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Mathematics Research in Kerala: A Network Based Study

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Abstract

Background: Kerala school of Mathematics is very famous for its contributions to calculus and astronomy. It flourished for a period of four hundred years from the beginning of 14th Century. Latter the school vanished for some unknown reasons. Research contribution to mathematics in the modern time can be identified only in the middle of 20th century. Educational institutions play a major role in the creation, preservation and expansion of new knowledge. Collaborative research is another crucial factor in the generation of new knowledge. Collaborations can create network and it is worth to study the performance of research institutions in the field of Mathematics using the techniques of network analysis. Social network analysis is a very established area of research. Tools and techniques in social network analysis is being used for the analysis and interpretation of network related data.

Method: In this paper we are studying the collaboration of Mathematical research institutions in Kerala for the period from 1981 to 2015. Data related to all the papers published in journals which have MR number and at least one author from an institution in Kerala. From the details collected we extract the institution codes and to represent the nodes in the network. We make an adjacency matrix of the network. If two institutions collaborate to publish a paper, then the corresponding value of the adjacency matrix is 1 and it is 0 otherwise. Using the weighted adjacency matrix of the collaboration matrix we rank the institutions in the order of their importance using the m-Ranking method.

Results:

In all period of study except 2010-15, 6-COCH (Department of Mathematics, Cochin University of Science and Technology) came first. But in the year 2010 – 15 the first position occupied by obtained by Department of Mathematics, NIT, Calicut.

Conclusions: Collaboration network of research institutions in Kerala in the subject of mathematics is studied in order to develop an idea about the progress of research in mathematics giving importance to the state of Kerala. The institutions are ranked according to the importance of the institutions in the network based on the strength of the collaborative research work carried out during the specified period.

Keywords: Complex networks, m-Ranking, Important institutions.

1. Introduction

By a network we mean a collection of objects, which are related with each other in some way. We can see networks everywhere in the Universe. It is identifiable in connection with some relation defined in a set of objects. Graphs are very popularly used to model networks. A graph is a nonempty set of vertices together with a set of edges which contains unordered pair of vertices. Elements in the vertex set represent the objects in the network and the elements in the edge set represent a relation that exists in the

network between the objects which are represented by the end vertices of the edge. Graph theoretic representation of networks facilitates the study of network in many ways. Structural properties of the representing graphs can easily catch attention, by which we can arrive at some useful conclusions. Graphs can be represented by many matrix forms. Adjacency matrix, Incidence matrix, Path matrix etc. are few examples. The matix representation is amenable to further algebraic treatments. This algebraic treatments and computational procedures can ensure very accurate and reliable study of the respective network. To understand the basic ideas readers may refer the book Social and Economic Networks by M. O. Jackson [4].

Changes of node's importance has been a fundamental issue in the study of complex networks. Many measures are being used by network scientists to study the importance of nodes in a network. Vertex degree, closeness and betweenness are three oldest and widely used measures to distinguish which nodes are more important than others. Some recently developed measures are PageRank [3], LeaderRank [6] etc. In addition to this, a method called k-shell decomposition [7, 8, 9], which can partition all nodes of a network into k shells by removing nodes iteratively. In Mixed Degree Decomposition [2], both residual degree (number of links connected to the remaining nodes) and exhausted degree (number of links connected to the removed nodes) are considered in the next level of decomposition. Neighborhood Coreness [5] is a method based on the assumption that a spreader node with more connections to nodes located in the core of the network is more powerful.

Designing an effective method to identify the node importance is still an open issue. All the methods mentioned above are designed for un-weighted networks. In 2012, Garas et al. [1] proposed a ranking method for weighted networks. Based on the adjacency matrix of collaboration, in 2017 Reji Kumar et al. suggested a new ranking method named m-Ranking [8] of nodes. In this method degrees of all nodes are considered to rank nodes of a network. Total power of each node is calculated using the formula

$$T(i)=\{\alpha[d_i^{(0)}+\frac{1}{\beta}\sum d_i^{(1)}+\frac{1}{\beta^2}\sum d_i^{(2)}+...]+(1-\alpha)[\sum W_i^{(0)}+\frac{1}{\beta}\sum W_i^{(1)}+\frac{1}{\beta^2}\sum W_i^{(2)}+...]\} \quad (1)$$

where $\beta>1$ is a parameter. Here, $d_i^{(0)}$ is the degree of the node i and $\sum d_i^{(j)}$ is the sum of the degrees of the nodes j away from i. In this paper the collaboration network of educational institutions in Kerala is studied. The data is collected from the abstracting an indexing site of of American Mathematical Society (mathscinet.ams.org) [10]. The computation and related procedure explained in the next section.

2. Materials and Methods

In this paper, the main objects of study are the educational institutions in the state of Kerala. These institutions get a unique identification code in MR database, called institution code. For example 6-COCH stands for Department of Mathematics and Statistics, University of Cochin. If a person affiliated to this institution publishes a research paper in a referred journal or a book or any article of considerable value in the field of mathematics, it is listed in the MR website. In this database articles are categorized based on year of publication, Author of publication, institution of affiliation of authors, subcategories of the subject etc. One can search the database selecting any one or more of these options and collect the relevant data. For conducting extensive search over many years Python code can be developed. This program can collect all relevant data and store the same in a specified folder. Subsequently the data collected can be combined into a single file using a programme written in C and this data is used to prepare a weighted adjacency matrix of the underlying network. This is done in Excel spread sheet.

Using this data, with the help of the programme written in C to calculate the value of each node using the formula (1), nodes are ranked according to their importance in the network.

A particular item in MR database represents an article. Author name, Institution code of their affiliating institution, name of the article, year publication, journal name, volume number, issue number etc. are available information relating to each article. First we list all institutions in Kerala where research activities are going on. Institutions are represented by nodes in the network. When one researcher from institution i and a researcher from institution j has n combined papers, the ij and ji entry in the adjacency matrix are set n. Thus we get a weighted adjacency matrix. This weighted adjacency matrix and the equation (1) are the basis of all the calculations given in the sequel.

3. Results and Discussion

There are 257 institutions which come under this study of which there are four foreign institutions. We categorize the papers published into 7 groups according to their year of publication. These groups are 1981-85, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015. Since some of papers published in 2016 may appear very late in MR, we restrict our study up to the year 2015. In 1981-85, there are only 3 institutions which published papers with no collaboration with other institutions. In 1986-90, there are 9 institutions having collaborations. For 1991-1995, the number of institutions collaborate are 14. In the next period the number increased to 20. For 2001-2005, the number of institutions collaborated increased only marginally (25). But during 2006-2010, the total number increased to 49 and in the last period the total number of institutions collaborated increased to 210. Using the above mentioned m-Ranking method we ranked the institutions in the collaboration network. For the years 1981-85, there are no papers with collaboration of institutions. So rank of all institutions are 0. For 1986-90, 6-COCH ranked first with the T value 3.0 and 6-TRCH ranked second with the T value 2.375. The institutions 6-COCH, 6-COCHT-P, 6-KERA, 6-VIKR-AP have papers, but have no collaborations. So, their ranks are 0. For the years 1991-1995, 6-COCH and 6-SRIV ranked first with maximum T value 1.75. The first 10 ranks for the different period of study are tabulated below.

Table. 1. Ranks of institutions obtained by m-ranking method.

Rank	1981-85	1986-90	1991-95	1996-00	2001-05	2006-10	2010-15
1	6-COCH	6-COCH	6-COCHT	6-VIKT-AP	6-COCHT	6-COCHT	6-NITC-M
2	6-KERA	6-TRCH	6-SRIV	6-VIKT-SE	6-COCHT-P	6-CALI-S	6-COCHT
3	6-VIKR	6-COCHT	6-CHT-DS	6-COCHT	6-GCKS	6-BITS-NDM	6-MNPIT-M
4	--	6-IIT	6-COCHT-D	6-VIKR	6-ASOCT	6-IIS-NDM	6-IIS
5	--	6-VIKR	6-COCHT-P	6-IITR	6-IITND-P	6-IITK-NDM	6-CECTL-M
6	--	6-COCH-P	6-PN-P	6-ANNA	6-CALI	6-MATSCI	6-KSOM
7	--	6-COCHT-P	6-VIKR-AP	6-ANNA-S	6-CALI-S	6-NITC	6-SSYEDC-M

8	--	6-KERA	6-VIKR-SD	6-CALI	6-CALI-P	6-STCT-S	6-NITC
9	--	6-VIKR-AP	6-COCHT-A	6-COCH	6-COCH	6-ISI-SMU	6-SILIT
10	--	--	6-COCHT-S	6-IIS	6-CPCHT-E	6-ALAG	6-NMIE-DM

4. Conclusion

In this paper we present a network based study of collaborative research of the institutions which produce research output in the form of research articles. This study focuses on a long period, which starts from 1981. First article which can be claimed by an institution in Kerala appeared in MR database only in the year 1981. Because of the importance of the institutions that have in the collaboration network, ranks of the institutions are obtained. This help us to identify the most prominent institution in the network, and the institutions having lesser importance etc. The research work presented here can be a seed for a much elaborate and in depth study of institution collaborations with emphasis to Kerala. Similar studies can be conducted for institutions in the whole Nation.

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