Recommender System using Knowledge Graph and Ontology: A survey

*Warisahmed Bunglawala [1], Dr. Jaimeel Shah [2], Prof. Darshana Parmar [3]

* [1] Parul Institute of Engineering and Technology, Vadodara, India.
*warisahmedb@gmail.com
[2] Parul Institute of Engineering and Technology, Vadodara, India.
jaimeel.shah@paruluniversity.ac.in
[3] Parul Institute of Engineering and Technology, Vadodara, India.
darshana.parmar2809@paruluniversity.ac.in

Abstract. In recent years, Users find it challenging to choose what interests them among the many options offered due to the abundance of information. And finding those choices from data itself has also becomes very challenging task for organizations. To handle this task, recommendation system is an important field of research in computer science. Despite several efforts to make RS more efficient and personalized, it still faces issues like cold start, data sparsity etc. And as it is designed to be readable by humans only, computer cannot process nor can interpret the data in it. Ontology facilitates the knowledge sharing, reuse, communication, collaboration and construction of knowledge rich and intensive systems. Adding semantically empowered techniques to recommender systems can significantly improve the overall quality of recommendations. There has been a lot of interest in creating recommendations using knowledge graphs as a side information. By this, we not only overcome the issues of traditional RS but also provide a flexible structure, which naturally allows integration of multiple entities all together. It is also helpful in explanation for recommended items. So, in this survey we collected recently published research papers on this particular field to enhance Recommender system, we provided a fine-grained information on this topic. Certain crucial datasets and tools are also offered for a better understanding of accessibility.

Keywords: Recommender system, Knowledge Graph, Ontology, top-down approach, bottom-up approach, challenges in KG, challenges in RS.

1 Introduction

The rapid progress of digital technology has resulted in a massive increase in data. Data is generated in large quantities on social media platforms like Twitter, Instagram, and Facebook. Furthermore, research and publications are also increasing day by day [15]. with this advancement of the data, it brings advantages and disadvantages both. Advantage can be described as we have a lot of data available within

adfa, p. 1, 2011.

seconds. Disadvantage can be stated as abundance of data has increased and due to that we are unable to get most relevant and required information.

To overcome this disadvantage recommendation system has been developed and still in research trend. A recommendation system is a type of information filtering system that attempts to predict a user's "rating" or "preference" for an item. The task of a recommendation system can be divided into two parts: (I) estimating a value of prediction for an item; and (ii) Recommending users about items [15]. To accomplish this objective, there are a variety of ways available, the most frequent or popular of which being Content-based Recommendation Systems and Collaborative Recommendation Systems. Hybrid Recommendation System is also developed by merging those techniques [15][9][16]. Recommendation systems require constant change because of the exponential growth of data and knowledge.

In recent years, introducing a knowledge graph as a side information in recommendation system has attracted a lot of researchers and organizations [1][5]. First Knowledge graph is introduced by goggle in May 2012 [4]. There are lot of definition on knowledge graph is available according to its usage. For ease of comprehension A knowledge graph is a heterogeneous graph in which the nodes represent entities and the edges reflect relationships between them [9]. Knowledge graph has the advantage of having a flexible basic graph structure and providing a model of how everything is connected. In this way knowledge graph is of great use in RS as side information and to help with explanation and integration of large data.

Ontologies are the foundation of a knowledge graph's formal semantics. They can be thought of as the graph's data schema. They serve as a formal contract between the knowledge graph's creators and its users over the meaning of the data included inside it. A user could be another person or a program that needs to interpret facts in a reliable and exact manner. Ontologies ensure that data and its meanings are understood by everyone [17]. So, we can say that ontology represent structure or schema and it has power to rules and reasoning, while knowledge graph captures the data.

Motivation behind this survey is to state the latest research in the area of recommender system as it is very important field of research now a days and in upcoming future. And to handle the abundance of data that are generating now a days we need some common and more scalable structure to handle it, that is why concept of knowledge graph and ontology is considered. So, we reviewed some research and articles combining these technologies.

2 Background and Related Work

2.1 Concept of Knowledge Graph

Although some people have attempted to establish a formal definition of knowledge graph, none of them can be said the standard definition. The phrase "Knowledge Graph" can be interpreted in a variety of ways. As an alternative to the definition, the following features of a knowledge graph can be presented [18]:

- It primarily describes real-world things and their interrelationships in the form of a graph.
- In a schema, defines the classes and characteristics of entities.
- Allows for the possible interconnection of arbitrary things.
- Covers a wide range of topics.

As shown in the figure below, entity is a thing present in a real world while concept is something define as a collection of individuals which have a same characteristic. Literal can be defined as a nothing but a specific value or strings of some relations. And the edge between entity or concepts can be define as a relation. For example, Yao Ming is individual entity and Basketball is a concept as so many players out there play basketball such as Kobe Bryant and Stephan Curry. While yao ming height can be define as a ”2.29m”, so this specific value can be said literal and on other hand yao ming have a wife ye li so wife is a relation between those two entities.

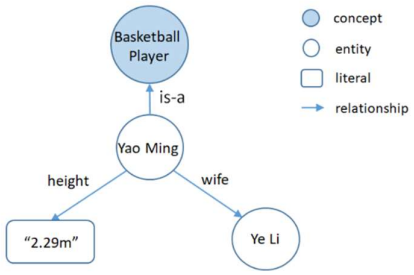

Fig. 1. Knowledge Graph [18]

It's worth noting that there are two sorts of knowledge in KG: schematic knowledge and factual knowledge [18]. Statements concerning concepts and qualities, such as (Asian Country, subClassOf(), Country), make up schematic knowledge. While factual information is made up of claims regarding specific situations, the triples in the graph above are all factual knowledge. The majority of the KG has a great quantity of factual information and a minor amount of schematic knowledge. The logical foundation of knowledge graphs is based on ontology languages such as Resource Description Framework (RDF) and Ontology Web Language (OWL), which are W3C-recommended creations (World Wide Web Consortium). RDF can be used to represent rich and complicated knowledge about entities, properties, and relationships, while Owl can represent both schematic and factual knowledge. So, using ontology as a basic logical foundation, a knowledge graph can be formed in one of two ways: bottom-up or top-down.

2.2 Literature Work

As we have reviewed latest work related to Recommender system using Knowledge graph and ontology, Various researchers have used various model and techniques. Some of the reviewed research and articles are mentioned below.

In paper [1] authors have mentioned MKR model for KG enhanced RS and within a short period of time one more research [2] mentioned extended MKR model. the system flow mentioned in the paper is, feature extraction - in this general feature are extracted using MLP layer and Text feature extraction is based on the Text CNN. After the feature extraction, recommendation module is there in that they have taken u and v where u is users and v are items as an input for this layer and predicted the probability of the user u engaging item v. after this knowledge graph embedding layer is there as a side information. And then cross compression unit is mentioned, in which two parts are there one is crossing part and another is compression part. Through cross-compression units, SI-MKR can adaptively adjust the weights of knowledge transfer and learn the relevance between the two.

In one research [3] authors applied a hierarchical design based on heterogeneous input features to recommendation systems to learn text features, behaviour features, graph structured featured, and spatio-temporal features from massive data. They introduced the classification model design of recommendation systems, which is divided into three layers: feature input, feature learning, and output layers. And they also mentioned the evaluation indexes like mean absolute error (MAE) and root mean square error (RMSE) for evaluating the RS. experimental comparison, and future development direction of recommendation systems are also mentioned.

paper [4] written by authors Jiangzhou Liu, Li Duan presents the basic knowledge of recommendation system and knowledge graph. After that they mentioned the key methods that used in the recommendation system with KG which includes path-based method, embedding based method and hybrid method further more they mentioned the user interest model, after that they have provided some basic future directions which include combination with graph neural network, enhanced representation of KG, KG completion and corrections. With same title paper [5] written by authors Qingyu Guo and others categorized recommendation methods based on knowledge graph into three categories: embedding based, connection-based methods and propagation-based methods and mentioned pros and cons on algo used in these methods. useful dataset is mentioned and categorized into different categories such as movies, books etc.

one of the detailed papers [6] mentioned KG based RS filtering approach into categories like ontology based, linked open database, embedding based and path based. in result they classified into two categories such as KG and semantic web and second is KG and AI methods. in first categories top 6 approaches mentioned some of them are KG and linked data, KGE and Ontologies, and in second category they compared different filtering approach and mentioned that hybrid system are most common. Future direction mentioned by the authors are interpretability of RS, explainable recommendation and KG based dynamic RS. In other paper [7] authors mentioned that there are two types of approach, bottom-up and top-down approach. Paper describes

bottom-up approach for knowledge graph creation. In that they first shown the architecture with different layers like knowledge extraction, Knowledge fusion, storage of knowledge graph and retrieval of KG has been described in details with their methods and tools available for it.

In one paper [8] authors created a scenic spot knowledge graph based on ontology, paper define the concept of ontology on why and how should we use ontology so that the purpose can be served is greatly explained in this paper. Also, they present architecture that includes steps like data gathering and ontology building, entity alignment and knowledge graph storage tool. They used neo4j for storage and mentioned that it is one of the great databases that stores structured data in the form of network. For the evaluation purpose they also describe precision and recall metrices. There model outperform the string similarity method.

In paper [9] authors mentioned that graph database is more efficient and expressive so they used a property graph. In that they represent a multi-layer graph model and constructed a knowledge graph and returned the various top end N recommendation. So, they mentioned 5-layer model in which layer 1 is for users and details, layer 2 is for needs, layer 3 mentioned features and related details while the layer 4 comprised of all nodes related to various items specifications and its associated details. The layer 5 comprised of all nodes related to various items and its associated details. The construction of layer 2, 3 and 4 can be carried out based of preoccupied knowledge. In the process a system model is defined as a combination of different recommendation techniques hence can be called hybrid model RS, so that more efficient top-N recommendation can be done.

In survey paper [10] along with review some great future directions are mentioned such as bringing in more side information into knowledge graph so that power can be enhanced, also connecting social networks to know how social influence affect the recommendation, explainable recommendation and GCN are also in trend.

for the purpose of explainable reasoning over KG for RS, one of the papers [11] has mentioned new model named KPRN- knowledge aware path recurrent network. Model allows effective reasoning over path to infer underlying rationale of user-item interaction. Also, they designed new weighted pooling operation to discriminate the strength of different paths in connecting users with an item. Datasets used in this paper relate to music and movie. They also used LSTM to capture the sequential dependencies.

In paper [12] authors describe the combination of ontology and collaborative filtering for mooc's recommender system. They mentioned basic components of personalized system as 1) techniques, 2) item and 3) personalization. Proposed method includes hybrid method as mentioned above and for computing similarity mooc's similarity extended cosine similarity used and for learners' similarity PCC is used. At last algorithm for generating recommendation is mentioned.

We also studied papers other than above, and some of that focuses on solving problems using KG related to covid-19 pandemic that worth mentioning. They are listed below.

- Cone-KG: A Semantic Knowledge Graph with News Content and Social Context for Studying Covid-19 News Articles on social media [13]
- Open Research Knowledge Graph: Next Generation Infrastructure for Semantic Scholarly Knowledge [14]
- COVID-19 Knowledge Graph: Accelerating Information Retrieval and Discovery for Scientific Literature [15]

3 Observation and Discussion

During survey we have read many recently published papers and articles and we find some very useful details which we present in this section as simply as possible. We explain some basic terms and challenges that one needs to understand for the work. And some of the useful dataset and tools are also mentioned to get started.

Most of the papers mentioned traditional algorithm as content based, collaborative and hybrid algorithm and then some personalized algorithm also mentioned such as demographic based, community based and knowledge-based algorithm. In knowledge-based algorithm some papers mentioned techniques or approach to achieve the recommendation using knowledge graph that are divided into four categories. For better understanding see the Figure-2 mentioned below. Among these categories ontology-based approach is popular due to the fact that it facilitates knowledge sharing, reusing and highly rich knowledge with semantics.

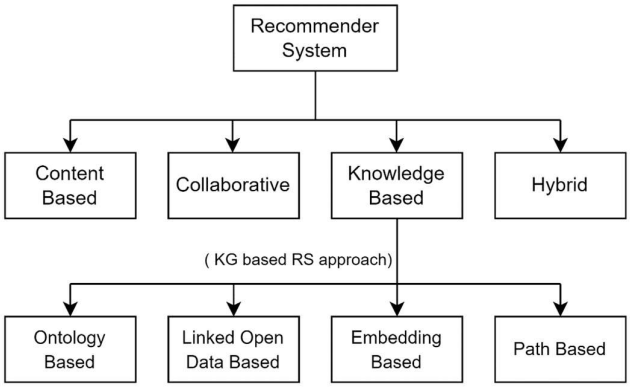

Fig. 2. Recommendation Techniques

3.1 Ontology-Based

While creating ontology-based knowledge graph two types of approach are there, top-down approach and bottom-up approach. None of these two methods is better than each other it's depends on the view of the developer. It may be easier for the developer to follow the top-down method if they have a more systematic top-down perspec-

tive of the domain. Or if they have better understanding at data level, they might follow bottom-up approach.

The combine technique, on the other hand, is easier for most ontology developers since it leverages the notion "in the middle," which is a more descriptive concept in domain ontology. For simplicity, we represent bottom-up architecture for KG using ontology just to understand the terms in overall process, as steps can be altered on base of approach developer use. To build an ontology, there are some useful software available which helps us in construction as well as in visualization of ontology, those are protégé, NeOn Toolkit, SWOOP, Neologism and Vitro [19].

In bottom-up approach, from Linked Open Data (LOD) or other knowledge resources, we extract knowledge instances. After knowledge fusing, to generate the entire KGs, the top-level ontologism is built using knowledge instances [7]. Bottom-up approach of KG is and iterative update process, which includes knowledge acquisition, knowledge fusion, knowledge storage and retrieval. for better understanding let us look at the following architecture of bottom-up approach.

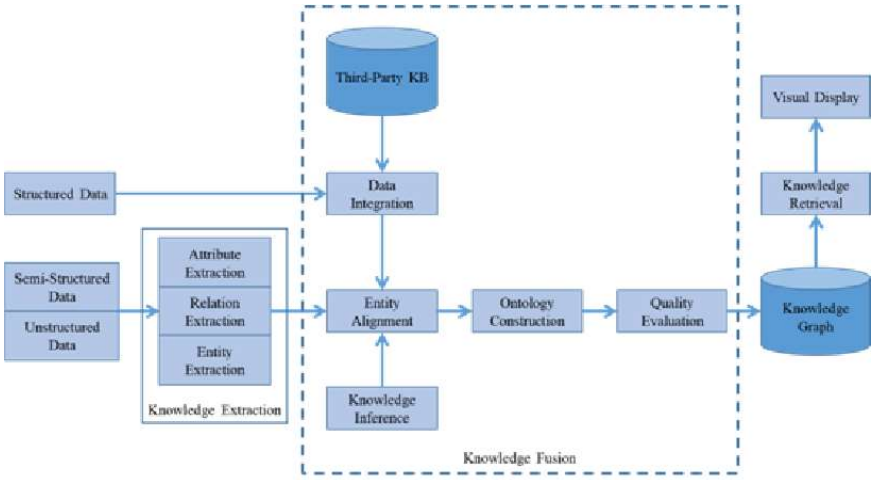

Fig. 3. Bottom-up approach for KG using ontology [7]

Structured data, unstructured data, and semi structured data are the three basic sources of knowledge acquisition, as shown in Figure 3. Attribute, relation, and entity extraction are all types of knowledge extraction. Following that, knowledge fusion can be defined as an iterative process in which we build the ontology and regularly review it for higher quality. NoSQL databases are more popular for storing and retrieving knowledge graphs.

In knowledge extraction, extracted knowledge is usually presented in machine readable formats such as RDF and JsonLD. There are many tools available for knowledge extraction depending on the needs and functions, some of them are Stanford NER, OpenNLP, AIDA, Open Calais and Wikimeta. While we can extract

knowledge from any sources such a website or any record and datasets available, now a days most of the instances extracted from DBpedia or Yago and Wikipedia. For semi-structured and unstructured data sources we need entity extraction, relation extraction and attribute extraction.

- Entity extraction is the process of identifying an entity from a large amount of data and categorizing it into predetermined categories such as person, place, or location.
- Relationships among those entities are analyzed after entity extraction to conceptually extract relations.
- Attribute extraction is to define the intentional semantics of the entity and it is important for defining the concepts of entity more clearly.

The purpose of knowledge fusion is to achieve entity alignment and ontology creation. And it is an iterative process. Entity matching is another name for entity alignment. The goal of entity matching is to determine whether or not various entities refer to same real-world object. It's worth noting that entity alignment typically relies on external sources like manually created corpora or Wikipedia links.

After that ontology construction and evaluation step is there, in that we create the ontology and constantly evaluate it for better performance of the application. To ensure the KG's quality, general ontologies such as FOAF and general metadata from schema.org are required. In terms of KG storage, it is often saved in a NoSQL database. There are two basic storage types: RDF-based storage and graph database storage. The benefit of using RDF is that it improves the efficiency of querying and merge-join for triple patterns. Better query results on the other hand, come at a high expense in terms of storage capacity. Some popular RDF based data storage is 4store, RDF Store, TripleT and so on, most of the native storage system provides SPARQL or similar like query languages. Graph-based storage, on the other hand, has the advantage of providing excellent graph query languages and supporting a wide range of graph mining methods. They do have drawbacks such as slow knowledge updates, expensive maintenance costs, and distributed knowledge inconsistency.

SPARQL is a popular query language for retrieving information, and practically every large-scale knowledge graph system has a SPARQL query endpoint. SPARQL generates output in JSON, JSON-LD, RDF/XML, XML, CSV, RDF/N3 and many more formats, with practically all of them being machine readable. Machine-readable forms necessitate visualization tools. the most popular of which are browser-based visualizations because some query returns formats are text-based. IsaViz, RDF Gravity, DBpedia Mobil, and Open Link Data Explorer are some of the most popular tools. Because ontology is based on description logic, knowledge retrieval is primarily based on logic principles.

3.2 Challenges in Recommender System

The most common issues or challenges associated with development of traditional recommendation system is cold-start, and sparse data [9][20].

Cold start problem can occur when system is unable to inference any information regarding users or item. This can happen when new user or the new item is added in

catalogue. In this situation we cannot predict the new user taste as no information is available. Furthermore, due to insufficient and erroneous findings, users are unable to rate or purchase the item. So, to avoid the cold start problem, numerous methods are suggested, including a) asking users to rate some items at the start, b) asking users to indicate their liking, and c) recommending items based on user demographic data. There may be sleepers in some circumstances; sleepers are items that are nice but not rated. We can manage this by employing meta-data or content-based solutions, such as item entropy, item personalization, or using Linked Open Data (LOD), which eliminates the need for consumers to supply explicit input.

Data sparsity can be understood as let's say we formed a cluster of similar data and we will recommend the product based on those cluster. Now as more and more variables included in dataset or we can say with huge amount of data, noise and uncertain data is also increased. In this situation data will be more uniform and we will struggle and we won't be able to do anything with those data. To overcome this issue many techniques like, multidimensional models, SVD techniques and demographic filtering can be used.

3.3 Challenges in Knowledge Graph

In knowledge graph most common challenges we can list out is knowledge completion, harmonization of datasets, Knowledge alignment [18][21].

Knowledge Completion: Incompleteness of knowledge graph is when there is a dashed line available in the graph or we can say that there appears to be a possible relationship between two entities from the solid facts. Completing a KG is a very challenging task for researchers and that is why knowledge embedding is an active research area in this field. The symbolic compositionality of KG relations is ignored by embedding-based techniques, which limits their application in increasingly complicated reasoning tasks. And to overcome this, several other approaches like multi-hop paths are developing [22]. So basically, due to the large amount of data and relations we can say that fraction of incompleteness in KG will always be there.

Harmonization Datasets: The ability to harmonize or integrate data from many sources is crucial to the creation of semantic knowledge graphs. However, different authors use different names to describe the same subject, which is a typical problem. As a result, it is possible to confuse one entity with another. We must use ontologies to tackle this difficulty since they give much more than just data harmonization. One of the functions of ontology is to provide a standard model of knowledge associated with a specific domain, as well as a common identifier that can be used to link it to other things in other ontologies.

Knowledge Alignment: Knowledge graphs have become more widely available on the Web in recent decades, but their heterogeneity and multilingualism continue to limit their sharing and reuse on the Semantic Web [9]. Basically, knowledge alignment is nothing but to discover the mapping (i.e., equivalent entities, relationships and others) between two KGs. Embedding and reasoning both can be used for these types of challenge but hybrid reasoning promises more encouraging result [9].

3.4 Available Tools and Dataset

As a data storage lots of database available to store knowledge graph and graph data. And most of the NoSQL databases are used to store the KG. Some are listed below [23][24][25].

Database Name	Link	Database Model
Neo4j	https://neo4j.com/	Graph
GraphDB	https://graphdb.ontotext.com/	Multi Model
CosmosDB:Azure	https://docs.microsoft.com/en-us/azure/cosmos-db/introduction	Multi Model
OrientDB	https://orientdb.org/	Multi Model
ArangoDB	https://www.arangodb.com/	Multi Model
Janus Graph	https://janusgraph.org/	Graph
Virtuoso	https://virtuoso.openlinksw.com/	Multi Model
Amazon Neptune	https://aws.amazon.com/neptune/	Multi Model
Stardog	https://www.stardog.com/	Multi Model
Dgraph	https://dgraph.io/	Graph

Table 1. List of Database

Also, there are many general as well as domain specific datasets available. Some of the popular general datasets are mentioned below along with few covid-19 datasets [23][24].

Dataset Name	Description
Kaggle: Cord-19 [26]	It has approximately 500,000 scholarly publications on COVID-19, SARS-CoV-2, and related to coronaviruses, with over 200,000 of them having full text.
CORONAVIRUS (COVID-19) TWEETS DATASET [27]	CSV files with the IDs and sentiment ratings of tweets about the COVID-19 pandemic are included in the collection. In real time, the Twitter stream is being monitored.
AYLIEN: COVID-19 [28]	Corona virus news datasets
WordNet [29]	Princeton University offers a free extensive lexical database of English [18].
YAGO [30]	Wikipedia, WordNet, and GeoNames have all contributed to this massive semantic knowledge base.
DBPedia [31]	DBpedia is a community-driven effort

	to extract structured content from the resources of different Wikimedia projects.
Wikidata [32]	It's a free, multilingual dataset that collects structured data to help Wikimedia Commons and Wikipedia.
Google KG [33]	There are millions of items in Google's Knowledge Graph that describe real-world entities.

Table 2. List of Datasets

4 Praposed Idea

Talking about the latest pandemic COVID-19 has claimed so many lives worldwide. And it increases the need for tools that enable researchers to search vast scientific corpora to find specific information, visualize connections across the data, and discover related information in the data. Several dedicated search engines have been built due to the need of information retrieval related to scientific literature on Covid-19. Search engines like Sketch Engine COVID-19, Sinequa COVID-19 Intelligent Search, Microsoft's CORD19 Search and Amazon's CORD19. However, this search engines return thousands of search result that overlooked the inherent relationships like citation and subject topics [6]. Also, they do not provide the tool to visualize relationships, which can be beneficial for knowledge discovery. So, we need the system that can be specifically used for knowledge discovery and information retrieval. Also, we need to use every unique data we can gather such as scientific data and social media data.

The motivation behind this study is to give a jump start and detailed information to researchers, who wants to pursue their research in this particular field. That's why study not only include basic information regarding system but also gives an overview on basic steps to follow for building the system. And study also include information available on datasets and tools that can be used. Also, this type of system can not only be used for ecommerce. But it can be majorly beneficial to the situation like Covid-19 where we want related data available within seconds for data discovery or in case of emergency.

To build this kind of system, proposed flow diagram is mentioned below. After getting enough information about both techniques, data gathering and data extraction depends on the system so in this case if we want to build a system for Covid-19 situation some useful available datasets are mentioned in previous section along with the details on buildiung knowledge graph using ontology.

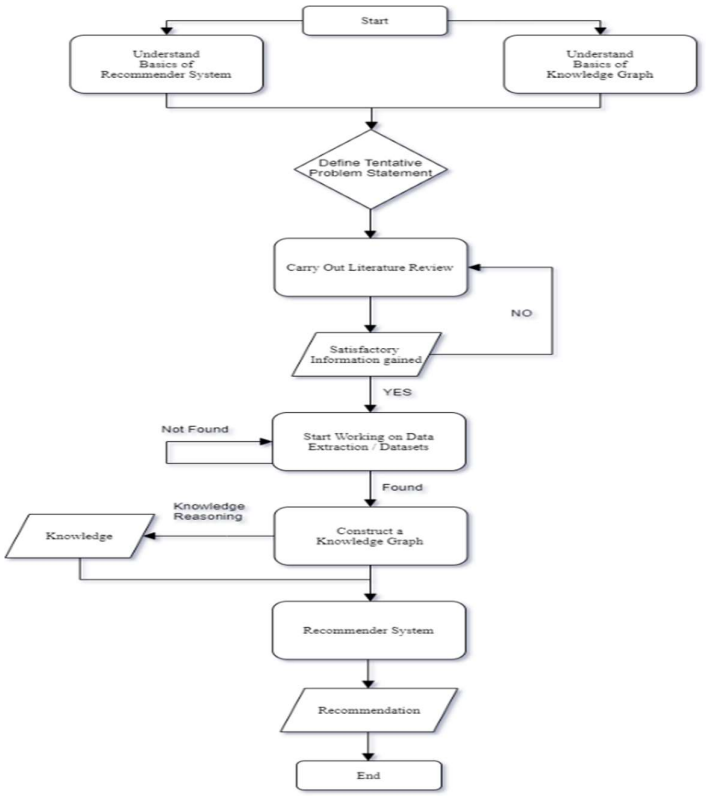

Fig. 4. Proposed Flow Diagram

5 Conclusion and Future Work

With a lot of data available we need a fine-grained recommendation system that can help us to discover knowledge as efficiently as possible. In situation like Covid-19 it can be very helpful to discover new knowledge and knowledge retrieval. Also, to enrich the recommendation system with knowledge we need a common structure. graph structure like knowledge graph can handle different types of data easily and efficiently. Therefor proposed system is using KG for RS and basic approach is mentioned to achieve this task based on ontology with some techniques. Also, some popular databases and datasets that are available is mentioned along with some Covid-19 datasets that can be helpful in the situation of pandemic.

For future work we can construct a generalized KG using these techniques, which can be used for Covid-19 scientific literature and/or social media recommender system to help in situation of pandemic. Also, this paper can also be used as a reference for creating similar applications with different goals and datasets based on ontology.

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