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PENGABDIAN KEPADA MASYARAKAT

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Pengabdian Kepada Masyarakat



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Bandarlampung, 22 September 2008

**Ketua Lembaga Penelitian
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THE TREE $T_{n,k}$ CONFIGURATIONS USING POLYA'S POLYNOMIAL OF ORDER 2 AND 3

Wamiliana and Asmiati

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Abstract

In graph theory, tree plays an important role because it used to represent many problems such as in design the telecommunication networks, distribution networks and so on. The $T_{n,k}$, is the tree with n vertex and k branches and Polya's polynomial is a polynomial in the form of cycle index. In this paper we will discuss the configuration of $T_{n,k}$ using Polya's polynomial for order 2 and 3.

Keywords: *Tree $T_{n,k}$, cycle index, Polya's polynomial*

Introduction

Graph theoretic concepts have proven to be useful in studying problems arising in network design and analysis. The graph structure is used to model or design complex network systems. Usually the nodes or vertices represent the components (stations, cities, computers, depots, etc) and the edges represent the relationship or interconnection between the components (railways, roads, cables, etc). On designing the network, there is some nonstructural information in the network that must be considered such as: cost, capacity, distance, reliability, time delay, equipment capacity, traffic density, etc. By assigning weights to the vertices and edges of the graph representing the network, these factors can be incorporated into the graph theoretical models (Wamiliana, 2002).

A graph G is defined as $G=(V,E)$, where $V = \{1,2,\dots,n\}$ is the set of vertices, $V \neq \phi$, and $E = \{e_{ij} \mid i,j \in V\}$. Two graphs G and H are called adalah isomorphic if there exists a one-one correspondence between the edges and vertices of G and H that preserve incidence (Deo, 1989).

Pölya's theorem uses some concepts in combinatorics such as permutation group and cycle index. Pölya's theorem is one formulae that can be used to count the orbital of the chemical compounds based on the cycle structure of the permutation group. (Harary, 1994).

This paper is organized as follow: in Section 2, literature review, we will give some terms, definitions and theorems used throughout the paper, in Section 3 we will give some observations concerning tree $T_{n,k}$ and its configurations using Pölya's polynomial, and in Section 4 we give conclusion.

1. Literature review

Tree $T_{n,k}$

Tree is a connected graph which not containing cycle and tree with n vertex and k branches is denoted with $T_{n,k}$ (Deo, 1989).

Automorphism

Isomorphism from graph G to itself is called automorphism (Gross and Yellen, 1999).

Below is six automorphisms by rotating the vertex clockwise direction and then reflexing it to the edge given.

Table 1. Permutation on $K_{1,3}$ graph

| Symmetry | Vertex permutation | Edge permutation |
|------------------|--------------------|------------------|
| Identity | $(u) (v) (w) (x)$ | $(a) (b) (c)$ |
| 120° rotation | $(x) (uvw)$ | (abc) |
| 240° rotation | $(x) (uvw)$ | (acb) |
| Reflected to a | $(x) (u) (vw)$ | $(a) (bc)$ |
| Reflected to b | $(x) (v) (uw)$ | $(b) (ac)$ |
| Reflected to c | $(x) (w) (uv)$ | $(c) (ab)$ |

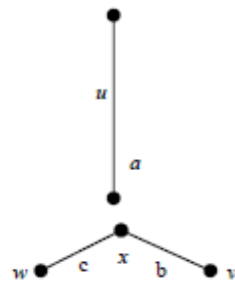


Figure 1. $K_{1,3}$ graph with 6 automorphisms

Automorphism group

Automorphism group from graph G is a group permutation of all automorphisms on graph G denoted as $Aut(G)$. Automorphism of V_G denoted as $Aut_V(G)$ and for E_G denoted as $Aut_E(G)$ (Gross and Yellen, 1999).

Grup Automorphism trivial and nontrivial

Automorphism that only consists of identity permutation is called as trivial automorphism. If there is exist other permutation except identity permutation then that permutation is called as nontrivial group automorphism (Biggs, 1993)

Cycle Structure

Suppose that $\mathcal{P} = [P : Y]$ is a permutation group on set Y consisting of n objects, and let $\pi \in P$. Cycle structure monomial of π is monomial n -variabel

$$\zeta(\pi) = \prod_{k=1}^n z_k^{r_k} = z_1^{r_1} z_2^{r_2} \dots z_n^{r_n}$$

Where z_k is a formal variabel and r_k is the number of k -cycle on the disjoint cycle form π (Gross and Yellen, 1999).

The figure below give the cycle structure for all vertices permutation and edge permutation on $Aut_V(K_4-K_2)$, and the table provides the results.

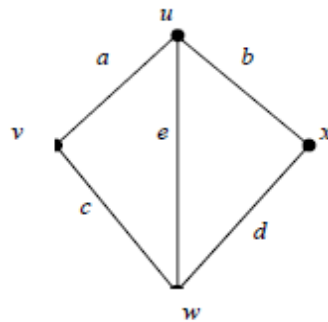


Figure 2. K_4-K_2 graph

Table 1. Cycle structure on $Aut_V(K_4-K_2)$

| Symmetry | $\pi \in Aut_V(g)$ | Cycle structure | $\pi \in Aut_E(g)$ | Cycle structure |
|--------------------------|--------------------|-----------------|--------------------|-----------------|
| Identity | $(u)(v)(w)(x)$ | z_1^4 | $(a)(b)(c)(d)(e)$ | z_1^5 |
| Reflected on the ordinat | $(u)(w)(v\ x)$ | $z_1^2 z_2$ | $(e)(a\ b)(c\ d)$ | $z_1 z_2^2$ |
| Reflected on the absis | $(v)(x)(u\ w)$ | $z_1^2 z_2$ | $(e)(ac)(bd)$ | $z_1 z_2^2$ |
| 180° rotation | $(u\ w)(v\ x)$ | z_2^2 | $(e)(a\ d)(b\ c)$ | $z_1 z_2^2$ |

Cycle Index

Suppose that $\mathcal{P} = [P : Y]$ is a permutation group on a set with n objects then cycle index \mathcal{P} is a polynomial $Z_{\mathcal{P}}(z_1, \dots, z_n) = \frac{1}{|P|} \sum_{\pi \in P} \zeta(\pi)$

(Gross and Yellen, 1999).

Pölya theorem

The sequence of configuration is resulted by substituting the sequence of numbers into the cycle index permutation group P ,

$$Z_{\mathcal{P}}(x_1 + \dots + x_k) = Z(P, \sum_{i=1}^k x_i) \quad (\text{Harary, 1994}).$$

Proof :

Suppose that $\mathcal{P} = [P : Y]$ is a group permutation on set Y that consists of n object, and $\pi \in P$. Also assume that z_k is a variabel and r_k is a number of k -cycle on disjoint cycle form π so that cycle structure monomial of π is monomial n -variabel

$$\zeta(\pi) = \prod_{k=1}^n z_k^{r_k} = z_1^{r_1} z_2^{r_2} \dots z_n^{r_n}$$

Add the two sides of this equation with all permutations permutasi $\pi \in P$, and then divide it by $|P|$, we get

$$\frac{1}{|P|} \sum_{\pi \in P} \zeta(\pi) = \frac{1}{|P|} \sum_{\pi \in P} \prod_{k=1}^n z_k^{r_k}$$

This result is cycle index $Z_P(z_1, \dots, z_n)$. By changing every variable of cycle index z_j with polynomial k -variate $x_1^j + x_2^j + \dots + x_k^j$ then we get:

$$Z_P(x_1 + \dots + x_k) = Z(P, \sum_{i=1}^k x_i)$$

Pölya's substitution and Pölya counting polynomial of order k

Suppose that $Z_P(z_1, \dots, z_n)$ is the cycle index polynomial of the permutation group $\mathcal{P} = [P : Y]$ on set Y with n objects. Pölya's substitution on order k of cycle index variable z_j is a k -variate polynomial $x_1^j + x_2^j + \dots + x_k^j$ and Pölya counting polynomial of order k is a polynomial found by changing each cycle index variable z_j with Pölya's substitution of order k , and it is $Z_P(x_1 + \dots + x_k)$

(Gross and Yellen, 1999).

2. The Tree $T_{n,k}$ Configuration

As we know that tree $T_{n,k}$ which we discussed in this paper is a tree with n vertices and k branches and also has property that it only can have trivial automorphism group. The number of minimal vertices of the tree with k branches that can form trivial automorphism group is :

$$n = \frac{k(k+1)}{2} + 1, \quad 3 \leq k < \infty \quad (\text{Nisa}', 2005).$$

The configuration that found from $T_{n,k}$ which only formed trivial automorphism group by using Pölya's theorms for order 2 and 3 can be seen on Tabel 2.

Tabel 2. Cycle structure and Cycle Index on Tree $T_{n,k}$

| Number of branches | Number of vertices | Cycle structure | Cycle Index | 2 order configuration | 3 order configuration |
|--------------------|--------------------|-----------------|-------------|-----------------------|--------------------------|
| 3 | 7 | z_1^7 | z_1^7 | $(x_1 + x_2)^7$ | $(x_1 + x_2 + x_3)^7$ |
| 4 | 11 | z_1^{11} | z_1^{11} | $(x_1 + x_2)^{11}$ | $(x_1 + x_2 + x_3)^{11}$ |
| 5 | 16 | z_1^{16} | z_1^{16} | $(x_1 + x_2)^{16}$ | $(x_1 + x_2 + x_3)^{16}$ |
| 6 | 22 | z_1^{22} | z_1^{22} | $(x_1 + x_2)^{22}$ | $(x_1 + x_2 + x_3)^{22}$ |
| ... | ... | ... | ... | ... | ... |

| | | | | | |
|---|------------------------|------------------------------|------------------------------|--------------------------------------|--|
| n | $\frac{k(k+1)}{2} + 1$ | $z_1^{\frac{k(k+1)}{2} + 1}$ | $z_1^{\frac{k(k+1)}{2} + 1}$ | $(x_1 + x_2)^{\frac{k(k+1)}{2} + 1}$ | $(x_1 + x_2 + x_3)^{\frac{k(k+1)}{2} + 1}$ |
|---|------------------------|------------------------------|------------------------------|--------------------------------------|--|

Conclusion

Tree $T_{n,k}$ which only formed trivial automorphism group has 1 cycle structure because it only consists of identity permutation so that the second order configuration of tree $T_{n,k}$ is

$$(x_1 + x_2)^{\frac{k(k+1)}{2} + 1}, \quad 3 \leq k < \infty$$

and third order configuration of tree $T_{n,k}$ is

$$(x_1 + x_2 + x_3)^{\frac{k(k+1)}{2} + 1}, \quad 3 \leq k < \infty$$

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