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A NOVEL APPROACH FOR PERVASIVE HEALTHCARE MONITORING SYSTEM (HMS) USING PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

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Abstract

The advancement of smart phones and hand held computing devices has enabled health care anywhere and anytime. A person can perform necessary day to day tasks while his health is recorded, controlled, and processed continuously using on body sensors and actuators with the pervasive health care system. In such a scenario, flawless and continuous operation of the Pervasive Health Management System (PHMS), is very important. For global acceptability of PHMS, it has to be tested and verified for their safe, long term usage and reliable operation under various dynamically changing environments. This paper proposes a novel technique to analyze a PHMS with Particle Swarm Optimization (PSO) under mobility induced dynamic changes in the context and constant interaction of the medical device with the human body. Results show that human mobility induced context changes can cause unsafe conditions such as drug overdose.

Index Terms- Wireless Body Area Network**,** Particle Swarm Optimization (PSO), Electronic Health Record & Ubiquitous Health Care (UHC).

1. Introduction:

Since the average age of human beings is increasing, the population of old people is growing and those older than 65 expected to double by 2050 [14]. Due to the expectation of the extended life the requirement of ”anywhere, anytime” Health Care Monitoring System (HMS) is expected to coming up very soon. The rapid development of embedded computing devices such as smart phones, iPads, and other personal electronic devices leads to support the health related applications such as tracking calorie intake [8], weight control [9], and pulse oximetry [2]. Wireless Body Area Network (WBAN) [1] is becoming popular for providing healthcare infrastructure. Trends show a rapid development towards Pervasive Health Monitoring Systems (PHMS). This system consists of several devices including tiny sensors which are placed in or around the body in close proximity to monitor the environmental and physiological conditions of a patient.

The data collected by various such sensors are send to a smart phone which acts as a computation and communication hub, or a base station, for these sensors - it collects sensor data and processes them to detect contexts, such as location, activities, or health emergencies, and it may upload information to a cloud to archive a history of person’s health (Figure 1).

As a result, elderly people or disabled persons are monitored all over and treated well in time in case of any emergency. The patients, especially elderly people having difficulties in moving around and not able to frequently meet doctor(s), really want Ubiquitous HealthCare (UHC). Since the smart phones are being recently considered as a medical device [15], PHMSes are expected to become significant infrastructures to support health and wellbeing of the populace.

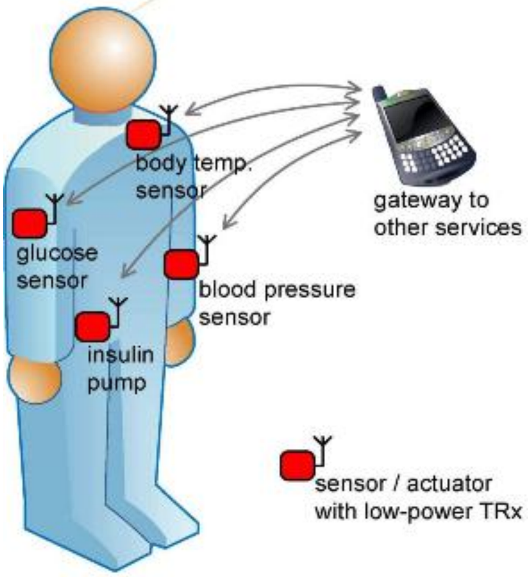

Figure 1: Sensors in PHMS.

The mobile communication infrastructure which facilitates communication between implanted bio sensors in or on the body and portable devices such as Personal Digital Assistants (PDA) is called the Wireless Body Area Network (WBAN). Wireless Body Area Network (WBAN) becoming popular nowadays thanks to its plenty of features. WBAN can provide data exchange and combination of data between various sensors and the collective data can be sent to an application which is running in a smart phone. Among the diverse medical sensors, For instance, Blood Pressure (BP) monitoring sensors are the most used sensors since the disorder of blood pressure is the indication of various diseases. Once the variation in BP is detected, it will be an evidence for the abnormal body condition of the patient. The top three mortality risks caused by hypertension are malignant neoplasm, cerebrovascular disease and cardiac disorder. Thus it is possible to reduce a death rate from cardiovascular disease and apoplexy by curing hypertension. Another impact of hypertension is the dementia and it is also possible to decrease the happening of dementia by controlling blood pressure.

In this paper, we propose an enhanced architecture for Heath care Monitoring System which automatically classify the data collected by WBAN sensors. This system evaluates the body disorders such as blood pressure, sugar level, heart beat rate etc., in a WBAN environment in real time then stores all the data into a Database for investigation. To analyze the enormous amount of data efficiently, PSO classification algorithm is used in this system. In many local and foreign researches, the development of PHMS applications, the functions are only limited to simple monitoring of data that includes vital signs or providing diagnosis of doctors about data stored in the Database.

Further in this paper, we propose a classification system based on the Particle Swarm Optimization (PSO) algorithm to classify the data by the vital signs generated from the body sensors which are stored in a database in a real-time environment. This enables evaluating the body condition in a PHMS environment and thus it could be possible to medically inspect and find chronic feeble people and prospective patients.

2. Related Research:

In existing system, to analyze an SMDCS (Smart Mobile Medical Computing System) four components have to be considered: a) the software of the mobile devices, which generates discrete events at deterministic times, b) random inputs from the user, which generate random discrete events at random times, c) dynamic context changes of the user, which change the user's environment following random processes, and d) the human physiology, which change physiological parameters following a continuous dynamics. Model Based Engineering (MBE) techniques are being widely used as a non-invasive method for analyzing and verifying system design. In that paper, they have proposed a model based engineering approach for analyzing safety and sustainability of SMDCSes. In this technique, before implementation and deployment of a system, a high level model is developed that mathematically characterizes salient features of the system with desired accuracy. Individual components of the model are then calibrated using real world experiments. The integrated model is then analyzed to evaluate the safety and sustainability properties of the system.

Dynamic analysis is a widely used technique to test operation of software under random user inputs. However, it does not incorporate interaction of the software with the human physiology. Stochastic hybrid automata is an advanced tool that can handle interaction of software events with human physiology and also allow randomness in state transitions. However, the analysis is only limited to linear ordinary differential equations and mostly exponential, which have finite variance. Apart from these theoretical tools, there are several modeling and simulation tools available for analyzing an SMDCS for satisfaction of system requirements, referred to as requirements analysis henceforth. However, they fail to comprehensively analyze SMDCSes for safety and sustainability under random context changes and non-linear spatio-temporal interaction. The main research problem is to analyze the interaction between software, user context, and human physiology. To avoid computational complexity, this paper proposes safety and sustainability analysis algorithms of polynomial complexity that can be used to simulate the execution of a SMDCS model with spatio-temporal aggregate interactions for a set of contexts.

Contribution:

A. Wireless Body Area Network (WBAN):

The rapid growth in physiological sensors, low-power integrated circuits, and wireless communication has enabled a new generation of wireless sensor networks. Modern advanced developments have facilitated wireless sensors to tiny, lightweight, and less power consumption devices. These wireless sensors have been used in the medical area with a wide range of capability. The body area network field is an interdisciplinary field, which could allow low-cost and constant health monitoring with real-time updates of medical records through the Internet. It enables doctors to monitor patients remotely and provide them suitable health information and support. Also physicians could give analysis to patients efficiently. A broad spectrum of requirements exists in the WBAN application area. Standardization of WBAN is the first step which is getting important recently [1].

WBAN is used to observe patients' circumstance inside the hospital and also convey patients' vital signs to doctors over the internet if the doctors are available outside the hospital. Figure 2 shows the WBAN service structure in a medical environment [4].

There are many research works have done earlier for the E-health care system. We discuss few of them here. In [5] V. Jones, et al, proposed a system the MobileHealth project in Modeling mobile health systems: an application of augmented MDA for the extended healthcare enterprise,". In [6] M. Blount, et al presented a Personal Care Connect(PCC) Open System Platform of IBM and Y. Xue, et al proposed the CareNet of Univ. Texas, Dallas for analysis of patient's status from collecting vital signs [7].

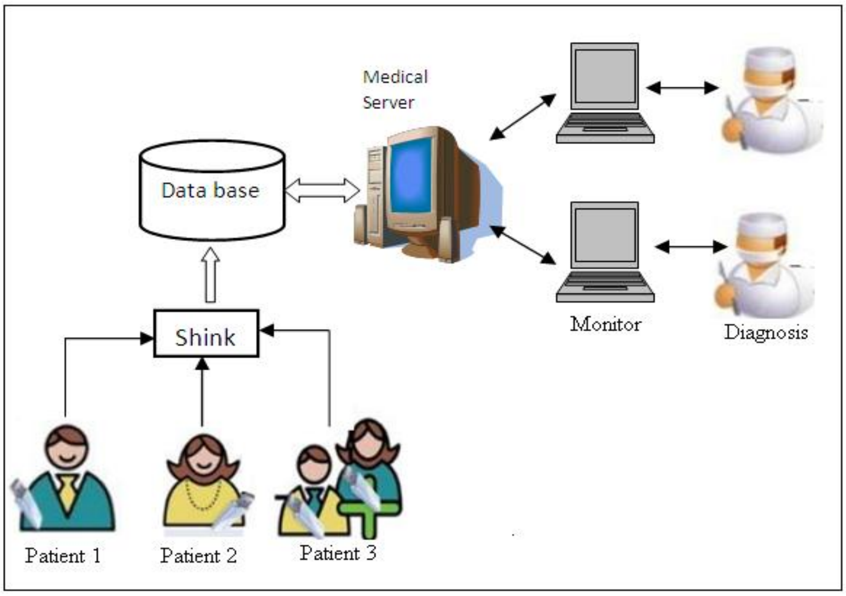

Figure 2: WBAN Service Structure in a Medical Environment.

Health Care Monitoring (HCM) system supports to finding the patients with Chronic Diseases (CD). Ambient Intelligence (AmI) for personalized healthcare monitoring is a promising solution that gives the medical services in minimum healthcare cost [3]. The author summarizes recent evolution in the field of AmI for HCM. Wireless Sensor Networks (WSNs) is used for research communication technology which is using wearable system for healthcare monitoring.

The Computational Intelligence (CI) has utilized in different king of medical application. Among them biomedical engineering has progressed into a one of the growing application part of computational intelligence. The author reviewed briefly about computational intelligence in biomedical application and also demonstrated the efficiency of the CI for medical diagnosis [4].

B. Particle Swarm Optimization Classification:

```
Input : training data

iteration number

Generate initial particles
(= classification rule) randomly

for iteration number do
  for each particle do
    calculate the fitness value using training dat
    find the pbest
  end for

  find the gbest

  for each particle do
    calculate velocity
    update particle
  endfor
endfor

output : rule corresponding to gBest
```

Particle Swarm Optimization (PSO) is an algorithm for optimization which is developed by Kennedy and Eberhart [14], considering the behavior of swarms in the nature, such as birds, fish, etc. PSO is a stochastic, population-based computer problem-solving algorithm [10], [11]. In this Algorithm, a candidate solution is presented as a particle. It applies a group of flying particles (changing solutions) in a search area (current and possible solutions) as well as the movement towards a hopeful area in order to get to a global optimum. The PSO Classification algorithm is built up by applying the PSO algorithm to the Classification problem. Figure 3 shows the PSO Classification algorithm [12][13]. One of the PSO problems is its tendency to a rapid and early convergence in mid optimum points. Much number of efforts have been made so far to solve this problem.

3. System Development:

In the PHMS enabled medical system a large volume of data is generated periodically and the Database is filled up with real time data. Due to the voluminous of data the space and time complexity arises when handling these data using the existing computing tools. In order to analyze and get more accurate results the users have to use a new computing system.

To overcome the drawbacks of the existing system, we suggest a new system that can analyze the body sensor data automatically. The body sensor data like blood pressure, sugar level, heart beat etc., are stored into the database in the real time and the new PHMS system can classify normal and abnormal cases by using the PSO algorithm.

PSO is a kind of evolution algorithm and it is applicable to huge amounts of data and has very good time performance, and as a result it fits the purpose of WBAN data analysis in a PHMS environment. For instance to measure blood pressure, we use Duo Care blood pressure sensor which is made by GENEXEL MEDICAL and T-mote is used for wireless communication.

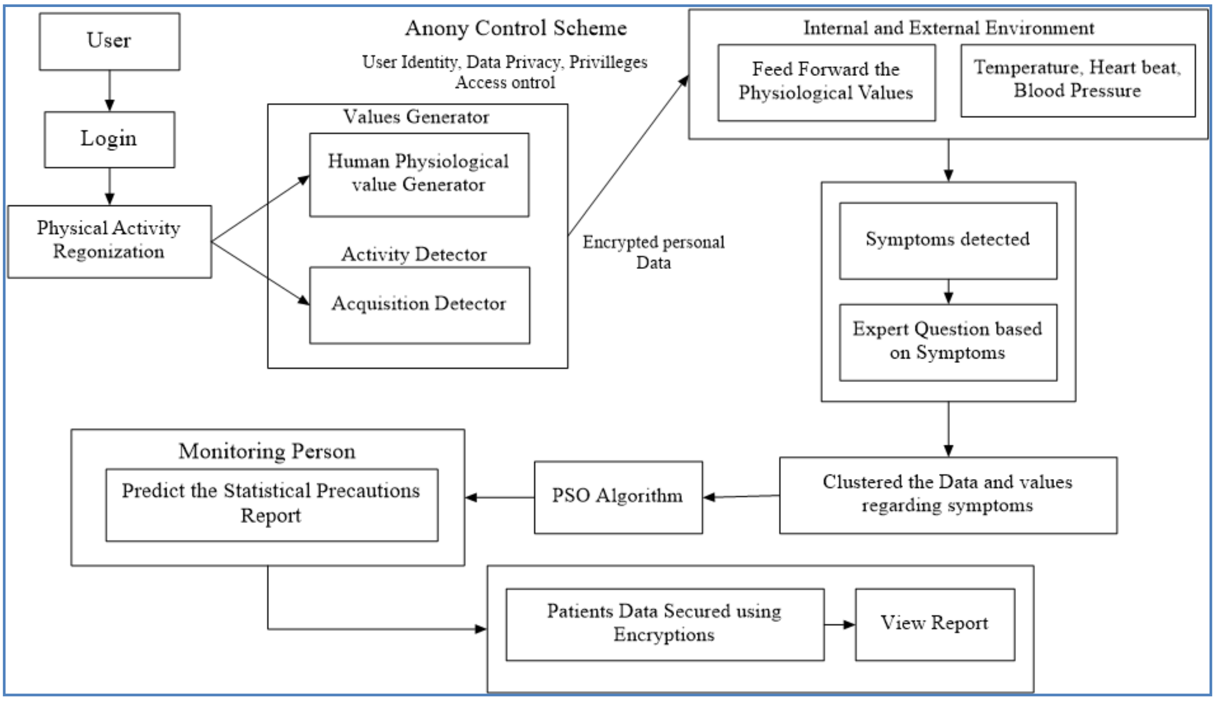

Figure 4: System Architecture.

The PSO has been stimulated by the communal activities of animals such as fish schooling, insect swarming and bird flocking. It involves a number of particles, which are initialized randomly in the search space of an objective function. These particles are referred to as swarm. Each particle of the swarm characterizes a potential solution of the optimization problem. The particles fly through the search space and their positions are updated based on the best positions of individual particles in each iteration. The fitness values of particles are obtained to determine, which position in the search space is the best. In k^{th} iteration, the swarm is updated using the following equations:

$$V_i^{k+1} = \rho^k V_i^k + c_1 r_1 (P_i^k - X_i^k) + c_2 r_2 (P_g^k - X_i^k) \quad \text{.................(1)}$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad \text{... (2)}$$

where X_i and V_i correspond to the current position and velocity vectors of the i^{th} particle, respectively; P_i is the best previous position of the i^{th} particle and P_g is the best global position among all the particles in the swarm; r_1 and r_2 are two uniform random sequences generated from interval[0,1]; c_1 and c_2 are the cognitive and social scaling parameters, respectively and r_k is the inertia weight used to discount the previous velocity of particle preserved. The inertia weight r_k may be defined ovary linearly from a maximum value r_{max} to a minimum value r_{min}. Velocity vector V_i is limited to a lower bound V_l and an upper bound V_u.

Before performing the actual classification, a process for aggregation is required to decrease the amount of sensor data. This is done by calculating the average of each hour data and divided into the activity period (day-time) and rest period (night-time). Also, in order to analyze the sensor data for a day, the average of sensor data for each day is calculated.

4. Results and Discussion:

In order to verify the effectiveness of the proposed method above, we took some experiments using a simulation environment.

4.1 Metrics:

The performance of the proposed PHMS with PSO algorithm is evaluated with the following metrics: accuracy, specificity and sensitivity. These measures are defined using True Negative (TN), True Positive (TP), False Positive (FP) and False Negative (FN).

Accuracy: It refers to the total number of records that are correctly classified by the classifier.

Accuracy = (TP+TN) / (TP+FP+ TN+FN) .... (3)

(OR)

Accuracy = (TP+TN) / N; where, TP+FP+TN+FN = N = Total Population.

Sensitivity: It is the proportion of people who are identified as having disease

Sensitivity = TP / (TP+FN) .... (4)

1. **Specificity:** It is the proportion of healthy people who have no diseases.

   Specificity = TN / (TN+FP) .... (5)

2. **Time Complexity**: It quantifies the amount of time taken by the algorithm.

4.2. Comparative Study:

The data are collected from a real time hospital database. Several attributes are used for analysis such as the age of the person, serum cholesterol level, fasting blood sugar, resting blood sugar, resting ECG results, Blood Pressure, serum cholesterol level, maximum amount of heart rate achieved and sex signifies the gender.

From these attributes, our proposed system PHMS focused on Heart rate, sex, age, blood sugar, BP, cholesterol, and additional factor as smoking. Figure 5 shows that the time complexity of different types of algorithm whose results show that the proposed PHMS obtained the hopeful results compared to other two algorithms such as regression tree and GA optimization.

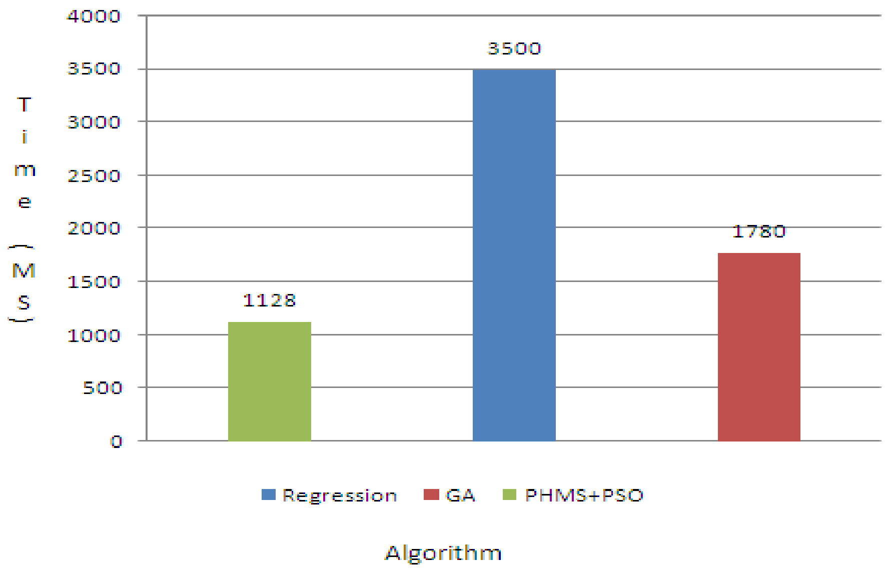

Figure 5: Time Complexity.

Figure 6 gives the comparison results in terms of specificity, accuracy, and sensitivity for three various systems such as regression tree, GA optimization, and proposed PHMS with PSO. The proposed system performs better in all conditions when compared with other two models.

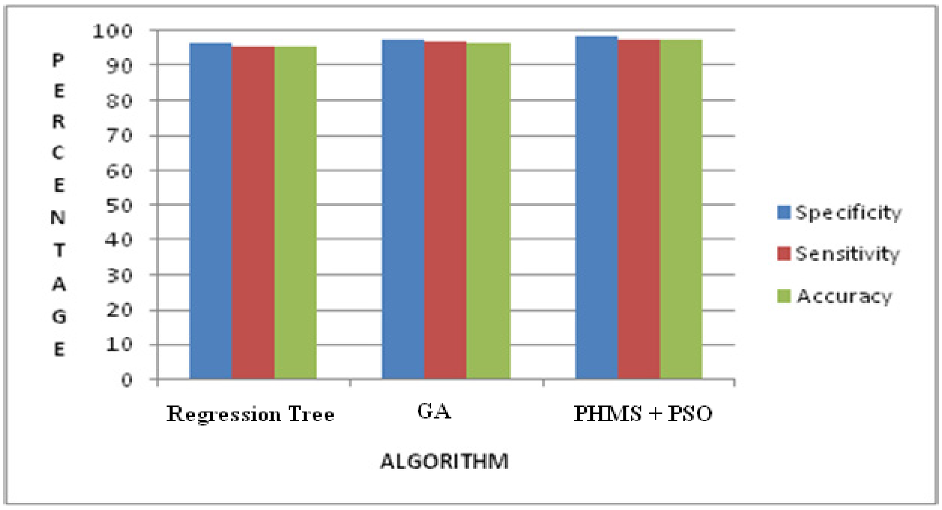

Figure 6: Comparison of Different Algorithms

5. Conclusion and Future Work:

There are a less number of doctors compared with the patients data to be handled so we propose a system to automatically analyze the body sensor data in a WBAN environment. To reduce the amount of sensor data in the WBAN environment, an aggregation procedure is carried out and aggregated data is stored in a Data Base. Modern Healthcare Monitoring System (HMS) provides sufficient computing power and offer media-rich and context-aware features that are suitable for electronic-health database. A more efficient way of recording and updating data to Electronic Health Record (EHR) of patients is provided through this application. In this paper, the PSO Classification algorithm is proposed for applying classification rules to improve the time performance. In the next five years, expect to see successful e-Health process in remote monitoring and consultation.

In future e-Health monitoring system can be developed using sensor and GSM technology. An e-Health care companies are expected to produce several drivers to be the increased penetration of capable devices and user / patient data demand on the market.

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