

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 applications from healthcare to agriculture to environmental and military operations. India is basically a country with sufficient natural resources and focussed on agriculture contributing to its economy and socioeconomic status. In the agricultural environment monitoring area, WSN plays a major role because of its cost-effective and comfortable deployment of WSN. WSN is in need to minimize the energy consumption through idle, transmission, etc. It requires additional energy efficient technique with data accuracy leads to long life for monitoring agriculture field. A powerful tool that can generate vast and diverse data including agricultural 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 agricultural sensor network which measures temperature, soil moisture, humidity and ARM based on ranking.

Index Terms— Agricultural environment monitoring, Association Rule Mining (ARM), Data mining, Ranking of association rules.

I. INTRODUCTION

WSN consists of numerous sensor nodes with radio communication capabilities [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 multiple parameters related to various physical phenomena which can get converted to electrical signals. These signals can be sampled and the data can be forwarded towards Base Station (BS).

In the agricultural field, different set of sensors is found to be useful and data can be accumulated introducing WSN through which data can be accumulated in the gateway and processed to produce effective results. Some alerts can be set on demand basis in order to check the variable measured has crossed its threshold or not and an alert can be send in the form of messages or e-mails. The field productivity is increased through automatic sensing technology and the inputs that are required 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. METHODOLOGY

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

A. 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 $P \Rightarrow Q$, 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 $P \Rightarrow Q$ (support $\sigma = 10\%$, 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.

1. Frequent itemsets whose support and confidence values should be more than user specified minimum support (σ) and minimum confidence (T) values respectively.
2. 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.

Most of the health-related mobile application based on sports and health monitoring. Currently, the survey shows that fast development in healthcare application and ambient – assisted living solutions [15]. This type of growth in demand and system leads to the notion of context awareness to aware social process [16]. Moreover, extensive data's has collected from a heterogeneous system that leads to new collective intelligence. Hence users turn as part of large urban super organisms [17]. Finally, it moves towards the next generation, trends and solution applied in context-aware technology. For illustrating those, we used sensing infrastructure for smart cities and collective action for crowd sourcing of information

IV. RECOMMENDER SYSTEM AND COLLABORATIVE FILTERING

Most of the recommender system involves in the field of knowledge discovery databases, in which companies utilize to discover a pattern in the last gathering of data. Moreover, in a typical recommender system, people recommend input, then system aggregate to direct the correct recipients [18]. More specifically; collaborative filtering produces a recommendation on a set of an item like books, music, films, health, and routes, based on user choice. The set of users will select elements based on rating preferred by the previous user [19, 21]. Collaborative filter trusts only large database for user evaluations. The primary focus CF recommendations on assumption of similarity user interest on same items.

CF methods are categories, allow to the data they utilize

1. *Memory-based methods*: This method uses the data matrix of all entries, rating, and relationships.
2. *Model-based methods*: It calculates the statistical models and functions based on data matrix.
3. *Hybrid methods*: This method integrates with previous two methods with content-based information to improve recommendations.

The proposed system focus on memory-based methods that are applied neighborhood search. It aims to find a group of similarity, preference, prediction by performing various techniques in recommendation system.

V. METHODOLOGY

Health Routes To Users

Most of the people take part of individual lifestyle due to medical recommendations based on the occurrence of health issues. Hence, this activity usually towards more emotions and few facts. Mostly this approach applies to the people for selecting activities like sports, exercise but they do not have proper guidance to follow and perform it. For example, jogging may be more beneficial for a person to determine the place to play it. Most of the people used to prefer it based on distance and weather. Some avoided factors while jogging like air pollution, crown density; it may lead to chronic disease for people.

For solving this type of issues, our approach provides real-time constraints and information from various sources namely real-time data from smart city infrastructure, usage of routes for people based on health condition. The system has some features like

- a. It used to prefer routes based on best-fit of user's requirement and preferences.
- b. Users can apply with smartphones.
- c. The System will offer both dynamic and collaborative in following the real-time modification. It consequence depends on variable monitoring by city sensor
- d. Users perform in sensor that provides information and experience to the systems.
- e. The user may inform the system regarding the unexpected condition that may affect other users.
- f. the user can show new routes, to enrich the system.

Context-aware recommender system software performs based on servers and preference of routes. The recommendation system involved main procedure of five-step; each corresponds to the numbers in fig 1.

- 1) The user provides bidirectional interaction with context-aware recommendation system to ask regarding recommending routes offered in the system. User duty to send information about his/her location.
- 2) Smart city's communication infrastructure acquired by real-time environment data is namely air quality, ultraviolet radiation, wind speed, temperature, and precipitation from sensors and transfer the data to context-aware recommendation system. This system estimates the information from the nearest sensor from individual routes in data storage known as matrices. The system also allocated based on three status to routes

Danger- The route may be harmful to the user's health. It will not be suitable for individual users.

Caution- Potential risk exists, for example, some user follows more environmental factors.

Idle- No proof of risk exists.

Context-aware recommendation system analyzes crowd sourced information when performing route's status.

iii) The system will check user's preference and employ a collaborative filter to the entire database of routes to decrease the top N preference. iv) The system utilizes healthcare data about user and information obtained from smart city to avoid danger routes, before cause harm to users. It automatically allocates "Caution" signal to routes with much indentation about users. After employ CF, if no route satisfies this case, system get back to the third step in performing a new set of recommendation. In the end, the system transfers the user a list of the N routes. Fig2 shows a description of Context-aware recommendation system decision flow or workflow. They have set of procedure to run until system prefers best fit to the user based on user's health condition and environment constraints.

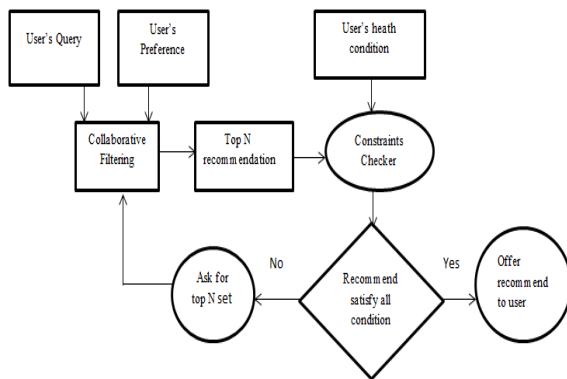


Fig 1: System architecture of content-aware recommendation system.

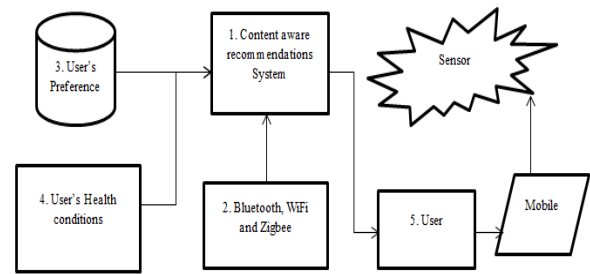


Fig.2. Shows description of Context-aware recommendation system decision flow.

VI. SMART ROUTES

Users can communicate with context-aware recommendation system by smart route mobile app that available in google store. This app used to view real weather data and air quality estimation form Catalan air –quality monitoring system.

i) Users can log into this app from home screen; we can view the closest route, specific route, top route. We need to create a route by checkpoints while walking.

ii) The app menu shows the users check and maintain their records from various route sessions and update users' health condition.

iii) The user is required to review whether and air quality formation in routes.

iv) The user needed to provide feedback regarding app (Like suggest in changing color and offer quality information).

v) Once the user selects a route, that application will display the starting point and destination point.

vi) Distance, duration, speed, alert and change in route. vii) The user can send an alert message regarding issues in route. Finally, the app shows an overall statistical collection during the process of sessions that utilized by users.

Dataset	Users	Routes
Tarragona	2000	11
Barcelona	10000	28

Table 1: Description of dataset in term number of users and route

VII. EXPERIMENT RESULT

To demonstrate this approach can perform two datasets from different cities like Tarragona and Barcelona datasets. The Tarragona dataset consists of 22 routes and, 2000 user and Barcelona dataset comprised of 28 routes and 10000 users in table 1. We construct the simulate users based on age and medical statistics form world health Organisation and world heart federation. User profiled based on health issues, and content aware recommendation rating routes depend on user's health report and features of routes. Further, we show technical documents: Implementation and validation of smart health applications [20]

By using those two datasets, we estimate our approach based on accuracy and robustness with sparse data. i) we perform for

10 to 50% of rating that stored in the datasets. ii) A predicate that evaluation by K –nearest neighbor approach. By employing this approach with $k=1$, while, we could have utilized large values of k using $k=1$ in decreasing the performance cost in practical. We also examine neighbors by using the Euclidean distance between used and control of same routes. Finally, estimating the MAE (mean absolute error) among original values and the value that procedure estimate.

From Tarragona datasets, we found that MAE of 12.20 with 10% of the undefined data and only 13.89 MAE with 50% of data. We know what percentage of unknown data is more, so it has an error, but still, it remains as low levels in satisfying the user preference.

In Barcelona datasets, MAE growing slow and value at a lower level. Hence it requires more referrals for more chances of identifying the similar users. Finally, we perform with the trial with 20 real users in Tarragona using the smart route to repository user preference and offer a recommendation. Being of small sample size, we find more difficult in identifying similarity users .when improving the amount of unknown data. A further recommendation showed accurate and more MAE below 17, 81 %. By comparing that two datasets, found that simulated data's are similar to those with real data.

VIII. CHALLENGES AND OPPORTUNITIES

i) Challenges

The concept of smart health performs independently in healthcare domain. The Certain parameter requires following by user in smart health namely technological, financial, logistic and psychological needs [8, 22]. Here some of the leading challenges that are examined and shown in smart health to overcome those things.

A) Multidisciplinary research interaction

Most of researcher and practitioners work in the same institution; it is more difficult to share knowledge among them that leads to interdisciplinary solutions. The concept of s-health based on communication and collaboration between many actors like government, researchers, physicians and practitioners to adopt common ground from starting the level, hence to neglect unnecessary design and over-spending.[21]

B) Sensor integration

One significant challenge facing during implementation process in which ambient intelligence is to help the sufficient account for co-existence of the heterogeneous system [21].It is performance based on topological and morphological dependence from the location at which it operates[21].Especially this statement will be right in case of dense urban locations, in which radio-electric affect provided by multipath propagation. In some scenario, body area network [23] has an element of complexity is added due to the impact of the human body presents in the wireless channel. Further privacy issues in urban sensing ecosystem need to address partially [24].

C) Big data management and cloud

In big general data classified into 3v's namely variety, velocity and volume. In a smart city, those 3v's plays a crucial role in the context of smart health. Variety- data collected by from sensors namely temperature, pollution, and allergens. Velocity-data needs to collect and examine in real-time offered by users. Volume-Large amount of data gathered from sensors has measured in every second. While managing large data's from real time, we are facing specific issues in storage and bandwidth. A particular way to approach this problem by including the cloud paradigm. Moreover, it will not be a direct method to implement this solution. Due to scalability has many implications for privacy, security, multi-tenancy, assess control, and so forth. Some more challenges in mining and analysis the large data with artificial intelligence and statistics communities.

D) Usability and human interaction

How the user will communicate with the city is still an open issue that needs to be solved. Design improved wearable, unobtrusive sensor, compactness, weight, autonomy, reliability is some problems need to be noted. To address those problems, we need succeed in smart cities and health.

E) Others

Further Postolache et al.[22] finds some more challenges in following pervasive healthcare such as financial constraints, the complexity of technical challenges, Organisation issue, a collaboration between entire stakeholders and describing the proper quality audit stage and culture process.

ii) Opportunities

Some open opportunities while developing new health-related application and services.[20,21]

A) Data collection, presentation, and analysis

Real-time data are gathered from patient and integrated with city data. Routes, health records are combined with data to define sensors, cameras, weather report, and forecasts.

B) Engaging patient and families in management

In smart health, users play a significant role in empowering and efficient in supporting the active user to maintaining their health. The system can use for medical data and offer guidance for action; habit made every day within the city. For example, smart health application may provide patients with storage issue with the best route by neglect areas consider as more atmospheric pollution.

C) Improving policy decisions

Smart health system may assist public health management. Both policies and decisions have personalized to the city, districts population, health hazards, climate, environment, and infrastructure. Most of the opportunities arise quickly due to mining data in associate with best public health decision making.

D) Epidemic control

Both smart health data and its methodology improve drastically due to its efficiency in detecting and access the epidemics. Location and actions can be used to identify essential new scenario during the epidemic, active finding areas for improving risk and optimal to maintaining a raging epidemic. Hence this methodology can employ to recognize and manage another unreasonable health risk like pollution radiation from industry.

E) Cost saving

The entire previous analysis, sector may have a significant effect on health care in reducing cost. Cost reduction may associate with improving the system efficiency in offering services. Optimized disease management and prevention may lead to decrease the unnecessary hospital view and sharp events from poorly maintained chronic patients. Moreover reduction time for action and efficient public health management may offer optimal result; meanwhile, it decreases cost worldwide

IX.CONCLUSION

Recommender system plays a crucial role in current medical research. Due to improvement in mobile technology and social network, it is effortless for the user to utilize recommender system efficiently. This paper describes regarding Content – ware recommender system in offering a personalized recommendation for exercise routes to people based on their health condition in which real-time data depends on the city they lived. Experiment analysis based on two datasets for estimating accuracy and robustness with sparse data. Most predominant used in medical research is K-nearest neighbors approach. It examines nearest neighbors by utilizing Euclidean distance between user and control of same routes. The system estimate based on a mean absolute error(MAE) between the original value and the value that procedure estimates. Finally, discuss challenges and opportunities play in context-aware recommendation system.

X. FUTURE ENHANCEMENT

We can perform with two types of users like i) one need to follow preference and other should avoid it. Long-term performance of data is from the user, smart city and health specialist to perform advantages of health activity in integrating with use of smart city information. We plan to offer more personalized recommendations using fusing data with information linked from EHR (electronic health record). We required integrating medical research to define the baseline information needed from history to improve recommendations based on other activity than proposed work.

REFERENCES

- [1] World Health Organization. (2013). Global action plan for the prevention and control of non-communicable diseases 2013-2020.
- [2] World Health Organization. (2010). Preventing Disease through Healthy Environments-Exposure to Air Pollution: A Major Public Health Concern.
- [3] Bogdanović, D., & Lazarević, K. (2014). Early Warning System and Adaptation Advice to Reduce Human Health Consequences of Extreme

- Weather Conditions and Air Pollution. In Handbook of Research on Democratic Strategies and Citizen-Centered E-Government Services. IGI Global.
- [4] Vos, T., Flaxman, A. D., Naghavi, M., Lozano, R., Michaud, C., Ezzati, M., & Abraham, J. (2013). Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis of the Global Burden of Disease Study 2010. *The Lancet*, 380(9859), 2163-2196.
- [5] Smith, J. C., Erickson, K. I., & Rao, S. M. (2015). Introduction to the JINS Special Issue: Physical Activity and Brain Plasticity. *Journal of the International Neuropsychological Society: JINS*, 21(10), 743.
- [6] Reiter, K., Nielson, K. A., Smith, T. J., Weiss, L. R., Alfini, A. J., & Smith, J. C. (2015). Improved cardiorespiratory fitness is associated with an increased cortical thickness in mild cognitive impairment. *Journal of the International Neuropsychological Society*, 21(10), 757-767.
- [7] Resnick, P., & Varian, H. R. (1997). Recommender systems. *Communications of the ACM*, 40(3), 56-58.
- [8] Solanas, A., Patsakis, C., Conti, M., Vlachos, I. S., Ramos, V., Falcone, F., & Martínez-Balleste, A. (2014). Smart health: a context-aware health paradigm within smart cities. *IEEE Communications Magazine*, 52(8), 74-81.
- [9] CERÓN-RIOS, G., LÓPEZ, D. M., & Blobel, B. (2017, May). Architecture and User-Context Models of CoCare: A Context-Aware Mobile Recommender System for Health Promotion. In *PHealth 2017: Proceedings of the 14th International Conference on Wearable Micro and Nano Technologies for Personalized Health 14–16 May 2017 Eindhoven, The Netherlands* (Vol. 237, p. 140). IOS Press.
- [10] Kaur, E., & Haghighi, P. D. (2016, November). A Context-Aware Usability Model for Mobile Health Applications. In *Proceedings of the 14th International Conference on Advances in Mobile Computing and Multi-Media* (pp. 181-189). ACM.
- [11] Costa, A., Guizzardi, R., Guizzardi, G., & Pereira Filho, J. G. (2007). CORES: Context-aware, Ontology-based Recommender system for Service recommendation. In *Proceedings of the 19th international conference on advanced information systems engineering (CAiSE'07)* (pp. 11-15).
- [12] Ilarri, S., Hermoso, R., Trillo-Lado, R., & Rodríguez-Hernández, M. D. C. (2015). A review of the role of sensors in mobile context-aware recommendation systems. *International Journal of Distributed Sensor Networks*, 11(11), 489264.
- [13] Pramanik, M. I., Lau, R. Y., Demirkan, H., & Azad, M. A. K. (2017). Smart health: Big data enabled health paradigm within smart cities. *Expert Systems with Applications*, 87, 370-383.
- [14] Schäfer, H., Hors-Fraile, S., Karumur, R. P., Calero Valdez, A., Said, A., Tarkanian, H., & Trattner, C. (2017, July). Towards Health (Aware) Recommender Systems. In *Proceedings of the 2017 International Conference on Digital Health* (pp. 157-161). ACM.
- [15] Rashidi, P., & Mihailidis, A. (2013). A survey on ambient-assisted living tools for older adults. *IEEE Journal of biomedical and health informatics*, 17(3), 579-590.
- [16] Lukowicz, P., Pentland, S., & Ferscha, A. (2012). From context awareness to socially aware computing. *IEEE pervasive computing*, 11(1), 32-41.
- [17] Zambonelli, F. (2012). Toward sociotechnical urban superorganisms. *Computer*, 45(8), 76-78.
- [18] Resnick, P., & Varian, H. R. (1997). Recommender systems. *Communications of the ACM*, 40(3), 56-58.
- [19] Su, X., & Khoshgoftaar, T. M. (2009). A survey of collaborative filtering techniques. *Advances in artificial intelligence*, 2009, 4.
- [20] Casino, F., Patsakis, C., Martínez-Balleste, A., Borrás, F., & Batista, E. (2017). Technical Report: Implementation and Validation of a Smart Health Application. ArXiv preprint arXiv: 1706.04109.
- [21] Casino, F., Patsakis, C., Batista, E., Borrás, F., & Martínez-Balleste, A. (2017). Healthy Routes in the Smart City: A Context-Aware Mobile Recommender. *IEEE Software*, (6), 42-47.
- [22] Postolache, G., Girão, P. S., & Postolache, O. (2013). Requirements and barriers to pervasive health adoption. In *Pervasive and Mobile Sensing and Computing for Healthcare* (pp. 315-359). Springer Berlin Heidelberg.
- [23] Jovanov, E., & Milenkovic, A. (2011). Body area networks for universal healthcare applications: opportunities and challenges. *Journal of medical systems*, 35(5), 1245-1254.
- [24] De Cristofaro, E., & Di Pietro, R. (2013). Adversaries and countermeasures in privacy-enhanced urban sensing systems. *IEEE Systems Journal*, 7(2), 311-322.