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Leveraging Dynamic User Profiles for the Assistance of Anxiety Disorders' Treatment using Inferential Rules

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Abstract— **While anxiety disorders exhibit an impressive spread especially in western societies, context-awareness seems a promising technology to provide assistance to physicians in psychotherapy sessions. In the present paper an approach addressing the assistance of the anxiety disorders' treatment is proposed. The suggested method employs the a priori association rule mining algorithm in order to achieve dynamic update of patient profiles according to generated rules describing the underlying relations between patients' main context conditions and their stress level. This method was evaluated by therapists specializing in the mental health domain and the feedback received was very encouraging with respect to the assistance dynamic patient profiles offer, during CBT sessions.**

I. Introduction

According to a research conducted by Kessler et al. in 2005 [1], 40 million American adults were affected by anxiety disorders in a given year. That amounts to the 18% of the U.S. population having some kind of anxiety disorder (e.g. Panic Disorder, Generalized Anxiety Disorder, Obsessive-Compulsive Disorder, Post Traumatic Stress Disorder, social phobias or other specific phobias), which is a remarkably high and worrying percentage. The impact of these disorders is severe both in personal (e.g. low self-esteem and isolation) and social aspects (e.g. family problems, low productivity and problematic interpersonal affairs).

Anxiety disorders are mainly triggered by social stimuli as the demands regarding the labor market are increasingly growing, the pop-culture of advertisements dictates behavioral patterns placing a great amount of insecurity among individuals, while the cost of living keeps increasing disproportionally with people's incomes. All these (and many other similar) factors add stress to everyday life and comprise the environmental parameters that cause the occurrence of anxiety disorders.

Although a lot of research has been done in the mental health domain, the exact reasons that provoke anxiety disorders to patients remain yet not clearly specified [2]. In general, areas of the brain that control fear responses seem to have a role in some anxiety disorders, whereas genes and biomes are also considered as possible causes of anxiety disorders. For instance, there exist cases where disorders may run in families, suggesting that a combination of genetic and environmental parameters can cause such disorders.

II. Context-Awareness

Stress-provoking situations are highly dependent on concrete attributes such as location, physical conditions, time and activity of a patient – or in other words, dependent on the context of a patient. The way and degree of affection that specific context aspects have upon stressful situations, as well as the symptoms a patient might present, may change during a patient's recovery period. This means that while some specific context instances could be indicative of stressing situations at a specific point in time, some other may take their place in a temporal extent. This highly dynamic nature of anxiety disorders requires the offered treatment to be based on a long-term monitoring of each patient, in order to verify several attributes as stressing situations and symptoms. Therefore an analysis of a considerable set of contexts should be performed.

Many approaches addressing context-awareness in healthcare [3]-[6] have been proposed, but are mostly focused in providing instances of healthcare treatments through the identification of a single context. Information on this context is not maintained afterwards and the next instance of the provided treatment will depend on a newly identified single context. Therefore, these methods are unable to support a long-term monitoring possibility, which is required in the case of anxiety disorders, as described above.

One common aspect of the research approaches mentioned above, along with the majority of the approaches regarding context-awareness in healthcare and other domains [7, 8] is the implementation of a rule-based personalization process regarding mainly the provision of proactive treatment. A rule-engine such as JESS [9] processes a set of manually created rules and (according to

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the identified context) the provided services are properly adjusted. Two main issues arise regarding the creation of such static rule sets in the domain of anxiety disorders:

- First, due to the dynamic nature of anxiety disorders, a dynamic adjustment of the rule sets is required, so that the content of the delivered proactive services will always apply to the present needs of the patients. A predefined rule set which is not dynamically updated may fail to provide the desired results in a temporal extent.
- Second, creating these rules manually is a really hard task and an automated creation process seems necessary when many context parameters have to be considered.

In order to cope with the aforementioned problems we propose a new method for the assistance of anxiety disorders treatment, introducing the dynamic creation and adjustment of patient-oriented user profiles based on dynamically updated rule-sets which are inferred by correlating the patient's health status with his/her context parameters. Thus a delineation of stress-provoking situations will be achieved and a more thorough image of the way that context parameters affect the patient's stress status will be obtained. Consequently, there is a need for a detailed identification of the context information that is of great importance for anxiety disorders.

III. Context Information Identification

Since the exact causes of anxiety disorders are not yet clearly defined, a correlation between the patient's mental health status regarding to his/her context conditions has to be examined. Therefore, in the present study, the patient context is considered to be comprised of two types of context information (i.e. main context and stress context) as illustrated in Fig. 1.

Stress context provides information regarding the stress status of a patient. More specifically, a set of physiological values is measured through appropriate sensors, which are able to accurately determine the stress level of a patient. According to a recent research addressing emotion recognition through biosignal processing [10], this can be achieved through a set of biosensors measuring muscle activity (EMG), heart activity (ECG), respiration and skin conductance activity (EDA). Acquiring these biosignals and using a stress scale we can then determine the respective stress level through a fuzzy reasoning process.

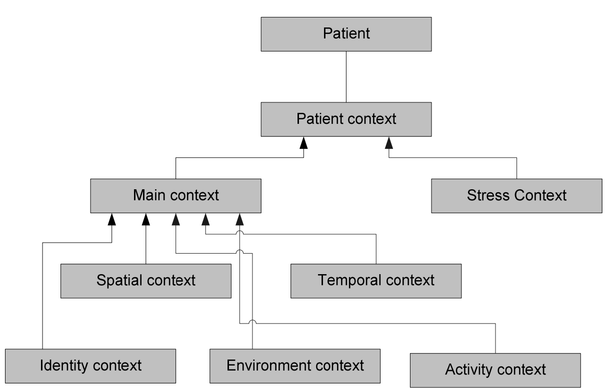

Fig. 1. Context Classification.

Main context refers to diverse context notions, which are considered to be spatial, temporal, identity, environmental and activity context.

A description as well as the reasons why the above context aspects are significant when trying to identify several attributes of anxiety disorders are comprehensively analyzed in [11]. For instance, 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. Ongoing activities can be either relaxing or stressing. Regarding location, an unknown city or even an unknown region of a patient's living town could result, most of the times, in increased stress. Some other context aspects can be used as well, such as the device context capturing available networks lying in the surrounding of the patient, device capabilities and available display formats of the device that the patient uses to access the network, services and applications. For reasons of simplicity such aspects will not be examined in this research.

IV. Dynamic User Profiling

A. Patient Profiles Architecture

A user-profile based personalization process generally consists of three steps. The first step describes the collection of the data that can be explicit, relying on information provided directly by both patients and medical staff, or implicit, based on self-learning methods such as Bayesian Networks and neural Networks. The final step is a personalization technique exploiting profile information in order to offer personalized services and/or applications to the patients and the medical staff.

The construction of a user profile is the middle step of the user-profile based personalization process and may be comprised by both static and dynamic context information. The static part is constructed from the explicit information gathered by patients and medical staff. This could be done through appropriate interfaces and/or premade e-forms through which patients and physicians may provide such kind of information. On the other hand, the dynamic part of the user profile is based on implicit information collection, without any kind of intervention by the users.

Data such as demographic details, personal information and social arenas a patient might interact with (e.g. work, home etc.) are static, meaning that this kind of information is maintained constant over a reasonable period of time. On the other hand, the majority of context parameters are highly dynamic while patients may visit different places, interact with a plethora of individuals, access diverse networks and address themselves to diverse tasks. In such cases, this specific dynamic part of a context could turn out to a valuable source of information for the psychiatrists while putting their efforts on determining relationships between stress factors and specific stress levels along with the attitude each patient adopts against them. Furthermore, this dynamic context information may assist psychiatrists to identify stress symptoms and keep track of the stress status of a patient within defined periods of time.

While the static part of the user profile feeds context reasoning with the appropriate information so that context is determined as accurately as possible, the dynamic part is fed with information derived from the reasoned context itself. In the present study, we mainly emphasize on the exploitation of the underlying information contained within the dynamic context data, considering the following dynamic tables:

- Stress status: Stress context defines the stress level of a patient in a given point in time and feeds the stress status table with this information.
- Stress factors: This table captures the instances of the main context aspects that occur in a specified stress context.

The stress factors table keeps track of the parameters that influence the stress status of a patient. Knowledge of the way each of these parameters affect the patient's stress level and discovery of relationships between the patient's current stress status and his/her main context conditions, make proactive service provisioning not only possible, but tailored to the specific needs and requirements of each patient as well.

In order to better adopt each patient's profile according to his/her needs, and identify adverse interactions between specific values of the patient's health status and various main context parameters, a systematic processing of the data contained in the previously mentioned tables is required.

B. *Data Correlation and Dynamic Update*

Because of the nature of anxiety disorders and their attributes, it is required to perform a dynamic adjustment of the set of rules that describe the relationships between the level of anxiety a patient suffers from and the main context conditions. In order to deal with this issue, a unique database for every patient containing records of his/her anxiety levels within the time interval of two subsequent sessions with the psychiatrist, is created during the data collection step. In order for this to be achieved, each patient is monitored several times per day with respect to his/her anxiety level as well as to the main context conditions (i.e. spatial, temporal, environmental and activity context).

After the database collection procedure is completed, the collected data are pre-processed and divided into two sub-datasets: The first sub-dataset will contain only itemsets of cases where the patient suffers from the highest level of stress and the second sub-dataset will comprise of all the collected itemsets. Then, an automatic ruleset creation procedure takes place. More specifically, the aforementioned sub-datasets are used as input to an association rule mining algorithm [12] aiming to reveal the underlying relations that lay hidden in the collected data. The examination for possible associations between the input data involves two directions. The first direction aims at the discovery of the relations of the main context conditions only at cases where the patient already suffers from the highest level of stress, whereas the second direction – which is of major importance with respect to the dynamic update of the patient's user profile – involves the detection of relationships or associations between specific values of the patient's main context conditions with respect to the level of stress he/she suffers from at that time.

For this purpose, in the present work, the a priori association rule learning algorithm [13] is employed using an improved candidate generation function, which exploits the downward closure property of support and a breadth-first search strategy to count the support of itemsets. The algorithm attempts to find subsets of itemsets in the input database that satisfy the predefined minimum support and confidence levels. In particular, by examining the first sub-dataset for possible associations using the a priori algorithm, a dynamic ruleset describing the relationships between the spatial, temporal, environmental and activity context conditions of the patient at situations where he/she suffers from the highest level of stress is produced. On the other hand, the analytic relationship examination of the itemsets contained in the second sub-dataset reveals associations between the aforementioned main context parameters with respect to the level of anxiety that the patient suffers from.

A practical problem is that at medium to low support values often a large number of frequent itemsets and an even larger number of association rules are found in a database. More specifically, when these techniques are applied to multidimensional data, as in the case of the patients' medical records, a huge number of patterns may come up, frequently comprised of useful but also of redundant rules. Therefore, in order to constrain the results, various techniques for pruning and summarizing rules [14] are employed in our approach, such as high complexity, high support and confidence values [15].

V. Experimental Evaluation

In order to evaluate the significance of the dynamically updated patient user profiles and the derived rulesets with respect to the assistance of the anxiety disorder treatment, experiments were performed on real and WoZ data. Unfortunately, there does not exist a standard method for evaluating the suggested approach and a comparison of the results of the proposed system against other approaches could not be performed directly due to inherent differences in resource types. Therefore, in the present work the evaluation was performed by psychiatrists of the Mental Health Centre (MHC) of Patras, specializing on the field of anxiety disorders, and the feedback received was very promising towards the helpfulness of the proposed approach in the anxiety disorders domain.

More specifically, the use of the a priori association rule learning algorithm for the analytic examination of possible relationships between the patient's context information and his/her stress level, has revealed useful information while viewing their profiles. For instance, a portion of the derived rules describing the context conditions that have occurred at cases where a patient suffered from the highest level of stress (5), is tabulated in Table 1.

TABLE I
PORTION OF THE DERIVED RULES DESCRIBING THE CONTEXT CONDITIONS THAT HAVE OCCURRED AT CASES WHERE THE PATIENT SUFFERED FROM THE HIGHEST LEVEL OF STRESS (5)

1	IF ***PLACE=DOWNTOWN***	THEN	suffers from ***STRESS=5***
2	IF ***ACIVITY=MEETING***	THEN	suffers from ***STRESS=5***
3	IF ***PLACE=SUBURBS*** AND ***TIME=21*** AND ***STATE=DRIVING***	THEN	suffers from ***STRESS=5***
4	IF ***PLACE=HOME*** AND ***TIME=15***	THEN	suffers from ***STRESS=5***
5	IF ***PLACE=HOME*** AND ***DAY=SUNDAY*** AND ***TIME=18***	THEN	suffers from ***STRESS=5***
	……………………….		

From the rules stated in Table 1 some appear to make perfect sense (like for instance rule No 2, since it is reasonable for a person to suffer from higher level of stress when he/she is at a meeting) but others (e.g. rule No 1) reveal underlying associations that may be of great importance to the psychiatrist during the CBT sessions. For example, from rule No 1 the psychiatrist may infer that since every time the patient goes downtown he gets extremely stressed, probably he suffers from some kind of social phobia and guide the patient properly. Furthermore, noticing rule No 3 he could discuss with the patient trying to identify what exactly is that stresses him/her out when he/she drives at 21:00 at suburbs.

VI. CONCLUSIONS AND PERSPECTIVES

The current paper proposed an approach where context-awareness is used as a technology that supports the long term monitoring of patients suffering from stress disorders. The presented method focuses in the construction and dynamic update of user profiles based on association rules, thus aiming to meet the challenges that the domain of anxiety disorders place on the widely used rule-based personalization in proactive service provisioning.

The proposed method was experimentally evaluated by therapists specializing in the mental health domain and the feedback received was very encouraging in respect to the assistance dynamic patient profiling offers, during CBT sessions.

Our plans for future work include the proper visualization of these profiles so that users can have a view of their structure and contents, as well as the exploration of possible relations between the main context conditions, the stress level of a patient and the symptoms that are associated with certain anxiety disorders. Therefore, in order to inference causal relationships between the patient's anxiety states, treatment and symptoms, a Bayesian Network model will also be employed. Finally, further examination of the presented approach either in its present state or when enriched with the aforementioned features, will be performed in cooperation with the medical staff of the Mental Health Centre of Patras.

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