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Online Health Monitoring using Household Activity Patterns from Smart Meter Data

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***Abstract*—** In recent years, people are migrating from rural areas to urban areas which became common. The people whoever suffering from ill-health must require health care services and providing those services to them is the most challenging aspect. Technological enhancements led to construct smart homes, which are equipped several sensor or smart meter for process automation of another electronic device. In addition to these smart meters are able to capture the patient's routine activities and also monitors their health situations by frequent patterns mining and association rules formed from smart meters. We introduced a model in this work which is able to monitor the patient's activities in home and could send routine activities to the respected doctor. We can retrieve frequent patterns and association rules from log data and can estimate the patient's health situations and suggest them based on this prediction. Our work is partitioned into three stages. Initially we record the patients' routine activities by allocating particular time period with three regular intervals. In second stage, we applied the growth of frequent pattern in order to extract the association rules from log file. In final stage, we applied k-means clustering for input and applied Bayesian network model to guess the patient's health behavior and suggest precautions accordingly.

Keywords- *frequent patterns, mining association rules, bayesian networks, health care data monitoring.*

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1. INTRODUCTION

The Internet of Things (IoT) refers to the collection of ubiquitous sensors and devices and their daily interactions for connecting physical and virtual things through seamless network. To construct a new process "anytime, anywhere any service for anybody", this IoT includes various heterogeneous techniques. IoT provided some likelihood probabilities which make this possible for providing various related applications to it. By those, a smart home is greatly developed research domain in smart automation systems as its motive to improve user's comfort and guarantees security for them and restricts with operation costs at cheaper. Since smart home has automated environment it has ability to monitor, detect and record daily activities by using various sensors and communication technologies. The user's daily activities generate patterns that play a key role in smart home environment. Such patterns are used in user's activity recognition which is going to be used in the enhancement of smart home applications in the sense of efficiency and energy management, healthcare and security etc.

The monitoring of users daily activities is done remotely. It is having applications in many domains such as health care and daily care [1]. Hence the research on home activity identification is achieving high interest, specifically because recent trends moved health care from hospitals to patient's homes and facilitates to independent life. For example, finding routine life activities also helps in home automation support and saving energy in smart homes/buildings. Home activity recognition depends on generating an inference through information fusion from different sensors and uncertainty relevance due to stochastic nature in human behavior and equipment with imperfect sensing. To recognize human activity in smart environment, several heterogeneous sensors are involved and these range from number of sensors for measuring heartbeat, walking patterns and environmental sensors. The choice of sensor's and their placement for recognizing essential activities are affected by the way how it affects the human activities and hence predict reasonable outcomes for this activity. Key constraints like intrusiveness, privacy, energy efficiency, cost, and providing more exactness in activity recognition with less number of least price and non-intrusive sensors are to be taken into consideration. Those are the challenges in recent research.

Fewer of the instances of activity recognition in smart home are working with D-S theory. This theory of evidence was proved by Lee et al. and also stated that this theory gives the way to incorporate and reduce the impact over uncertainty efficiently. The D-S theory of evidence together with a lattice structure is utilized for finding basic human activities, like flushing a toilet, for the purpose of assistive living. In this paper we argue that important everyday activities are identified only with the usage of energy monitors like smart meter data. In India every home is going to be equipped with a smart meter by 2030 and with the similar trends in the remained developed countries. There is no need to have extra hardware since every home will be equipped with sensors to perform identification of home activity.

The remainder of this paper is organized as shown in below. Our related work and literature study is depicted under Section

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2. Under Section 3 we represented our proposed work. Section 4 depicts the results and discussion. Conclusions are drawn in Section 5.

2. Related Work

Many researches introduced IoT related smart home environment to enhance security and protection and resident's comfort with less operation costs. Vividly, the usage of sensors in smart homes is indispensable for identification of users' activities. Activities Daily Living (ADL) of residents is monitored and the common activity patterns are designed on the basis of user's position in his/her environment. With that any normal/abnormal behavior of activity pattern is found. Additionally other researchers were used to minimize the activity recognition related risks with few of varied approaches in various activities of real world. However, the diversity and complexity in activities are often very high in daily living.

In [3], the EM-algorithm helps in grouping of similar objects. This is easy and fast but its efficiency depends on the number of input features, objects and includes with iteration number. Jakkula et al. [4] suggests dividing with a centroid through k-means clustering approach. This approach is called distance measurement allocates a score to least value cluster. Inspite of the efficiency of algorithm relies on several clusters, cluster center selection and iterations.

In [5] a hierarchical clustering algorithm used in a distributed environment calculates its performance and exactness by applying valid measures like entropy, time and coefficient of time. It is not necessary to define the count of clusters before and it is easy to implement. Inspite this hierarchical paradigm produces clusters with low quality and consumes more time for execution when huge dataset was given. The SOM algorithm [6] provides the high accuracy in objects classification into related clusters. In addition to this it produces fair results over k-means and EM-clustering algorithm whenever random datasets are used. Inspite as 'k' (number of clusters) improves considerably there is decrement in performance otherwise with the use of huge dataset, this algorithm yields poor outputs.

Usually, there exists some ambiguity during processing of noisy data having in clustering algorithms. In fact that noise made complicated to include an object to specified cluster because the outcomes of the algorithm's get influenced by that noise. To resolve this risk there is an algorithm called K-pattern clustering. On the rest of side, some tasks integrate user behavior through activity recognition. Identifying user activities generally resembles the collection of observation order for recognizing new events. Some models for activity prediction involves the expectation of sequential activity with the use of decision trees, the k-nearest neighbor and the Markov or Bayesian models.

Alam et al. [7] utilizes probabilistic models like Hidden Markov Models (HMM) for modeling the activities of the user. This method is extensively utilized to find the spatio-temporal relationships between the sensor data and also to detect time series prediction [8, 9]. Even so, the execution consumes more time for huge data. In [10], On C4.5 classifier basis another classification model for recognition of activity is taken into consideration. This technique provides better results. Its performance in recognition exactness is not much greater than the neural network algorithm; because of diversity and complexity of activities in real world [11]. Here we have discussed some more literature study of our work from last three years.

In 2015 K.Jack and K.William proposed their work on home appliance-level electricity demand and whole-house demand from UK homes. A dataset that is possessed from disparate homes was adopted in this paper. Whichever the smart homes are equipped with smart devices contains huge number of meter readings. This meter reading varies from home to home on the users' equipment usage level basis. This paper presents an approach to data assembling from smart homes on use of installed appliances [12].

In 2016 M. S Hossain proposed in his paper work regarding patient's behavior identification system for healthcare by the use of speech and facial expressions. This paper describes a method for mentioning the total framework on healthcare. It primarily deals with the concept of finding patient's situation to give better accuracy in recognition to have model at low cost. This paper mainly depends on two types of inputs like audio and video which are attained in multi-sensory environment that gives an average of 98% efficiency in detection.

In 2016 M. U1Alam, N Roy, M. Petruska and A Zemp proposed their research work on smart energy group variation on the basis of behavioral anomaly recognition. This paper work introduced to access a data analytic that classifies the abnormalities in utilization of energy on the basis of inhabitants' behavioral deformity. Research reports significantly relies on finding everyday utilization of appliances ranges between smart meter and smart plug data that focus on everyday activity even though during days and nights and then to study energy consumption of every appliance. Majorly this paper's provide basic technologies which are non-intrusive health monitored are deployed at high scale with no additional sensors are need to be equipped in any home with multi-inhabitants.

In 2015 C.Chelmis, J.Kolte and V. K Prasanna proposed their work related to big data analytics to demand response: Clustering much time and space. This paper describes that usage of various data representations on electricity consumption. It also depicts the behavior structures usages identified at (i) differed times in a day, (ii) per week (iii) per annum for a clientele and similar one's are mined at clientele's with varied features by precise time-series data clustering.

2.1 DM algorithm in Healthcare

Healthcare covers detailed processes related to diagnosis, treatment and prevention of disease, injury and other physical and mental imbalances in humans [13]. In many countries the healthcare industries are rapidly increasing. Such industries are considered as the places with high quality of huge data and

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also include electronic medical records, administrative reports and their benchmarking finding [14]. But this data is not utilized much. These healthcare industries utilize different procedures and are described in below:

2.1.1. Anomaly Detection

It identifies the primary variations in a dataset [15]. Bo Lie et al [16] used three different methods namely anomaly detection method, standard support vector data description, density induced support vector data description and Gaussian mixture to measure the preciseness of anomaly detection on a dataset of uncertainty liver disorder and collected from UCI. It can be evaluated by UCI accuracy. The results to a balanced dataset are yielded with the 94% aggregate. For the same dataset 2.63 is average standard deviation. The datasets with uncertainty are ignored in existing datasets. The best way to resolve this is provided by the anomaly detection method. We are not concentrating on effectiveness of this method in this paper.

2.1.2. Clustering

It is a theoretical task which is common and one could detect finite collection of clusters for data description. Rui Velosoa [17] was used vector quantization method for clustering in predicting readmissions in intensive medicine. This method uses algorithms like k-means, k-mediods and x-means. The datasets whichever used in this paper are from diagnosis process of patients and their results from laboratory. Every algorithm is evaluated with the utilization of Davies-Bouldin Index. The k-means, x-means and k-mediods yields better, fair and poor results respectively. On the basis of those results the researchers selects the good result that helps in characterization of various types of patients with greater probability of readmission. We are only focused on vector quantization method in this paper.

2.1.3. Classification

It refers to the process of predictive learning function discovery that performs classification of a data item into multiple predefined classes. The following are the subsections that cover the classification related work.

2.1.4. Statistical

The MTS is applied mostly in multivariable statistical analysis. The Mahalanobis Distance (MD) is for building statistical judgments for separating a group from the remaining and Mahalanobis space (MS) is for representation of degree of abnormality on the basis of known reference group. In the sense of statistical classifiers, Su et al. utilized the Mahalanobis Taguchi System (MTS) to design the prediction pattern of pressure ulcers. When we use data mining algorithms it get affected by skewed distribution often at the time of using imbalanced skews or datasets.

2.1.5. Decision Tree

Many research studies explored the decision tree method for analyzing clinical data. Authors Sharma & Om [18], Wang et al. [19] and Zolbanin et al. [20] used the decision tree algorithm for their related research work. To perform prediction It is essential to have nature to examine data and make the tree and its rules are utilized. All the works mentioned above are used decision tree for dataset to improve the performance in accuracy terms. The utilized dataset in this research work is a balanced dataset.

2.1.6. Swarm Intelligence

The authors Yeh et al. [21], Fei 2010 [22] and Abdi & Giveki [23] used this method to create their scheme for diagnosis. The PSO (Particle Swam Optimization) algorithm detects optimal or related solutions in large search spaces efficiently. All the authors mentioned above worked for clearance of optimization problem that involves with the classified problems features. If we use less features the the process of classification becomes speedy and more exact. From the studies the PSO related model proved to improve the total classification results as PSO is used for selecting relevant parameters in the involved classifiers.

2.1.7. K-Nearest Neighbor

The k-nearest neighbor is an instance related classifier method. The parameters units contains samples which are used in this method and its algorithm and then that complete instances related to points are taken into sight in *n*-dimensional space *RN*. This paradigm is so easy because the content in training data will never get lost. This paradigm is only suitable when the training data set is huge. This algorithm requires more time during processing each sample of training set while recent data classification and this process requires long time to classify.

2.1.8. Bayesian Classifier

The Bayesian classifiers are well known for its efficiency in computational aspects and it is able to manage missed data naturally and efficiently. With this advantage the both authors (mentioned earlier) attained better accuracy from the generated models. Since the models are implemented by the utilization of Bayesian classifier also proved that the model is suitable because the average rate of this paradigm led to improve accuracy in prediction and enables authors to extract additional features from data without over fitting. This method is good enough if the datasets containing with skipped data.

3. Proposed Approach

Figure 1 shows our work flow. It is initiated by preprocessing the data like data cleaning and preparation of data and then we have applied FP mining to identify the relationships between various appliances. This helps to find which common appliances are together working. In such case, we used cluster analysis to identify the relationships between appliance and time. Next to these dual steps, now the system can retrieve the appliance's pattern and this will be given as input to Bayesian network for short and long term forecasting. The result of framework is utilized by the applications of health care depending upon the intended usage. We explained briefly the theoretical concepts of the methods used in next section.

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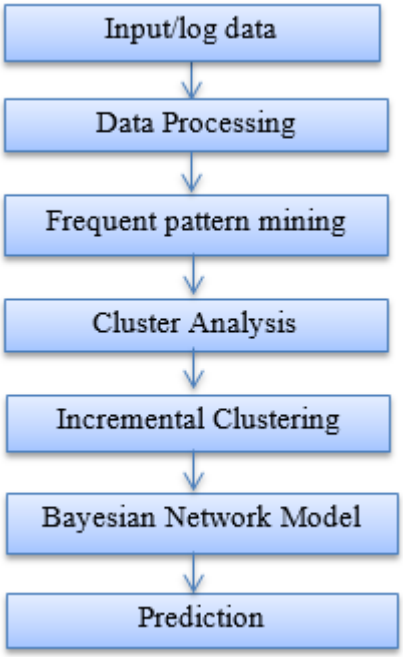

Figure 1: Flow of proposed work

3.1 Data Preprocessing

It is sometimes trivial, but in the case of data mining process it is non-trivial. If data set is having irrelevant and noisy data it becomes tough to train the data in knowledge discovery process. The final results gets affect by the input data quality. To attain exact results eventually, data must be preprocessed efficiently and make the process of data mining easier whenever we use for data cleaning, integration, transformation and data reduction. Those stages are represented in Figure 2. In our work, we almost collected the values of attributes, and hence there is no chance of having any empty values and also there is consistency in getting better results by the time we considered our work is a stipulated one. We are gathering the details of patient and their everyday activities including different appliances exist in smart home. Binary values are used for the representation of appliances usages. Let us consider Television is an appliance is either ON or OFF. For ON we represent binary value as '1' and '0' represents OFF.

3.2 Mining Frequent Patterns from Log Data

The main objective of our work is to recognize the patterns related to human activities through smart meters. There are having various activities such as "Watching Television", "Using Laptop", "Using Micro oven"," Using Washing Machine " and so on. We have to find frequent patterns from the given activities, which is needed in applications of health care that monitor the changes that occurs suddenly in patient's behavior. The doctor can see the log data and could suggest some measures to patients by observing generated frequent patterns/ association rules generated. In the essence, if patient is in rest for a long period, by observing association rules the doctor suggest the patient. We need to set different time intervals between 30 minutes to 60 minutes, so that patient will upload the data of smart meter and frequent patterns are generated accordingly. The numbers 1, 2, 3 represents the various daily activities. This concept was chosen from FP-growth technique on the basis of Divide and Conquer strategy.

Let $\{I_1, I_2, \text{and } I_3 \ldots I_n\}$ be item sets comprising 'n' number of items. I_k is referred as the 'k'th item in the item set I_n. The association rules are generated in the form of X➔ Y in support and confidence framework. The preprocessing our data set using numeric to binary is shown in Figure 3.

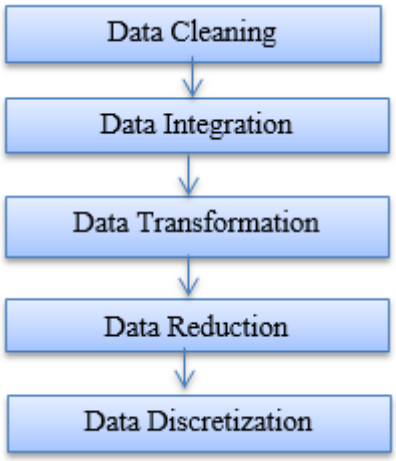

Figure 2: Data Pre-processing stages

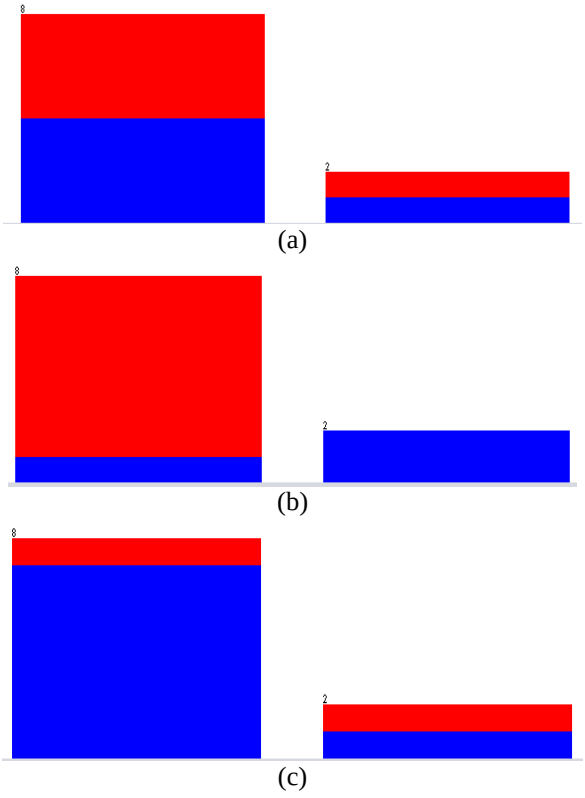

Figure 3: Result of Numeric to Binary Filter for our data set.
(Only three attributes are shown in (a), (b), (c)).

3.3 Cluster Analysis

The determination of the associations between time and appliances is significant to health applications that monitor the everyday activities of patient's on basis of time. We used cluster analysis for determining the appliance's utilization in terms of time. For instance if patient is watching Television in particular time in a complete day i.e. (00:00-23:59) and this

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activity will be monitored by the session of the day in three slots (i.e. morning, afternoon and evening). The underlying data and the relationship between the appliance and time are captured by smart meter data. The recorded data stores in database and we can integrate as a set of products that the patient is utilizing in particular time. For example if a patient is utilizing a washing machine and micro oven at similar timings between 07:00 to 8:00 then, then these two activities are taken under single group and creates a cluster. Whenever we upload a new activity, there performs incremental clustering and the clusters are created accordingly and respected clusters are represented. Eventually we combine the identified patterns and the relationship between time and appliances and will be allocated to machine learning model known as Bayesian network model for activities prediction. This network model is a directed acyclic graph, which comprises of nodes and edges. The former represents random variables and the later denotes probabilistic dependencies. We selected this model because of its key feature "casualty". We show a sample Bayesian network model with '6' nodes in Figure 4.

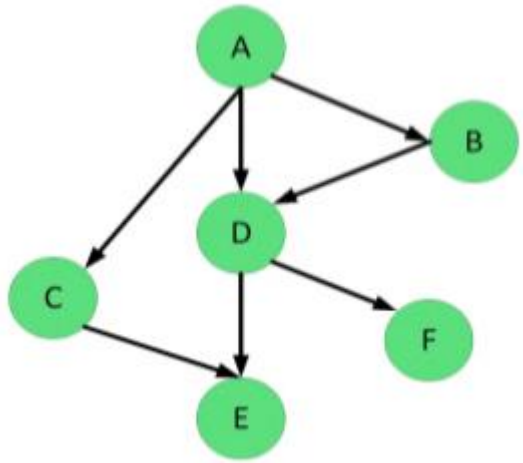

Figure 4: Bayesian network with '6' nodes.

4. Results and Discussion

The summary of our entire work is as follows. Firstly the patient's must undergo for registration by providing their details in online. We are managing a list of specialists' doctors in different diseases. As a starting step a patient could send a request for getting doctor's appointment. Whenever the doctor agrees the patient's request then the doctor is able to monitor the patient's activities done at home. In the meanwhile, the doctor can send messages to patients to suggest him by considering some climatic and environmental conditions. The patient is able to upload everyday activities through his login. The details will be sent to doctor and so that he could suggest the patient based on the patterns and association rules created from the log file data of the user. We utilized a model in our work by which a patient can send the data file. Instead of that we utilized sensors for automatic recognition of patient's activities at smart homes. We implemented this technology by using IoT in a better way. Here in this we are providing three patient's details and their log data, association rules created and the outcomes of our cluster analysis. The activities are gathered in the time period of 60 minutes at three regular intervals in morning, afternoon and evening.

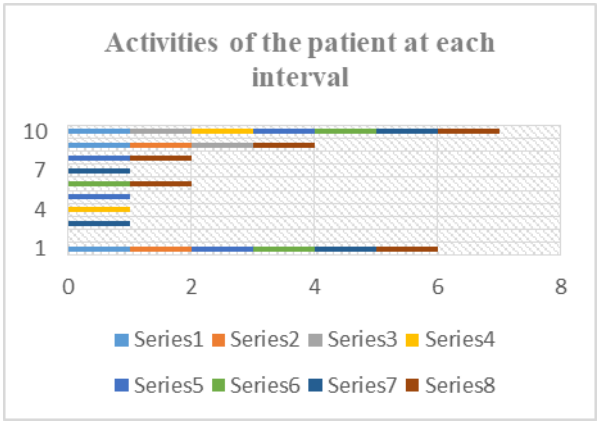

Figure 5: Activities of the patient at each time span.

We can also add high security to attain confidential data and to prevent misusage. In our work we utilized a few appliances which are able to capture the data by smart sensor. The ON or OFF represents the status. If a patient using particular appliance then the status is 'ON', otherwise the status is OFF. The activities of the patient at each time span are shown in Figure 5 and sum of the working time of the patient is shown in Figure 6 and status is shown in Figure 7.

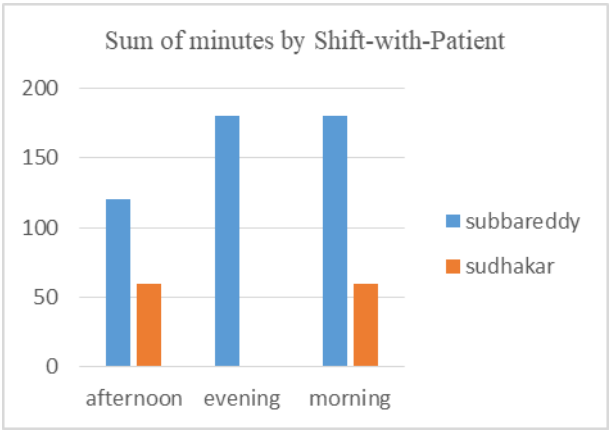

Figure 6: Sum of the working time by shift.

WORK	FOOD	WORKOUT	REST
OVER	OVER	LOW	OVER
LOW	LOW	LOW	LOW
LOW	LOW	LOW	AVERAGE
LOW	LOW	AVERAGE	LOW
LOW	AVERAGE	LOW	LOW
LOW	AVERAGE	LOW	AVERAGE
LOW	LOW	LOW	AVERAGE
LOW	AVERAGE	LOW	AVERAGE
OVER	LOW	AVERAGE	AVERAGE
AVERAGE	OVER	OVER	OVER

Figure 7: Status of the patient for various activities

5. Conclusion

Health care services are one of the most challenging aspects which is essential to the people with abnormal health. Data mining play a vital role towards healthcare industries, especially in various diseases prediction. During diseases prediction the medical diagnosis is widely utilized. As conclusion there need not to be any data mining for risk

resolving in data sets of healthcare. We must create hybrid model that helps in resolving mentioned risk. Initially we record everyday activities of patient by the use of particular time period at three regular intervals. Likewise we applied growth of frequent pattern for retrieving association rules from the data log file. Eventually, we applied k-means clustering for the input followed by Bayesian network model for predicting patient's health behavior and suggest some measures accordingly. It helps in attaining greater accuracy among classifiers which is very important in medical diagnosis by handling the features of data with care. For making improvements in predictions including with the data of real time sensor meter by utilizing hybrid models is our future work.

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