A Cloud Based Autonomic Mental State Monitoring System Using Wearable Body Sensors

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Abstract

Development of body- and bio-sensor network opens a new horizon of healthcare especially to measure the vital physical signs of personnel for diseases diagnosis and patient monitoring. And the cloud computing technology is enabling patient monitoring service dynamically scalable and ubiquitously accessible. Physical and mental health, both are important for the existence of human being with happiness and smartness. The success of mental health monitoring system depends on real life data accusation from patient with mental diseases and some historical data about patients and also his predecessors. This paper proposes a ubiquitous mental state monitoring system on cloud environment. In this system, patient's real-time vital diseases symptoms are collected through body sensor network (BSN) and then analyzed the collected data on the healthcare agent of cloud including patient's historical repository of diseases, habits and rehabilitations. Here, we model the mental statuses of patients as the discrete set of states of hidden Markov model (HMM) and BSNs data with clouds facts as the observations of HMM. Finally, we use Viterbi, a machine learning algorithm to generate the most probable mental state sequence of the patients. By deploying this method on mental patients dataset, we validate the proposal.

1. Introduction

According to the definition of Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), the mental disorders is conceptualized as a clinically significant behavioral or psychological syndrome or pattern that occurs in an individual and that is associated with present distress (e.g., a painful symptom) or disability (i.e., impairment in one or more important areas of functioning) or with a significantly increased risk of suffering death, pain, disability, or an important loss of freedom [1]. Conversely, mental health is the nonexistence of mental disorder. Mental health monitoring is more challenging than the physical health monitoring because human mentality varies dynamically and it is difficult to fetch the patterns from the mental behavior. Also, mental behavior differs over so many metrics like age, ethnicity, education, marital status, family history and habits etc. However, human brain chemistry changes over different mental disorders but still causes and effects are not fully explored. And pinpointing the location of mental disorder in our brain is very difficult (almost impossible) as our brain consists of about 100 billion neurons and glial cells, and the neurons form the telecommunications network in the brain to communicate each other and also carry the signals back and forth between your brain and the rest of your body [2]. As a result, it is not possible to diagnose most of mental diseases like bipolar disorder using some definite pathological examination.

Mental state monitoring is necessary to diagnose different mental disorders, like to identify the manic and depressive episodes of bipolar disorders. The motivation of this research is not solely to diagnose the mental diseases, rather in this research we want to monitor the mental states irrespective of mental disorders.

The individuals of different mental disorders have atypical, suicidal and/or homicidal tendency [3][4]. Even some people who don't have any record of mental illness may have atypical, suicidal and/or homicidal tendency. Atypical, suicidal and/or homicidal mental state can even develop within a moment and without any prerecorded symptoms. For that reason, we define mental states broadly as normal, atypical, suicidal and homicidal.

2. System Description

In our proposed cloud based autonomic mental state monitoring (CBAMSM) system, we collect patient's statistics or diseases symptoms through body sensor networks shown in figure 1. Each and every patient registered to the cloud healthcare agent to get the cloud based healthcare service. On the time of registration, patient is identified with his social security number and his sink nodes mac address is also used for authentication purpose.

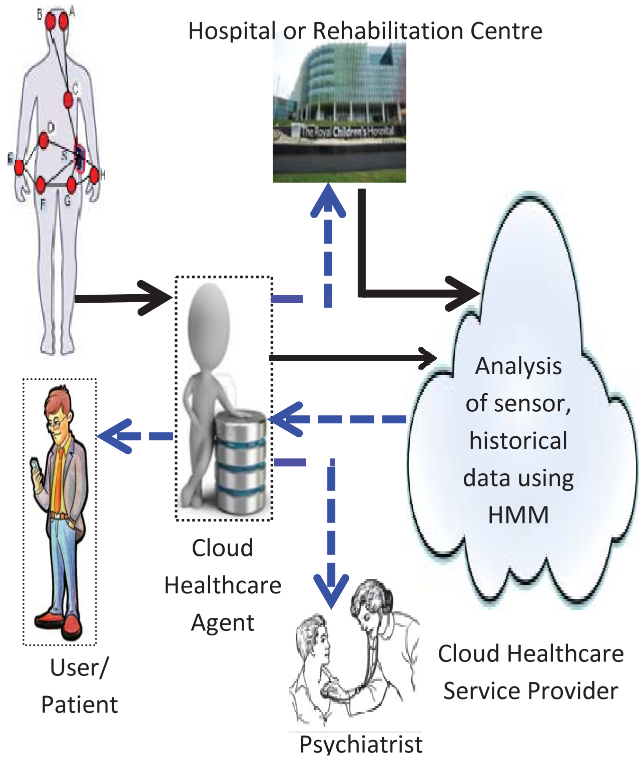

Fig. 1 CBAMSM system scenario

Cloud healthcare agents is responsible for collecting data from patients BANs and transfer it to the public clouds healthcare service providers platform as a service (PaaS) cloud to compute the mental state sequence using machine learning tools. After that the cloud healthcare service provider send back the computed result to cloud healthcare agent. Finally, cloud healthcare agent send the current mental status of the patient to corresponding hospital, psychiatrist and sink node of the patients BANs.

In our proposal, BAN consists of four types of body sensors and including sink node the sensors are eight in number. Electro-dermal activity (EDA) sensor [5] is used to measure the stress level and emotional state, electroencephalography (EEG) sensor is used to measures pivotal brain disorders and sleep disorders, Ultra-compact blood flow (BF) sensor is used to measure blood flow to monitor alcohol consumption and irritation level, non-invasive blood pressure (BP) sensor is used to diagnose hypertension and measure systolic and diastolic pressure.

We consider that the patient's historical data stored on the cloud and we extract 25 other features from cloud like patient's age, sex, ethnicity, marital status, living alone or not, history of any long term sickness, history of drug misuse, prevalence of alcohol misuse, history of predecessor's violence, history of previous violence and prevalence of mental illness etc. All these features are influential towards mental state changing.

3. System Modeling and Algorithm Design

In our proposed cloud based autonomic mental state monitoring (CBAMSM) system, we consider total M states, and all states are hidden, which follows ergodic HMM model of M states $S=\{s_1, s_2, \cdots, s_M\}$.

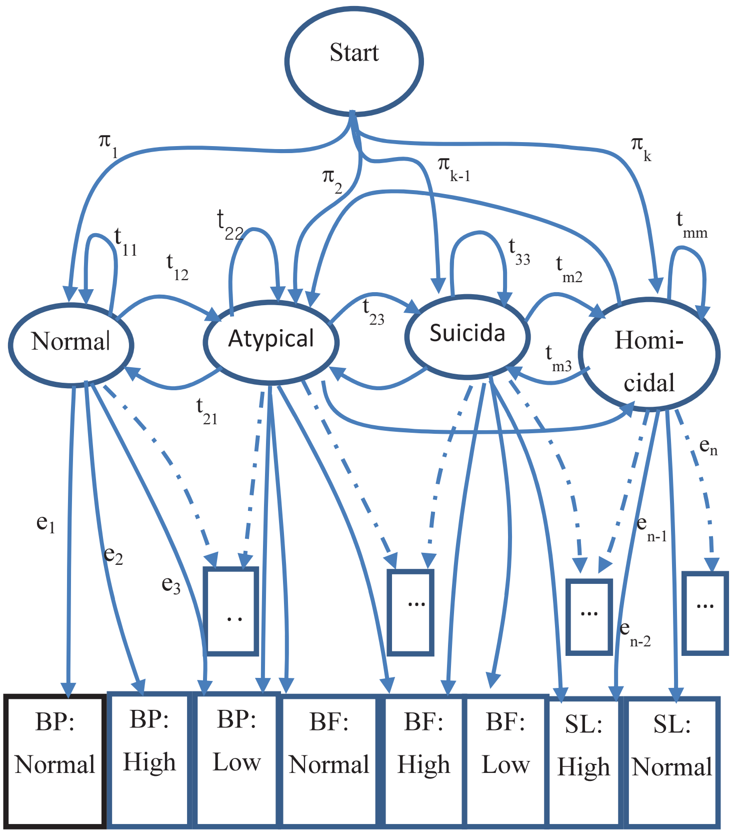

Fig. 2 Markov Model of CBAMSM system

The observations are partially taken from patient's body sensor networks sensor observation and partially taken from cloud i.e patient's historical data.

To model the system, we may consider the systems observation set as $O =\{ o_1, o_2, \cdots, o_N \}$, where N is the number of total observations. Our goal is to find out a state sequence $Q=\{ q_1, q_2, \cdots, q_p \}$ of S using the given observation sequence $V=\{ v_1, v_2, \cdots, v_p \}$ of O at a given time t.

Now, we can demonstrate our system using the Hidden Markov Model $\lambda = \{\pi, T, E\}$, where π is set of initial states probabilities $\pi = \{\pi_i \mid \pi_i = P(q_0 = s_i)\}$, state transition probabilities $T = \{t_{ij} \mid t_{ij} = P(q = s_j \mid q' = s_i)\}$, where q' is the previous state sequence, and emission probabilities $E = \{e_{ij} \mid e_{ij} = P(v = o_j \mid q = s_i)\}$.

We use Viterbi algorithm to find out the most likely state sequence as the output of our proposed method of mental state monitoring. As Viterbi algorithm [6] requires the initial state probabilities, transition probabilities and emission probabilities to generate the most likely state sequence, we should train it get those necessary probabilities. For training purpose we use Viterbi Path Counting (VPC) algorithm [7], which is efficient than Baum-Welch algorithm in comparison of convergence time. Our training algorithm is as follows:

$$\text{VPC\_Training}(\lambda_0, V = \{v^1_{Tr_i}, v^2_{Tr_i}, \ldots, v^V_{Tr_i}\})$$

1. $\lambda = \lambda_0$
2. for i ← 1 to L
3. Q = null
4. for all training data on V
5. Q_t ← Calculate maximum joint probabilistic state sequence using Viterbi Algorithm from λ
6. Update Q using Q_t
7. End for
8. $\overline{\pi_i}$ = Average number of occurrences of s_i at the starting time (t = 1)
9. $$\overline{T_{ij}} = \frac{\text{Average number of transitions from } s_i \text{ to state } s_j}{\text{Average number of transition from } s_i}$$
10. $$\overline{E_{ij}} = \frac{\text{Average number of times in state i and observing symbol } v_j}{\text{Average number of times in state i}}$$
11. End for

4. Performance Evaluation

We evaluate the performance of our proposed CBAMSM system, using precision (P) and recall (R) measurement. The precision is the percentage of identified state that is perfectly matched, and recall is the percentage of states which are truly recognized. We divide our total data set into three parts. We use 1/3 of total data set for training purpose, 1/3 for cross validation set and 1/3 for testing purpose. In our data set, we consider total 62 features and 200 subjects. For evaluation purpose, we change our sensor observations of four type of sensor and measure the precision and recall of our testing data.

Table 1 Performance evaluation of CBAMSM system

Sensor node	Precision	Recall (R)
EDA	89.82	89.01
BF	88.71	88.75
BP	83.32	84.88
EEG	88.90	88.51

5. Implementation

We implement the CBAMSM system by configuring XenServer as the hypervisor for virtualization in private cloud and also develop an android application as an emulator to evaluate the performance of the proposed system.

6. Conclusion

The successful implementation of MONARCA project opens the doors of monitoring the individuals of mental illness. Predicting mental states using some tiny sensors and cloud computing technology is a novel initiative to monitor patients of some mental disorders, and also to prevent some undesirable and unwanted live loosing like in Sandy Hook elementary school, USA. Inadequacy of standard dataset is the key barrier of its prosperous implementation.

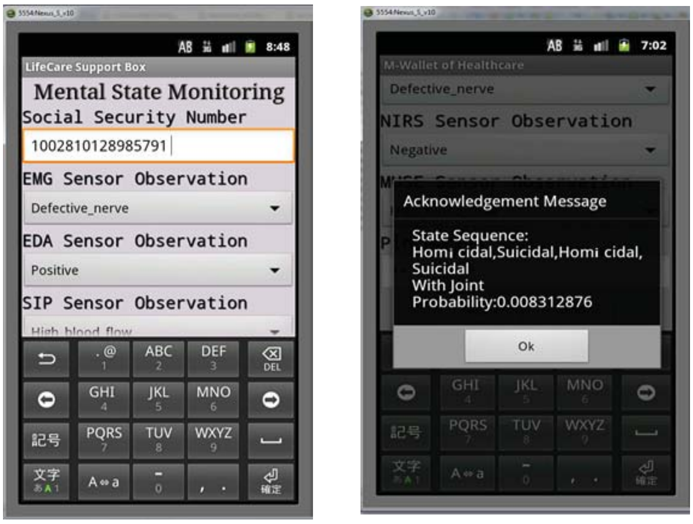

Fig. 3 Android application or emulator of CBAMSM system (a) Sensor observation (b) most likely state sequence

Acknowledgements

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