Community Detection in Scientific Co-Authorship Networks using Neo4j

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***Abstract*—Community structure in scientific collaboration network has become an important research area. Co-author of a paper can be thought of as a collaborative document between more than one authors. Community detection in co-authorship network reveals characteristic patterns of scientific collaboration in computer science research and help to understand the identity-organization of the author community. Louvain algorithm is a simple, easy to implement and efficient to recognize community in huge networks. In this paper, it is used to examine the structure of community in Computer University's coauthor network in Myanmar. Neo4j is also used to visualize the co-authorship network analysis results. Modularity is used to measure the quality of the cluster structure found by community discovery algorithms. In experiment, Louvain algorithm gives more effective qualitative community structures than other algorithms in co-authorship network.**

Keywords—co-authorship network, community detection, modularity, Neo4j

I. INTRODUCTION

Co-authorship relationship is well documented form and one of the most visible of scientific collaboration. Co-authorship networks analysis is used to rank most influential authors in a co-author network, or to estimate future research collaboration, to determine the most appropriate reviewers for a manuscript. [1]. Research collaboration and co-authorship is science in an interesting multi-faced phenomenon. In co-authorship network, nodes represent paper's authors, and two authors are connected by a relationship in which they published at least one research paper.

Co-authorship social network is one kind of the social relationship network. A community is a cluster of a network where internal nodes connections are closer than external nodes. Detection community in social relationship network help to understand the network structure, to identify subgroup and to visualize the result communities. Community detection in social networks are limited and no ground truth solution to compare and it may have more than one solution to the problem. Researcher have been developed many kinds of community detection algorithms to detect community in social networks.

Bibliographical record of University of Computer Studies, Mandalay are collected from UCSM research repository [2]. The UCSM research repository is an open access institutional repository that provides search access to research publication written by UCSM staff and students. Community detection in UCSM co-authorship network reveals type of scientific collaboration in the university. It also helps us to understand the own-community of UCSM community authors. Next several years, UCSM co-authorship will emerge. At this time, current time community form can be compared with overtime community form. Co-authorship community structure can get many advantages such as collaborative work among research increases research productivity both in terms of quality and quantity of publication. Sometime, two or more researchers who have different community should collaborate to emerge new trend or technology. The purpose of this paper is to provide overview of growing research on co-author network approach to research collaboration, identifying gaps for future research.

Neo4j Desktop is a convenient way for developers to work with local Neo4j database. Graph algorithm in Neo4j library is installed as plug-in and launched the Neo4j Desktop. Louvain algorithm in Neo4j's graph algorithms is used to detect graph community structure. It is one kind of community detection algorithm that relies upon a heuristic for maximizing the modularity [3]. In this paper, the communities structure of UCSM co-authorship network is detected by using Louvain community detection algorithm in Neo4j. According to the previous research findings, it has been used with success for many kind of networks and it is suitable for more than hundred million node and billions of edges. It has been the most widely used method for detecting communities in large networks [4].

The next parts of the paper are described as follow. The theory background of network community detection algorithms is described in section II. In the next sections, section III explores the literature reviews and section IV presents the dataset collection. Section V is the experimental results and section VI gives conclusion.

II. BACKGROUND THEORY

In this section, the necessary background knowledge of network community detection, modularity structure, co-authorship network, community detection algorithm and about Neo4j are presented.

A. Community Detection

Formation of communities is common in all types of networks and identifying them is essential for evaluating group behaviour and emergent phenomena. This information helps to infer the behaviour or similar preferences of peer groups, assess flexibility, find nested relationships, and provide information for other analysis. Community detection algorithms are also commonly used to produce network visualization for general exploration [5]. A community is a subgroup of a network where internal connections are part of a denser network than external connections. Detecting communities helps to understand network structure, to identify cohesive sub-cluster, and to draw a readable network's map.

The method of detecting by the community is to partitions which maximize connection density within a group by taking into account the connection density between groups and

finding dense optimal sub-graphs in large graphs. Many community detection algorithms have been developed to find optimal communities in reasonable fast time.

B. Modularity

There are many kind of evaluation metrics to measure the quality of result community. Evaluation metrics are based on internal connectivity, external connectivity, consider on both internal and external connections and model of network.

Modularity Q is a model of network based quality metric. It is used to measure the quality of partitioning the network into cluster detected by the proposed algorithm. It is the measure of the density of intra-community relationship as compared to inter-community relationship [6]. Modularity Q can be calculated by using equation 1.

$$Q = \frac{1}{M}\sum_{ij}[A_{ij} - \frac{d_i d_j}{M}]\delta(c_i, c_j) \qquad (1)$$

where M=2e, e is the number of edges, A_{ij} is 1 if there exists the actual number of edge between i and j else it is 0, d_i is the degree of node i, d_j is the degree of node j, c_i is the cluster of i, c_j that of j and δ function is 1 if i and j reach in same cluster and 0 otherwise.

Step by step calculation of modularity are described as followed. Input of given network is edges list text file. Example network structure's edge lists are (1—2, 1—3, 2—3, 3—4, 4—5, 4—6, 5—6). Louvain method detects two community structure for the example network. One community contains node 1, node 2 and node 3 (C1= {1,2,3}) and next community contains nodes 4,5 and 6 (C2={4,5,6}). To calculate modularity Q, M=2*7, A_{ij} is the adjacency matrix of each node (nodes defined by the row and the column have different element values) and $\delta(c_i, c_j)$ is 1 if node i and node j are in the same community. Delta function use the result community structures C1={1,2,3} and C2={4,5,6}. After replacing the corresponding values in equation 1, modularity Q will be produced. In this example, Q is 0.3571429.

Q's value lies in the range [−1, 1]. For most real-networks' result community structures, the value of Q is above 0.3. Higher modularity values imply strong community structure. Most of the traditional and proposed community detection algorithms aim to optimize modularity value.

C. Co-Authorship Network

Co-authorship network is two authors have a connection if they write together at least one paper. Node in a co-authorship network represents author in which author published at least one paper. The network of co-author is one of the most tangible and well documented forms of scientific collaboration. Co-authorship network analysis is useful in understanding the structure of scientific collaborations and individual author's status.

The co-authorship network is represented as a graph G= (V, E). In which, the V is the set of researcher and E is the set of relationships if two researchers have co-authored a paper together. The primary application of co-authorship networks is to study the structure and evolution of scientific collaboration. Figure 1 shows the sample visualization of co-authorship network using Neo4j. In this network, author Aye Aye and author Mya Mya wrote a paper together and Soe Soe and Aye Aye also wrote a paper together. Analysis of the co-author network reveals characteristics of the academic community that can help us to understand the collaboration research works and to identify prominent researchers [7].

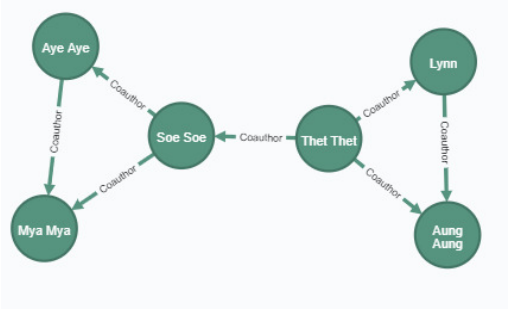

Fig. 1. The sample co-authorship network(S)

D. Neo4j

Neo4j is world's learning graph database management system developed by Neo technology, Inc. It is designed to optimize fast management, storage and traversal of nodes and relationships. Graph visualization takes the understandable features one step further by drawing the graph in variety of formats, making it easier for users to work with the data. Neo4j has two visualization tools called Neo4j Browser and Neo4j Bloom that are built and designed to work with data in Neo4j's graph database. In this paper, Neo4j Browser is used for graph visualization [8].

Cypher is Neo4j's graph language and it can easily express graph structure. Graph algorithm library is installed in Neo4j Desktop. Neo4j graph algorithms help in several areas such as a route search to find the shortest route or evaluate the availability and quality of routes; determine the centrality about the importance of separate nodes and uncovering community that evaluates how groups are clustered or determines the importance of separate nodes in the network. In this paper, Louvain algorithm is used to detect community structures for co-author networks.

E. Community Detection Algorithms

There are many conventional community detection algorithms. Most of the algorithms get effective results in small and middle scale networks. For large scale networks, researcher have proposed various kind of effective community detection algorithm. They purposed to solve the scalable and time complexity challenges. Among them, some community detection algorithms are discussed in this section.

Edge-betweenness algorithm [9] finds edges connection separate modules have high edge betweenness as all the shortest paths from one module to another must pass through them. It performs by calculating the edge betweenness of the graph, removing the edge with the highest edge betweenness score, then recalculating edge betweenness of the edges and again removing the highest score edge. It returns a community object.

Infomap algorithm [10] uses random walks to analyses the information flow through a network. It is assumed that a random walker will enter the community if he spends some time traveling through the nodes of the community.

Label propagation algorithm [11] uses the information of the neighborhood node to identify community structure. Every node is labeled with their own value. Then the label of each node are replaced with the most spread in its neighborhood.

This process is repeated until one of several conditions is met or no label change. The last label value is the result communities or size of communities.

Leading eigenvector algorithm [12] applies the eigenvalues and eigenvector of modularity matrix. Firstly, it calculates the leading eigenvector of modularity matrix then the graph is divided into two group. Modularity improvement is maximized depend on the leading eigenvector. In each sub division of a network, modularity is calculated. This process is repeated until the satisfy modularity result.

Louvain algorithm adopts one kind of hierarchical method called agglomerative. Each node owns a unique community. Then nodes are assigned to the community which achieve the higher modularity result and merge the communities. This process terminates when there exists only node or modularity value can't improve. Louvain algorithm is one of the fastest community detection algorithm and works well with large graphs. The advantage of Louvain is to minimize the time of computation. This mathematical method has become quite popular and consists in calculating a number of each partition which quantifies the quality of the partition and then finding the maximal modularity partition. Louvain algorithm can be called in Neo4j Desktop software when installing Neo4j's graph algorithm library.

III. Literature Reviews

Communities in social graphs may indicate groups of people with common interest. Most conventional community detection techniques are based graph partitioning, hierarchical clustering and modularity optimization algorithm [13]. Graph partitioning algorithm divides the graph into predefined size. So graph partitioning based algorithm need to know the number of community. Hierarchical clustering techniques are based on the vertex similarity measure. These techniques don't need a predefined size and number of communities.

There are two types of categories: agglomerative and divisive algorithms. Agglomerative algorithm is bottom up approach. It starts with each node as a separate cluster and iteratively merged them based on high similarity. Divisive algorithm is top down techniques. It starts with the entire network as a single cluster and iteratively splits it by eliminating links joining nodes with low similarity and ends up with unique communities. Modularity optimization techniques is based on the modularity value to get quantitative community structure. The larger the modularity value, the better the partition.

IV. Dataset Collection

Co-authorship network has been constructed from the publication list of UCSM research repository in "https://www.ucsm.edu.mm/ucsm/". These data are crawled by web crawler and then collect coauthors information. Coauthor information can be gotten from their publication lists. Figure 2 is the publication information on the UCSM webpage. This data is collected at November, 2019 from UCSM webpage. When creating UCSM co-authorship network, it contains 80 authors and 189 relationships between authors. In this network, if a paper is write only one author, this publication will be ignored. If one publication has three author a, b and c, its relationships will be a-b and a-c [14]. Co-authorship network is constructed based on UCSM research repository's publication, and then visualize and analysed with Neo4j.

V. Experimental Analysis

The experiments are implemented on a laptop with Core i7, 8GB of RAM, 64-bit Window operating system and using neo4j-desktop-offline-1.2.3-setup. Neo4j is used for the co-authorship network analysis. Sample co-authorship network (S) that are shown in figure 1, is used as the example to detect the community. It contains six nodes and seven edges. Firstly, create six nodes and edges using the following cypher language.

Create Node:

```
MERGE (ThetThet:Author{id:"Thet Thet"});
MERGE (Lynn:Author{id:"Lynn"});
```

Create Edge:

```
MATCH (a:Author), (b:Author)
WHERE a.id = "Thet Thet" AND b.id = "Lynn"
CREATE (a)-[: CoAuthor]->(b)
RETURN a,b;
```

After creating graph structure, detect the community structure of network by using Louvain algorithm in Neo4j graph library. The cypher query for detecting community is described as follow.

```
CALL algo.louvain.stream("Author", "CoAuthor", {})
YIELD nodeId, community
MATCH (user:Author) WHERE id(user) = nodeId
RETURN user.id AS user, community
ORDER BY community;
```

No.	Title	Subjects	Date	Type	Publication Title	Authors	Communities
1	Feature Selection to Classify Healthcare Data using Wrapper Method with PSO Search	Data Mining and Machine Learning	2019-09-08	Journal Article	International Journal of Information Technology and Computer Science(IJITCS)	Thinzar Saw [3] , Phyu Hninn Myint [6]	Data Mining and Machine Learning Lab, Faculty of Computer Science
2	Analysis on Skin Colour Model Using Adaptive Threshold Values for Hand Segmentation	Image and Signal Processing	2019-09-08	Journal Article	International Journal of Image, Graphics and Signal Processing(IJIGSP), Hong Kong, 2019, Volume 11, No-9, pp. 25-33	Phyu Myo Thwe [2] , May The` Yu [6]	Image and Signal Processing Lab, Faculty of Information Science
3	Feature Representation and Feature Matching for Heterogeneous Defect Prediction	Software Engineering	2019-08-07	Conference Paper	International Conference on Intelligence Science (pp. 1-14). Springer, Cham.	Thae Hsu Hsu Mon [1] , Hnin Min Oo [4]	Software Engineering Lab, Faculty of Information Science

Fig. 2. UCSM's research repository page

Louvain community detection algorithm produces two community structures for sample network S that are shown in Table I. According to result table, {Thet Thet, Aung Aung, Lynn} are in the same group and {Aye Aye, Mya Mya, Soe Soe} are in the same group. Then, the quality of result communities is measured using the modularity Q. Modularity value gets 0.3571429.

From UCSM's co-authorship network, not only network's community information but also other co-author information can also be extracted. Author and his or her co-author information are extracted from graph database. Table II shows the query result about the co-authors who worked together. In this table, Author Thet Thet wrote publication papers together with Soe Soe, Lynn and Aung Aung. If the paper is written with co-author, it will provide more value, wisdom, and improve research efficiency. Figure 3 shows the graph based structure for the author Thet Thet and her coauthors using cypher query language.

TABLE I. COMMUNITY STRUCTURE OF SAMPLE CO-AUTHORSHIP NETWORK

"User"	**"Community"**
"Thet Thet"	0
"Lynn"	0
"Aung Aunt"	0
"Soe Soe"	1
"Aye Aye"	1
"Mya Mya"	1

TABLE II. CO-AUTHORS' INFORMATION OF SAMPLE CO-AUTHORSHIP NETWORK

"Author"	**"Coauthor"**
"Thet Thet"	["Soe Soe", "Lynn", "Aung Aung"]
"Aye Aye"	[Mya Mya]
"Lynn"	["Aung Aung"]
"Soe Soe"	["Mya Mya", "Aye Aye"]

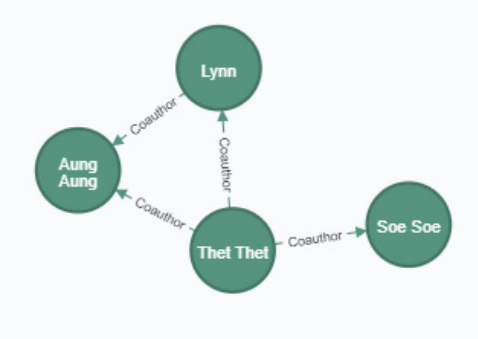

Fig. 3. Specific author "Thet Thet" and her relationship

By using sample co-authorship network S, various type of co-authorship network analysis is described. In Table III, each author's publication information is extracted in Neo4j graph databased and shows with table structure. Next experiment is tested on UCSM's co-authorship network. Firstly; this graph is created and stored in Neo4j graph database. The graph structure of the UCSM co-authorship network is shown in figure 4. Current time, this network is a disconnected network between some authors and the network will emerge as large scale network at the coming years. Louvain method in neo4j graph library is used to detect the community structure in that co-authorship network.

TABLE III. EACH AUTHOR'S PUBLICATION INFORMATION

"Name"	**"First Author Publication Count"**	**"Second Author PublicationCount"**
"Thet Thet"	3	0
"Aunt Aung"	0	2
"Aye Aye"	1	1
"Mya Mya"	0	2
"Lynn"	1	1
"Soe Soe"	2	1

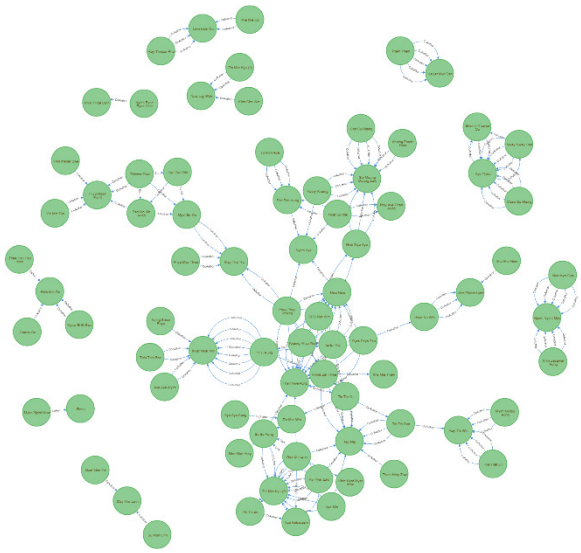

Fig. 4. UCSM co-authorship network

Table IV is the result community structures of UCSM co-author network. In table IV, "Author" column is the group of member name in each community and "Community" column is only the identify group label for each group. The table describes the coauthor community structure of UCSM's co-authorship network. When learning the result communities, members in same community have similar research field and they interest in the same area. Most influence member in each community is the supervisor or head of its research area. He or she have many relationships to other members in the same community. If authors in same community collaborate the new research, these finding can improve. When two different communities work together, new technology trend will be emerged. Carlos Medicia Morel et.al presented that co-

authorship network analysis could help address, providing a substantial contribution to global health [15]. After getting community results found by the proposed community detection algorithm, the result community's quality is measured by using Modularity Q in equation 1.

TABLE IV. RESULT COMMUNITY STRUCTURES OF UCSM'S CO-AUTHORSHIP NETWORK

"Author"	**"Community"**
["Than Nwe Aung", "Yi Yi Aung", "Nwe Nwe", "Phyu Phyu Khaing", "Ei Ei Thu", "Khaing Phyo Wai", "Tin Tin Yu", "Pyae Phyo Thu", "Khine Zar Thwe", "Mie Mie Thaw"]	0
["Myat Myat Min", "Aye Aye Myint", "Thin Thin Soe", "Kaing Sabai Phyu"]	1
["Aye Thida", "Nway Nway Han", "Chaw Su Hlaing", "Sheinn Thawtar Oo"]	2
["Zin Mar Kyu (2)", "Nu War", "Kyi Pyar Zaw", "Nay Chi Lynn", "Su Su Aung", "Aye Min", "Khin Myat Myat Moe", "Thi Thi Zin", "Ikuo Kobayashi", "Thein Htay Zaw"]	3
["Sai Maung Maung Zaw", "Si Si Mar Win", "Sint Sint Aung", "Hnin Mya Aye", "Chit Su Hlaing", "Myat Su Wai", "Yu Mon Aye", "Kathy Khaing", "Nyein Aye", "Khaing Zarchi Htun", "May Aye Chan Aung"]	4
["Nyein Nyein Myo", "Khin Zezawar Aung", "Myo Myo Swe"]	5
["Kay Thi Win", "Tin Tin San", "Htet Htet Lin", "Myint Myitzu Aung"]	6
["Phyu Hninn Myint", "May The` Yu", "Thinzar Saw", "Myat Su Oo", "Yin Min Tun", "Zan Mo Mo Aung", "Phyu Myo Thwe", "Thiri Marlar Swe", "Kyu Kyu Win"]	7
["Lwin Lwin Oo", "Kay Thinzar Phu", "Mie Mie Oo"]	8
["Thein Thein", "Kalyar Myo San"]	9
["Hnin Min Oo", "Kyaw Ei Ei Swe", "Thae Hsu Hsu Mon", "Cherry Oo"]	10
["Htwe Nu Win", "Mar Mar Nwe"]	11
["Nyein Pyae Pyae Khin"], ["Khin Thida Lynn"]	12
["Naw Lay Wah", "Zin Mar Kyu (1)", "Khin Cho Win"]	13
["Zin Mar Win", "Aye Aye Aung", "Moe Moe Htay"]	14
["May Thu Lwin", "Myat Mon Oo", "Su Mon Linn"]	15
["Myint Myint Maw", "Renu"]	16

Most of data mining and machine learning tasks contain training data and testing data information. Social network analysis task does not have ground truth solution to the problem. So, the quality of result is tested using quality metrics. If the given network has ground truth result, Normalize Mutual Information can be used [16]. It compares the similarity between the detected community and ground true community of the same network. In this paper, there is no ground truth community result for UCSM co-author network. So, modularity is used to test the quality of result community.

To compare the quality of Louvain algorithm in Neo4j's graph library, four kinds of community detection algorithm such as Edge-betweenness algorithm, Infomap algorithm, Label-propagation algorithm, Leading-eigen algorithm are used. Table V shows comparison of quality metric, modularity for five algorithms on UCSM's co-authorship network. In table V, modularity Q column is modularity value of the result community structures of each algorithm and Number of Community (NC) column is the number of cluster for given network that is just knowledge about the cluster information.

According to the Table V, all of the algorithm get suitable modularity result. Among them, Louvain algorithm get highest modularity value than other algorithms. This means that the quality of result community structure using Louvain algorithm is better than the other algorithms.

TABLE V. COMPARISON OF FIVE COMMUNITY DETECTION ALGORITHMS BASED ON MODULARITY VALUE

Algorithm	**Modularity (Q)**	**Number of Community(NC)**
Edge_Betweenness	0.7862182	19
Infomap	0.6067019	26
Label_prop	0.7725848	20
Leading_eigen	0.7532404	16
Louvain (Neo4j)	0.7912292	17

Researcher comprise as a community that entrance to success in this research field. Paper publication information of researchers are also visualized using Neo4j. Ten author's publication information in the co-authorship network is described in Table VI.

TABLE VI. SAMPLE TEN AUTHORS' PUBLICATION INFORMATION

"Name"	**"First Author Publication Count"**	**"Second Author Publication Count"**
"Nay Chi Lynn"	6	0
"Nway Nway Han"	4	2
"Tin Tin Yu"	4	2
"Si Si Mar Win"	6	0
"Pyae Phyo Thu"	6	0
"Khine Zar Thwe"	4	2
"May The` Yu"	0	6
"Chaw Su Hlaing"	6	0
"Khin Zezawar Aung"	4	0
"Myo Myo Swe"	5	0

Visualization is a main component for social network analysis. It gives meaning to the analysis and both complement each other. Today, Neo4j Browser is being increasingly used to visualize co-authorship network. Neo4j can be used to run complex queries. According to the above experiment, when using Neo4j user can find most influential member in this community, automatically determine the most appropriate reviewer for manuscript or to predict future research collaboration and can understand structure and evolution of the related academic society.

VI. CONCLUSION

Community detection in social relationship network has become important research area in social network analysis. Co-authorship social network is used to detect the community in co-author network. The main contribution of this paper is

that the strongly connected component of co-authorship graph own clear community structure. Author belonging to the strongest connected components are grouped into no-overlapping cohesive subgroup. One of the useful tools for graph clustering and visualization, Neo4j is used for co-authorship network analysis. Neo4j is suitable if data is represented using the graph model such as network and can run complex queries. In experiment, Louvain algorithm in Neo4j's graph library can detect more effective qualitative community structures than other algorithms.

The main drawback of Louvain algorithm is resolution limit. Resolution limit is a phenomenon in which communities that are smaller than a scale, are not specified. So, future research direction aims to propose effective and efficient improve Louvain algorithm for finding community structures on large co-authorship networks. Not only modularity but also other kind of quality metrics will be used to evaluate the community structure results. It will be implemented using Spark framework and Neo4j.

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