Monitoring of patients suffering from special phobias exploiting context and profile information

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Abstract—**Context acquisition and active context construction is key to delivering personalized services and ubiquitous medical treatment to patients suffering from special phobias, which are disorders caused by excessive anxiety. User profiles turn out to be a critical tool for this. This paper proposes an active context construction method, which exploits user profiles to resolve active contexts. Moreover, it analyzes context information investigating the parameters that play significant role in certain phobias. We also propose an ontology based context and profile information model and an active context-aware framework based on a standardized computing environment that adds the appropriate functionality to our approach, while handling security and interoperability issues. In order to show the significance of active context-awareness and user profiles in the psychology domain, a discussion regarding patients, medical stuff and personalized medical treatments is made.**

I. Introduction

NOWADAYS, especially in western societies, the fast-paced life, rush hour traffic, competiveness, unreasonable deadlines at work, need for increased productivity, increasing levels of unemployment and cost of living are just some factors that introduce stress in our daily life. Some articles indicate that technology itself played a crucial role so that stress becomes a part of our life, by importing a huge amount of automatization in our everyday life, resulting in increasingly less manual work. That's where the paradox comes out: Technology is requested to contribute to the treatment of disorders caused by her adaption in people's routine.

The billions of cells that the brain consists of are attached with each other through an endlessness of combinations. For the normal operation of the brain's functions (e.g. memory, feelings, perception, decision and thinking), nerve cells and established attachments between them must operate normally. Cells and respective attachments operate through a continuous electrobiochemical processing. Stress is a disorder closely related to anomalies regarding this processing.

The occurrence of stress can be expressed either physically or mentally. Physically it is expressed through the autonomous nervous system (e.g. increased heart beats and cold sweat), while mentally it is expressed through unspecified disquietude, obsessive ideas (obsession and compulsive disorders), special phobias such as agoraphobia, nosophobia, claustrophobia, acrophobia and zoophobia, or through perceptual disorders such as seeing things that do not exist or hearing weird sounds. The way stress will be expressed depends on biomes, biological factors and genes. It must be mentioned that stress as a biome is important, just like physical and mental pain, so as an individual will act and react during his lifetime. But, every human has two stress thresholds, an upper and a lower, which defer from human to human. The closer to the upper threshold stress is, the more stressed and vulnerable to disorders the human is. Moving beyond the upper threshold results in disorders depending on the duration the patient is experiencing this overstressing, his biomes and corresponding environmental parameters.

This paper focuses on special phobias caused by excessive anxiety. These special phobias are situational disorders which occurrence, tension and duration depends mainly on environmental parameters. For example, an agoraphobic could get a panic attack when feeling the presence of many people gathered around him, while an acrophobic would not feel strange in a situation like that, but get dizzy and overstressed finding himself in the balcony of the 15th floor of a building. Tension of each critical situation could vary depending on the number of people or the altitude, respectively. Duration depends on the potential of the phobia itself, the time of exposure to factors resulting in critical episodes which are called panic attacks, or even the present mood of the patient.

These parameters are rather dynamic while individuals move from one place to another, interact with a wide range of other individuals and address themselves to diverse tasks. Thus, providing a ubiquitous healthcare service to patients suffering from such kind of disorders, context-awareness seems to be quite necessary in order to identify the context of each individual at a certain point in time. Context is any information that can be used to characterize the situation of an entity (in our case the entity is a patient) [1]. Context-awareness allows an entity to adapt its behavior to the circumstances in which it finds itself [2].

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The ability to identify the active context of a patient is key to delivering personalized services to patients suffering from such kinds of phobias. A context is active when it is adapted to a certain environment at a certain moment in time. It defines the relationships and causalities of a patient to a particular number of physical resources at certain a moment in time, in a certain environment [2]. When considering the healthcare domain, context-awareness has been a really challenging issue for many researches so far [7]-[12]. Most of these researches indicate active context as key to deliver ubiquitous personalized services and appropriate medical treatments, but they don't address user profiles as a critical tool to capture it. Context information, acquired by diverse sources and reasoned contexts, on their own, can not describe a patient's situation in a manner psychology domain requires. It just provides an abstract set of data, leaving many critical questions unanswered. Thus, we can not talk about an appropriate treatment, to which context-awareness aims. On the other hand, exploiting user profiles to evaluate the acquired set of information, leads us to active contexts which fully describe the situation of a patient, enabling the most appropriate treatment. A user profile is a data record that electronically represents/contains information on the context of the entity it reflects upon [2].

We propose an active context construction method (**ACCM**) in order to reach an active context-awareness. This method has a major benefit of identifying a high level context, and then evaluating the information it provides retrieving only the exact user profile information that this context indicates, avoiding retrieving and processing the whole set of data a user profile hosts. Consequently, we result in lower processing demands and lower network resource requirements. ACCM consists of three levels described below.

On the first level a low level context is obtained by directly measured values. Unfortunately these kinds of contexts (i.e. low level contexts) do not represent the exact patient's situation. For example this context would contain loose information such as George, Mary, Nick, 16:00, Tuesday, Athens, talking etc. On the second level, these low level contexts are converted, in a semantic level, into high level contexts, through reasoning processes and inference rules. The previous loose pieces of information could be arrayed as "*George is in Athens talking with Nick and Mary on Tuesday at 16:00*".

Still this high level context is not useful as it does not indicate who these people are (we consider George as the patient), what city Athens implies for the patient (living town or not), and for what this talking is about. These people could be family, relatives, partners, friends, or even some customers George is serving on behalf of the company he works for. On the third level, many of these doubts are erased exploiting user profiles. Continuing our example, if Mary and Nick are partners and Athens is a city their company has an agency, the derived active context could be that "*George is on a business trip with his partners*". If these people are friends and Athens is George's living town, then the active context could be that "*George is out with friends talking*" and probably having fun. Consequently, an active context is constructed aggregating high level context and profile information, while implementing an inference mechanism.

The previous example shows that the active context of a patient obtained at the third level of the ACCM, describes the patient's situation more accurate and efficient than the contexts obtained on the previous levels. Considering that most of the patients suffering from the previously mentioned special phobias feel safe and remain calm while enjoying the company of people very familiar to them, the first context where George is with his partners - combined with measured values of some other physical parameters - would be a harbinger of a forthcoming panic attack while the second context would not. Furthermore, these different contexts will result in different services delivered tailored to patient's preferences, physician's guidelines and requirements settled by each context.

This paper is organized as follows. In section 2, we analyze the different aspects of the context and identify the parameters which play a major role to special phobias that this paper addresses. In section 3, we design an ontology based context model and describe the components of the proposed active context-aware framework. Section 4 shows how patients, physicians and medical treatments, in the psychology application domain, can benefit from active context-awareness. Finally, section 5 concludes the paper.

II. DECOMPOSING CONTEXT INFORMATION

A patient context describes several aspects of the situation a patient has been, is or will be in. Some of the context information is quite static while other is rather dynamic as the patient moves from place to place interacting with diverse entities. A part of the overall context information is provided by directly measured values while the rest is only available when user profiles are exploited. It is important to categorize context information in order to implement structured and organized proccessing methods. Following the work of [2] we consider six different categories of an active context:

- **Environment context** captures all the information regarding the entities constituting the environment of the patient. These entities can be a mobile device, individuals interacting with the patient and physical conditions such as temperature, humidity, level of lightning and noise. Furthermore, this type of context contains information about the available network, device capabilities and user profile and network resources.
- **Identity context** contains information of the patient's physiological and psychological situation. Physiological context contains information such as blood pressure, oxygen level, temperature and pulse. Psychological context contains information such as stress level and present mood. Identity context also contains information on the patient's demographic data.
- **Activity context** consists of two different contexts which are the task the patient performs and the role of

the patient in it. Hobbies, scheduled activities and related actions are also sub-contexts of the activity context.

- **Time context** captures the time, day, season, month and year of the active context a patient is in.
- **Location context** provides information such as location, direction and speed. It also contains information about the different social arenas of the patient described with a name (work, home etc.) and a location.
- **Social context** describes the different individuals interacting with the patient (friends, relatives etc.). A sub-context of this type is the patient's role in these interactions and the different social arenas. A role can be described with patient's status and actions relative to it.

When it comes for special phobias, several context parameters that play significant role for a patient's situation are identified. A combined evaluation of them, exploiting user profiles, will lead to an active context which will define the actions that should be performed in order to provide them with personalized, customized and situation-dependent telemedicine services and applications. The outcomes of our research are the following.

Considering environment context, humidity, noise, intense light and atmospheric pollution are crucial for the stress level of a human. As their value rises, stress level is increased. Intense heat or sharp frost and decreased rate of oxygen in the atmosphere (e.g. at high hills) result in increased stress. Knowledge provided by this specific context information can be used for the proactive aspect of a medical treatment, while most of the information provided by physiological context (sub-context of the Identity context) would indicate a panic attack, initiating the reactive aspect of a medical treatment. High or low pulse, sudation, shaking, dry skin, unexplained and intense pruritus and gastritis are some attributes indicating a panic attack. Additionally, pregnancy and increased secretion of hormones such as thyroid result in increased stress. Concerning psychological context, information regarding basic stress level, optimism, angriness and various present emotions is quite useful in order to evaluate the situation of a patient.

Ongoing activities can be either relaxing or stressing. Information on which activities are relaxing or stressing is not something measurable. It is provided either explicitly by the patient or implicitly, in a self learning manner, through analysis of sequences of contexts and reasoning about how certain activities affect the situation of a patient. For example, one patient might like his job and feel relaxing while performing activities relative to it, while another patient might not. Location context provides the geographical area of a patient along with the present social arena. An unknown city or even an unknown region of a patient's living town could result, most of the times, in increased stress. Furthermore, the presence of family members or friends in his social arena gives the patient a feeling of safety, making him less vulnerable to his phobias. The role in each social arena is also important as superior roles are considered more stressful than inferior ones.

It must be mentioned that all the parameters that affect the stress level of a patient are factors affecting the behavior of special phobias as well, due to the fact that stress is the root of these disorders. Increased stress results in patients being more vulnerable to their special phobias, while being a harbinger of a potential panic attack triggering various defined context-dependent proactive actions. In the above, general factors regarding the whole of special phobias where examined. Each special phobia has some key factors though, that play crucial role for it but do not affect the rest.

For example, an agoraphobic would get overstressed and panic attacked finding himself among a plethora of other humans. The number of surrounding people that can lead a patient to a possible panic attack varies from patient to patient. Considering zoophobia, appearance of a specific animal stresses out the patient. Nosophobia breaks out when thoughts of or conversations about any kind of disease takes place, while claustrophobia causes panic attacks in places like elevators, tunnels and all kinds of narrow spaces.

Context parameters, that play fundamental role regarding special phobias, form a set of fuzzy variables that user profiles should host. A fuzzy reasoning could be employed during the inference process aiming to resolve the active context. User profiles could contain two types of entries:

- Explicit: Patients and physicians could supply explicitly the information that will determine the patient's status. For example, alerting thresholds of measured values such as blood pressure and heart rate, levels of humidity and noise increasing stress significantly, relatives, partners, friends and the way each of them affects the patient, social arenas, hobbies and personal information can be part of this type of entries.
- Implicit: Context parameters within user profiles could be classified in two types; relaxing and stressing. Every time a parameter increases stress, it could be updated by a positive weight. Reversely, it could be updated by a negative weight each time it decreases stress. User profiles will be constantly updated, defining the role of each parameter in a patient's status.

User profiles could be initialized with user-specified entries defining the way specific context parameters affect a patient's situation and get redefined in a statistical manner over the time. These user profiles should be fully cooperative with those employed by emerging advanced telecommunication infrastructures (e.g. Next Generation Networks – **NGN)** that contain aggregate values of a user's mobility (location, speed, direction etc.) and network resource requirements [13].

In the following section, we propose an active context-aware platform in order to provide the functionality needed to realize the ACCM. This platform aims to support context acquisition as well as active context construction. Furthermore, it enables context reasoning processes through ontology and inference rules and evaluation of high level contexts exploiting user profile information, in order to construct active contexts.

III. ACTIVE CONTEXT-AWARE PLATFORM

A. Context and Profile information Modeling

As mentioned in the introduction there are several active contexts that can be derived by the high level and very abstractive contexts and the low leveled ones, when user profile information is taken into account. The high and low level contexts, on their own, capture only some parts of the patient's active context. In order to describe context and profile information in a semantic level and get to understand how the structuring of contexts and user profiles should be, we need to model context and profile information. An ontology based approach for context and profile modeling would meet these objectives while enabling interoperability between sensor-readings and profile information as well as context reasoning using first-order logic. A major benefit using this model would be to identify the crucial spots where high level context information should be combined with user profile information, in order to construct an active context.

We use Web Ontology Language (**OWL**) to design the ontology based context model. OWL [3] is a Semantic Web language derived from the DAML+OIL language [4] and based on the Resource Description Framework (**RDF**) [5]. Using OWL we can describe an application domain in a semantic level by defining classes and their properties, define individuals and assert properties about them while reasoning about these classes and individuals [6].

The modeling approach adopted, aims to a layered structure of context and profile information as shown in Fig.1. There is a set of ontologies comprising the upper layer, which is stable, and a set of ontologies comprising the lower layer, which varies depending on the application of concern. The upper layer hosts the ontologies that capture generic information, common for all application domains or even for applications of the same domain, which in our case is the psychology domain. The lower layer hosts the application and domain-dependent ontologies that provide the properties of the context ontologies lying on the upper level according to the delivered application or the referring domain.

The overall active context information is provided by the

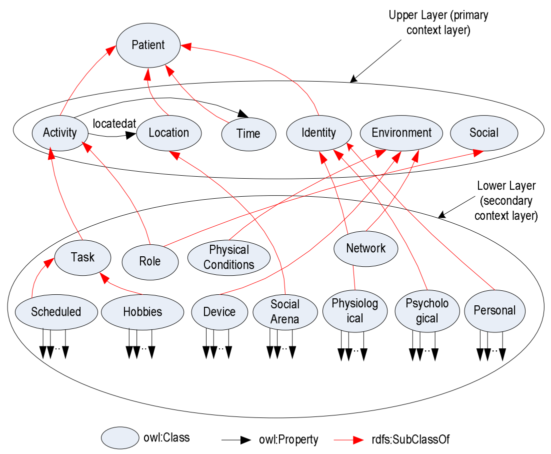

Fig. 1. Graph representation of the ontology based context model

Patient ontology. There is one instance of the class Patient for each patient. The ontologies of which the upper level is comprised, define the concepts of activity, location, time, social, environment and identity, giving answers to some crucial questions such as who, what, when and where. The properties of these classes (Activity, Location, Time, Identity, Social and Environment) are defined in the lower layer according to the special phobia of each patient. For example the Identity ontology owns the Physiological ontology, the Psychological ontology and the Personal ontology which provide a complete set of data describing the situation of the patient itself.

In this model the properties of the ontology classes leading to an active context are a combination of directly measured values and profile information, which enables the evaluation process on the third level of ACCM, whereas a non-active context representation would have properties lacking of values or ontologies lacking of properties. For example, the Physiological ontology contains information of the measured blood pressure provided by sensors as well as information about the alerting threshold of its value obtained from the user profiles. If this ontology had only the measured values as properties, it would provide a high level context without giving the opportunity to infer about the criticalness of the situation described by these values. Having the alerting thresholds of the measured values the emergency, or not, of the patients situation can be identified. The above example shows how the proposed model indicates the spots where user profile information should enrich acquired context information so as to construct an active context and why this enrichment is necessary in order to define the exact situation of a patient.

B. Active Context-Aware Framework

The proposed active context-aware framework (Fig.2) aims to offer the functionality needed for the three levels of the ACCM. It is based on the OSGi service platform which provides a standardized, component-oriented, computing environment for networked services. OSGi delivers a common platform for service providers, content providers, software and hardware developers to deploy, integrate and manage services to a wide range of environments such as building, home and mobile in a coordinated way.

OSGi framework offers many benefits such as standardized hardware abstraction, flexible integration platform based on open standards, hosting of diverse services from diverse providers on a single gateway platform and various levels of system security. Developing the proposed active context-aware framework on top of the OSGi open standard can provide a platform-independent and dynamically configurable infrastructure in order to develop, deploy, integrate and remotely manage context-aware services. Furthermore, the proposed framework is enriched with a set of functionalities and services provided by the OSGi framework. The active context-aware framework consists of the following components:

- Context providers: They obtain the diverse context data from sensors, external sources and the used devices converting them to OWL objects. These service components provide contexts on the first level of the proposed ACCM, i.e. the low level contexts.

- Aggregating agent: An aggregating agent gathers all the context data from the context providers. This component processes the collected data and reasons, depending on the application, about the redundant and the useful data with which the inference agent will be fed. Decision about useful data is based on user profile information. User profiles are hosted at a Medical Server (**MS**) that resides at a healthcare centre.
- Inference agent: An appropriate interpretation of sensor-readings is needed in order to capture the high level context. This software component uses semantic information defined by the ontology context model, healthcare related knowledge base, and inference rules, to form the contexts of the second level of our method. Thus, high level contexts are created and the result is transmitted to the service adaptation agent.
- Profile agent: User profiles have a really dynamic nature. Patient's preferences, information added explicitly by each patient, social arena information, physician's prescriptions, medicine, alerting thresholds of measured values and context-related actions change continuously. This component has the responsibility to download, store and keep the patient's user profile updated, in order to deliver it to the other components of the active context-aware framework whenever they request it. Finally, it transmits the reasoned active context back to the MS, so that a context history is maintained.
- Service adaptation agent: This agent queries the Inference Agent and the Profile Agent so as to obtain the reasoned high level context and the user profile respectively. The agent compares the context data of the reasoned context with the user profile data, applying semantic matching, and defines the active context as well as the actions that should be done, through reasoning processes. This is the most crucial component because it has the responsibility to provide the active context. The most accurate the reasoned context is, the most accurate the treatment will be. The outcomes are communicated to the appropriate service components so that the service will change its behavior according to the requirements of the active context and the patient's and physician's preferences. Finally, the identified active context is transmitted to the profile agent.

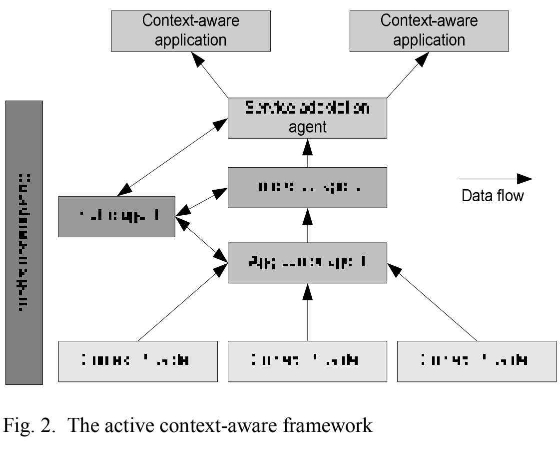

Fig. 2. The active context-aware framework

- Service coordination agent: The context-aware framework consists of several agents and sensing devices that need to interact with each other. The service coordination agent provides the functionality for this interaction by processing queries for contextual data between the agents and the agents and the sensing devices. It supports discovery of context providers located at the environment of the patient as well as context interpreters, context aggregators, profile agents and service adaptation agents, so that they can be located by services and applications.

The OSGi platform is a Java based component-oriented framework. Every component of the context-aware framework can be developed in a bundle format according to the OSGi specifications. Implementing these components in Java makes them independent of underlying system platforms, as long as a Java Virtual Machine (**JVM**) is implemented, offering interoperability between service providers and hardware vendors. OSGi framework enables the downloading of a bundle to a remote gateway (the MS in our case) and handles the life-cycle management as well as the management of the installation and update of each bundle within the active context-aware framework. Each bundle publishes its services to the coordination agent through the service registration function provided by the OSGi framework, so that the service's functionality is available to other bundles. Each bundle is only initialized when the published service is actually needed by another bundle. Furthermore, the OSGi framework provides a query mechanism that enables a bundle to request the services it needs, enabling the queries between the service adaptation agent, the aggregator agent and the profile agent.

IV. DISCUSSION

Systems proposed in [9], [10], and [11] do not incorporate user profiles, while ERMHAN [8] and CAMMD [14] exploit physician-oriented user profiles (including variables such as scheduling and availability). Furthermore, these researches deal with limited context parameters such as location, people, time and physiological values. CAMPU [13] exploits patient-specific user profiles but the profiled information is limited to personal and physiological data. As a result, none of these proposed frameworks meets context-awareness the way psychology requests it. Considering psychology many context parameters get into a tangle when a patient's medical status is determined. While mass context parameters affect the patient's active context, associations between them are rather fuzzy and inference rules quite complicated. Finally, none of the above platforms and systems, offer context history records which are extremely crucial for psychology.

The proposed platform that realizes the ACCM and exploits patient-specific user profiles, offers a wide range of benefits both to patients and physicians. On the patient's side, the offered application could act in a proactive manner, so as to inform a patient about abnormal values of physical conditions or measured vital signs such as blood pressure, and offer some advice in order to prevent a critical situation. For example, consider an agoraphobic patient who is on holidays and moves around the visited place. Based mainly on external sensors measuring population density, the patient could be informed of places with high density of people and advised to avoid visiting them at a certain point in time On the other hand, in a reactive manner, in case of a serious panic attack, the application could notify some relatives offering location information and establish a voice call between patient and physician. Considering that physician's voice itself relaxes the patient, a voice call between them could offer significant help to the patient in order to deal with a panic attack. Furthermore, there are some typical benefits context-awareness offers to patients, such as reminders to take prescribed medicine or fulfil recommended exercises and reminders of arranged sessions with attendant physicians.

On the physician's side, the proposed ACCM in conjunction with context history records offer knowledge regarding the sequence of identified active contexts. When a patient discusses with the attendant physician, while in psychotherapy sessions, the crucial question "Where were you and what did you do when panic attack started?" always comes up. The place where panic attack occurred is something almost all patients remember. What they did after it has occurred is not always answered. This happens due to the excessive pressure exerted to the patient's nervous system as well as the loss of control some patients experience during intense seizures. Sometimes, patients even lie about what they did, being afraid of getting rebuked. Physicians have the opportunity to identify the actions following each panic attack and guide their patients regarding the actions that should have been done, or applaud their efforts to deal with their phobias. Active context "speaks" to them. Furthermore, physicians have the opportunity to interact with their patients in an offline mode, monitoring their recovery status and forwarding new medicine or altering the alerting thresholds of physiological values that indicate some kind of anomaly.

Finally, there is a set of outstanding advantages addressed by the use of user profiles, regarding the medical treatment itself. User profiles could store values indicating the period of time each patient finds himself in some defined stressful situations, which bring him some steps away from a possible panic attack, trying neither to panic nor to run away to a more relaxing environment. Exploiting this information each patient can try to hang in these difficult situations for more and more amount of time before running away. While doing this, the patient grows stronger and stronger against his phobia. Additionally, the critical factors, as well as the combinations of different context parameters, which vary from patient to patient due to the different way each human perceives things and situations, leading to panic attacks could be indicated through context analysis and become fundamental part of psychotherapy discussions.

V. CONCLUSION

This research provides insight into the need to exploit user profiles in order to identify the active context of a patient and presents the wide range of advantages user profiles and active context-awareness offer, in the psychology domain. We categorized context information and analyzed it for some specific disorders, called special phobias, aiming to identify the context parameters that affect the status of a patient and which information user profiles should host.

Furthermore, an active context-aware platform was proposed, aiming to realize the ACCM. There are numerous challenges and design issues in implementing such a platform, which mainly depend on the available network resources, storing and processing capabilities of the MBU, context and profile data processing policies and security issues placed by patients and attendant physicians.

For future research, we will study about the interactions between high level contexts and user profiles, context evaluation methods exploiting user profiles and accuracy of the active context constructed on the 3rd level of our proposed method.

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