Epione: An Innovative Pain Management System Using Facial Expression Analysis, Biofeedback and Augmented Reality-Based Distruction

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***Abstract*—An innovative pain management system, namely *Epione*, is presented here. *Epione* deals with three main types of pain, i.e., *acute pain*, *chronic pain*, and *phantom limb pain*. In particular, by using facial expression analysis, *Epione* forms a dynamic pain meter, which then triggers biofeedback and augmented reality-based destruction scenarios, in an effort to maximize patient's pain relief. This unique combination sets *Epione* not only a novel pain management approach, but also a means that provides an understanding and integration of the needs of the whole community involved i.e., patients and physicians, in a joint attempt to facilitate easing of their suffering, provide efficient monitoring and contribute to a better quality of life.**

Keywords-Epione; pain management; facial expression analysis;biofeedback; augmented reality-based distruction

I. INTRODUCTION

Pain is the oldest medical problem and the universal physical affliction of mankind, yet it has been little understood in physiology until very recently. We talk about pain as though we are all talking about the same thing; yet history reveals pain is different for every person who experiences it, and understood differently in different times and places. Nowadays, pain is generally agreed-upon as an experience which involves more than just physical sensations. It is now recognized that pain, particularly chronic pain, involves a combination of physical, psychological and neurological factors. This is further deduced by the International Association for the Study of Pain (IASP)'s definition of pain as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage' [1].

The most common types of pain are [1] *acute pain* (results from disease, inflammation, or injury to tissues) and *chronic pain* (is widely believed to represent disease itself), which both remain a huge problem. Moreover, many amputees are frequently aware of severe *phantom limb pain* in the absent limb, since the brain cells affected by amputation do not simply die off, but neurons in the brain remain dynamic and excitable. Phantom limb pain is real and is often accompanied by other health problems, such as depression. Today, pain has become the universal disorder, a serious and costly public health issue, and a challenge for family, friends, and health care providers who must give support to the individual suffering from the physical as well as the emotional consequences of pain. According to the American Chronic Pain Association [2], pain is the No. 1 cause of adult disability in the U.S. It is estimated that in the USA one family in three contains someone suffering from pain and chronic pain sufferers are two to ten times more likely to commit suicide. Furthermore, the economic costs associated with unrelieved pain run into the billions, setting chronic pain as ‘a medical and social emergency.’ Latest statistics released by IASP indicate that one in five people suffer from moderate to severe chronic pain, and that one in three are unable or less able to maintain an independent lifestyle due to their pain. Between one-half and two-thirds of people with chronic pain are less able or unable to exercise, enjoy normal sleep, perform household chores, attend social activities, drive a car, walk or have sexual relations [3]. The effect of pain means that one in four reports that relationships with family and friends are strained or broken.

The goal of pain management is to easing the suffering and improving the quality of life of those living with pain, enabling them to work, attend school, or participate in other day-to-day activities. Treatment approaches to long term pain include pharmacologic measures, interventional procedures, physical therapy, physical exercise, application of ice and/or heat, and psychological measures, such as biofeedback and cognitive behavioral therapy, like relaxation and the use of imagery as a distraction that provides relief [4]. Actually, pain management sets a challenging field, where edge technology could be incorporated within pain management approaches to create an effective environment that could contribute to better pain handling; hence, improving the quality of life at a global level.

Adopting the spirit of the UNESCO and the World Health Organization (WHO) principles [e.g., the UNESCO Chair for Life Sciences Initiative about pain mechanisms and management [5], Project “Drawing the pain of AIDS” Cambodia UNESCO/UNICEF, and the WHO global effort to relieve chronic pain [6], especially to draw global attention to the urgent need for better pain relief for sufferers from diseases such as cancer and HIV/AIDS], the proposed system, namely *Epione* [1], aims at creating a novel environment of pain management that could assist patients, with different levels and types of pain, and physicians during

[1]*Epione* (*Ηπιόνη*) was the goddess of the soothing of pain. She was the wife of the medicine god *Asklepios*, and the mother of a number of minor healing gods, including *Hygeia* (Good Health), *Panakeia* (All-Cures) and *Iaso* (Healing).

the process of easing of suffering, contributing to the new culture of *Personalized Healthcare*[2].

Adaptation to personalized pain behavior via facial expression monitoring, adapted 3D distraction strategies, wireless biofeedback and augmented reality-based limb reconstruction, are all combined and implemented in a revolutionary ‘vault-like’ 3D-space (*Epione Vault*). The latter, draws information from social networks (e.g., Facebook, Tweeter, Skype) via Web services and/or user's feeds, creating a personal space at the *Epione Server*, where the patient interacts and communicates with more ‘natural’ modalities (e.g., gestures, voice commands). Friends, colleagues, personal physicians, supporting groups, are all visualized and distributed in a user-defined hierarchy at the Epione Vault 3D space, creating an on-line network of interaction and socialization. A series of relaxing and imagery activities within the Epione Vault (e.g., 3D navigation through Microsoft Virtual Earth, user-defined relaxing-entertaining environments) are initiated, following the physician’s therapy schedule.

During the interaction, a user-transparent monitoring system, based on the PC webcam video capturing, continuously analyzes the user’s facial expression, by involving advanced face detection-tracking-classification algorithms, informing the *Epione Control Center* (Epione CC) with the appropriate feedback for his/her current pain level. According to the latter, the Epione CC performs the appropriate adjustments (e.g., triggering appropriate RSS feeds into the Epione Vault that fit to the user’s interest, alters the biofeedback intensity of the wearable wireless TENS[3]), trying to increase the destruction and decrease the pain feeling.

Using a 3D limb model (e.g., hand model) embedded in the Epione Vault via augmented reality (AR), the user, by wearing specific AR-glasses, gets the feeling of the missing limb, and by wearing wireless accelerometers could move the reconstructed hand to perform specific tasks. In this way an 'augmented mirror box' is developed to allow artificial visual feedback to be remotely generated (i.e., generated independently of contralateral limb movement), thus facilitating presentation of noncontingent phantom limb movement. If phantom pain experience is influenced by contradictory proprioceptive and visual feedback, manipulation of the association between ‘felt’ movements and visually presented movements could have therapeutic potential.

All interactions and pain episodes are archived in the *Epione Diary*, at the *Epione Server* site, so statistical analysis, comparisons and reports are also outputted from *Epione*, providing valuable information, both to the patient (self-monitoring) and the physician (patient-monitoring). The latter, by also using the Pocket PC interface of *Epione* (*Epione On-the-Go*), is capable of interacting with the on-line patients (e.g., via direct connection and live interaction) and/or review the statistics (e.g., pain alarms, usage of specific tasks) of his/her patients, according to the scheduled therapy plan, evaluate his/her progress and adjust the therapy plan, even when he/she is away from his/her office.

II. EPIONE'S COMPONENTS

Epione can be divided into five distinct, yet integrated, modules, described in details in the following subsections..

A. Epione PC Application

The *Epione* PC Application system serves as the system control unit; it:

- provides the main pain management environment to be used during the therapy session with patients
- guides the physician to initialize the pain management environment according to each patient’s characteristics (i.e., level of pain sensitivity, type of pain, etc)
- provides a pain management palette available to the physician to create therapy scenarios
- offers the physician with a customization tool to be used for the organization of the therapy structure (i.e., steps of pain handling, level of support, stimuli, categories of activities, types of material, etc)
- monitors the raising of alarms, with regard to the pain level and emotional status of the patient during the interaction with the Epione’s environment and adjusts accordingly the pain relief strategies (i.e., combination of destruction and biofeedback)
- outputs a series of scoring parameters regarding to each patient’s progress

Apart from hosting the interface in the form of the Epione Vault, the Epione PC Application carries out a series of operations transparent to the user. In particular, video data captured from the PC (or laptop) Webcam are subjected to a series of advanced image processing and computer vision analyses, in order to estimate the patient’s emotional state, focusing at his/her pain level, as it is expressed through his/her facial expressions. This procedure includes face tracking, incorporation of specific patterns of variability in shape and grey-level appearance captured by statistical models that can be used directly in image interpretation, action-units identification and feature extraction, along with support vector machine classifiers that categorize each user’s pain sensitivity to a pain ladder up to 16 levels. The latter, accompanied with the user’s selections and type of interactions (e.g., group therapy, imagery process activation, etc) within the Epione Vault, are used by the Epione Control Center, hosted at the Epione PC Application, which identifies the status of the pain level and the interaction strategy and adjusts accordingly the level of discriminative, prompting and reinforcement stimuli. This involves the

[2] *Personalized Healthcare* is an important new approach to medicine, providing great benefits to patients, by improving treatment, enabling people to monitor their own health, increasing compliance and providing inputs to computer systems and associated communications networks and embedded devices that will make it possible to organize, interpret and interrogate this information and apply it to tailoring medical treatment. Personalized Healthcare is at the core of the European Community Initiative ‘European Research Area 2030: Preparing Europe for a New Renaissance-A Strategic View of the European Research Area’ [7].

[3] Transcutaneous electrical nerve stimulation (TENS) is the popularized name for electrical stimulation produced by a portable stimulator and used as a biofeedback system for the pain treatment [8].

activation of RSS feeds, TENS adjustments (hence, communication with the Epione Biofeedback Application- see below), and appropriate feedback (e.g., pain meter-like preview) either to the patient (self-monitoring) and/or the physician (local and/or distant monitoring). It also handles information from the Epione Phantom Limb Pain Application (Bluetooth-based, see below) as an augmented reality-based interfacing (involving AR-based glasses and wireless accelerometers) with the Epione Vault. Moreover, it analyzes patient's activity for possible patterns and structures that best fit the therapy scenarios via the Epione Diary, and reflect progress in pain handling for further evaluation by the physician

B. *Epione Biofeedback System (TENS)*

The *Epione* Biofeedback System is a wearable device[4] involving TENS, designed and realized by the Epione Team. TENS cover the complete range of transcutaneously applied currents used for nerve excitation [8], [9]. TENS are connected to the skin using two or more electrodes. The battery-operated TENS unit is able to modulate pulse width, frequency and intensity according to the Epione Control Center handling at high frequency (>50 Hz) with an intensity below motor contraction (sensory intensity) or low frequency (<10 Hz) with an intensity that produces motor contraction. Data are handled by a local microprocessor and transmitted to the Epione PC Application via Bluetooth link.

C. *Epione Pocket PC Application (Epione On-the-Go)*

The Pocket PC application serves as a progress monitoring tool for the physician by acquiring information from the Epione Server Application (see below) via Web Services along with real-time communication with the Epione PC Application via the Epione On-the-Go; it provides:

- real-time (during the therapy session) monitoring of patient's progress by connecting to the Epione Server Application
- real-time intervention-interaction with the patients (e.g., at emergency cases, consulting processes, etc) by connecting to the Epione On-the-Go
- revision opportunities about the structure of the therapy task
- alarm history related to the emotional state and pain level of each patient during the therapy task
- correlation of the therapy content-scenarios with the activated alarm
- summary of patient's pain handling progress and convergence to more balanced emotional response (minimization of pain alarms) for a period of time
- information about patient's interaction activity within the Epione Vault (task characteristics, time of interaction, activity statistics, etc).

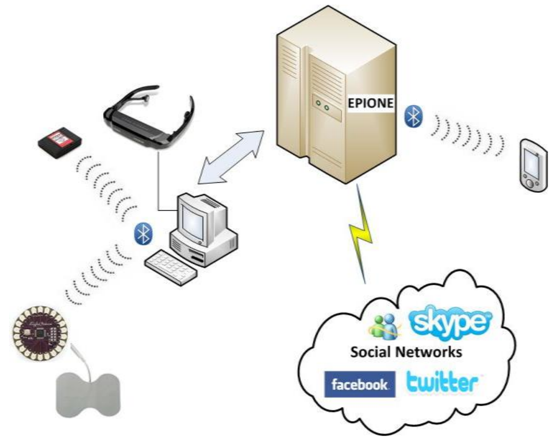

Figure 1. Block-diagram of the Epione's application functionality.

D. *Epione Phantom Limb Pain Application*

The Epione Phantom Limb Pain Application serves as a means to extend the use of the Epione PC Application to the augmented reality (AR) domain, in order to provide to the specific patient category (amputees) with a novel solution in the handling of their phantom limb pain; it:

- acquires information from patient's gestures/voice commands activity, using wireless accelerometers[5] and speech recognition[6], and transmit it via Bluetooth to the Epione Vault for multimodal interaction and task performance (e.g., gesture-based navigation throughout the Microsoft Virtual Earth using the reconstructed missing limb)
- employs AR-based glasses[7] for creating a 3D stereoscopic view of the Epione Vault with embedded augmented reality (e.g., including to the AR-world the model of the missing limb), to enhance imagery interaction in a more experiential way.

E. *Epione Server Application*

The *Epione* server is composed of

- an MS SQL Server 2008 R2 database containing
- information about the registered users needed for user identification (patients, physicians) and patient's characteristics needed for Epione PC Application adaptivity,
- user's profile information (drawn from social networks, like Facebook, Tweeter, Skype, or fed by the user) used to form the Epione Vault structure
- a dynamically updated therapy-based material (relaxing scenarios, imagery tasks, entertaining etc)
- information related to pain management realization (pain alarms, settings, task durations, statistics etc)

[4]LilyPad Arduino (http://www.arduino.cc/en/Main/ArduinoBoardLilyPad), which is a microcontroller board designed for wearables and e-textiles. It can be sewn to fabric and similarly mounted power supplies, sensors and actuators with conductive thread.

[5] WiTilt v3.0 (http://www.sparkfun.com/commerce/product_info.php?products_id=8563) with tilt output in degrees, triple axis accelerometer (MMA7260) and single axis gyro (MLX90609-150).

[6]Microsoft Speech API (SAPI) 5.3

[7]Vuzix iWear VR920 (http://www.vuzix.com/iwear/products_vr920.html).

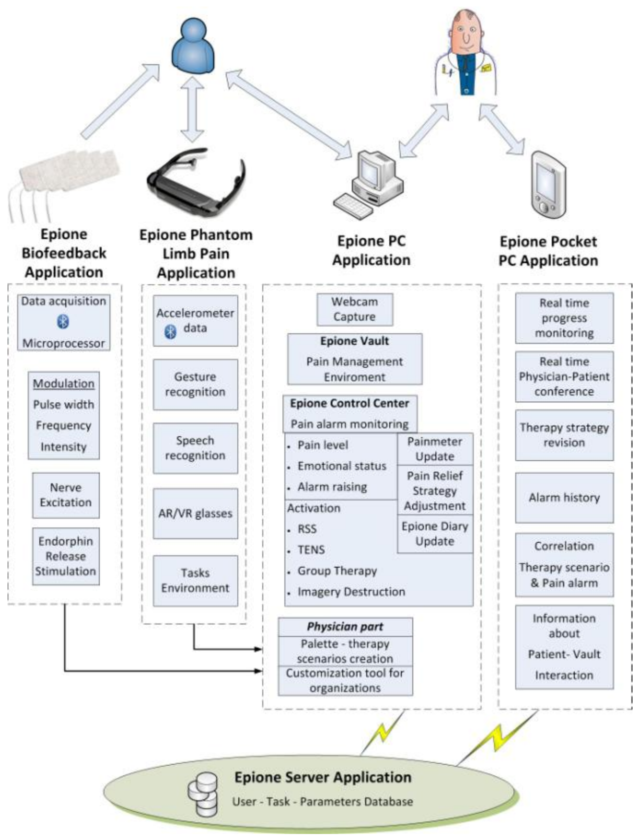

Figure 2. Organizational block-diagram of the Epione system.

- data acquired from Epione Pocket PC and Phantom Limb Pain Applications
- an IIS 7.0 Web Server hosting Web Services for the exchange of the aforementioned data between the server and the Epione Pocket PC Application.

The functionality of the aforementioned modules is depicted in Fig. 1.

III. EPIONE'S ARCHITECTURE

The organizational architecture of *Epione*, based upon the components described in Section II, is depicted in Fig. 2. From the latter, the client-server structure is evident, providing different modalities of communication and activation of the corresponding application components, according to the pain management scenarios. Some specific modules are shortly analyzed in the succeeding subsections.

A. Epione Patient's Pain Status Identification Module

Pain is typically assessed by patient self-report. Self-reported pain, however, is difficult to interpret and may be impaired or in some circumstances (i.e., young children and the severely ill) not even possible [10], [11]. To circumvent these problems, behavioral scientists have identified reliable and valid facial indicators of pain. Hitherto, these methods have required manual measurement by highly skilled human observers. In the Epione, an approach for automatically recognizing acute pain without the need for human observers was implemented; hence, pain is automatically detected. The *Epione* patient's pain status identification module (hosted in the Epione PC Application) realizes the steps of the block-diagram illustrated in Fig. 3 (up). In particular, a statistical approach (Active Appearance Model-AAM [12]) is adopted, in which a model is built from analyzing the appearance of a set of labeled image examples where structures vary in shape or texture, it is possible to learn what are plausible variations and what are not. A new image can be interpreted by finding the best plausible match of the model to the image data. Frame-level ground truth was calculated from presence/absence and intensity of facial actions previously associated with pain. Active appearance models (AAM) (Fig. 3 (bottom-left)) were used to decouple shape and appearance in the digitized face images. Support vector machines (SVM) [13] were further employed using information from the change of the activated action units (AUs), defined by the Facial Action Coding System (FACS) [14] (Fig. 3 (bottom-right)), within the representations from the AAM predicted model, resulting in a pain level classification. The latter is formed by the equation of

$$\text{Pain} = AU4 + (AU6 \| AU7) + (AU9 \| AU10) + AU43, \quad (1)$$

that is, the sum of AU4, AU6 or AU7 (whichever is higher) AU9 or AU10 (whichever is higher) and AU43 to yield a 16-point scale of pain [AUs are scored on a 6-point intensity scale that ranges from 0 (absent) to 5 (maximum intensity). Eye closing (AU43) binary (0 = absent, 1 = present)].

B. Epione TENS Functionality

The *Epione* TENS functionality employs the regulation of the TENS activity (Fig. 4), according to the pain level. Basic science studies show that high and low frequency TENS produce their effects by activation of opioid receptors in the central nervous system [15].

Specifically, high frequency TENS activates delta-opioid receptors both in the spinal cord and supraspinally (in the medulla) while low frequency TENS activates mu-opioid receptors both in the spinal cord and supraspinally. Further high frequency TENS reduces excitation of central neurons that transmit nociceptive information, reduces release of excitatory neurotransmitters (glutamate) and increases the release of inhibitory neurotransmitters (GABA) in the spinal cord, and activates muscarinic receptors centrally to produce analgesia (in effect, temporarily blocking the pain gate). Low frequency TENS also releases serotonin and activates serotonin receptors in the spinal cord, releases GABA, and activates muscarinic receptors to reduce excitability of nociceptive neurons in the spinal cord.

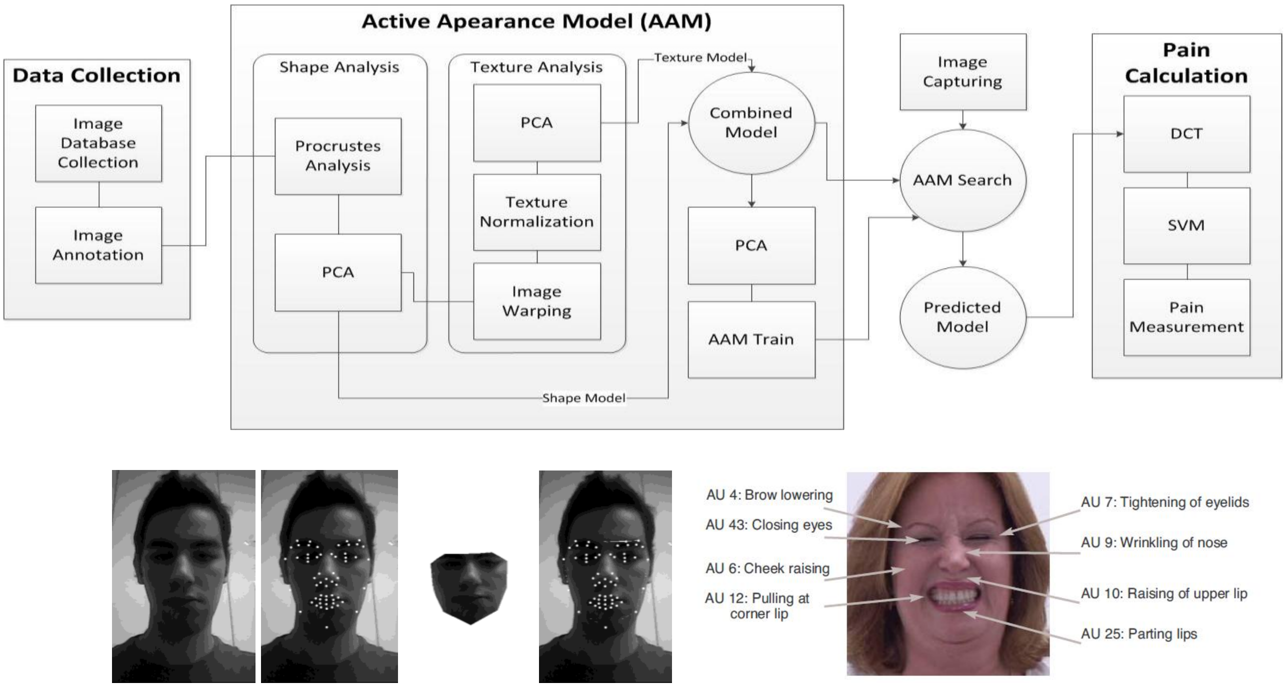

Figure 3. (up) Block-diagram of the Epione's patient's pain status identification; (bottom) An example of the predicted image model when applied to the original image (left); An example of facial actions associated when a person is in pain. In this example, the activated action units (AUs), defined by the Facial Action Coding System (FACS) [13], are: 4, 6, 7, 9, 10, 12, 25 and 43 (right).

C. *Epione On-the-Go module*

Epione On-the-Go module serves as a progress monitoring tool for physician by acquiring information from the Epione Server Application via Web Services (see Fig. 5). The Pocket PC Application allows real-time monitoring of patient's progress in a transparent way. It offers revision opportunities, inspection of pain alarm history, summary of patient's pain management progress and convergence to more relaxed states (minimization of pain alarms) for a period of time, information about patient's task characteristics, such as time of interaction, self-monitoring scores, etc.

D. *Epione Augmented Reality (AR) Module*

The Epione AR module provides stereoscopic preview of the Epione Vault to the amputee using AR-glasses (Fig. 6), in order to enhance his/her illusion about the reconstructed missing limb (Fig. 6). In order to establish completely independence between the existing and the AR-reconstructed limb, an accelerometer (Fig. 6), mounted on the missing limb site, is used to capture the movement of the remaining part of the amputee limb, driving the movements of the AR-reconstructed limb[8]. The amputee can then interact with the Epione Vault, either following specific tasks with varied difficulty, and/or using free gesture interaction.

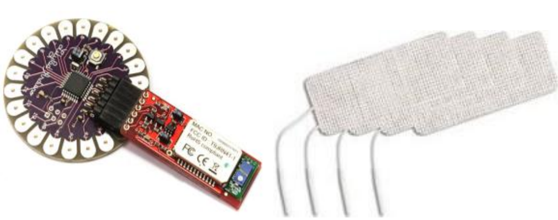

Figure 4. LilyPad Arduino microprocessor (left) and the TENS electrodes (right).

IV. Epione's Technologies

The technologies used for the development of *Epione* are:

- Servers: IIS 7.0; SQL Server 2008 R2.
- Development Tools: Visual Studio 2010 Professional, Visual Studio 2008 Professional SP1 - Other Technologies: .NET Framework 4.0 (C#, WPF, WCF, ASP.NET); Windows 7 Professional; Windows Mobile 7.0; XML Web Services; MS DirectX 11, Microsoft Expression Suite 3, Microsoft Speech API (SAPI) 5.3, MATLAB R2010a, Autodesk 3D Studio Max 2010, Facebook API (Facebook Developer Toolkit), Twitter API (twitterizer), Skype API, Bing Maps 3D, OpenCV (emguCV).
- Hardware: Vuzix iWear VR920, Arduino Lilypad, Sparkfun Witilt v3.0.

[8]For the extreme case where there is no remaining part for the mounting of the accelerometer, the latter it is placed on the other hand and mirrored to the user in the Epione Vault.

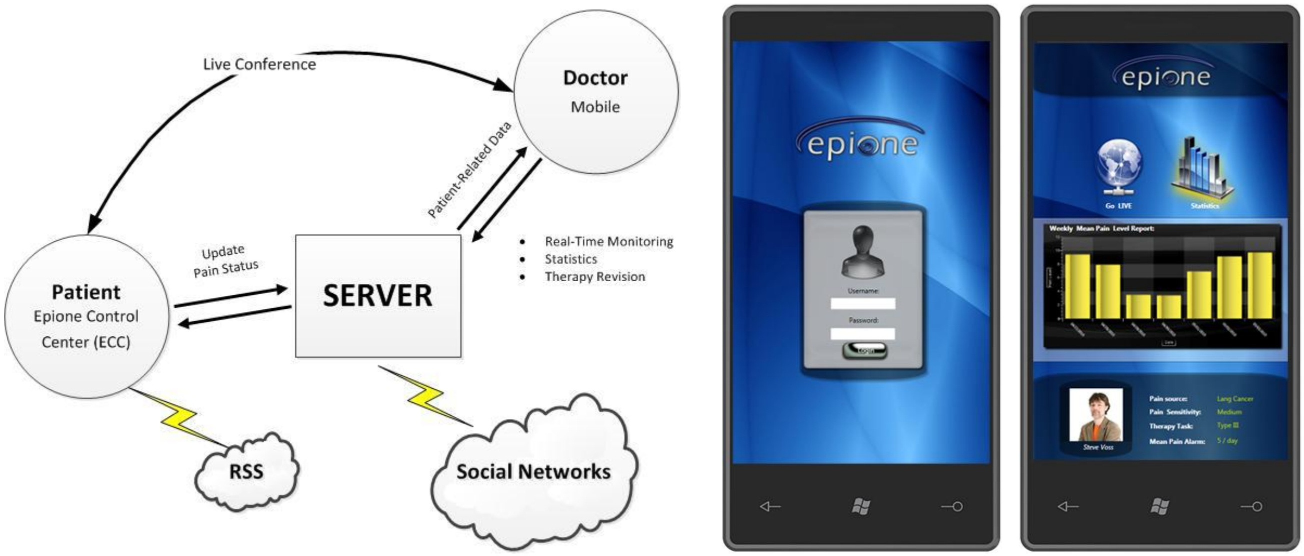

Figure 5. The Web Services architecture of Epione system (left) and two screenshots from the Epione On-the-Go interface (right).

Figure 6. The AR Vuzix iWear VR920 glasses (left-up), the hand model used (right-up) and an amputee user interacting with the Epione Vault via AR-reconstructed hand (down).

V. USER'S SCENARIOS

Epione aims at the development of a novel Personalized Healthcare environment that could assist patients and physicians during the process of pain management. This could be achieved as described through the following user scenarios.

A. *Scenario #1: Hello Epione World*

Dimitra is a secretary at Aristotle University of Thessaloniki, Greece. Because of the sedentary nature of her job, she suffers from low back pain. Lately, she was informed [9] by her personal doctor about an innovative technological approach to her problem, *Epione*, and decided to give it a try. After installing the *Epione* software, she follows the instructions for setting up a new account. She initializes her profile, by filling all the needed personal information and preferences, as well as (optionally) linking her social network profiles with her *Epione* profile. Right afterwards, she goes through a brief, yet very meaningful test procedure, so that clues about her relation to pain and her tolerance-thresholds towards it can be inferred. As a consequence, the *Epione* system has now adapted to Dimitra's specific likes and needs, being able to provide Personalized Healthcare services.

B. *Scenario #2: Meet the Vault*

Having finished with the sing-up process, Dimitra is being introduced to the main environment of *Epione*, the 3D Epione Vault. She was really excited to be able to enjoy a brand new world, where she can interact with its objects in a novel way, using speech, body gestures or even special stereoscopic glasses. Epione Vault is her personal space that depicts her personal likes and is enriched with her social contacts from various social networks. As a result, she feels surrounded, embraced by her social circle, especially by the most beloved people, since they are positioned at special layout in space. In the Epione Vault, Dimitra can undergo various activities (social contacts, imagery, interesting RSS feeding that increase destruction from pain), not only

[9] Pending URL: www.epione.gr

following her physicians schedule, but also for fun and relaxing purposes.

C. Scenario #3: Helping hand

She enjoyed *Epione* so much, that she introduced it to her friend Mike, her best friend, who has been fighting lung cancer for the last 2 years. She knows that not only relaxing, but mainly also psychology is of great importance for him, and she was right. Through *Epione*, Mike got in touch with many people around the globe facing the same difficulties and forming supporting groups that proved to be very valuable. It is so important to always have an extra helping hand from someone that shows understanding and shares the same experiences.

D. Scenario #4: Smart PC or 'I feel your pain'

Mike soon found out that not only his friends, but also his computer could understand his physical and emotional state. During the interaction with the computer, an invisible subsystem of *Epione* is discretely using his webcam to analyze his facial expression through advanced face detection-tracking-classification algorithms. In case of a pain alarm, his best friends and a predefined group of people get informed about his status, so that he can find the support needed. Aside from that, the *Epione* system can provide feedback in various other ways, such as activating (and driving automatically the intensity of) a TENS device for pain relief, distracting the patient's attention from his pain through special activities (entrance into the Epione Vault, change of Epione Vault's environment, imagery distraction). Finally *Epione's* status is saved to his personal log via Web services, so that a personal 'pain diary' is kept automatically on his behalf at the Epione Diary module. This serves not only as self monitoring, but is also a complementary tool of great value for his personal doctor, John.

E. Scenario #5: Boosting Epione

That is why John advised and helped Mike to train and adapt the *Epione* face tracking algorithm on his own special facial characteristics, in order to boost its performance. Now John gets better informed about Mike's health state. He can access his pain diary not only in case of high pain level alerts, but anytime, anywhere, via Web services and/or a mobile application using Epione On-the-Go. This way, John (the doctor) can have an enhanced insight of the Mike's status over time, being thus able to monitor his progress and the treatment effectiveness. Depending on the findings, he can contact him immediately, either for pure psychological support and/or in order to suggest activities on how to lower the pain level.

F. Scenario #6: Phantom in the... Brain

Another patient of John is Mat, a right arm amputee. His case is of great interest, since he experiences a real, intense pain, at a phantom arm. He usually practices every day for half an hour with a mirror box, so that the visual feedback of the missing arm could be used to sooth his phantom pain. Thanks to Epione Phantom Limb Pain module, Mat now has an extra option to contemplate the traditional treatment. He can now use a 'digital' mirror box that is both realistic and functional. With the use of a head mounted display and a camera, *Epione* offers Mat an Augmented Reality subsystem that visualizes the amputated arm on top of a video stream of the real world. The use of *Epione's* technology makes his phantom pain treatment much more attractive and easy to use, as well as more realistic, since it does not follow the 'mirror' approach: it visualizes the amputated arm autonomously from the other (existing) hand. Furthermore, the treatment can also take place inside the Epione Vault, augmenting its functionality, and can become less of a 'chore', since it takes the form of an exercising game with adaptive difficulty, to keep Mat's interest on and increase the effectiveness of training.

VI. Discucssion

Epione is a revolutionary system aiming at providing to pain sufferers and caring physicians an integrated pain management environment. It is the first pain management tool, which translates the medical needs to technology-based procedures that take into account patient's response in an adaptive way that fulfills each patient's specific therapeutic needs and provide to the physician a plethora of treatment scenarios.

The innovations behind *Epione* consist of a broader approach to the problem examined. Most pain management centers gather information from the patient in a static way, simply using questionnaires in order to set up different therapeutic tasks. In this case, the physician has to consider a variety of parameters combined with patient's pain behavior in order to construct the optimum course for each one. On the contrary, our system is designed to circumvent the above drawbacks considering the user's needs. In particular, based on computer vision inference algorithms and social behavior markers, *Epione* combines all the necessary information to automatically construct the appropriate computer-based pain management environment (Epione Vault) for each patient.

Moreover, it incorporates biofeedback stimulation (TENS) during the therapeutic session, adjusted, accordingly, to the activation of pain alarms. Moreover, without distracting patient's attention, *Epione* provides valuable information to the physician, both on-line (during patient's therapeutic task) and off-line (asynchronously, during an evaluation and meta-cognitive procedure upon the therapeutic scenario set by the physician). This information is used as a way for reaching a more realistic evaluation of patient's progress curve, taking into account patient's physical, psychological and neurological factors.

The involvement of transparent monitoring of the patient's interaction with the Epione Vault, the adaptivity of the latter to increase destruction, imagery relaxation and variety in therapeutic scenarios (according to the pain type and/or patient's categorization), along with the augmented reality-based solution for the phantom limb pain sets Epione as an integrated solution for the pain management problem, providing a bed-set for normalization of the pain management procedures to each patient's needs (personalized healthcare).

The American Chronic Pain Association [2] sets pain as the main cause of adult disability in the U.S. IASP indicates that one in five people suffer from moderate to severe chronic pain, and that one in three are unable or less able to maintain an independent lifestyle due to their pain [3]. Moreover, the economic costs associated with unrelieved pain exceed $70 billion per year. *Epione*, by providing therapeutic tools that facilitate the physician, adjusting the pain management process to patient's needs has a deep impact to this social group.

Until now, pain management software refers to questionnaire analysis and patient's history data gathering. Using advanced signal processing and cutting-edge technology *Epione* provides an integrated pain management environment which is closer to the patient's needs and, therefore, realistic and more efficient. *Epione* provides the physician with flexible ways of setting, evaluating and expanding his/her therapeutic material, combining information from the patient's response, capturing the essence of his/her pain sensitivity and adjusting his/her therapeutic rhythm, under a vast variety of different case-study scenarios.

Probing to the future, Epione could foresee the following updates and improvements:

- Cross-case testing and evaluation of the feedback from the target group, regarding the expandability and functionality of *Epione*, gained through ongoing contact with pain management infirmary patients and physicians from the AXEPA hospital and EUROMEDICA clinic of Thessaloniki, Greece.
- Extension of *Epione* to a multilingual system, including a variety of pain therapy imagery tasks, structured upon different cultures and social ethics, enabling international use.
- Further increase in the variety of phantom limb pain tasks, including various 3D models of different missing limbs.
- Further customization of pain therapy tasks to different pain sources and patient's age (kids, elders), combining further physiological information inputs (e.g., EEG, GSR, HRV).
- Implementation of roaming profiles, enabling the physician to login from different PDAs.
- Communication between distant users, structuring collaborative psychological consulting tasks within Internet-based communities (e.g., http://www.communitypsychologicalconsultants.com/commpsychconsults/Home.html; http://www.cancer-pain.org/).

VII. Conclusions

An innovative pain management environment, namely Epione, has been presented here. Epione uses advanced signal processing techniques to analyze the user's facial expressions in a real-time context, from where it results in a pain meter index. The latter is used to form the level of biofeedback to the user and adaptively adjust Epione's 3D AR-based interacting environment. In this way, a distraction strategy is initiated in order to ease down the user's pain feeling. The holistic approach and modular development of Epione allows for flexible expansion to many user-scenarios, making it a supporting environment to the whole community involved i.e., patients and physicians, providing efficient monitoring and contributing to a better quality of life.

References

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