integration between the Context Manager and the behaviour analysis system.

The analysis should highlight unexpected behaviours of the elderly and/or deviations, e.g. delay in sleep and early wake up; resting instead of exercising and eating instead of housekeeping; no/less exercise/housekeep activity. However, the analysis should also be powerful enough to limit false positives: for instance, if a user wakes up late and takes breakfast late, this behaviour should be considered normal if the other activities are done as usual.

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4 CONCLUSIONS

We have presented the approach proposed for monitoring and behaviour analysis. We have described the technological infrastructure (the Context Manager) that is being developed to gather the relevant data concerning user behaviour. It will exploit, among other inputs sources, also the sensors developed by Plux.

We have also described the novel method developed for performing the behaviour analysis aiming at identifying deviations with the support of task models.

Next year, we plan to implement the support for this intelligent behaviour analysis, which may require some improvements in the used notation for task modelling.

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5 REFERENCES

Mori, G., Paternò, F., and Santoro, C., CTTE: *Support for Developing and Analysing Task Models for Interactive System Design*, IEEE Transactions on Software Engineering, pp.797-813, August 2002 (Vol. 28, No. 8), IEEE Press.

Ni , Q., García Hernando, A.B. and Pau de la Cruz, I., *The Elderly's Independent Living in Smart Homes: A Characterization of Activities and Sensing Infrastructure Survey to Facilitate Services Development*, Sensors 2015, 15, 11312-11362; doi:10.3390/s150511312

Paganelli, L., and Paternò, F., *Tools for Remote Usability Evaluation of Web Applications through Browser Logs and Task Models*, Behaviour Research Methods, Instruments, and Computers, The Psychonomic Society Publications, 2003, 35 (3), pp.369-378, August 2003.

Paternò, F., 2000. *Model-Based Design and Evaluation of Interactive Applications*. Springer Verlag.

Serral, E., Valderas, P., Pelechano, V., *Supporting Ambient Assisting Living by using Executable Context-Adaptive Task Models*. International Journal On Advances in Software, volume 7, numbers 1 and 2, 2014, pp.77-87. ISSN: 1942-2628

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