A Survey on Community Detection Algorithm and Its Applications

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Abstract- Modern network science has made great improvements in the analysis of a large dynamic world. The existence of a community structure is one of the most prominent factors in these networks. Many algorithms have been proposed to detect structural characteristics and dynamic behaviour of networks over recent years. In this paper, present such a detailed study of recent community detection algorithm techniques such as clustering, modularity, dynamic, overlapped, etc based on various factors and their task in the analysis of the social network. Community detection enables us to evaluate participants with mutual interests or to discover a set of similar people on the basis of an area of interest, proposed a node influence k-nearest neighbours (NI-KNN) algorithm for detecting the community. Community detection is useful in many applications such as Recommendation Systems, Health care, politics, economics, e-commerce, social media, communication network, etc. A comparative analysis of different methods of community detection is also reported.

Keyword- Community Detection, Clustering, Modularity, Dynamic, Overlapped Community Detection.

1. Introduction

Nowadays, every individual can text, audio, video, and image to any number of friends they choose on the Internet, thanks to social networks. As a result, the amount of information have on the internet is increasing rapidly; as a result, the use of social networks is accelerating exponentially. Discovering user communities in social media is critical in many marketing, studies, research, and customer development processes. Just after the invention of Big Data and Semantic Web technologies, Social Network Analysis (SNA) has become a very popular and important subject for researchers. There are numerous social media platforms, but the most popular are Facebook, Twitter, and LinkedIn **(Rao, G. P. C.,2021)**. Because the data generated by these social networking services is so large and massive, it is used in a variety of analyses. Community Detection is a fundamental analysis of this data **(Javed et al., 2018 & Ji et al.,2020)**. Every social network has a community structure that is based on user interaction. Users' communication in social networks can be classified according to their position, partnership, activity, interest, occupation, or even location. For detecting communities, a large number of studies have been published, demonstrated, and applied.

In Social Network Analysis, Graph Theory in Computer Science has played an important role. An undirected Graph G = (V, E) is being used to describe a social network, also known as a Social Graph, in which the vertices V represent the network's entities such as users and organizations, and the edges E represent the relation or connection between the entities **(Deng et al., 2017 & Lu et al.,2020)**. The subject of community detection is significant because it has inspired research in a variety of fields, including social networks, healthcare, marketing, bioinformatics, pattern recognition, financial applications, and so on.

A group of people that belong to a religion, place, country, etc and also those who have liked sports, reading books, etc. these groups form a community and share their information through social media platform like Facebook, Twitter, Instagram, etc. A community also named a cluster is a group that is composed of a set of nodes that are closely connected or have similar characteristics. C1= {A, B, C, D}, C2= {E, F, G, H}, C3= {I, J, K, L}. In figure 1 the dotted lines show the three communities C1, C2 and C3. Community detection is the process of discovering the connected groups or clusters in the network known as community detection. There are two types of community disjoint community and overlapped community, the intersection of two community is empty then it disjoint community otherwise it is overlapped community, In figure 1: show the disjoint community and dotted line represent the communities like C1, C2 and C3 and figure 2: show the overlapped community and in this figure, two or more communities share the nodes like node Q, U, O.

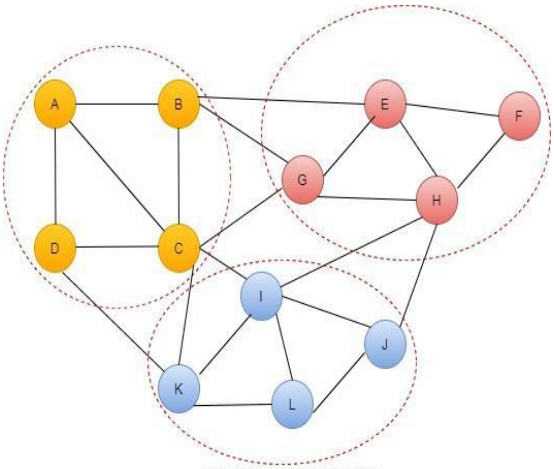

Figure 1: Disjoint Community

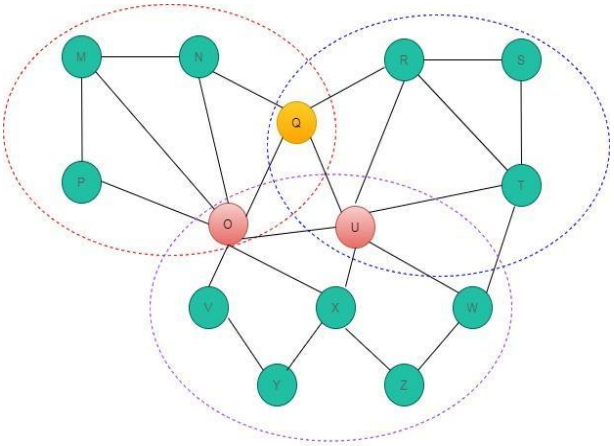

Figure 2: Overlapped Community

In this paper, the work is divided into several sections. Section 2 introduces the related work of Community detection algorithms like Clustering-based algorithm, modularity based algorithm, dynamic based algorithm and overlapped Community detection algorithms, etc. there summarization, Section 3 introduces different applications used in community detection algorithms, Section 4 proposed a node influence k-nearest neighbours (NI-KNN) algorithm for detecting the community, In section 5 it concludes the article and discussion the survey that has been done on the community detection algorithms and their observations are made in the table format.

2. Related Work

To identify the community based on an overlapped community detection algorithm and disjoint community detection algorithm that is further divided into three categories are Clustering-based algorithm, modularity based algorithm and dynamic based algorithm. This section review and classify of these algorithm using seventeen articles published between 2016 to 2020 and the Summarization report of Literature Review is presented in Table 1. This table is divided into Eight columns, First show the serial no. of the article, Second its uses for reference of the article, Third, it shows the article published year, Fourth it is used for the main task of the article, Fifth it is detecting the community detection algorithm, sixth It represents the algorithm used in the article, Seventh it represents the data sets like real and synthetic, Eight It represents the type of graph-like directed and undirected used in the article.

2.1. Clustering Based Algorithm

Partition clustering classifies the data into many groups on the basis of similarity and characteristics of the data. In this algorithm dataset is denoted as D, data set contain a number of the object denoted as N and these object partition based on the user-specific K data in every partition. A partitioned cluster is said to be $K \leq N$, Hierarchical clustering is an unsupervised learning algorithm and it has a set of clusters that are connected in a tree structure. There are two popular algorithms used in this clustering are agglomerative algorithm and divisive algorithm and graph partitioning algorithm divides the whole graph into a small graph, the size of graph

partitioning is predefined in order to get the number of vertices in the clusters based on cut size and the size of cut based on the requirement of the graph partition it may be minimum or the maximum cut.

Ji, Q., Li, D., & Jin, Z. (2020) Proposed to remove intercommunity edges using a novel divisive algorithm over community detection. The time complexity of this algorithm is O(Nd2) and it works on real as well as synthetic data sets. After the iteration, the network size increases linearly and finding the relationship between node clustering coefficients defined from a micro perspective through an undirected graph and node clustering coefficients into the divisive algorithm can greatly improve the time efficiency. **Deng, X., Zhai, J., Lv, T., & Yin, L. (2017)** Proposed a triangle structure in directed graphs based on conventional community detection algorithms. In this network information transfer gain (ITG) of nodes is evaluated for clustering the graph, then combining the different clusters based on the influence coefficient ITG. Social media produces a large data set in the real world, to analyze the data, using an artificial network to process this data fast and accurately and our algorithm ITG-DWCC time complexity correctness is acceptable.

Lu, H., Sang, X., Zhao, Q., & Lu, J. (2020) Present complex network algorithms DPCSNMF and DPCNMF over community detection, which merged nonnegative matrix factorization(NMF) algorithm with enhanced density peak clustering (DPC) algorithm and compared with newly new NMF methods three advantages are parameter-free algorithms, The number of communities can be detected exact rather than manual preference automatically and for centre selection of community enhanced DPC method. Based on the recommendation of centre nodes can find out large scale communities and this method is tested on a series of standard undirected graphs and real datasets. **Zhou, H., Xi, B., Zhang, Y., Li, J., & Zhang, F. (2019)** Proposed a theory based on direct and indirect attraction force for detecting the communities of complex networks. The concept is divided into three parts, First, detect the similar node in the undirected graph using direct and indirect attraction force, Second improve the initial centre-point selection method in similar nodes and Finally to complete the clustering process enhanced K-Medoids algorithm. Attraction-force Cluster algorithm finds out the complex network community structure using two real datasets of Political Blogs and DBLP and undirected graphs for detecting node attribute and structural feature of the community. **Aksoylar, C., Qian, J., & Saligrama, V. (2016)** Present a graph partitioning issue that detects and minimizes cut partitions under minimum size check of partitions to detect Community with Imbalanced Clusters size. This procedure specifies a family of graphs by interchange and balances the node degrees on a fixed node-set, allows a set of specific relative cuts reflecting various levels of imbalance node and optimizes these parameters to solve the problem of imbalance clustering. It proposed exactly a ceiling cut analysis outcome to justify this method and demonstrate the advantage of our approach through observation of real datasets and synthetic datasets of clustering data using community detection and semi-supervised learning for detecting the community.

2.2. Modularity Based

Modularity based algorithms are used to measure the structure of the graph, especially its design to check the strength of the partition graph like groups, communities, etc. there are various optimization methods for community detection are external optimization, spectral optimization greedy optimization and genetic algorithm. **Liu, Z., Xiang, B., Guo, W., Chen, Y., Guo, K., & Zheng, J. (2019)** Present an overlapping community detection algorithm on local overlapped modularity and coarsening, First, to reduce the network area of the community adopt the triangle-based strategy. Second, detect the initial community and perform this strategy to a large network and find out the dynamic distance between communities. Third, refine and reverse the non-overlapping community structures. Finally, the overlapped community is detected by the strategy based on local incremental overlapping modularity. Then, the new similarity measuring strategy is designed to reduce the number of outlier communities. The experimental result is based on real and Synthetic dataset used to identify the outlier communities using Label propagation-based algorithms (LPAs).

Kamakshi, S., & Sriram, V. S. (2020) Present to solve vehicular ad hoc network (VANET) broadcast storm problems using clustering algorithms based on community detection. Community detection is broadly used in social media and it can be less dynamic or static networks. At intervals of Edge and modularity are plenty to detect balanced communities in social networks. Due to the high speed of vehicle movement in VANETs, detecting balanced communities requires mobility information. Hence apart from modularity gain, the degree of cohesion between the communities based on their relative speed and distance has also been considered for aggregating them into a single community. The result of this work provides modularity gain weightage 70% and balanced communities bonding degree weightage 30%, reduce packet loss ratio, packet collision ratio, end-to-end delay, and increases reachability & throughput. **Yang, L., Cao, X., He, D., Wang, C., Wang, X., & Zhang, W. (2016)** Proposed a deep learning-based non-linear model to enhance the representation power of a huge complex network and also to expand an algorithm based on a non-linear model for finding the community in the network. And further, it continued this technique to semi-supervised learning algorithm with deep nonlinear reconstruction

algorithm integrates pair wise restraint. The experimental result is based on real and synthetic data sets for the identification of network communities. **Jin, D., Zhang, B., Song, Y., He, D., Feng, Z., Chen, S., ... & Musial, K. (2020)** Present a Markov Random Field (MRF) approach assigning modularity as an energy function that represents the problem constraints and properties and also it uses max sum belief propagation (BP) to figure out the parameters of the model. a new MRF method, namely ModMRF, to assign modularity as the energy function for detecting the community in undirected static networks, the experimental results display that this approach offers to enhance the performance than the state-of-the-art algorithms, In linear case the time complexity ModMRF has reduced and very efficient for community detection algorithm. The experiments result in the ground-truth of communities on both synthetic and real-world networks.

2.3. Dynamic Based

A dynamic Algorithm is used to optimize a big part of a sub problem based on the small part of a sub problem. It is used to store the data or information about the problem. This algorithm is categories into three categories are Random Walk, Spin model and Synchronization. **Li, X., Xu, G., Lian, W., Xian, H., Jiao, L., & Huang, Y. (2019)** Present an influence relation based multilayer network method on local community detection model, to combine this community the direct and indirect influence relation network is used. Based on the similarity of this network influence relation is used to measure the length of the path and calculate the weight of the local nodes connected in a multilayer network. It compared with six datasets and found the correctness and stability of this method. **Chen, N., Hu, B., & Rui, Y. (2020)** presents an Incremental algorithm with Coherent Neighbourhood Propinquity (ICNP) for community detection network. This approach exploits the history of data and analyzes the real-time community of the network by deleting nodes, cutting edges, adding nodes and adding edges in this network. This work reviews variables attribution as well as the structure of the variable direct and indirect neighbors. ICNA algorithm can use both direct and indirect type of network for using the experimental result and also use the real and artificial dataset to identify the communities. This artical also review the relational neighbour node and enhance the influence range of moving nodes.

Zeng, X., Wang, W., Chen, C., & Yen, G. G. (2019) present a novel consensus community-based particle swarm optimization (CCPSO) is used for dynamic community detection. In CCPSO, to extract the information of the existing present population of frequent communities and the population of the previous step introduced by the consensus community, in present population give direction which is similar and based on previous step structure the community. This approach finds out the dynamic structure of the community with high accuracy. The experimental research of CCPSO of three real-time data sets of the networks and two artificial data sets of the networks and also uses undirected network type for performing the result. **Luo, W., Zhang, D., Jiang, H., Ni, L., & Hu, Y. (2018)** Proposed a dynamic membership function based on local community detection algorithms for two communities and this process performed in three phases. First, in this phase detect nodes and their local community with the greatest influence bisect rate to be added for local community design a dynamical membership function. Second, the intermediate phase's main goal is to connect the local community near to other structures of the community and for this design another dynamical membership function. Third, based on the enhanced dynamical membership function the nodes of the local communities are further improved and that be included in the structure of the community. The dynamical membership function result is performed on both real-time and artificial data sets and the network type is used undirected for finding the local communities.

2.4. Overlapped Community Detection Algorithms

Alduaiji, N., Datta, A., & Li, J. (2018) present community detection based on temporal interaction biased (TIB) for dense and active communities, the whole process is divided into four phases: partition approach, influence propagation model, expansion driven algorithms, and verify the effectiveness of the above. This approach influences the active user based on their frequencies with other users, if the active user is weakly connected to others then it has a small influence at that time after expansion it highly connected to others the redefine the process based on their influences. **El Kouni, I. B., Karoui, W., & Romdhane, L. B. (2020)** Proposed a label propagation algorithm for overlapping community detection and enhanced this algorithm as Node Importance- Label Propagation Algorithm (NI-LPA) in a complex network community to detect the communities based on the node of the network. NI-LPA is utilizing the characteristics of nodes to complete the process of label propagation algorithm. This algorithm uses a new refining method for detaching useless labels, improving the robustness and validity of the community. The prototype and its outcome based on real-time and synthetic data sets with different sizes, mass and complexities, it expresses the efficiency of this method using an undirected network type for detecting overlapping communities.

Tian, Y., Yang, S., & Zhang, X. (2019) Proposed to find the optimal overlapped community through different community centers and their degrees using fuzzy clustering the algorithm is evolutionary multi-objective

optimization based fuzzy method (EMOFM). In addition, this algorithm can be noticed as a suitable fuzzy threshold value for each node of the community, in order to ensure the various structures of overlapped communities is not covered. The proposed prototype method with six state-of-the-art structures of overlapping community detection algorithms and its result is based on the characteristics and scales of different synthetic and real-world networks datasets and also this method using an undirected network type for detecting overlapping communities. **Huang, F., Li, X., Zhang, S., Zhang, J., Chen, J., & Zhai, Z. (2017)** Proposed Line graph theory, Ensemble learning and Particle Swarm Optimization (LEPSO) for detecting the overlapped communities. Respectively, a Discrete Particle Swarm Optimization (PSO), is a calculation based approach for optimizing the problem and using the iteration the solution of the problem is improved based on this process the quality is measured. It designs a bottom-up merging approach and hierarchical agglomerative for the generation of the post of overlapped communities. The experimental result compared with randomized and non-randomized approaches for best in the phrase of robustness and validity using LEPSO and also it revamps the quality using real-time and synthetic data sets and undirected network type for detecting overlapping communities.

Table 1: Summarization of Literature Review

Sr. No.	Ref. No.	Year	Task	Community Detection Technique	Algorithms	Data Set		Network Type	
						Real	Synthetic	directed	undirected
1.	Ji et al.	2020	removing intercommunity edges	Partitioned clustering	divisive	√	√		√
2.	Lu et al.	2020	perform a series operation	Partition clustering	DPCNMF and DPCSNMF	√		√	√
3.	Kamaks hi et al.	2020	reduce weight and modularity gain of community	Modularity	clustering algorithm	√			√
4.	Jin et al.	2020	Markov Random Field (MRF) is used to detecting the community	Modularity	belief propagation (BP) algorithm	√	√		√
5.	Luo et al.	2018	Enhanced the relationship between the neighbour nodes	Dynamic	Incremental algorithm with Coherent Neighborhoo d Propinquity (ICNP)	√	√	√	√
6.	Zhou et al.	2019	Direct and Indirect Attraction-force	Graph Clustering	attraction-force cluster	√			√
7.	Liu et al.	2019	Reduce running time in an outlier community	Modularity	Label propagation-based algorithms (LPAs)	√	√		√
8.	Li et al.	2019	integrate the influence relationship between multi-layer communities	Dynamic	clustering algorithm	√			√
9.	Zeng et al.	2019	consensus community-based particle swarm optimization (CCPSO) is used for dynamic community detection	Dynamic	particle swarm optimization (PSO)	√	√		√
10.	El Kouni et al.	2020	detach useless labels and improves the validity of the community	Overlapped community detection	Label Propagation Algorithm (LPA)	√	√		√
11.	Tian et al	2019	detecting optimal Overlapped community	Overlapped community	fuzzy clustering	√	√		√

				detection					
12.	Chen et al.	2020	the local communities collecting some nodes that should not be omitted.	Dynamic	dynamical membership function	√	√		√
13.	Alduaiji et al.	2018	Enhanced Influence Propagation Model for weak community	Overlapped community detection	temporal interaction biased (TIB) algorithm	√			√
14.	Deng et al.	2017	perform a paralleling operation	hierarchical clustering	ITG-DWCC	√		√	
15.	Aksoylar et al.	2016	Community Detection with Imbalanced Clusters	graph partitioning	semi-supervised learning	√	√		√
16.	Yang et al.	2016	Enhanced the representation of a complex network	Modularity	semi-supervised learning algorithms	√	√		√
17.	Huang et al.	2017	Improve DPSO for overlapped communities	Overlapped community detection	Particle Swarm Optimization (PSO)	√	√		√

3. Applications of Community Detection

Community detection is worked by researchers in many of the areas of social media such as E-commerce, Recommendation system, health care, politics, Economics, communication networks, social network, etc. In this article, point out the applications and their uses in chronological order.

3.1. E-commerce

It is a platform for selling and buying the goods and their services and also transferring the data or funds atop of this network, on the basis of a transaction the e-commerce is divided into B2B (business-to-business), B2C(business-to-consumer), consumer-to-consumer. Social media users connect through a network and form a community based on their common interest, mostly users interact with each other online behaviour **(Kwahk et al., 2018)**. An e-commerce community is a way of detecting online groups for marketing things smartly to produce interesting applications like advice about the product, outlets; promotion of things based on the community, etc. It is an online e-commerce community that has a complete history of the user and professional reviews, based on the reviews the ranking of the community is decided **(Aivalis et al., 2016)**.

3.2. Recommendation system

It is used to advise the user based on user profiling or the reference characteristics of another user, these characteristics can be based on Collaborative filtering and content-based filtering. In Collaborative filtering, the prediction based recommendation system is used for user preferencing and interacts with the result between them **(Karataş et al., 2018)**. This type of filtering offers good results in respect of user's expectation and in some cases, it is used by less number of users. This filtering is used to try to include more human beings in filtering the system because it can compute the documentation as good as any kind of computer task. In content-based filtering describe the content as a user data model of items and based on the content user done rating whether the information is useful or not. The rating is a relation between user and information, based on this rating the recommendation system shows the result of recommended items. It provides the facilities to use every day for buying things, listening to music, watching videos on social media platforms, community detection play a vital role in this because it has different communities for user rating and profiling and it is a backbone of recommendation systems.

3.3. Health care

Healthcare can be defined as using electronic devices and mobile phones for testing the disease, improving the treatment of the patients, and enhancing the quality of life. Community-based healthcare technology such as the Internet of Things, advanced data analytics, Big Data, and various other technological transformations have turned

conventional healthcare into smart healthcare and it also provides data sharing between patients and health service for different communities **(Karataş et al., 2018 & Abbasi et al., 2014)**. It is a great diagnostic gadget for good treatment of human health, the gadgets can improve the quality of healthy life. The whole concept is based on the services of eHealth and mHealth. eHealth is an electronic record of health that is easy to access based on information and communication technology (ICT) for health. Like it includes patient's treatments, supervised for research, educating the health manpower, tracking diseases based on history, and monitoring the health of the public. mHealth is a stand for mobile health **(Li et al., 2011)**. The terms mHealth provides all the medical and public health-related support in mobile devices like smart phones, patient monitoring devices like wearable gadgets, personal digital assistants like applications, and these all the things are connected to the community of health and provide complete support for patients and improvement of health.

3.4. Politics

Community is the power relations between individual persons, such as the distribution of information or status of political parties. The political theories are connected to the community of politics and the whole concept is known as political science. It covered all the activities of the government of the country and tracked the complete record of the discussion. In social media lots of platforms like YouTube, Twitter, Whatsapp, Facebook, Instagram, etc **(Karataş et al., 2018)**. and it contains a lot of community-related to different political parties, these platforms contain all the information regarding the speech, its commitment, its future plans, etc. these community also represent the thinking of the communities, sometimes the message is viral then political parties uses these platform there is no matter whether the information is right or wrong **(Bilal et al., 2019)**. The political community plays a vital role to recommend and connect to the people of our country.

3.5. Economics

It is related to the utilization, production, arrangement and distribution of stock and service. According to the researchers how to use these resources for the peoples, authorities of the country, industrialists, etc. It concentrates on the issues of economics and its interaction with people and they're working. Microeconomics is work as a group or community and it analyses the general component of the economy, tracks brokers and retailers, their discussion and interaction, and finally generates the report. a single broker may be a seller, buyer, firms, owner, etc. community examine the system of economics like production, arrangement, distribution, storing of stock, there are many factors that have directly or indirectly affect public policies, capitals, currency inflation, growth of economics, employment, labour resources, etc these are the component of economics **(Papageorgiou et al., 2020)**.

3.6. Communication networks

The communication network is designed for the members of the community and it tracks the flow of information and the number of persons involved in the process based on the magnitude of the organization and nature of communication **(Javed et al., 2018 & Papageorgiou et al., 2020)**. The pattern of communication networks is Vertical Network, Circuit Network, Chain Network, Wheel Network and Star Network. The communication networks are the interface between the community over social media and their applications like MANETs (Mobile Ad Hoc Networks). The communication of these applications is based on the routing in MANETs are a special attraction because it contains all the features regarding social networks. It provides an efficient routing algorithm compared to the traditional routing algorithm for community detection **(Javed et al., 2018 & Li et al., 2011)**. Still and the entire routing algorithm are not used for dynamic MANETs because it required a proper processing time and complex computation, for different network topology recomputation of structure community-based network is changed.

3.7. Social network

An online social networking form a community of social networks like interacting with users, sharing information with other users and establishing a relation between them. These people are connected through the web and Facebook, Twitter, Whatsapp, Skype, Instagram, etc are offered the social networking service **(Javed et al., 2018)**. in case of Facebook users have our own page to share, like, comment for the recommendation, Twitter is used for blogging and provides the services where user interact with the post and the messages, Whatsapp provide an interface between one user to another who can share voice messages and text messages, video calls and voice calls and also share the photos, documents, location, etc **(Karataş et al., 2018)**. Skype is an application of telecommunication that provides chatting and voice call between electronic gadgets such as mobile devices, tablets, computers, etc, it also allows conference calls between them. Instagram is the most updated social

networking platform such as simple, easy to capture content like edit, share photo, video, message, the status of friends and family.

4. Proposed Methodology

The work proposed in a three-tier framework based on the node influence k-nearest neighbours (NI-KNN) algorithm for detecting the community. This methodology is mainly divided into three modules: pre-processing, normalization, and screening.

4.1. Preprocessing

In this module each node is classified as a community and each node is given a unique label, also known as an identifier, just like in the basic k-nearest neighbor's algorithm and This K indicates the node in which community. The node influence of all vertices in the graph is then calculated. Each vertex may belong to more than one community if communities overlap. As a result, this work must allow a node to contain multiple community identifiers in order to find overlapping communities.

4.2. Normalization

This is the central module of NI-KNN that contains multiple iterations. This process is based on its neighbors' influence node in the iteration of $(k - 1)$ and updates the influence node in the same iteration k. Thus, it's proposed that the nodes should be sorted in a fixed order to solve the KNN instability problem, that the random node selection should first be avoided and that the algorithm converges to a stable result, unlike the KNN which gives distinct results depending on the order of the nodes.

4.3. Screening

At the conclusion of the normalization module, each node includes a list of pairs. Some of these identifiers are useless because their degree is so low in comparison to the degrees of the other identifiers. It delete the pairs with a degree less than or equal to the limit of 4, which is calculated based on the node's degree. If a node's degree is 5 or higher, the node is an influence node. The rest of this work limit 5 is decided by this phase. It should be noted that this limit is only used in community filtering.

5 Conclusion

In social network analysis, community detection is crucial, many methods for identifying communities based on topological features and node attributes have been used, including community size, modularity, clustering, dynamic, and overlapped. Mostly algorithms concentrated only on the undirected graph and some are in the directed graph or both and this algorithm used both datasets real and artificial and this work proposed a node influence k-nearest neighbours (NI-KNN) algorithm for detecting the community using undirected graph. There are various applications that benefit from the use of community detection, including recommender systems, healthcare, economics, social media, e-commerce, communication networks, etc. A comparative analysis of the different methods of community detection has also been reported.

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