Ontologies for intelligent e-therapy. Application to obesity[1]

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Abstract. In this paper we propose a new approach for mental e-health treatments named intelligent e-therapy (e-it) with capabilities for ambient intelligent and ubiquitous computing. The proposed e-it system supposes an evolution of cybertherapy and telepsychology tools used up to now. The e-it system is based in a knowledge base that includes all the knowledge related to the disorder and its treatment. The use of ontologies as the best option for the design on this knowledge base is introduced. A first e-it system for obesity treatment called etiobe is also presented.

Keywords: Obesity, intelligent e-therapy, ontology, cognitive behavioural therapy, ambient intelligent.

1. Introduction

Recently a new concept of psychological therapy ha s appeared. This new intelligent e-therapy (e-it) adapts itself to the patient's lifestyle, offering a 24/7 monitoring to the patient. E-it can be applied to many different disorders, such as: mental health (depression, anxiety, PTSD,…, ED), enhance adherence for non-mental health (cancer, obesity, stroke rehabilitation, cardiac rehabilitation), solutions to social problems (elderly, child violence, immigrants insertion).

This new intelligent e-therapy aims as an evolution of the Computer Aided Psychotherapy (CAP) [1], [2] to solve the need of a continuous and ubiquitous customization for each patient.

From a technological point of view, an e-it system is based on four fundamental axes:

- Ambient Intelligence, that permits through network and sensor technologies to capture the physiological, psychological and contextual information of the user/patient.
- Persuasive computing that allows the generation of contents with the objective to change and/or to reinforce conducts of the user/patient.
- Ubiquitous computing that makes it possible for the user/patient to access the system in any place, at any hour and using multiple technological platforms supports.
- Virtual therapy that includes technology of distributed virtual reality, augmented reality, natural interfaces and virtual agents.

Figure 1 and Figure 2 show the functional diagram of the e-it concept.

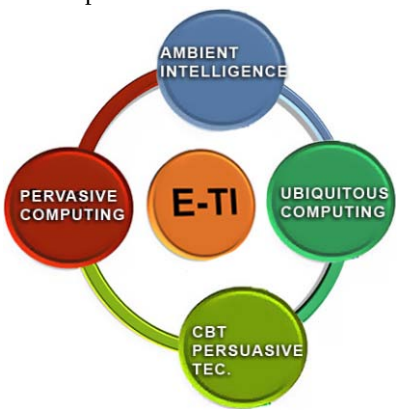

Figure 1: e-IT fundamental axis

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[*] Corresponding author. E-mail: editorial@iospress.nl. Check if the checkbox in menu *Tools/Options/Compatibility/Lay out footnotes like Word 6.x/95/97* is selected if you make a footnote for the corresponding author.

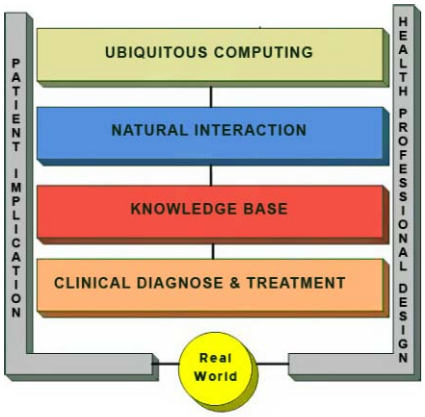

Figure 2: e-IT functional diagram

The intelligent aspect of an e-it system is based on the use of sensors that allow to obtain all the relevant information related to the patient (contextual, physiological and psychological) and in the existence of communication and computer applications capable of transferring the above mentioned information, to store it, to manage it, to interpret it properly and to react to it offering a set of contents, personalized depending on the characteristics, information and answers of the patient ,capable even of being generated by other possible users of the system, as for example the therapists.

The therapeutic aspect of an e-it system is based on the purpose of the above mentioned contents, and the persuasive aspect on the nature of the same ones and on the way in which these contents are offered to the patient. On one hand, these contents will be orientated to change and / or reinforce the behaviour of the patient, and in order to do it in a persuasive way there will be in use, besides the conventional mediums (text, audio, image, video), those that are directly related to the cyber therapy, technology of recognized therapeutic efficiency: virtual reality and augmented reality scenarios, virtual intelligent agents and natural interfaces interacting with them.

The accessibility of the user / patient to this type of systems, independently wherefrom he is and of the platform that he uses for it, represents the ubiquitous aspect of an e-TI system and is based on the use of communication and computer applications capable of adapting the previously mentioned features to the nature of the device and the communication network that is in use.

As shown in **¡Error! No se encuentra el origen de la referencia.** an e-it system is based in a knowledge base that includes all the knowledge related to a specific the disorder and its treatment. We proposed the use of ontologies as the best option for the design of the knowledge base of the intelligent e-therapy.

2. Ontologies for intelligent e-therapy

Ontologies have become the knowledge representation medium chosen in recent years for a range of science areas including medicine [3], bio-medicine [4], bio-informatics [5], semantic web [6], agents [7], etc. However until the moment the design of ontologies for psychology is not very common.

The term ontology was first defined by T. R. Gruber in 1992 as a “formal specification of a conceptualization” [8] which is “the objects, concepts, and other entities that are presumed to exist in some area of interest and the relationships that hold among them."

Following are mentioned the main advantages of the use of ontologies:

Share common understanding of the structure of information among people or software agents

- To enable reuse of domain knowledge
- To make domain assumptions explicit
- To separate domain knowledge from the operational knowledge
- To analyze domain knowledge

It could be very interesting for psychological treatments to use a common vocabulary and to share what other people is doing in different parts of the world. Ontologies provide important advantages such the ones previously mentioned.

The process of designing an ontology is costly enough, since it needs a previous phase of knowledge extraction, it is an iterative process in which the knowledge of the professionals in the domain is acquired up to coming to a useful, functional and as specific as possible solution.

The idea is to develop a modular and reusable *Therapy Knowledge Base (TKB)* that let the therapists around the world applying e-it treatments on different patients and with different disorders. For this reason a first ontology on CBT (Cognitive Behavioural Therapy) has been designed. Different ontologies can extend this first one and complete it for a concrete therapy, as example an ontology for obesity has been designed.

3. An e-it system for obesity

Obesity is increasing among the population of all the ages, for this reason we have chosen obesity as an appropriate disorder to be treated with intelligent e-therapy and a first system of intelligent e-therapy for obesity has been developed.

In the developed system there can be distinguished 4 layers that are commented below.

Sensor layer: This layer is in charge of integrating in the development environment all the sensor devices (localization and physiological sensors). The sensor layer is also responsible of receiving and processing the data from the physical and logical sensors and to transform them into manageable information for the environment.

A sensory intelligent platform has been designed. This platform catches physiological and contextual information of patients undergoing the therapy. For this first phase there has been designed a multiplatform that retrieves different physiological measurements (respiratory rate, heart rate, conductance of the skin) and contextual information (caloric consumption, physical activity level, position). All these measurements are sent to a computer or mobile device using a special protocol taking advantage of wireless communications (Bluetooth).

Communication layer: The role of this layer is to allow the communication among the different layers of the development environment, including the communication among different devices and platforms. Due to the heterogeneity of the devices that can be used (wireless sensors, mobile telephones, PDA, PCs, …) the communication layer is based on "web services". Sensors and applications to communicate are able to invoke the methods exposed by the web services in a platform and language-independent fashion. This layer defines the protocols that the rest of layers have to use to communicate among them.

At the transport layer, communication between sensors and the mobile phone is based on Bluetooth; communications between the mobile phone and servers are based on IP over UMTS. Communication between desktop clients and web servers are based on convention HTTP over TCP/IP.

Data management layer: This layer is responsible of storing and controlling the information needed and generated by other components of the environment. Due to the huge amount of information the system has to manage is really important the organization of this information.

Data management is based on an ontology based schema. The use of ontologies facilitates the automatic reasoning it means, without human intervention. Starting from a few rules of inference, an engine of reasoning can use the information of the ontologies to infer conclusions of them. The set of rules has to be defined taking into account the knowledge extract from the professionals in the domain. This layer will be commented in detailed in the next section.

Application layer: This layer is in charge of implementing all the applications that will run in the different platforms. The e-it system has three main applications to the users' eyes:

The therapist application (CSS, Clinical Supporting System): is an application for clinical support that the therapists uses in his consultation, offering them the possibility of designing an adapted protocol for each patient, as well as its monitoring, being able at any moment to modify and to update it depending on the evolution of the patient. In addition the application allows the therapist to communicate with the environment involved in the treatment (for example patient's relatives).

The home application (HSS, Home Supporting System): is an application for home support that is installed in the patient house. This application is used by the patient from his house on a PC platform connected to Internet. In this type of applications a set of contents of persuasive computation including communication with the therapist is going to be exposed to the patient. In addition, if the application is for children, it includes functions for their relatives such as private communication with the therapist. For example, the relative might include information of the habits of the child, if he has realized a specific task or not.

The mobile application (MSS, Mobile Supporting System): this application runs in mobile devices, allowing the patient ubiquitous communication at any time with the therapist and to receive advices and instructions from the virtual agent that is in charge of his treatment.

In the following subsections the main developments done in these layers for the obesity system are described.

3.1. Data management layer. An obesity ontology

Data management is based on an ontology based schema. The use of ontology permits a conceptual, rigorous and exhaustive scheme inside a domain, in this case obesity-related behavior.

From a basic CBT ontology a new ontology needed to collect all the information related to the obesity system (physiological variables, contextual variables, cognitive variables, etc.) has been designed and developed. In our obesity ontology we can find 4 main entities:

Agent: Any user of the system is considered as an agent. Each agent has a name, a surname, a login and a password. We can distinguish three different kinds of agent: patient, relative or professional. There are also two types of professional: doctor or psychologist.

A patient is an obesity user that is going to be treated. For each patient lot of data is stored such as: profile, diagnosis, treatment, evaluation, relative, doctor, etc.

A relative is a user that is going to help a patient during the treatment. Since a relative is an agent has a name, surname, login and password. Relatives are really important when the patient is a child; in this case the relative (mother or father) participation is essential (since the mother is the one that cooks for the child).

The professionals are the doctors or psychologists that are going to treat the patient. As in the rest of cases as are agents have a name, surname, login and password. Professionals have also information about the patients that are treating (their profiles, evaluation, diagnosis, treatment, etc.).

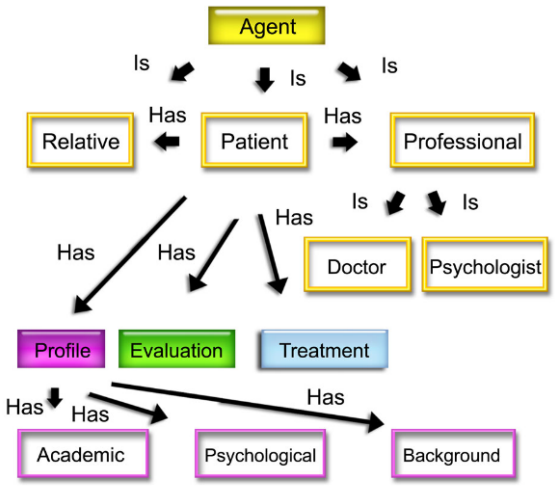

Figure 3: Agent concept of the obesity ontology

Evaluation: This concept represents all the variables under control and measurements obtained from the patient. We have different type of measurements: psychological, obtained from the tests done by the psychologist, physiological obtained by the doctor or by a device connected to the patient and contextual related to the environment of the patient (activity done by the patient, position, etc.).

Physiological measurements are important due to the risk that obese people have to suffer diseases of diverse type, especially cardiovascular [9]. These measurements are collected by a device connected to the patient and analysed by the doctor to evaluate patient's situation and his evolution.

Contextual measurements give information about the habits of the patient. In the obesity treatment is very important the activity done by the patient and the alimentary habits. These measurements are collected by a device connected to the patient or asking directly to the patient. This information is analysed by doctors and psychologist.

Psychological measurements are important because obesity can have implications in the state of the people who suffer it [9]. For this reason psychologist done several test to the patients to know how they felt. These tests are done at the beginning of the treatment and repeated during the treatment and several months after the treatment is finished.

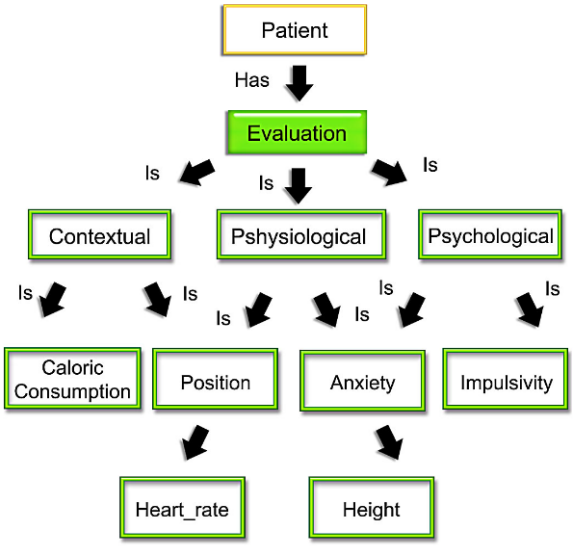

Figure 4: Evaluation concept of the obesity ontology

Treatment: This concept represents the planning done by the psychologist to treat the patient. It also includes the general objectives of the treatment and the monitoring of the patient.

A treatment is defined as a set of modules After analysing the psychological information obtained from the tests initially done to the patient the psy-

chologist decided the appropriate modules for this patient (not all the patients need all the modules, sometimes is useful to focus only in some specific modules).

A number of sessions has to be specified for each selected module and for each session specific objectives are defined. As well as objectives a session also has information about what is going to be done in this session. In each session the psychologist defines some tasks that the patient should do during the week. The results of these tasks can be consulted by the psychologist at any moment.

There are three types of tasks the psychologist can order to the patient: games, information and self-records (measurements that should be done by the own patient and report to the system)

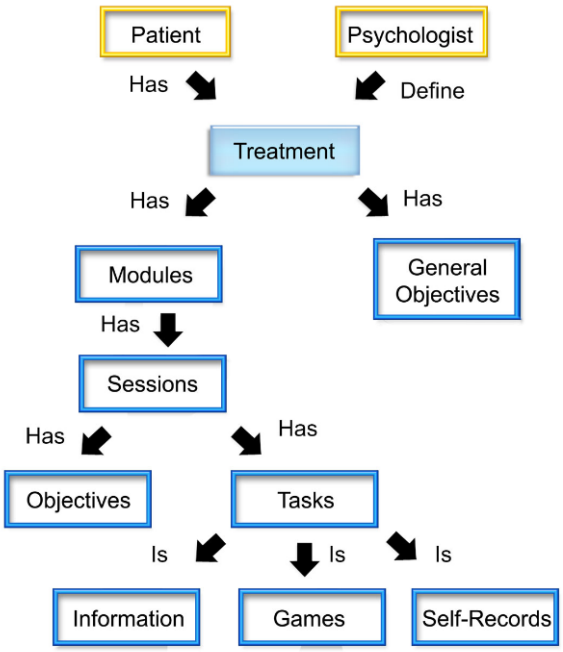

Figure 5: Treatment concept of the obesity ontology

Alarms: This concept represents warnings to the patient or the professional (doctor or psychologist) that a variable under control is out of the allowed range.

Most of these measurements have a maximum and minimum possible value, in other words a range is defined for them. When a new measurement is obtained its value is checked and if this value is not in the defined range an alarm is launched. Alarms are stored in the system.

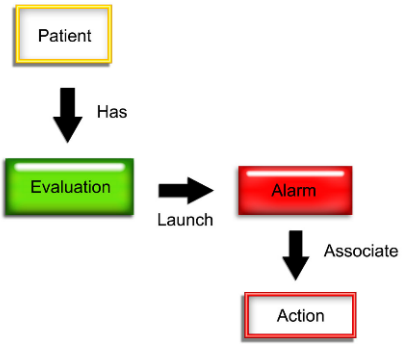

Figure 6: Alarm concept of the obesity ontology

Although the definition of ontologies is really important, since it allows, among other advantages, to reuse and to share information, to do inferences, etc, due to the huge volume of information an e-TI system manages it is necessary also to have a good information storage system. With this aim a library that allows obtaining a Mysql database from the OWL file of the ontology has been developed.

Hereby in the data management layer we have the advantages of the ontology (semantics of the information, sharing information, inferences,…) and the advantages of the database (speed in the information access, persistent storage, controlled concurrent accesses, etc).

3.2. Sensor layer.

A sensory intelligent platform has been designed. This platform catches physiological and contextual information of patients undergoing the therapy. For this first phase there has been designed a multiplatform that retrieves different physiological measurements (respiratory rate, heart rate, conductance of the skin) and contextual information (caloric consumption, physical activity level, position). All these measurements are sent to a computer or mobile device using a special protocol taking advantage of wireless communications. First applications to test this platform have also been developed.

Figure 7 shows the developed platform scheme:

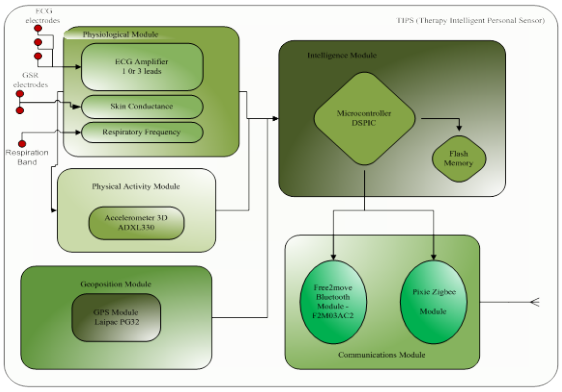

Figure 7: General scheme of TIPS

The TIN (Therapy Intelligent Network) is an open platform that tries to establish a sensor network [10] ,[11] where the focus is the patient, that captures information in real time, so much of physiological like contextual data. In this first phase TIPS shows the personal platform (Personal Therapy Intelligent Sensor) that it will carry the patient to develop the first scenes of therapy .

The main characteristics of the TIPS are:

- Wireless communication
- Low Power Consumption
- Capturing physiological signals (ECG, Skin Conductance, Respiratory Signal)
- Geoposition Service Context-Aware
- Physical activity detection (intensity, duration & frequency)
- Own intelligence for pre-processing and transmitting signals
- Transmition Protocol
- Reduced size

From a functional point of view the system can split into the following blocks:

Intelligent Module: Capable module to receive the information of the different modules of acquisition, pre-processing and use a transmission protocol in order that it is transmitted inside the TIN (Therapy Intelligent Network).

Transmission Module: Capable module to transmit the parcels of data in real time to other elements of the TIN of a wireless way. (ZIGBEE & Bluetooth)

Geoposition Module: Capable to detect the outdoor patient's position.

Two applications have been developed for testing this module. A first application for PDA devices that can send the GPS (global positioning system) information and a web server application that represents the points of coordinates in a geographical map. The system also can receive points of the map (beacons) and send them to the PDA, this way we can know when the TIPS is near to the beacon and interact with the patient [12] , [13], [14].

Physical Activity Module: Module in charge of determining the physical activity and the energy output of the patient.

An algorithm to detect levels of activity and orientation of the patient in the space using accelerometer and cardiac signals has been developed. [15], [16], [17].

Two applications have been developed for testing this module. On one hand a PC application that registers the values of the accelerometer and allows realizing marks in activity or position changes. These marks allow calibrating the validity and the detection mistake of our algorithm. On the other hand a small version of the algorithm has been implemented in PDA to make possible the detection of these conditions in real time, receiving the signals sent by the TIPS at any environment.

Physiological Module: Constituted by the placed captators for register the physiological signs (Heart Rate, Respiration Rate, and Skin Conductance). [18], [19]

3.3. Application layer

The different modules of this layer (CSS, HSS and MSS) have been developed. Following are shown some screenshots of these developments.

CSS: The principal aim of this application is to provide to therapists a simple, agile and functional tool for the treatment of obesity in children population, allowing a joint and easily monitoring for all the members who act in the treatment.

During the treatment every user has established a role (doctor, therapist, etc) that allows him to accede to one or other functionalities of the system.

Figure 8: CSS Screenshot I

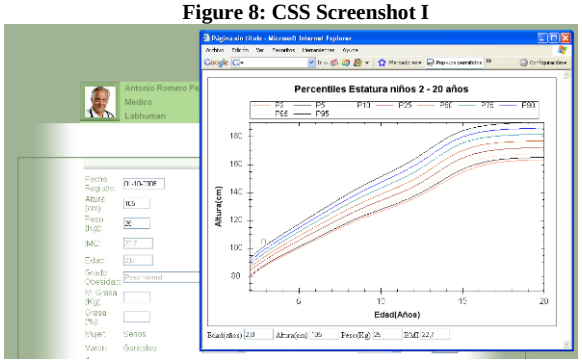

Figure 9: CSS Screenshot II

HSS: It is a web application that allows the children to consult about the tasks assigned by the therapist, to realize the above mentioned tasks, to consult about nutritional information, etc. One of the fundamental parts inside the project is to establish an attractive connection among the treatment, the nutritional information and the patient. For this reason a web specializing and orientated to the children has been created. The system tries to create a social network of those children who follow the treatment, for this reason each activity done gives punctuation and there is a global ranking.

Figure 10: HSS Screenshot I

Figure 11: HSS Screenshot II

MSS: This application allows the patient to introduce self information to the system. In this version the patient can realize two types of self-records: food and activity. After filling in the self information a virtual agent or avatar appears with a message of reinforcement.

Figure 12: MSS Screenshot I

Figure 13: MSS Screenshot II

4. Results and Conclusions

At this moment the development of a first version of the system is completed. The different modules of the system have been tested separately and in the next months the whole system is going to be tested with real patients.

The objective of the obesity intelligent e-therapy is to improve the efficiency of the obesity treatment, since until the moment the treatments that are being applied for this disorder are not having good results.

Recently a new concept of psychological therapy has appeared. This new intelligent e-therapy (e-ti) adapts itself to the patient's lifestyle, offering a 24/7 monitoring to the patient. E-ti can be applied to many disorders, and it is based in a knowledge base that includes all the knowledge related to the disorder and its treatment.

The benefits provided by the use of ontologies made this technique the best option for the design of the knowledge base of the intelligent e-therapy.

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