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Agent Based Health Monitoring of Elderly People in Indoor Environments Using Wireless Sensor Networks

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Abstract

This paper presents a design of a health care monitoring system based on wireless sensor networks (WSN) which is capable of collecting, retrieving, storing and analysing the vital signs of the patient. Vital signs such as body temperature, blood pressure, pulse rate and respiratory rate are monitored. To manage these sensors and for collecting and storing data in a database, a Multi Agent System (MAS) is used. The dynamic nature and mobility of the agents make them suitable for maintaining these sensors in the WSN. The proposed MAS consists of four agents namely Admin agent, Control agent, Query agent and Data agent. Admin agent plays the role of invoking and terminating other agents. Control agent is responsible for storing the data sensed by the sensors into the database. Data agent performs data reduction which is achieved using Epsilon approximation. The use of Data agent in the proposed scheme reduces data traffic and the requirement of secondary storage space. Query agent is responsible for providing a GUI for the doctor to view the patient's vital sign details. The proposed agent based system has been implemented using Java language in JADE environment and the results are validated.

Keywords: Multi agent system; Data reduction; Health monitoring; Wireless sensor network.

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1. Introduction

Body Area Network (BAN) or Body sensor network (BSN) are terms used to describe the application of wearable computing devices. BSN consists of a large number of smart sensors that have limited computing, storage, communication and energy resources. The sensors that are worn in the human body will collect various physiological changes in order to monitor the patient's health status. The information will then be transmitted to a system/home pc which processes the data and then transmits it to the server at frequent intervals, where the data is stored in a uniform format in relational database irrespective of client side systems database format.

A software agent is a computer program which works towards goals in a dynamic environment on behalf of another entity human or computational, over a period of time, without continuous direct supervision or control, and exhibits a significant degree of flexibility and even intelligence in how it seeks to transform goals into action tasks. Agents integrate several disciples like objects and distributed object architecture, artificial intelligence, distributed algorithms and processing. Agents do not require interaction of user. They may invoke tasks like communication between agents. They are generally adaptive, mobile, persistent, goal oriented, communicative, flexible and active/proactive [7]. These characteristics make the agents suitable for the development of sensor network based applications. These agents are mainly advantageous because of their ability to change according to the nature of the surrounding.

The method proposed in this paper is a multi-agent system that is used for health monitoring of elderly people in indoor environments. Agent based technology is helpful in healthcare domain. These agents can reside in one system and they can be invoked based upon the need by any of the systems that are connected through a network. Thus this agent based approach reduces the need for the presence of the healthcare system in each PC. The amount of data gathered is also huge in health monitoring. The proposed system includes a method of data reduction and hence the amount of data that has to be stored is minimized.

The rest of the paper is organized as follows. Section 2 gives a detailed description about some of the existing health monitoring systems. Section 3 gives the proposed architecture of the agent based system used. Section 4 describes the data reduction algorithm. Section 5 discusses the results. Section 6 concludes the paper.

2. Related Work

One of the wearable health monitoring system that is in existence use wireless sensor platforms using Zigbee compliant transceivers and ultra low-power micro-controllers to measure clinical parameters like ECG , EMG, blood pressure. The u-healthcare system[1], which consists of custom 802.15.4 capable nodes that interface with ECG and blood pressure sensors as well as with a basic cell phone device for data display and signal feature extraction. LiveNet is a flexible distributed mobile platform aiming at long-term health monitoring applications with real-time data processing and context classification. It uses a Linux based PDA mobile device, a modular sensor hub for gathering, processing, and interpreting real-time contextual data and an integrated physiological board, which incorporates a 3-D accelerometer, electrocardiogram, electromyogram and galvanic skin conductance sensors. The recently developed wireless body sensor network hardware, which uses the recently allocated medical implant communication service band also exist. The system prototype consists of a pulse rate and a temperature sensor, a central control unit and a receiver station at a medical centre. HeartToGo is a cell phone based wearable platform, capable of continuously monitoring the user’s ECG signal via a wireless ECG sensor.

A multiagent system (MAS) [5] uses smart wearable devices and mobile technology for caring home alone geriatric patients. The MAS is based on an advanced Zigbee wireless sensor network (WSN).

Monitoring of subjects' vital signs with the help of biosensors/physiological sensors and environmental sensors to form heterogeneous systems to monitor patient activity with help of Bluetooth sensor networks has been a wide area of focus [6].

In MobiCare, a body sensor network and health care servers employ short-range Bluetooth between the BSN and BSN manager and GPRS/UMTS cellular networks between BSN manager and health care providers. CodeBlue is the only existing project that employs wireless sensor networks in emergency medical care, hospitals and disaster areas as an emergency message delivery system. With Mica motes, CodeBlie uses pulse oximetry and electrocardiogram sensors to monitor and record blood oxygen and cardiac information from the large number of patients.

The existing algorithms for reduction of the database with numerical values that are gathered over a period of time, are FAST and epsilon approximation. The FAST algorithm is mainly used for association-rule mining [4]. The two methods used in FAST for the selection of the final sample are growing and trimming. The trimming method removes the outliers from the sample.

The drawbacks of the existing systems can be summarized as follows: The amount of data that is being stored is high. The power consumption is high while transmitting the huge stored data. Hence,the way in which they are transmitted must be designed with care to reduce power consumption. There is also a problem in storing huge amount of data since the monitoring would be continuous. The use of wired connections in the system would not be comfortable for the users. The frequency of measurement of the data also plays a vital role in the performance of the system. The system for managing the tasks such as data gathering, storing and analyzing must be scalable and portable.

To overcome the above mentioned problems in the existing systems, an agent based approach is proposed in this paper [2]. The agent based system is capable of gathering, storing and analyzing the data about the vital signs of the patient. The proposed system consists of four agents, each of which is responsible for a specific function. The problem with the storage of huge amount of data is avoided in the proposed system. The proposed system integrates a data reduction method and it saves the storage space by minimizing the data that has to be stored. The proposed system has some advantages. The multi-agent based system is portable and there is no need for these agents to be present in each system all the time [3]. They can be invoked when they are needed. The storage requirement is also reduced by the use of proposed data reduction method. The need to store all the values that were gathered becomes meaningless at later stages and hence the reduction of the past data is useful.

3. Agent Architecture

The complete health monitoring system is automated and managed with the help of an agent system which is responsible for data collection, coordination and storage. Since manually managing the data is a daunting task, automated process is opted using the agent system. The agents are coordinated by a single head agent that is programmed to coordinate, invoke and kill other agents in the system when necessary. The use of agent based system is advantageous because the agents can be invoked when required. They are also portable and can be moved to any system without much difficulty. The agent system proposed here is known as a multi agent system. It consists of four agents namely (1) Admin agent (2) Control agent (3) Query agent (4) Data agent. Each of these agents has a specific purpose and controlled by the admin agent. The location of each agent and the means of communication between them are shown in Fig 1. By allotting a specific function to each agent, it becomes easy to modify the system later and also to keep track of the changes. Even if there is an error with one of the agents, it does not affect the whole system because each agent is not completely dependent on the other. Thus the use of the multi agent system is advantageous.

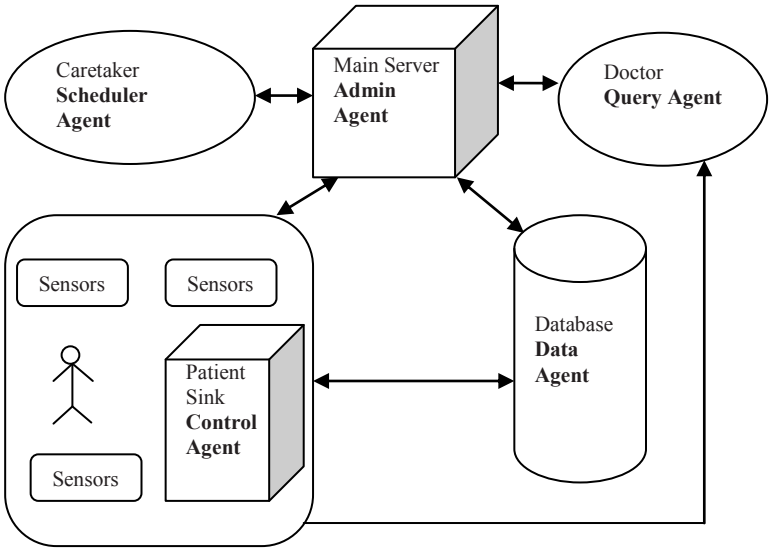

Fig. 1. Agent Architecture

1. Register the SL0 content language
2. Register the mobility ontology
3. Initialize Admin GUI
4. Get the list of available locations and show it in
    a. GUI using the GetAvailableLocationsBehaviour(this);
5. Initialize the counter and the flag
6. Add agent behaviors to increment the counter and serve incoming messages
7. Invoke the beforeMove() method for initializing agent behaviors before moving to next platform
8. Invoke the afterMove() method for initializing agent behaviors in the new platform
9. Check if the migration is via RMA the variable netSite can be null migrate.
10. Get the list of available locations from the AMS and clone agent as given below: CLONE_EVENT:

    a. Iterator cloneParameters = ev.getAllParameter();
    b. nextSite = (Location)cloneParameters.next();
    c. doClone(nextSite,"clone"+cnt+"of"+getName());

break();

Fig. 2.Pseudo code for Admin Agent

3.1. Admin Agent

The Admin agent is responsible for the administration of the multi agent system by invoking and terminating other agents based on the requirement of specific functionalities by the user or doctor. It receives incident reports like database errors, unexecuted plans, security notifications and informs control

agents regarding those incidents according to their priority levels. The function of the admin agent plays an important role in the system. Since it is responsible for coordinating all the other agents, this forms main agent in the proposed multi-agent system.

The functionality of the admin agent is presented in the form of pseudo code in Fig 2. Agents use a different language for communication with other agents and they have an encoding mechanism for the messages that are transmitted. The first step is to initialize the content language for the agents using the register SL0. The content language specification includes the specification for the encryption and the language that is used. In a multi agent system, this is important so that the agents can be in a common communication mode. The admin agent needs to be mobile in order to gather data from various agents in different systems. So there is a need to specify the mobility mechanism for the admin agent. The mobility functionality helps the agents to be created in the system from where the request for that functionality has raised. This can be stated as the key role of the admin agent. Thus, the need for the presence of the agent program in each system is eliminated. Then, the UI for the agents is used and the available locations are listed. The agent is capable of responding the incoming messages with the help of the specified language. The Remote Monitoring Agent (RMA) helps in migrating agents to different systems for gathering data. The Agent Monitoring System (AMS) is used to know the set of available locations and also the status of the other agents in the system.

3.2. Control Agent

These agents are responsible for getting the data values from the sensors and storing them in the database. The format in which the data is stored has to be decided carefully so that there is no difference in that format for each parameter. The format of the table for each parameter that is used here is <time, value, status>. Control agent primarily focuses on classification of data into normal and abnormal based on the threshold values that are defined for each of the vital signs that are monitored. These agents are responsible for monitoring the patient data.

3.3. Query Agent

The query agent helps the doctor/ caretaker to view the required data about any specific patient by providing a user friendly interface. This agent has a GUI that allows the user to specify the patient's id and also the time instance for which the data has to be fetched. The query agent is created when there is a request by the user/doctor to view the patient details. The process of creation is carried out by the admin agent.

3.4. Data Agent

Data agents perform the reduction part as explained in the section 4. The data agent runs once in a day during the end of the day so that the past data is reduced and stored in the database. This agent is an additional functionality in the proposed system and it helps to overcome the issues with the existing health monitoring systems. Allowing the agent to do the data reduction is also advantageous because the behaviour of an agent can be defined and this would help to run the agent properly once in a day without any issues.

4. Data Reduction

The main problem with remote health monitoring system is that it has to be continuous to provide good support for the patients at home. And hence there is a need to measure the required parameters in regular intervals of time and then the gathered data is analyzed to know the condition of the elderly

people. The parameters, for example let us consider the body temperature data need to be measured every 10 minutes interval. Thus if we need to store the gathered data for analysis, over a period of time, the data will be huge. Out of these huge data, only some would be needed for later reference. So it is a waste of memory to store all the gathered values. Thus there is a need for the data reduction in such health monitoring systems.

```
Input : stream[n]
Output : sample[m]
Begin
   j <- 0
   sample[j] <- stream[0]
   index <- j
   j <- j+1
  for i=1 to n do
   if data[index] ± range ==data[i] do
      continue
   else
      index <- i
      sample[j] <- stream[index]
      j <- j+1
  end (for)
End
```

(a)

Input : subset S_0
Output : S
Begin
for all the values
Initialize δ_i with square root of (1- exp(-ln(2m)/ 2^k-1))
end (for)
$Q_{i,1} = Q_{i,2} = 1$
for each item in S_0
color it red
for each halving k
$Q^{(r)} = 0$, $Q^{(b)} = 0$
Calculate $Q_1^{(r)}$, $Q_2^{(r)}$ using $(1+\delta_i)\ Q_{i,1}$ and $(1-\delta_i)\ Q_{i,2}$
Calculate $Q_1^{(b)}$, $Q_2^{(b)}$ using $(1-\delta_i)Q_{i,1}$ and $(1+\delta_i)\ Q_{i,2}$
$Q^{(r)} = Q_1^{(r)} + Q_2^{(r)}$ + param1
$Q^{(b)} = Q_1^{(b)} + Q_2^{(b)}$ + param2
if $Q^{(r)} < Q^{(b)}$
//color it red
$Q_{i,1} = Q_1^{(r)}$
$Q_{i,2} = Q_2^{(r)}$
else
//color it blue
$Q_{i,1} = Q_1^{(b)}$
$Q_{i,2} = Q_2^{(b)}$
end (for)
if colored red
set S = S U item
end (for)
End

(b)

Fig. 3 (a) Initial step of Data Reduction; (b) Data Reduction based on Epsilon Approximation

The method that is used for the purpose of the data reduction consists of two steps. Initially sampling is done. It is done from the original data set based on the status of the value. It has been mentioned earlier that the collection of the whole data was of no use at later stages. That is, only the data that deviates from the normal range will be needed for diagnosis. Thus by making use of this, sampling is done on the normal values and then the data is reduced. The abnormal values are retained so that it would be helpful for later analysis. The proposed data reduction algorithm is based on epsilon approximation algorithm. This ensures that the reduced set of data is close to the original data set and they both vary only by a factor less than epsilon.

The algorithm has two main steps. First one is to select a subset from the initial set of values and avoiding the repetitive values by sampling. The second step is to create the final reduced set of data. The final selection uses a penalty function, Q and the delta, δ that controls the variation of the penalty function from its equilibrium position.

Fig. 3(a) shows the sampling algorithm which is the initial step of data reduction. The input to the algorithm is a data set that has n values and the output is a data set with m values where m < n always. The sampling algorithm helps to choose the initial subset from the original data by discarding the closer and the repetitive values. The important parameter in this algorithm is the range. The range can be specified for each parameter and the value of the range can be decided depending upon the set of data that has to be reduced. For example, for temperature data set, the range with value 0.3 is chosen as best choice after experimentation.

Fig. 3(b) shows the algorithm used for reduction purpose. The algorithm takes the data subset S0 as input which is the output of sampling algorithm and gives the reduced set of data S as output. The value delta δ is initialized in such a way that the penalty function Q resides well within the equilibrium. The algorithm works by coloring the data set as red and blue (indicated as suffix r and b respectively). And depending on the value of the Q, we assign the data to a particular set that is, either red or blue. Finally the set with color red is selected as the output. This gives us the reduced data set.

The penalty function is calculated for each value and it is used to decide whether the value is selected or discarded. It is based on the deviation of the value from its acceptable range and also the previously selected values. The variables param1 and param2 are used to specify the distance of the value from its acceptable range. The resultant set is also dependent on how many values are selected before this current value and how many are discarded before.The final reduced set is stored in the database overwriting the existing table along with all the abnormal values and this will be used later.

5. Results

The data agent that is responsible for reduction of data that is stored in the database is integrated into the developed multi agent system. The reduction is done using the epsilon approximation algorithm and hence, it guarantees the accuracy of the results obtained to that of the original values.

The reduction ratio for each parameter according to the results of the above explained algorithm is presented as a line graph in Fig. 4(a). Fig. 4(b) represents the line graph with x-axis as the number of queries given and y-axis as the number of queries answered by both the original dataset and the reduced dataset.

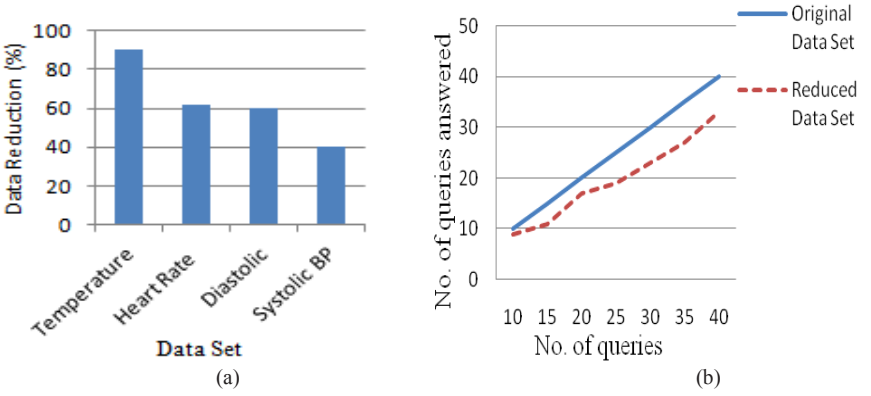

Fig. 4 (a). Reduction Ratio; (b) Performance Measure

The percentage of reduction is high for the temperature data while quite less for other parameters. The reason is that the temperature values are close to each other and they vary only by a few decimal points. The performance of the reduced table is measured by using the number of queries that it can answer when compared to that of the original dataset. It is observed that when the complexity of the query increases, there are some differences in the number of queries answered with the original data set and the reduced data set.

6. Conclusion

A Multi agent system (MAS) is used to manage these sensors for collecting data from them and storing them in a database. The proposed MAS consists of four agents namely Admin agent, Control agent, Query agent and Data agent which performs data reduction using Epsilon approximation. The use of Data agent in the proposed scheme reduces data traffic and the requirement of secondary storage space. The proposed agent based system has been implemented using Java language in JADE environment and the results are validated. The reduction algorithm used here gives a reduction ration of about 80 percent. The performance of the reduced set of values is close to the original set and the query agent uses these reduced values to answer the queries later.

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