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Energy Efficient Wireless Sensor Network for Precision Agriculture

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ABSTRACT

Wireless Sensor Network (WSN) is the latest technology which provides the best and cheaper solution for a broad range of computer programs from healthcare to agriculture to (related to surrounding conditions or the health of the Earth) and military operations. India is basically a country with (good) enough valuable things from nature and focussed on farming adding/giving to its (process of people making, selling, and buying things) and (the social level people are at based on how much money they have). In the farming-based (surrounding conditions) watching/supervising area, WSN plays a big part because of its (producing a lot for a given amount of money) and comfortable use/military service of WSN. WSN is in need to (make something as small as possible/treat something important as unimportant) the energy use through (not operating or working now, but able to), transmission, etc. It needs/demands added/more energy (producing a lot with very little waste) way of doing things with data (quality of being very close to the truth or true number) leads to long life for watching/supervising farm-related field. A powerful tool that can create huge and (many different kinds of people or things) data including farming-based datasets is Association Rule Mining (ARM). A topic that is of attention in data mining of late is ranking of association rules. This work deals with farming-based sensor network which measures temperature, soil moisture, humidity and ARM based on ranking.

Keywords : Agricultural environment monitoring, Association Rule Mining (ARM), Data mining, Ranking of association rules.

I. INTRODUCTION

WSN consists of many sensor nodes with radio communication abilities [1]. WSN node is made up of sensors, micro-controller, Analog to Digital convertor (ADC), radio frequency electronics, DC-to-DC power convertor and very small power source. One or more sensors can be supported by a sensor with many limits/guidelines related to different physical (important events or patterns of things) which can get converted to electrical signals. These signals can be sampled and the data can be forwarded towards Base Station (BS).

In the farming-based field, different set of sensors is found to be useful and data can be piled up introducing WSN through which data can be piled up in the gateway and processed to produce effective results. Some alerts can be set on demand basis in order to check the (number or thing that changes) measured has crossed its (dividing line/point where something begins or changes) or not and an alert can be send in the form of messages or e-mails. The field working well and getting a lot done is increased through automatic sensing technology and the inputs that are needed/demanded for such application is reduced. Monitoring and controlling multiple parameters in agriculture is made available through

the WSN development technologically. The advancement in radio frequency (RF) for wireless and sensor and connecting internet to their convergence has made it possible the increased applications in the sensor systems of agriculture.

Precision agriculture is achieved by the wireless technologies emerged with the help of both low power and data rate capabilities. The most suited technology is WSN which can examine the environmental parameters of agriculture. WSNs used in agriculture are similar to that of the one used in industrial controls, automation building and security systems [2]. The basic nutrients needed for the growth of plants depend on environmental conditions in which a plant grow including soil temperature and moisture, light, ambient temperature, humidity and CO2. Climate factors directly affect the quality and productivity of plant growth. All factors are interrelated and without the effect on others, it cannot be considered. A farmer must be aware of the potential problems and have a better understanding of those factors. Also knowing those factors correlation helps in formulating the plans and proper measures in preventing these issues.

The process of development of plant such as photosynthesis, absorption, transpiration and flowering are influenced by temperature. The range of temperature for each plant is different and when this range is altered, the enzymes become inactive and the processes that are necessary for life stop. So, it is absolutely essential to uphold temperature at an optimal level.

The moisture loss from plants is controlled through humidity. Through numerous miniature pores in the leaves entry of CO2 and exit of oxygen take place. The plant development can also be affected by high humidity as fungal diseases will spread easily and saturation of air will take place with water vapor through with transpiration is restricted.

An important energy source for plants is light. Unlike human and animals, plants get their energy from sunlight through photosynthesis. In the lack of light, energy cannot be produced by plant. The growth of various organs of plants also takes place through light. Experiments conducted on the plants growth on both normal light and total darkness was proved in [3].

Another important factor is soil moisture which determines the duration of irrigation and the right amount of water supply. Through root system, water is taken and is vanished through transpiration. Soil condition, air-flow, relative humidity in air and temperature in the environment determines water loss rate. Farmers should be knowledgeable enough to know the consequence of increasingly moist soil and also the decrease of oxygen content of the root substrate if there is flooding of soil. Ultimately, the root will unable to extract water and nutrient from the soil. So, sufficient water must be supplied to plants all the time and this is otherwise called 'precise irrigation'.

There are many disadvantages of the biotype monitoring system as the growth cycle of crop is long and covers field impedance, difficulty in maintenance, increased energy consumption, inequality in consumption of node, decreased service time and many other issues.

One of the effective techniques of data mining is ARM [4] which search hidden or preferred pattern among huge data. The central point in this technique is finding the association between various items in a database that is transactional. The elements are discovered out through ARM which can correlate on a repeated basis within a dataset which consists of many non-dependent selections of elements including purchasing transaction and to discover rules. While selecting top among them, a large volume of rules are created. Therefore, it is significant to rank rules from biological data which is yet another important area of research.

For agriculture, rank-based association rule mining is proposed. Relevant literature is discussed in section 2; techniques and methodology is studied in section 3; and section 4 explains the result and its explanation in detail and section 5 conclude the work.

II. LITERATURE SURVEY

To overcome the difficulty of dilatation method in agriculture, Yu [5] developed an improvement of DV-Hop Algorithm which locates the nodes with quadrilateral range positioning method. For the algorithm, analog test is developed for average of location error. Discussion and illustration on the proportion relations of average error, connectivity and anchor nodes are also made. Based upon the results of the analog test, better effect is obtained by the algorithm on average of location error that enhances accuracy.

WSN is presented as the finest way to solve agricultural problems by Kassim et al [6], that relate to optimization of farming resources, land monitoring and decision making support. Real-time information is provided by this approach about lands and crops which will aid farmers to make right decisions. The fundamental principle of internet and WSN technology is used in which hardware, network architecture and software process control of irrigation system of precision agriculture systems based on Internet Of Things (IOT) are explained in detail. Data from sensors is monitored by the software in a feedback loop which activates the devices of control based on threshold value. The usage of water fertilizer is optimized by the implementation of WSN and the yield of crops is thus maximized.

As the agriculture sector is the backbone of Indian economy both in terms of Gross Domestic Product (GDP) and a source of employment to millions in the subcontinent, it should be focussed. In agricultural decision production process, soil characteristic and weather play a prime role. Numerous data mining techniques are assessed by Geeta [4] with its application to evaluate a variety of associate data mining techniques together with soil science database in order to establish proper correlation. From Soil Science India, a huge dataset related to soil is collected and this paper provides data mining techniques used in agriculture including Apriori.

Rank-based weighted association rule-mining (RANWAR) is proposed by Mallik et al., [7] in which the rules are ranked with the help of interestingness measures. Namely, rank-based Weighted Condensed Support (WCS) and Weighted Condensed Confidence (WCC) measures are used to bypass the problem. Weight is assigned to each of the items or genes based on the rank of items or genes obtained using those measures. Compared to the latest association rule mining algorithms, RANWAR generates reduced number of frequent item-sets with the reduced execution time of algorithm. Using gene expression and methylation datasets, RANWAR is run through Gene Ontologies (GO). The genes satisfying peak rules are validated biologically and analyzed through KEGG pathway. With respect to related diseases, relationship between top ranked rules that are extracted from RANWAR and conventional Apriori are found. Ultimately, the top rules evolved from RANWAR are not reported in Apriori.

Two innovative rule-interestingness measures are used in Rank-Based Weighted Association Rule Mining (RANWAR) in order to rank the rules. Gene rank is the basis for such kinds of measures. The weight of each item is based assigning weight on the rank that generates fewer number of frequent itemsets compared to State-of-the-art using rule mining techniques. However, based on this technique, it takes a long time to generate frequent itemset. The Temporal Apriori algorithm was proposed by Premalatha&Nandhini [8] that rank the items with the help of weighted condensed support and also measures based on weight condensed confidence. Based on the rank values, weight values

are calculated for every itemset. Finally, it was concluded that proposed method yields superior performance compared to Temporary Apriori algorithm.

III. METHODS AND MATERIAL

Here a detail discussion on association rule mining, association rule mining in WSN and rank based weighted association rule mining.

- **Association Rule Mining (ARM)**

Association rule is one of the prime techniques of data mining. Frequent patterns, correlations, associations or informal structures are detected through association rule among sets of items or objects in transactional databases and other storehouses of information. There is a theatrical increase in volume because of the data generated in daily activities. So, through mining association rules, there is an enormous volume of data in the database which interests many industries which help in many processes of decision making. Relations are identified between items through the techniques which discover association rules from data through which some sort of human behavior is shown, for instance, analyzing the buying behavior or the pattern through the items are brought together by the user. So, a specific local pattern is determined through the association rules that can be easily interpreted and communicated [9]. Knowledge discovery is the fruit of association rule mining from agricultural databases, which includes data about the details regarding soil, cultivation and geographical conditions. Decisions related to selection of crops, resources, proper environment and so on are obtained by rule mining [10].

Support and confidence are two main basic measures of association. Suppose, there are two items, then the definition of support is the ratio of occurrence of that two items and cumulative transactions. If the rules have greater support than a user defined support, then it is minimum support. Confidence is the possibility of seeing the rule's consequence under the condition of transactions. Minimum confidence is one where rules provide more confidence than user-defined consequence.

An Association rule is an implication of the form P=>Q, where $P \cap Q = \Phi$ and P & Q are subsets of all itemset I. There are two measures of rule interestingness i.e. Support (σ) and Confidence (T). They reflect the usefulness and certainty of the rules. The rule P=>Q (support σ = 10%, confidence T = 80%) indicates 10% of all the transactions under analysis involves simultaneous purchase of items P and Q by customers and 80% of confidence shows that customers who purchased item P also brought item Q [3]. Association rule is used to relate objects to each other and group them together. Association rule is classified in numerous ways, based on type of values (Boolean or Quantitative), dimensions of data (Single dimension or Multidimensional) and level of abstractions involved (Single level or Multilevel).

For mining, various algorithms have been proposed for the association rules and can be decomposed in two phases.

I. Frequent itemsets whose support and confidence values should be more than user specified minimum support (σ) and minimum confidence (T) values respectively.

II. Desired association rules are found through frequent items and so the parameters should satisfy minimum support (σ) and minimum confidence (T).

With regard to existing association rule mining, Apriori algorithm is a immense accomplishment. Until now, it is one of the most popular rule mining algorithm. Moreover, the assumption is that itemset is of lexicographic order. The candidate itemsets are generated by Apriori by connecting large itemsets of previous pass and the subsets that are small in the previous pass are deleted from the database. By considering large itemsets of the previous pass, reduction in the number of candidate large itemsets is achieved.

- **Association Rule Mining (ARM) in WSN**

Sensing, processing and transmitting are performed using sensor nodes. WSNs consists of multiple sensor nodes whose main function is sensing the area around it and detected events are sent to a node called sink through multi-hop fashion. There is periodic relay of detected events transmitted to sink and there the sensed value is checked against threshold. From the data values sensed by the sensor nodes, rules are derived at the sink. Weighted rule mining for data is extracted and used throughout the system. Then weighted support and confidence values are calculated and is utilized for the process of data mining. The data transfer traffic is reduced by the system and also data scan time is reduced during rule mining process. Under production process, the weight values are assigned with respect to quality factors.

Problem of mining sensor association rules is the definition of association rule with its proposition of the transactional databases' domain. However, much study has not been done with regard to the definition of association rules for WSNs where the main object of extracted rules is the sensors themselves, irrespective of their values. An event is detected by a sensor and not its value if there is an interested sensor. Let $S = \{s_1; s_2; \ldots; s_m\}$ be the set of sensors in a particular sensor network. The time is divided into equalized slots $\{t_1, t_2 \ldots t_n\}$ such that $t_{i+1} - t_i = \lambda$ for all 1 <i< n, where λ is the size of each time slot, and T_his= tn - t1 represents the historical period of the behavioral data defined during the data extraction process. P= (s1, s2 . . . sk} is a pattern of sensors.

If the targeted application's frequency and confidence are greater than or equal to a specific minimum support (min sup) and minimum confidence (min con) percentage, then there is interest of sensor rule to the targeted application. It is noted that the frequency and support can be interchangeable and the minimum number of epochs that the frequency of rule should be satisfied is supported if it is represented by min sup. Given a specific time slot size and historical period, database of epochs are generated with minimum support and minimum confidence. Then the issue of mining sensors' association rules is to promote the interest rules of all those attributes present in the given behavioral data. Two steps are involved in mining association rules:

1. Frequent pattern generation, that is, those that have frequency ≥ min sup;
2. Generation of rules that can satisfy the min conf restriction. The rules with regard to sensor association might be straight forward and it does not take a long runtime.

Two possible modalities are presented through the mining system while extracting the behavioral data that is required to mine sensor application rules from WSANs. Direct reporting is the first technique in which there is transfer of data to sink without the sensor nodes involvement in the process of reporting; the second is overall limited resources of the network where each is optimized to the number of messages that sent. Ultimately, the network architecture and the methodology will be described in detail.

- **Rank-based Weighted Association Rule-Mining (RANWAR)**

An updated measure of RANWAR is Apriori (i.e., WCS and WCC). RANWAR's performance is compared with that of other existing rule mining techniques. At various minimum support values, the number of frequent itemsets is compared in RANWAR.

The most relevant and useful results provide ranking of rules from medical datasets. In order to accomplish this process, support and confidence are introduced.

But the issue is in developing increased number of frequent items leading to increased time in computation. In order to overcome this issue, ranked or weighted rule mining in gene dataset is named. This is otherwise called rank-based weighted association rules.

IV. RESULTS AND DISCUSSION

Utilizing agricultural sensor network, simulation is conducted through several runs and dataset of 50000 readings were collected from all sensors. The performance was evaluated through the investigation that was carried out with respect to the number of messages, time of execution and memory usage. The cumulative number of sensors used is 150 and time consumed is one minute. Table 1 to 3 shows the number of messages, execution time and memory usage for varying support values. Figure 1 to 3 shows the same.

Table 1. Number of messages ranked for varying support value

Support value	Number of messages
0	23142
0.1	21423
0.2	18652
0.3	12879
0.4	11678
0.5	9854
0.6	8924
0.7	6532
0.8	3321
0.9	1896

Input : Data matrix D (rows=genes, columns=samples), original gene-list A1 according to D,rank-wise gene-list A2 (according to p-values of genes by Limma), flag of sorting the evolvedrules sortFlag (w.r.t. either wcs or wcc), minimum support threshold min wsupp,minimum confidence threshold min wconf.

Output: Set of rules Rules, support RuleSupp, confidence RuleConf.

1: procedure RANWAR
2: Normalize the data-matrix D using zero-mean normalization.
3: Calculate rank of genes (i.e., rankk(:)) according to original gene list A1.
4: Assign weights wt(:) to all genes according to their ranks rankk(:).
5: Transpose the normalized data-matrix.
6: Choose initial seed values for using k-means clustering.
7: Discretize the transposed matrix applying standard k-means clustering sample-wise.
8: Apply post-discretization technique.
9: Initialize k = 1.
10: Find frequent 1-itemsets, FIk = {i|i ∈A1 ∧wcs(i) ≥ min wsupp}.
11: repeat
12: k=k+1.
13: Generate candidate itemsets, CIk from FIk–1 itemsets.
14: for each candidate itemset, c ∈CIk do
15: Calculate wcs(c) for each candidate itemset, c.
16: if wcs(c) >= min wsupp then
17: FIk ← [FIk; c].
18: Generate rules, rule(:) from the frequent itemset, c.
19: Determine wcc(:) for each rule(:).
20: for each evolved rule, r ∈rule(:) do
21: if wcc(r) >= min wconf then
22: Store the r in the resulting rule-list Rules with its wcs and wcc;Rules ← r, RuleSupp ← wcs(r) and RuleConf ← wcc(r).
23: end if
24: end for
25: end if
26: end for
27: until (FIk = ∅)
28: end procedure

Table 1 shows the number of messages required to report the sensors behaviour for different support value. Support values have been expressed as

percentages of the number of epochs present in the databases for the simulator and the real data. The number of messages obtained using direct reporting is given at zero support value. It is observed that the number of messages reduce with increase in support value.

An Intel I3 2.2 GHz processor with 2 GB RAM was used to measure the execution time and memory usage.

Table 2. Execution time for varying support values

Support value	Execution time in second
0.1	16.1
0.2	12.2
0.3	11.1
0.4	9.6
0.5	7.4
0.6	6.4
0.7	4.8
0.8	3.7
0.9	2.1

Table 2 shows the execution time for varying support values required to report the sensors behaviour for different support value. Support values have been expressed as percentage of the number of epochs present in the database for the simulator and the real data. Results show that when support value increases, the execution time is reduced.

Table 3. Memory usage for varying support values

Support value	Memory usage (Mb)
0.1	365
0.2	320
0.3	310
0.4	260
0.5	210
0.6	160
0.7	140
0.8	90
0.9	80

Table 3 shows the memory usage for varying support values required to report the sensors behaviour for different support value. Support values have been expressed as percentage of the number of epochs present in the database for the simulator and the real data. Results show that when support value increases, the memory usage is reduced.

V. CONCLUSION

A modern technology which integrates knowledge of sensors, automation control, digital network transmission, information storage and information processing is WSN. Of late, the efficiency and quality is improved through tools and technologies but the effect of environment on crops is reduced. The energy is saved by varying the count and threshold value because when the node senses the hard threshold value, more energy is consumed. An important data mining technique is ARM which is used to detect relationships between items. The estimation of the number of messages sent was studied with reference to execution time and memory usage. For all the performance metrics, the initial value of support vector is best and when the support value increases, the performance metrics such as number of messages, execution time and memory usage is lowered.

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