**UNIVERSITI PUTRA MALAYSIA**

# STRUCTURE OF CO-AUTHORSHIP NETWORK IN UPM JOURNAL PUBLICATIONS DATABASE FROM 2007-2010

**ZURITA BINTI ISMAIL**

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**STRUCTURE OF CO-AUTHORSHIP NETWORK IN UPM JOURNAL PUBLICATIONS DATABASE FROM 2007-2010**

By

**ZURITA BINTI ISMAIL**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science**

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**Chair** : **Hishamuddin Zainuddin, PhD**
**Faculty** : **Institute for Mathematical Research**

Co-authorship is one of the most tangible forms of research collaboration. A co-authorship network is a social network in which the authors through participation in one or more joint publications are linked (undirectedly) to each other. The present work used social network analysis to study co-authorship network of UPM journal publications database for the first four years of Research University (2007-2010) with the aid of Mathematica 11.

The structure of the coauthorship network of publications between 2007 till 2010 was analyzed using the micro-level indicators such as degree centrality, closeness centrality, betweenness centrality and assortativity to observe changes of structure in the network over the early research university years. The study also determines the most connected authors and their influence among coauthors through comparison of their centralities.

Community structure is another typical structure found in social networks. Using modularity approach, the community structures are analysed for each year's co-authorship network and found that then fall naturally onto closely associated areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**STRUKTUR RANGKAIAN KERJASAMA DALAM PANGKALAN DATA PENERBITAN JURNAL UPM DARI 2007 SEHINGGA 2010**

Oleh

**ZURITA BINTI ISMAIL**

**Jun 2018**

**Pengerusi : Hishamuddin Zainuddin, PhD**
**Fakulti : Institut Penyelidikan Matematik**

Penulisan bersama adalah salah satu bentuk kolaborasi penyelidikan yang paling ketara. Kolaborasi penulisan bersama adalah rangkaian sosial di mana penulis terlibat dalam satu atau lebih penerbitan bersama (secara tidak langsung) dengan satu sama lain. Penyelidikan ini menggunakan analisis rangkaian sosial untuk mengkaji kolaborasi penulis menerusi pangkalan data penerbitan jurnal UPM bagi Universiti Penyelidikan untuk empat tahun pertama (2007-2010) dengan bantuan perisian Mathematica 11.

Struktur jaringan kerjasama penerbitan antara 2007 hingga 2010 dianalisis dengan menggunakan penunjuk peringkat mikro seperti pemusatan darjah, pemusatan kedekatan, pemusatan keantaraan dan kesisihan untuk melihat perubahan struktur dalam rangkaian kolaborasi sepanjang tahun bermula awal pengiktirafan universiti penyelidikan. Kajian ini juga menentukan penulis yang paling berkolaborasi dan pengaruh mereka di kalangan penulis yang lain melalui perbandingan pemusatan.

Struktur komuniti juga adalah struktur tipikal lain yang terdapat dalam rangkaian sosial. Menggunakan pendekatan modulariti, struktur komuniti bagi kerjasama rangkaian dianalisis untuk setiap tahun dan mendapati ianya kawasan berkaitan antaranya.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

**Hishamuddin Zainuddin, PhD**
Associate Professor
Institute for Mathematical Research
Universiti Putra Malaysia
(Chairman)

**Mohamed Othman, PhD**
Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

______________________________
**ROBIAH BINTI YUNUS, PhD**
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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# INTRODUCTION

## 1.1 Introduction to Network

Studies in social networks (Wasserman, S et al, 1994) began a long time ago before complex networks became popular. Social network is a set of people or groups, each of which has connections of some kind to some or all of others. In social network analysis, the people or groups are called ‘actors’ and the connections ‘ties’. Both actors and ties can be defined in different ways depending on the questions of interest. An actor might be a single person, a team, a community or a company. A tie might be a friendship between two people, collaboration or common member between two teams, or a business relationship between companies (M.E.J Newman, 2010).

Social network analysis started in 1930’s by psychiatrist, Jacob Moreno, a Romanian immigrant, to America who became interested in the dynamics of social interactions within groups of people. This social network analysis has become one of the most important topics in sociology (Wasserman, S et al, 1994). In recent times, the computer revolution has provided scholars with a huge amount of data and computational resources to process and analyze these data. The size of real networks one can potentially handle has also grown considerably, reaching millions or even billions of vertices. The need to deal with such a large number of units has produced a deep change in the way graphs are approached (Albert Reka et al, 2002).

The most important things to know about social networks is that there are many different possible definitions of an edge in such a network and the particular definition one uses will depend on the questions one wants to answer. Edges may represent friendship between individuals, but may also represent professional relationship, communication patterns, disease infections or many other types of connection. Moreover, the techniques one uses to probe different types of social interaction can also be quite different, so that, different kinds of studies in social network respond to the different questions being addressed.

Historically, the study of networks has been mainly the domain of a branch of discrete mathematics known as graph theory. Since its birth in 1736, when the Swiss mathematician Leonhard Euler published the solution to the Königsberg bridge problem (consisting of finding a round trip that traversed each of the bridges of the Prussian city of Königsberg exactly once), graph theory has witnessed many exciting developments and has provided answers to a series of practical questions (Boccaletti, S et. Al, 2006).

## 1.2 Types of Real World Networks

Different types of real world network have been widely studied in M.E.J Newman (2010) and will be briefly reviewed in this section. The research of networks is largely dependent based on observations of network properties exhibited by each network.

Networks are also called graphs in the mathematical literature where collections of vertices are joined by edges. Vertices and edges are also called nodes and links in computer science, sites and bonds in chemistry and actor and ties in sociology. Table 1.1 gives some examples of vertices and edges in specific networks in M.E.J Newman (2010).

**Table 1.1: Vertices and edges in network. Some examples of vertices and edges in particular network in M.E.J Newman (2010).**

| Network | Vertex | Edge |
|---|---|---|
| Internet | Computer or router | Cable or wireless data connection |
| World Wide Web | Web page | Hyperlink |
| Citation network | Article, patent, or legal case | Citation |
| Power grid | Generating station or substation | Transmission line |
| Friendship network | Person | Friendship |
| Metabolic network | Metabolite | Metabolic reaction |
| Neural network | Neuron | Synapse |
| Food web | Species | Predation |

One can loosely categorize four different types of network, namely social networks, information networks, technological networks and biological networks. For instance, information networks are networks that contain information-theoretic aspects carried by computers or web pages in World Wide Web or citation network of publications. For the World Wide Web, the nodes represent the web pages whereas the edges represent the links between two web pages. Such links are provided by the hyperlinks contains in the web pages and they are directional and are described by directed edges. A.-L. Barabasi et. al (1999) have shown that the World Wide Web possessed the self-organization and scaling properties of random networks. Other examples are the network of citation between US patents and peer to peer networks which are virtual computer networks that allow file sharing among computer users.

Social networks as earlier described are the networks whose vertices represent people and edges represent the interaction between these people. Examples of the social networks are kinship among people, friendship among Facebook users and in society, co-authorship in publications and others. For publication networks, M. E. J Newman (2001) studied the scientific collaboration networks within the disciplines of biomedical sciences, physics and computer science. For friendship network in Facebook, Amanda L. Traud et al (2012) has studied the structure of friendship from various connection group of people all over the world.

## 1.3 Networks Models

At the same time, much attention has also shifted to create network models which can help us to understand the topological structure of an observed network, how these Real World networks came to be, and how the individual components interact with each other.

### 1.3.1 The Random Graph Network

A random graph as defined by B. Bollobas (1985) is a collection of points, or vertices, with lines, or edges, connecting pairs of them at random. The study of random graphs has a long history. Starting with the influential work of Paul Erd˝os and Alfr´ed R´enyi in the 1950s and 1960s discussed in P. Erdos et. al (1959), P. Erdos et. al (1960) and P. Erdos et. al (1961), random graph theory has developed into one of the mainstays of modern discrete mathematics, and has produced a prodigious number of results, many of them highly ingenious, describing statistical properties of graphs, such as distributions of component sizes, existence and size of a giant component, and typical vertex-vertex distances. In almost all of these studies the assumption has been made that the presence or absence of an edge between two vertices is independent of the presence or absence of any other edge, so that each edge may be considered to be present with independent probability p. If there are $N$ vertices in a graph, and each is connected to an average of *z* edges, then it is trivial to show that $p = z(N-1)$, which for large $N$ is usually approximated by $z/N$. The number of edges connected to any particular vertex is called the degree *k* of that vertex, and has a probability distribution $pk$ given by $Pk = \binom{n-1}{k} p^k (1-p)^{n-1-k}$ where the second equality becomes exact in the limit of large *N*. This distribution we recognize as the Poisson distribution i.e the ordinary random graph has a Poisson distribution of vertex degrees.

Random graphs however turned out to have severe shortcomings as models of real-world phenomena. Studies have been performed on real network such as the network of contacts by which a disease is spread in D. D. Heckathorn (19970, networks of friendships within a variety of communities discussed in C.C Foster et. al (1963), T. J Fararo et. al (1964) and H. R. Bernard et. al (1988), networks of telephone calls by J. Abello et. al (2000) and W. Aiello et. al (2000), airline timetables by L. A. N. Amaral et. al (2000), and the power grid by D. J Watts et. al (1988), as well as networks in physical or biological systems, including neural networks in D. J Watts et. al (1988), the structure and conformation space of polymers by S. Jespersen et. al (2000), metabolic pathways in D. Fell et. al (2000) and H. Jeong et. al (2000), and food webs in W. Aiello et. al (2000) and L. A. N. Amaral et. al (2000).

It is found in Grossman, J. W et. al (1995) and Grossman, J. W et. al (2002) that the distribution of vertex degrees in many of these networks is measurably different from a Poisson distribution. This strongly suggests, as has been emphasized elsewhere in A. L Barabasi et. al (1999), that there are features of such networks which we would miss if we were to approximate them by an ordinary (Poisson) random graph.

Another very widely studied network is the world-wide web, whose web pages are vertices of the graph and their hyperlinks are edges. Empirical studies have shown that this graph has a distribution of vertex degree which is heavily right-skewed and possesses a fat (power-law) tail with an exponent between −2 and −3. This distribution is also very far from Poisson, and therefore we would expect that a simple random graph would be a very poor approximation of the structural properties of the world-wide web. In addition, the web differs from a random graph in another in the sense of being directed. Links on one web page to another may be not reciprocated by the other web page.

### 1.3.2 Scale Free Network

In studies of the networks of citations between scientific papers, De Solla Price, D. J. (1965) showed that the number of links to papers- i.e., the number of citations they received, had a heavy-tailed distribution following a Pareto distribution or power law. Thus that the citation network is said to be scale-free. However, the term "scale-free network", is only defined after a few decades of this discovery. In a later paper in Price, D.J. de Solla (1976) also proposed a mechanism to explain the occurrence of power laws in citation networks, which is called "cumulative advantage". Today it is more commonly known under the name preferential attachment.

Recent interest in scale-free networks started in 1999 with the work of A.-L. Barabási et. al (1999) which mapped the topology of a portion of the World Wide Web. They found that some nodes, which they called "hubs", had many more connections than others and that the network as a whole had a power-law distribution. A few other networks, including some social and biological networks, also had heavy-tailed degree distributions, for which they called them as "scale-free network". L. A. N. Amaral et. al (2000) showed that most of the real-world networks can be classified into two large categories according to the decay of degree distribution.

A.-L. Barabási et. al (1999) proposed a generative mechanism to explain the appearance of power-law distributions, which they called "preferential attachment" and is essentially the same as that proposed by Price, D.J. de Solla (1976).

### 1.4 Problem Statement and Motivation

The study of scientific collaboration network in Malaysia is still new. It is not known how collaborative tendencies among scientific researchers are structured in Malaysia's research ecosystem. In other countries, the research in this area is utilized of future research strategies in respective organization.

On 11th October 2006, the Malaysian Cabinet has recognized several public universities as research universities. The declaration of these research universities has profound impact in many aspects of research activities of universities. Universiti Putra Malaysia (UPM) is one of the four universities recognized by the Ministry of Higher Education. Recognition of a research university is based on eight (8) selection criteria determined by the Assessment of Research Universities Committee. These criteria have been developed with a focus on aspects of Research (R) and Development (D) which are based on the criteria adopted by several leading international rating agencies. One of these criteria is to increase the quantity and quality of research and that include increasing number of publications in cited and highly impact factor journals. As one of the strategies, UPM has established mentor-mentee system to encourage established researchers in helping junior researchers to publish in their respective fields.

It is does timely to consider local study of scientific collaboration in Malaysia practically and the research university. In this research, we study the collaborative structure in Universiti Putra Malaysia through coauthorship network for journal publications. Authors (nodes) are linked if they are connected via co-authorship (edges) in papers. From the coauthorship graphs, we will study community of co-authors that play the main role for niche areas in UPM's publications and the various network centralities and structures.

For this study, we constructed coauthorship networks using the raw data of UPM journal publications from UPM's Research Management Centre for the period of 2007-2010. This coincides with the early years of during the early years of UPM's research university. All UPM authors are considered as nodes along with as well as collaborators within and outside UPM. Edges are formed if any authors or nodes have once coauthored a paper in the year considered. The raw data will be curated for this manipulation in a scientific software. Mathematica 11.0 software will be used to visualize and manipulate the data into various forms and calculate relevant quantities. We use the analysis from developed programs to answer a broad variety of questions about collaboration patterns in UPM and identification of key authors who collaborate prolifically and strategically.

## 1.5 Objective

The research objectives of this study consist of:

1. To construct graph theoretic structure of UPM scientific coauthorship networks and study their network features.
2. To extract network-theoretic quantities from UPM scientific coauthorship network.
3. To compare the UPM scientific co-authorship network for each year in the period of 2007-2010 in order to extract possible network tendencies.

## 1.6 Limits on the Scope of Study

It is important to highlight that this study is limited to the network construction of UPM co-authorship network for journal publications the period of 2007-2010 which coincides with the early years of research university status. Since there is no such study before, the present work serves as a baseline study for which future work and analysis can be based on. The journal publications considered are those from journal from Scopus cited journal in all sciences. The selected four years duration of the study is assumed to be sufficient for the network structure to stabilize during the early years of RU status.

By studying co-authorship networks, it must be emphasized that the magnitude of co-authorship does not in any refer to quality of research made by authors. The study merely points out the network structure of co-authorship available in UPM, which may assists engineering of scientific collaboration and in no way makes statement on scientific quality.
Study also makes no attempt of developing new network theoretical structures. It only computes well known quantities from network studies based on UPM journal publications data as stated above.

## 1.7 Overview

The remainder of this thesis will be organized as follows. In chapter 2, the theoretical background for this thesis is stated. Together with a review of some of well-known co-authorship networks and known co-authorship network studies local and literature review. Network models are also briefly mentions.

In chapter 3, the dataset used in this work is briefly described. The theory and dataset used in this network are briefly described. This includes construction of co-authorship network, network centralities and other network theoretic-quantities. Programs and computation for the network analysis are developed in using Mathematica software.

Network analysis and findings will be discussed in chapter 4 using the method proposed by M. E. J. Newman (2001a) and M. E. J. Newman (2001b). This analysis includes degree centrality, closeness centrality, betweenness centrality and extended analysis in assortativity as mention earlier.

Comparison of network centralities for each year and their community structure will be discussed in chapter 5. In particular, we will highlight authors of high centralities in those periods and possibly draw some conclusions.

Lastly, the conclusion and potential future research will be presented in the final chapter of this thesis.

## REFERENCES


A. Scala, L. A. N. Amaral and M. Barth´el´emy (2001). Small World Networks and The Conformation Space of a Lattice Polymer Chain. cond-mat/0004380.

A.-L. Barabasi and R. Albert. (1999). Emergence of Scaling in Random Networks. *Science* 286: 509–512.

A.-L. Barabási (2003). Scale-Free Networks. *Scientific American,* 288: 50-59.

A.L. Barabási, H. Jeong, Z. Neda, E. Ravasz, A. Schubert, T. Vicsek (2002). Evolution of the Social Network of Scientific Collaborations. *Physica A,* 311: 590-614

A.-L. Barabási, R. Albert, H. Jeong (1999). Mean-Field Theory for Scale-Free Random Networks. *Physica A,* 272: 173–187.

Abbasi, A., Chung, K., and Hossain, L. (2012). Egocentric Analysis of Co-Authorship Network Structure, Position and Performance. *Information Processing and Management,* 48:671– 679.

*Albert, Réka; Barabási, Albert-László. (2002). Statistical mechanics of complex networks. Reviews of Modern Physics. 74 (1): 47–97.*

Amanda L. Traud, Peter J. Mucha, Mason A. Porter (2012). Social Structure of Facebook Networks. *Physica A: Statistical Mechanics and its Applications*, 391: 4165 – 4180.

B. Bollobas. (1985). Random Graphs. *Academic Press, New York*.

Boccaletti, S., Latora, V., Moreno, Y., Chavez, M., Hwang, D. U., (2006). Complex Networks: Structure and Dynamics. *Physics Reports*, 424:175-308.

Borgatti, S.P. (1995). Centrality and AIDS. *Connections,* 18 (1): 112–114.

Burt RS. (1995). Structural Holes: The Social Structure of Competition. *Harvard University Press; Cambridge, MA*

C. C. Foster, A. Rapoport, and C. J. Orwant (1963). A Study of A Large Sociogram: Elimination of Free Parameters. *Behavioural Science*, 8:56–65.

Cheng, M. Y., Hen, K. W., Tan, H. P., and Fok, K. F. (2013). Patterns of Co-Authorship and Research Collaboration in Malaysia. *In Aslib Proceedings: New Information Perspectives,* 65: 659–674. Emerald Insight.

D. D. Heckathorn. (1997). Respondent-Driven Sampling: A New Approach to the Study of Hidden Populations. *Social Problems,* 44:174–199.

D. Fell and A. Wagner (2000). The Small World of Metabolism. *Nature Biotechnology,* 18: 1121–1122.

D. J. Watts and S. H. Strogatz (1988). Collective Dynamics of 'Small-World' Networks. *Nature*, 393: 440–442

*De Solla Price, D. J. (1965). Networks of Scientific Papers. Science, 149 (3683): 510–515.*

Fatt, C. K., Ujum, E. A., and Ratnavelu, K. (2010). The Structure of Collaboration in the Journal of finance. *Scientometrics*, 85:849– 860.

Freeman, Linton C. (1979). Centrality in Social Networks Conceptual Clarification. *Social Networks*, 1(3): 215–239.

Grossman, J. W. & Ion, P. D. F (1995). Congressus Numerantium 108:129–131.

Grossman, J. W (2002). Congressus Numerantium 158: 202–212.

H. Jeong, B. Tombor, R. Albert, Z. N. Oltvai, and A.- L. Barabasi (2000). The Large-Scale Organization of Metabolic Networks. *Nature,* 407: 651–654.

H. R. Bernard, P. D. Kilworth, M. J. Evans, C. McCarty, and G. A. Selley (1988). Studying Social Relations Cross Culturally. *Ethnology,* 2: 155–179.

J. Abello, A. Buchsbaum, and J. Westbrook (2000). A Functional Approach to External Graph Algorithms. *Proceedings of the 6th European Symposium on Algorithms.*

J. M. Montoya and R. V. Sole (2002). Small World Patterns in Food Webs. cond-mat/0011195.

Kumar, S. and Jan, J. M. (2013). Mapping Research Collaborations in the Business and Management Feld in Malaysia, 1980-2010. *Scientometrics,* 97:491–517.

L. A. N. Amaral, A. Scala, M. Barth´el´emy, and H. E. Stanley (2000). Classes of Small-World Networks. *Proc. Natl. Acad. Sci. USA,* 97:11149–11152.

M. E. J. Newman (2001). The Structure of Scientific Collaboration Networks. *Proc. Natl. Acad. Sci. USA,* 98: 404–409.

M. E. J. Newman (2001a). Scientific Collaboration Networks: II. Shortest Paths, Weighted Networks, and Centrality. *Phys. Rev. E,* 64 (016132).

M. E. J. Newman (2001b). Scientific Collaboration Networks: I. Network Construction and Fundamental Results. *Phys. Rev. E,* 64 (016131).

M. E. J. Newman (2002). Assortative mixing in networks. *Phys. Rev. Lett.* 89: 208701.

M. E. J. Newman (2004). Coauthorship Networks and Patterns of Scientific Collaboration *Proc. Natl. Acad. Sci. USA,* 101: 5200–5205.

M. E. J. Newman (2000). Models of the small world, *J. Stat. Phys.* 101, 819–841.

M. E. J. Newman (2010). Networks: An Introduction. *Oxford University Press.*

M. Girvan and M. E. J. Newman (2002). Community Structure in Social and Biological Networks. *PNAS*, 99 (12): 7821-7826.

M. E. J Newman (2001). *Proc. Natl. Acad. Sci. USA,* 98:404–409.

P. Erdos and A. Renyi (1959). On Random Graphs. *Publicationes Mathematicae,* 6: 290–297.

P. Erdos and A. Renyi (1960). On the Evolution of Random Graphs. *Publications of the Mathematical Institute of the Hungarian Academy of Sciences,* 5: 17–61.

P. Erdos and A. Renyi (1961). On The Strength of Connectedness of a Random Graph. *Acta Mathematica Scientia Hungary,* 12: 261–267.

Price, D.J. de Solla (1976). A General Theory of Bibliometric and Other Cumulative Advantage Processes. *Journal of the American Society for Information Science*. 27(5): 292–306.

R. J. Williams and N. D. Martinez (2000). Simple Rules Yield Complex Food Webs. *Nature,* 404: 180–183.

S. Jespersen, I. M. Sokolov, and A. Blumen (2000). Small-World Rouse Networks as Models of Cross-Linked Polymer. *J. Chem. Phys.* 113: 7652–7655.

T. J. Fararo and M. Sunshine (1964). A Study of a Biased Friendship Network, *Syracuse University Press, Syracuse, NY*.

Tan, H., Ujum, E., and Ratnavelu, K. (2014). A Scientometrics and Social Network Analysis of Malaysian Research in Physics. *Frontiers in Physics*, 1588:241–245.

W. Aiello, F. Chung, and L. Lu (2000). A Random Graph Model for Massive Graph. in *Proceedings of the 32nd Annual ACM Symposium on Theory of Computing*.

Wasserman, S., & Faust, K (1994). Social Network Analysis: Methods and Applications. *Cambridge: Cambridge University Press,* 8.

Watts, Duncan J.; Strogatz, Steven H. (1998). Collective Dynamics of 'Small-World' Networks. *Nature*. 393 (6684): 440–442.

# BIODATA OF STUDENT

Zurita Ismail was born on 16 June 1980 in Kluang, Johor, Malaysia. From 1987 to 1997 she attended primary and secondary schools in Johor and Melaka. She continued her study at Johor Matriculation in 1998 for one year. Then she pusued her degree in 1999 at Universiti Putra Malaysia with Bachelor of Science (Honour) in Mathematics. She graduated in 2002. She starts working at Institute for Mathematical Research (INSPEM), UPM in 2003 as a Science Officer and change her job as a Research Officer in 2008 until now. She is now working on Complex Networks as her main research and will continue her interest in this research for her expertise.

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