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IoT-based health and emotion care system

Andreas P. Plageras, Kostas E. Psannis*

Department of Applied Informatics, University of Macedonia, Thessaloniki, Greece

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Abstract

A "Smart Healthcare-Room" has been installed in a local network. This form of network grants controlled network access to patients and tenders huge safety of their data which have been swapped at the time cure is given and the time the patient stays in the room. In order to manage the "Data Learning" approach from all the procedures and the communication of the sensors, an "Emotion Care System" has been installed. The data will be sent through the network to the IoT framework application which will notify the medical staff for the health and emotional condition of the patient.

Keywords: AI; Big data; Cloud computing; IoT; Security

1. Introduction

Surveillance could be defined as "the close observation of behavior and activities". In several cases, surveillance has been adopted by people in order to affect, manage or secure. Sensors and camera devices or other equipment are important for monitoring and superintendence processes [1]. With the use of such technologies, observation is possible from far away, through electronic devices or getting access to information which may contain plain and relational technology procedures.

A use of "Video Surveillance" (VS) is the application of VS over "Wireless Sensor Networks" (WSNs). This has been used almost in all cyber–physical systems which includes analyzing the traffic, providing safety to the public, and monitoring the environment and healthcare. Typical problems in data transmission derive from the unwired node connection facility in WSNs. Thus, for VS applications the processing and transmission of a huge amount of video data at each wireless node is still challenging [2,3].

Telecommunication networks could be used by surveillance technology since they transmit videos or information produced by surveillance devices. In order for the information to be transmitted a device needs to be connected to the network. The geographical location of a mobile device can be defined much easier, even if the phone is in standby mode, with the use of a technique which is known as multilateration. In other words, an inactive device can be traced by calculating the differences in the time which is needed for a signal to travel from one cell phone to any cell tower close to the owner of the phone [4,5].

Furthermore, there is a new technology in telecommunications field called "Internet of Things" (IoT). All physical objects equipped with sensing devices and connectivity to a network make up IoT offering to these objects the ability to collect and interchange data. IoT technology is the upcoming major step, which brings huge changes in business functionality. Through the upcoming years, a large and rapidly growing variety of connected devices like placed applications, and the operations that they would implement, are expected [4–6].

The collected data will be used to enhance performance or identify certain needs, and provide for specific requirements. In order to completely take advantage of the technologies mentioned above, it is obligatory to combine them in order to succeed the optimization of superintendence technology through the IoT.

Moreover, wearable devices can be integrated in healthcare frameworks, since they offer innovative capabilities and numerous approaches in a wide diversity of social and medical criteria. Apart from the fact that they help to increase the provision of medical services, the quality of people's life that are chronically ill and handicapped, the application seems to

* Corresponding author.
E-mail addresses: a.plageras@uom.edu.gr (A.P. Plageras), kpsannis@uom.edu.gr (K.E. Psannis).

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have a financial benefit, as it saves health care costs by minimizing hospitalization or by preventing the disease early or by assisting to provide sufficient resources for an independent living [7]. By preventing the disease early the financial consideration is significant. Millions of people suffer from grave medical problems, like diabetes, asthma, and heart diseases, which are responsible for most of the healthcare costs.

The big contribution of this work is the efficiency of the wireless network and its functionality. The recommended network would provide more simple communication, better information interchange, and better interaction between the doctor and the patients in an insulated and secure network during and about the therapy.

Specifically, the basic aim of this work is to gain better conditions in healthcare with the practice of multiple new technologies and tenders to patients and doctors allowing them to be more capable of interchanging messages and measures, more adaptive and relevant healthcare providing ease, fun, and access. This could happen by installing a direct network between the doctor and the patients' devices offering the capability of communication through a network that will begin by the doctor at the start point of the patient's cure in the room and will close at the end of the treatment by the doctor.

The remaining chapters of the paper are the following. Section 2 deals with the proposed network architecture, and in Section 3, the experimental results can be observed. Finally, in Section 4, the conclusions and future directions have been presented.

2. Proposed system design

In a smart healthcare room, which may be part of a hospital or part of a patient's house, was created a local sensor network. Through this network the doctor can easily connect with patients to a secure and detached network in which they can communicate about and during the healthcare.

More specific, the main purpose of this research is to offer an optimum healthcare environment by using multiple new technologies and techniques. This could be done by establishing a direct network with health and environmental devices. These devices have the ability to communicate over this network [4–7].

The network hosts sensor nodes that produce values over time. These values depending on their quantity can be called "Big Data" (BD). To transmit data generated by the sensors and the images taken by the camera, the "Extensible Messaging and Presence Protocol" (XMPP) seems to be one of the best solutions. The specific protocol is an open standard. It is based on the efficient publish/subscribe model which provides safe and efficient communications. The XMPP also interacts efficiently with the cloud and storage systems and meets all the needs.

The sensors are low-power devices that are connected to a "Broker" in patient's smart device. The Broker is software that holds these values produced over time by the sensor devices under a specific topic. For example the heart rate values are under the topic "HR". Each value has a weight in order to be recognized among the other HR values. These values will be displayed on smartphone's screen, but not managed or analyzed by the patient in order to keep his/her emotions in a normal level and not in a level that will transform the values.

For example, the temperature of the patient is 36.6 degrees and the patient only sees this number. The sensors used in the proposed network are the heartbeat sensor, the blood volume sensor, the skin conductance sensor, the temperature and the body temperature sensors, the humidity sensor, and a camera device that records eyes and mouth gestures and grimaces. Respectively to the sensor devices there are the topics "HR", "BV", "SC", "Temp", "Humm", "BTemp", and "CD". Then, the Broker holds the values under the specific topics and publishes these weighted values.

All devices are connected to a microcontroller via Wi-Fi or Bluetooth Low Energy (BLE). The microcontroller is then responsible to connect with the Broker and transmit the values through a Bluetooth 5 module or Wi-Fi module to the smart device. The following algorithm (Algorithm 1) presents the programming of the nodes. The "v" in this algorithm means a value specified for each sensor in order to make the comparison and send less data to the broker device.

Algorithm 1. Programming the sensor nodes

```
#define libraries
#define variables & ports
#define ssid, password, & host to connect
#setup() function  for data exchange
#loop() function for programming of nodes
   # add the produced value in cache memory
   # compare with previous value
   # if((valueA ± v) ≥ valueB) && ((valueA ± v) ≤ valueB){
      # publish value to Broker
      #database and apps can migrate data published
   }
  # else{
      # delete value from cache memory
      # repeat for the next value
   }
```

The application which runs on patient's device was developed in JavaScript with the use of a PHP Framework. The framework itself provides authentication for each patient and privacy. So, after the Broker publishes the topics the application subscribes to these topics and gets the values displayed. The values are immediately stored on a local database under the specified topics. This kind of network offers confined access to the Internet by patients and also provides efficient security for sensitive data interchanged during the patient's care. In the following Fig. 1, the proposed node communication flowchart for the publish/subscribe protocols has been presented.

In the following Fig. 2, the proposed system architecture can be observed. The system consists of wearable sensors which monitor the patient's health condition and a "Camera Device" (CD). The data are first analyzed locally and then compressed and moved to a cloud server for better analysis. In the local network there is also a WSN which monitors the environmental conditions in the smart room and makes them perfect for the patient's living.

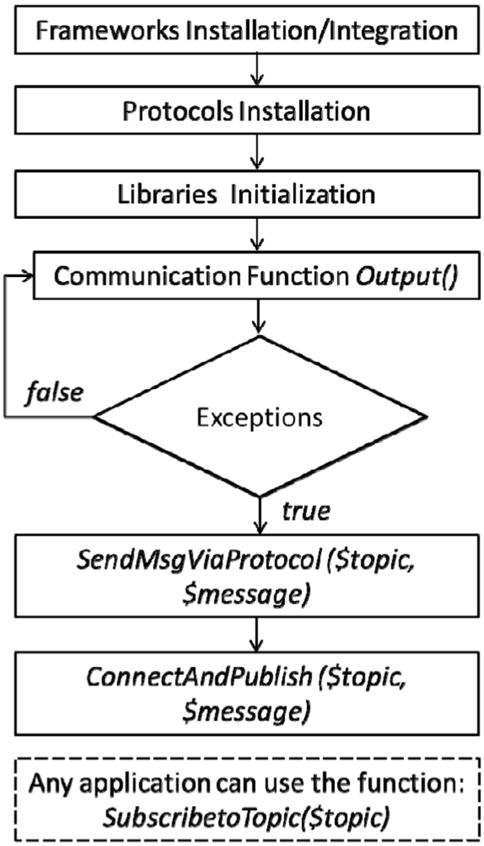

Fig. 1. Proposed node communication flowchart for the publish/subscribe protocols.

In this research work, the prediction of emotions was taken also into consideration. Since, sensors were used to monitor "Heart Rate" (HR), "Blood Volume" (BV), "Skin Conductance" (SC), and "Body Temperature" (BT) the design and development of an "Emotional Intelligent System" had become a challenge. This intelligent automatic system will be part of the patient's application. While registering, the patient was asked to answer some questions and fill up some fields with personal data such as the full name, the age, the gender, the weight and height, and the fitness levels. Some questions asked to answer are if there is anxiety or irritability, if there is general fear, if there is upset or panic, and how the patient feels in general. Then, the monitoring system can be attached to the patient [8–10].

In order to extract knowledge from the signals, two conditions have been taken into consideration, the metrics arousal and valance from the IoT sensors and a machine learning scenario that is based on a "Convolutional Neural Network" (CNN) [11].

About the first condition it can be observed that decreased arousal and increased valence shows that the person rests. Increased arousal and increased valence shows that the patient has positive emotions. Decreased arousal and decreased valence means the patient has negative emotions. Increased arousal and decreased valence means the patient is afraid of something. These four states can describe the feelings of the

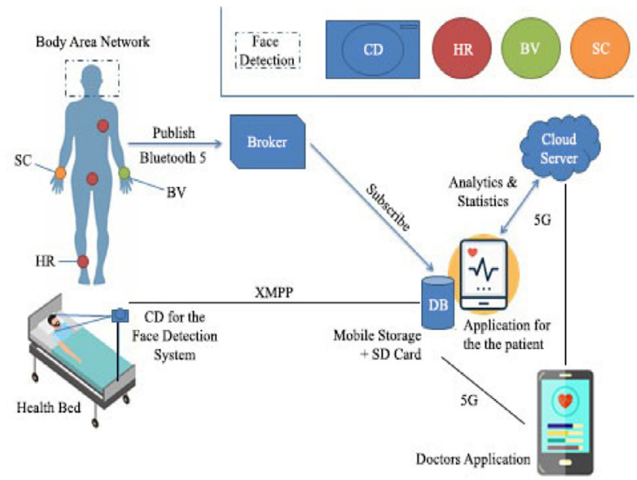

Fig. 2. Proposed network architecture.

patient. But, there are also some more aspects which play significant role in emotion recognition [12,13].

About the emotional condition, the idea was to use filters so that, knowledge can be extracted from the images which have been taken during the healthcare. Due to that, there is a need to train an algorithm in order to recognize different emotions of a human. To train the efficient algorithm, the Tensorflow framework was used. Tensorflow is an open source platform for training machine learning algorithms and models. Using this framework and setting multipliers to filter images made possible to group and fit images with same sequences in order to extract features and recognize face/lip-morphisms [14,15].

3. Experimental results

For the implementation of the emotional condition, the CNN has to make a comparison of the sequences of the images. A CNN is an artificial neural network which organizes these images. Since there are many deformations between images of the same emotion for each person, what we need is to classify all possible and different morphisms into a single unit. To better understand this mechanism the following Fig. 3 explains in detail how the algorithm was trained for a restful emotion of a person or just a normal lips-morphism.

Numbers for each pixel of the image were used because computers read numbers in order to understand an image. Number 1 is for the pixels in gray-scale that represent the lips morphisms and number −1 is for the pixels that should not be taken into consideration. Then using normal techniques the images are compared and pixels with number 1 were grouped.

Moreover, the CNN compares the pixels which are the features that need to be matched in order to recognize the different lips-morphisms for a single emotion. Different groups of features play the role of filters used to understand each emotion. Finally, when the two conditions are compared the emotions can be predicted more accurately.

Let us first train an algorithm for the emotion of happiness. The first step is to check if the parts of the first image are matching the parts of the second image. Since they match, one part is picked up and put on the second image. If these parts

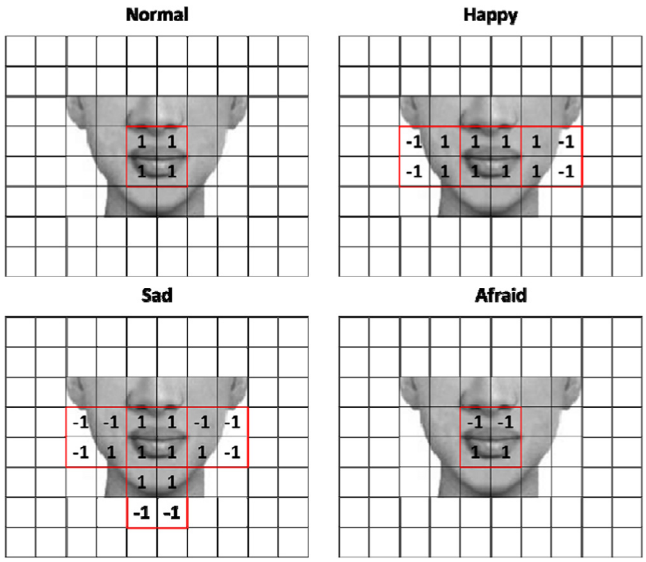

Fig. 3. Group of features that match in each image.

match each other, then, the classification was done perfectly. Moreover, the parts that are marked were moved in all possible positions in the image in order to multiply each pixel of the two images by the corresponding part. After the multiplication what should be done is to add these values and then divide with the total number of the pixels. The result should then be put into the correct cell of the matrix. The same was done for all the parts of the first image. Finally, the output was another matrix which was for one particular pixel. The same should be done for all three parts and the result was three matrices.

Also, all the negative values were replaced with zeros because if they were summarized the result would be zero and that must be avoided. This was done with the use of the following Eq. (1):

$$\mathbf{G(y)=0} \text{ for } \mathbf{y<0} \text{ and } \mathbf{g(y)=y} \text{ for } \mathbf{y>=0} \tag{1}$$

In the final stage the classification was done in which the size was reduced more and the matrix became a single list of elements. From the single list, the elements that were high in exact positions of the list will be for the emotion of happiness. The same was done for the other three emotions.

4. Conclusions

A “Smart Healthcare-Room” has been installed in a local WSN, in which several functions work. All technologies that have been used offer a novel, efficient, safer and high-speed wireless network in the smart room which consists of sensors and actuators. Some of the network’s advantages that are offered are the limited access to the Internet by the patients and as an extension of it offers better protection of the sensitive data that are interchanged. An application has also been developed with the use of various frameworks in order to gain interoperability, authentication of the patient and simplicity.

Moreover, emotions were predicted through the data analysis and through efficient algorithms. Due to these algorithms the healthcare and emotion care system can work together by sharing the same resources. Last but not least, the system integration was advantageous in terms of energy efficiency from other systems proposed. Finally, for further analysis of the data and more storage the mobile cloud computing technology is on the table.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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