Recommender System in internet of things: An overview with their challenges

[1]Partibha Ahlawat, [2]Dr.Chhavi Rana,

[1]Research Scholar, [2]Assistant Professor

[1,2]Department of Computer Science and Engineering,

U.I.E.T, Maharshi Dayanand University

Abstract

IoT (The Internet of Things) is a rising network that interconnects the things to create applications and services in various types of application spaces for example, wellbeing observing, sports checking, to upgrade retail administrations, agriculture monitoring, smart cities, education etc. Recommendation techniques can help the Internet of Things with suggestions of the relevant objects to enhance the efficiency and autonomy. In this article, an overview of existing recommendation advancements in the Internet of Things is given with some new advanced recommendation techniques to solve genuine world IoT situations.

Keywords: Recommender System, Internet of Things

1. Introduction

Recommender system is the information prediction system which predicts information by considering prioritization, personalization and preferences from the overloaded dynamic information. Recommender System can be defined as the information filtering system that recommends the interesting or useful items and objects by user preference. Recommendation technologies are applicable in many application domains like e-commerce, social networking, scientific libraries, mobiles based applications and are delivering valuable reverberation.

There are many recommendations techniques like collaborative filtering, content-based filtering, hybrid recommendation. Most commonly used collaborative filtering recommendation technique is based on the similarity of user's interest and preferences and useful in many application areas like GroupLens, Amazon and Ringo. Content-based filtering (cognitive filtering) recommendation technique recommends the item by comparing the used one with the new one. Domain-dependent algorithms are used by content-based filtering techniques that emphasize on the analysis of item attributes for predictions. There are some problems associated with collaborative filtering technique (cold start, scalability, data sparsity, synonymy) and content-based filtering (limited content analysis, content over-specialization) that can be overcome by hybrid filtering techniques which is the combination of collaborative filtering and content-based filtering. Hybrid filtering techniques are further categories in to weighted hybridization, switching hybridization, cascade hybridization and mixed hybridization.

Beside aforementioned recommendation techniques there are some more recommendation approaches like knowledge base recommendation, utility based recommendation, group based recommendation. The recommender systems based on knowledge techniques uses explicit knowledge, rules and constraints about item and user preferences. Utility based recommendation techniques uses the concept of multi-attribute utility theory (MAUT).Group based recommendation techniques consider the interest and preferences of the group rather than a user.

Recommendation process includes information collection phase, learning phase and prediction or recommendation phase. Information is collected either by explicit feedback or by implicit feedback in information collection phase. Learning phase applies learning algorithm to exploit and to filter the user preferences or items attributes. Prediction phase recommends the items or objects that are filtered on the basis of information collection phase. Recommendation algorithms can be evaluated by accuracy and coverage metrics. Accuracy metrics is further divided into statistical accuracy metrics and decision support accuracy metrics.

Recommender system is the information retrieval system that solves the information overloaded problem and provide new opportunities to retrieve personalized information.

IoT(Internet of Things) is the developing platform which visualizes a framework where all the devices can be interconnected irrespective of their applications. By extending the internet connectivity to the physical devices, IoT gives the remarkable contribution in many application domains like smart cities, smart homes, health monitoring, wild life monitoring, e- commerce , transportation, building and home automation, manufacturing, agriculture, metropolitan scale development, energy management, environment monitoring etc. Hence, it is the hybridization of the physical network (hardware) and cyber network (software). In the future, Internet of Things will become a worldwide hybrid network with nondeterministic nature and leads to the connection with 30 billion devices by 2020. With the technologies of auto-organized or intelligent entities and virtual objects Internet of Things will be act independently depending on the environment, context information and current circumstances. Future IoT products and IoT solutions use a variety of modern technologies to support context aware automation and intelligence. The architecture of IoT system consist of three layers: layer 1st device, layer 2nd the end gateway, layer 3rd cloud enabled device consisting of network joined things like sensor or actuator found in IoT equipments and use the protocol like modbus, zigbee, BLE, Lora, 5G to interconnect the IoT end gateway path. That the IoT gateway is the combination for the hardware and software whose primary motive is to enables device with device and device to cloud communication. IoT gateway positioned near to devices or at the edge is responsible for the execution of the services and composed of a device manager, protocol manager, application manager, data manager as in Fig1. Enhanced IoT Gateway also have adding functionality like auto configuring and recommending technique which help user at configuring of gateway and in recommendation of helpful services, automatic rules, apps, IoT devices, protocols based on gateway settings and users preferences and priorities.

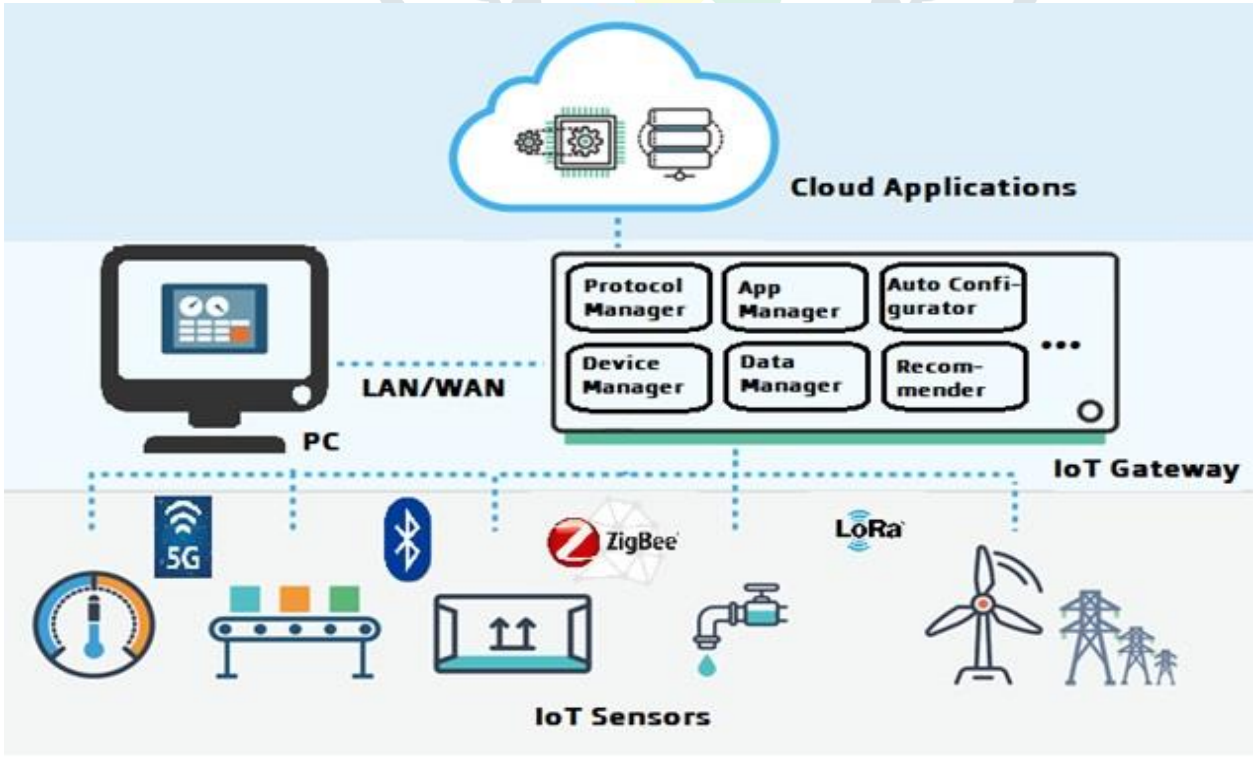

Fig. 1 Building environment of the IoT platform

The third layer clouds serves to increase efficiency in everyday task and to provide a pathway to travel the massive amount of data generated by the IoT devices. The benefit of the cloud computing for the Internet of Things is that it enables better collaborations which are essential for today's developers by allowing storage and access of data remotely. Rest this paper is composed as: Section 2nd consists how recommendation techniques are helpful in IoT, Section 3 involves the Literature Survey, Section 4 describes the challenges involved in the recommendation techniques due to dynamic and heterogeneous nature of IoT and in the last section the conclusion is given.

2. Recommender System and IoT

Recommendation technologies and IoT can be integrated for enhancement and betterment for both the fields by taking advantages of each other positivity. IoT is the one of the biggest contributor for dynamic and heterogeneous data. Recommendations technologies can take the benefits by the IoT generated data for improvement of their prediction quality and can lead to a new era of recommendation technologies with better understanding of individual user preferences and priorities. On the other hand recommender systems are helpful in IoT for an adaptive and modular advanced gateway(AGILE Project). Recommendations technology can benefit to recognize similar artifact in the IoT context and can establish any of major key technology in the upcoming IoT solution. Existing traditional recommendation techniques needs some improvisation to fit in the IoT context, that leads some challenges that should be sorted so that IoT can use recommender system for their ameliorate.

When we talk about the recommendation systems with respect to IoT, they essentially suggest for the items & objects of relevance. The examples of such systems in the landscape of IoT include instances such as- the applications to be installed on a gateway, the info texts that are meant to be portrayed on the public displays, additional devices to be managed and deployed on a gateway, similar information sending protocol with an objective for completion of any particular task on the gateway, and similar software & hardware component which can inculcated on the top-ramp IoT services. The upcoming applications of the recommender systems in IoT arena is the recommendation of workflow, the recommending technique in the case customized in-store shopping outlines (for example- on the basis of customer position in a actual store, deciding products for recommendation), recommending any of eatable things, as well as health monitoring (depending on the prevailing physical conditions and eating behavior of a person, the recommendation of sports exercises and food items). In a major part of these scenarios, the flexible IoT gateways play the most crucial role. The recommender systems can primarily used along several purposes in order to help IoT arena. Moreover, it validates the theory of how recommending technique of content-based filtering, collaborative filtration, group recommendations, and knowledge-based recommendation can be implemented for supporting IoT context based conditions. Nevertheless, there are also various circumstances where the basic recommendation technologies are made extensible so that they can be able to handle complex items. Figuring out appropriate recommendations in such complex scenarios also demands personalized search methods and their applications that can help in predicting the relevant components for the users. In area of deploying complicated recommender systems for IoT configuration, optimal searching mechanism need to be improved which can permit personalized & efficient searching solutions even though they are resistant with the complex & huge configured knowledge basis.

2.1 Basic recommendation technologies in IoT

Collaborative filtering: Collaboration filtering technique depends upon the plan of finding the resembling users by nearest neighborhood method or latent factor methods by comparing the rating given by them. There are also some unified models that combine the nearest neighbor and latent factor method both.

Content-based filtering: It differentiates the things of already used things with the fresh items that needs recommendation. This is based on domain-dependent algorithms and applies when resemblance across text information's can be collected for example recommendation of web pages, publications and news.

Utility-based recommendation: Depending upon multi attributing utilization theory the ranking of the item to be recommended is determined. This recommendation technique comes under the knowledge-based recommendation.

Group -based recommendation system: This procedure depends on the possibility that suggestions are not decided for a solitary client but rather ought to be happy with the entire gathering. Suggestions in this setting are regularly decided based on collective choice heuristics. For instance, least hopelessness is a heuristic that inclines toward proposals with the property that the wretchedness of all gathering individuals is limited. Likewise with regards to aggregate recommender frameworks, half and half methodologies can be created, i.e., singular gathering suggestion heuristics can be joined with one another.

Hybrid recommendation: By combining the basic recommendation technologies that are described above a hybrid recommendation technique can be built that compensate the disadvantages of each other. In internet of things it is the better recommendation technique than simple basic recommendation technique by taking care of the challenges like homogeneity, scalability and distributed environment.

2.2 Advanced recommendation technologies in IoT

Sequence Based Recommendation: This technique is used where the recommendation of new item depends upon the sequence of past recommendable items and is based upon the sequence based pattern mining. Sequence based design mining is utilized to know the sequence based pattern on the decisions of previously recommendations. There are various algorithms to find such patterns and that are helpful to analyzing user behavior by finding the sequential patterns.

Recommendation technique for complex items: All the aforementioned recommendation techniques are used for simple item recommendation, however in IoT there us a need for recommendation of complex items like recommendation for configurations to enhance running time output of configuration. We can develop a configuration recommender to enhance the outcome of Constraints Satisfaction Problem solved with help of recommendation technique of heuristic information.

Recommending diagnoses: There are recommendation techniques that support in the inconsistent situations called recommendations for diagnoses helpful for settling irregularities viably as far as runtime and exactness. In learning based design, seek interfaces need the particular of prerequisites and show an answer if the necessities are reliable with the suggestion information base. Be that as it may, as a rule the arrangement does not exists for a given arrangement of prerequisites and the client needs backing to turn out this circumstance. In this specific situation, conclusions can be prescribed that assistance to settle irregularity.

3. Literature Survey

Erdeniz et al. proposed an enhanced recommendation system approach in IoT enables mobile applications in the area of Quantified-self(self-data tracking) for personalized healthcare services. The users get recommendation for updated active plan, IoT dependabe mobile health device, application, health based nutrition which enhance the user to enhancing their life. These recommendation act like a virtual coach and a virtual nurse. In first case collaboration recommendation technique is used by identifying k-nearest neighbours and in second case content based recommendation technique is used to recommend updated activity plan depending upon real and assumed measurement. This work can be extended by detecting difficulties in Quantified own activity plan and give recommendation to interested user and physician.

Hamlabadi et al. explain a structure for intellectual recommender framework in IoT that can learn and improve its execution while working in another condition by taking the assistance of dynamic and conveyed nature of IoT condition. This structure comprise of three layers necessity layer, psychological procedure layer and thing framework layer. Necessity layer portray the objective and conduct of the system by a

Cognitive Specification Language (CSL). In the Things System Layer (TSL), the things sensors and proposal list are assigned dependent on nearby arrangements of the things in the IoT. The Cognitive Process Layer(CPL) is executed utilizing the intellectual motor lived in the subjective recommender motor. This structure is the principal system dependent on intellectual frameworks for the recommender frameworks in the IoT. In this system, the recommender motor watches the things sensor. At that point, the data about clients and things are utilized to fathom client/thing forecast issue. This structure can be a reference structure for future research in the field of the recommender frameworks. The proposed structure was contrasted and other existing arrangements as for four measurements general purpose, cognitive, flexible, information sharing.

Salman et al. introduced a proactive multi-type context aware recommender system - that pushes recommendations to the user without explicit request according to the current situation in the research area of recommender system in IoT. Generally recommender frameworks are consolidating setting and social data of the client, creating setting mindful recommender frameworks. Later on, they will utilize certain, neighborhood and individual data of the client from the Internet of Things; where anybody and anything will be interconnected at whenever and anyplace. In Internet of Things, and the development of proactivity idea prompts this framework plan, where a multi-type as opposed to one sort of suggestions will prescribe diverse kinds of things proactively under the Internet of Things. Here, setting mindful administration framework utilized a neural system that will do the thinking of the setting to decide if to push a suggestion or not and the kind of thing to be prescribed.

Forestiero et al. purposed a a multi-agent algorithm that uses decentralized and self sorting out technique to assemble a conveyed suggestion framework in IoT condition. Things are spoken to through piece vectors, the thing descriptors, got through a territory saving hash work that maps comparative things into comparable piece vectors. Digital operators deal with the thing descriptors and trade them based on specially appointed likelihood capacities and helps disclosure and suggestion tasks quicker. Exploratory examination demonstrates that the calculation accomplishes a viable redesign of thing descriptors and the empowering execution.

Kang et al. magnifies about the Social Internet of Things Environment suggesting Social correlation group based Recommender System (SRS). SRS helps out for a similar interest havinf group of people for the proposal and getting views in any regard for any Social IoT services. It attribute data for specific required information for upcoming adaptive service. Thus establishment of social relationship for connected devices other than humans and further increasing the interaction using collaborative filter with content base recommending system, moreover can help out for the medical services and roaming across.

Baltrunas et al. emphasis for Context Aware Recommender System using specific situation where using items. It will help for lowering computation expense. Most fertile technique was Tensor Factorization helping the best prediction by data analysis of contextual information. This also helped out for the beneficial effect against the data available depending upon the domain.

Debnath et al. proposes a hybridization of collaborative filtering along content based recommendation system based on importance for users calculating their social network graph with similarities of items by regression analysis combining sparse regression and isometric projection.

Mashal et al. identifies services such as self monitoring healthcare and environment monitoring using graph based recommender system. It is important in the aspects of IoT for user base available to assign the required services concluding smart homes, smart cities, agriculture, etc. It proposed weighted nondirected tripartite diagram depending model having weight spread technique suiting services in IoT.

Frey et al. refers to selling of any physically available object with the help of noting up the requirement with the help of applications in any Smartphone. Even the smart lights, TV, coffee maker are easily operated in this manner. Digital inventory helps out further creation of need too by analysis of the data history choice. Revolutionary thing was barcode scanning app foe mobile to know details about the object without being electrically functional.

Valtolina et al. impressively showed details of multilevel recommendation system for analyzing the mass data and accounting it for decision making process easy by implementing with the social and crowd sourcing data analysis tools. This takes things by identifying, extracting, visualizing, and understanding useful information from big data with the help of multi level recommendation system. Further implementation of it is in data mining, machine learning and granular computing of decision tree algorithm.

4. Challenges

Gateway Automony: Recommendation Techniques in IoT need the additional information outside of the local gateway and also need the cloud based applications for implementation. If the gateway have basic functionalities then it can implement the recommendation techniques even if the network and internet connections are unavailable.

Expandability of algorithm: In certain situations, suggestion calculations can be sent in the cloud which has no genuine restrictions with respect to computational assets. Normal instances of such a setting are the suggestion of IoT applications and the proposal of work processes yet proposal functionalities that help the errand of asset adjusting or functionalities supporting the reconfiguration of a portal establishment ought to be found straightforwardly on the entryway and should work for the situation that the door isn't associated with the Internet. If the IoT gateway acquire the autonomy then the existing algorithm should also modified to stand with the limited resources and information.

Evaluation using Dataset: The improvement of recommendation system for IoT situations is a fairly youthful control and forecast nature of the proposal can be accomplished by the accessibility of more IoT datasets. With regards to end-client advancement support in IoT situations, datasets are useful that incorporate logs about the improvement of IoT work processes on remote portal establishments. The gathering of IoT informational collections that are dynamic and conveyed is extremely an intense and tedious occupation.

Distribution of data analysis: The dispersed idea of the Internet of Things and relating high measures of gathered information is a test for existing information examination strategies. As contrast with huge information investigation the parallel and superior processing examination approaches in IoT situations are frequently restricted because of the constrained data transmission and vitality supplywhich results in decentralized calculations.

Context sensitive recommending approach: Contrasted with conventional setting based proposal approaches, IoT situations increment the quantity of applicable setting measurements. For instance, in gathering based situations (e.g., a gathering of vacationers intrigued things to be suggested (e.g., traveler goals) yet in addition to extra measurements, for example, data about potential congested driving conditions, climate conjectures, inhabitance rates of goals, and accessibility of open transport (just to make reference to a couple). Every one of these perspectives must be considered when building proposal arrangements which additionally requires the reconciliation of information sources. Suggestion and setup innovations supporting the increase of IoT frameworks need to consider extra angles, for example, topological data important for the IoT condition (e.g., on account of creature observing applications) and natural information (e.g., with regards to air contamination checking). Such perspectives are not applicable in increasingly conventional suggestion and setup situations.

Relationship diversity: The heterogeneous connections and interdependencies between elements (individuals and things), information, data, and learning in the IoT are developing exponentially, prompting intricacy and gross wasteful aspects. Inability to recognize the different sorts of relations may result in off base proposal results.

Dynamic nature: The recommendation algorithms that are vulnerable in nature can suddenly modify their state with the continuously changing position of things will always present remarkable recommendation results, but the formulation of such algorithms is a challenging task. Hence the dynamic nature of the IoT environment is the major challenge to resolve.

Spatiotemporal correlated: The two main factors that affect recommendation conducted on things are characteristically related to both space and time and the divergent nature of spatiotemporal information is a major challenge for suggestions techniques in IoT scenario. The collection and the design of analytical approaches for such data is the big challenge as compare to the traditional recommendation algorithms.

Incomplete description. Generally the traditional algorithms are associated with the textual information but in IoT scenario, there is no scope of gaining the textual information and if it is possible than information will be ambiguous and incomplete. To describe the things categories, social tags, time and space tradeoff is used that is different from the textual information on which basic recommendation algorithms works.

5. Conclusion

With the help of this review paper, first we give an introduction how existing recommendation techniques can relate with the Internet of Things (IoT). By introducing recommender systems and IoT world and some existing basic recommendation techniques, we explain how the recommendation can enhance the services of internet of things. Some advanced recommendation techniques are also discussed that seems to be applicable to the IoT scenarios .Last section describe the challenges faced by recommendation techniques in the context of Internet of things. In this work, we analyzed that recommendation technologies are helpful for the extension of the flexibility and autonomy of IoT services.

References

1. Alexander Felfernig, Seda Polat-Erdeniz, Christoph Uran ,Stefan Reiterer, Muesluem Atas, Thi Ngoc Trang Tran, Paolo Azzoni2 , Csaba Kiraly, Koustabh Dolui, *An overview of recommender systems in the internet of things*, Springer, Journal of intelligent information systems, 2018.
2. Ahmed Al-Nazer,Tarek Helmy, Mohammed Al-Mulhem, *User's Profile Ontology-Based SemanticFrameworkforPersonalizedFoodandNutritionRecommendation*,Elsevier,Egypyian Imformatics Journal,2015.
3. Alexander Felfernig, Seda Polat Erdeniz, Michael Jeran, Arda Akcay, Paolo Azzoni, Matteo Maiero, Charalampos Doukas, *Recommendation Technologies for IoT Edge Devices*,Elsevier, The 3rd International Workshop on Internet of Things: Networking, Applications and Technologies (IoTNAT 2017).
4. Souvik Debnath, Niloy Ganguly, Pabitra Mitra, *Feature Weighting in Content Based Recommendation System Using social Network Analysis* (2008) ACM.
5. Seda Polat Erdeniz, Ilias Maglogiannis, Andreas Menychtas, Alexander Felfernig and Thi Ngoc Trang tran, *Recommender Systems for Iot Enabled m-Health Applications*,2018
6. Kamran Gholizadeh HamlAbadi, Ali Mohammad Saghiri, Monireh Vahdati and Mehdi Dehghan Takhtfooladi, *A Framework For Cognitive Recommender Systems in the Internet of Thing*,Universal Scientific Organization,2017.
7. Yasmeen Salman, Abdallatif Abu-Issa , Iyad Tumar, Yousef Hassouneh, *A Proactive Multi-Type Context-Aware Recommender System in the Environment of Internet of Things*,IEEE,2015.
8. Agostino Forestiero, *Multi Agent Recommendation System in Internet of Things*,IEEE,2017.

9. James Davidson,Benjamin LieBald, Junning, *The Youtube video Recommendation System*, ACM,(2010).
10. Mario Munoz-Organero, Gustavo A. Ramirez-Gonzalez, Pedro J. Munoz-Merino and Carlos Delgado Kloos, *A Collaborative Recommender System Based on Space Time Similarities*,IEEE (2010).
11. LInas Baltrunas, Bernd ludwing, Francesco Ricci, *Matrix Factorization Technique for Context Aware Recommendation* ,ACM,(2010).
12. A. Felfernig, R. Burke, *Constraint-based recommender systems: Technologies and research issues*, in: ACM International Conference on Electronic Commerce (ICEC08), Innsbruck, Austria, 2008, pp. 17–26.
13. S. Valtolina, M. Mesiti, B. Barricelli, *User-Centered Recommendation Services in Internet of Things Era*, in: CoPDA2014Workshop, Como, Italy, 2014.
14. M. Munoz-Organero, G. Ramirez-Gonzalez, P. Munoz-Merino, C. Loos, *A Collaborative Recommender System Based on Space-Time Similarities*, IEEE Pervasice Computing 9 (3) (2010) 81–87.
15. R. Frey, R. Xu, A. Ilic, *A Novel Recommender System in IoT*, in: 5th International Conference on the Internet of Things (IoT 2015), Seoul, South Korea, 2015, pp. 1–2.