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EDITORS
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Preface: The 5th International Conference on Research and Education in Mathematics

This volume consists of the refereed papers presented at the 5th International Conference on Research and Education in Mathematics (ICREM5) held on October 22-24, 2011 at ITB, Bandung, Indonesia. This conference was jointly organized by the Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung Indonesia, Institute for Mathematical Research, Universiti Putra Malaysia (INSPEM) Malaysia, Institute of Mathematics, Vietnam Academy of Science & Technology (IMVAST) Vietnam, Indonesian Combinatorial Society (InaCombS) and Indonesian Mathematical Society (IndoMS).

The conference was attended by around 300 participants from all over the countries: Japan, Malaysia, Vietnam, Thailand, Philippines, India, Pakistan, Singapore, Australia, USA, Romania, Norway, Russia, Bangladesh, Iran, Iraq, Germany, Turkey, Spain and Indonesia. There were 18 keynote, plenary and invited talks in this conference. Especially, Professor Cedric Villani (Institut Henri Poincare, Fields Medalist 2010) gave a keynote talk. In this volume, we also include some abstracts of the keynote, plenary and invited talks which are not included in the full proceedings.

The organizers are grateful to Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung (ITB), Institute for Mathematical Research, Universiti Putra Malaysia (INSPEM); Institute of Mathematics, Vietnam Academy of Science & Technology (IMVAST); Indonesian Combinatorial Society (InaCombS) and Indonesian Mathematical Society (IndoMS) for their collaboration to jointly organize this conference. We would like also to thank to the Rector of ITB, Directorate General of Higher Education - Ministry of Education and Culture Indonesia, Abdus Salam International Centre for Theoretical Physics (ICTP); United Nations Educational, Scientific and Cultural organization (UNESCO), and France Embassy in Indonesia for their invaluable support.

We also thank all organizing, program committee members and referees for the excellent work. Our high appreciation is to all the principal speakers: Cedric Villani, Ragni Piene, Johnny W. Lott, Mohd Rizam Abu Bakar, Sergey Borisenok, Wono S. Budhi, Phan Thi Ha Duong, Cristodor Ionescu, Mat Rofa Ismail, Udjianna S. Pasaribu, Sri R. Pudjaprasetya, Oleg Ivanovich Reino, Yoshihiro Sawano, Vu Ngoc Phat, Nguyen Minh Tri, George Willis, Hishamuddin Zainuddin, and Tudor Zamfirescu, and to all the participants for making this conference successful and enjoyable.

Bandung, April 2012

Editors:
Edy Tri Baskoro
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Keynote Talk

Optimal transport, from economics to physics to geometry to economics

Cédric Villani

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This talk is about the Monge-Kantorovich problem, from its birth to its use in economics by Nobel Prize Kantorovich, then in physics in fluid mechanics and diffusion equations, then its connection with differential geometry (Ricci curvature) on which I worked, finally its unexpected reappearance in some economics problems (McCann and other researchers).

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Plenary Talks

A survey on the reachability and the convergence of Sand Piles Model and its extensions

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Sand Pile Models where introduced in 1988 by Bak, Tang and Wiesenfeld to highlight Self-Organized Criticality (SOC). SOC characterizes dynamical systems having critical attractors, i.e. systems that evolves toward a stable state from which a small perturbation has an uncontrolled consequence on the system. In the classical SPM, the evolution rule considers that at each step, one grain falls to the right (sequential model). Many extensions of this model were introduced by relaxing the evolution rule: grain can fall to the right and to the left, many grains can fall parallely, etc. In this paper, we present a survey of the behavior of these models. We show the characterization of reachable configurations and the order struture of the space of all reachable configurations. We give also the explicit formula for the stable configurations of these models. By this way, we show the strong relation between the set of stable configurations in the sequential model and in the parallele model.

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A characterization of the corona product of a cycle with some graphs based on its f-chromatic index

Adiwijaya, A. N. M. Salman, Djoko Suprijanto, and Edy Tri Baskoro

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A characterization of the corona product of a cycle with some graphs based on its f-chromatic index[1]

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Abstract. An f-coloring of graph $G(V,E)$ is a generalized edge-coloring such that every vertex v in V has at most $f(v)$ edges colored with a same color. There are many applications of the f-coloring, for instance we can use it in order to solve some scheduling problems and some network design problems. The minimum number of colors needed to f-color G is called an the f-chromatic index of G, denoted by $\chi'_f(G)$. Any graph G has f-chromatic index equal to $\Delta_f(G)$ or $\Delta_f(G)+1$, where $\Delta_f(G) = max_{v\in V}\{\lceil d(v)/f(v)\rceil\}$. G is called in the *class-1*, denoted by $G \in C_f1$, if $\chi'_f(G) = \Delta_f(G)$; otherwise G is called in the *class-2*, denoted by $G \in C_f2$. In this paper, we show that the corona product of C_n with S_m is in C_f1. Besides that, we characterize the corona product of C_n with either W_n or K_n based on f-coloring.

Keywords: corona product, f-chromatic index, f-coloring, graph
PACS: 02.10.Ox

INTRODUCTION

Throughout this paper, $G(V,E)$ is a simple and finite graph with the vertex set $V(G)$ and the edge set $E(G)$. We refer to [6] for undefined terms. Let f be a function from $V(G)$ to a subset of the positive integers. An *f-coloring* of G is a coloring of edges such that each vertex v has at most $f(v)$ edges colored with a same color. The minimum number of colors needed in the f-coloring of G is called an *f-chromatic index* of G, denoted by $\chi'_f(G)$.

A problem in the f-coloring is how to determine $\chi'_f(G)$ of a given graph G. It arises in many applications, including the network design problem, the scheduling problem, and the file transfer problem in a computer network [4]. The file transfer problem in a computer network is modeled as follows. Each computer is represented by a vertex and every two computers in the file transfer process is represented by an edge. Each computer v has a limit number $f(v)$ of communication ports. If we assume that the transfer time is constant for every file, we can use an f-coloring to manage transferring all files along the minimum time needed.

Let $d(v)$ denote the degree of $v \in V$. By extending the well–known theorem of Vizing (1965) to f-colorings, Hakimi and Kariv [5] showed that

$$\Delta_f(G) \le \chi'_f(G) \le \Delta_f(G)+1,$$

where

$$\Delta_f(G) = \max_{v\in V(G)}\left\{\left\lceil \frac{d(v)}{f(v)}\right\rceil\right\}.$$

According to [5], G is called in the *class-1*, denoted by $G \in C_f1$, if $\chi'_f(G) = \Delta_f(G)$; otherwise G is called in the *class-2*, denoted by $G \in C_f2$. Holyer [7] proved that the edge-coloring problem is an NP-complete. It is reduced from the 3SAT problem. Consequently, the f-coloring problem is an NP-complete problem.

Hakimi and Kariv [5] showed that any bipartite graph is in C_f1. Moreover, for any graph, they showed that, if $f(v)$ is even for each $v \in G$, then G is in C_f1. Yu et al. [8] gave sufficient conditions for fans to be in C_f1. Zhang and Liu [10] found the f-chromatic index for complete graphs and gave a classification of complete graphs on f-coloring. Let,

$$V_0^*(G) = \left\{v : \frac{d(v)}{f(v)} = \Delta_f(G), v \in V(G)\right\},$$

and

$$V^*(G) = \left\{v : \left\lceil \frac{d(v)}{f(v)}\right\rceil = \Delta_f(G), v \in V(G)\right\}.$$

Zhang and Liu in [9] gave some sufficient conditions for a graph to be in C_f1 as follows.

Theorem 1. *Let G be a graph. If the subgraph induced by $V_0{}^*(G)$ is forest, then $G \in C_f1$.*

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Theorem 2. *Let G be a graph. If $d(v^*)$ is not devided by $f(v^*)$ for every $v^* \in V^*(G)$, then $G \in C_f1$.*

Two above theorems will be used in the part of the proof of our results. In 2008, Zhang *et al*. [11] gave a sufficient condition for a regular graph to be in C_f2. In [1], we generalized the result as stated in Theorem 3.

Theorem 3. *Let $G = (V,E)$ be a graph and let $g = \gcd(d(v) : v \in V)$. Let $f : V \to \mathbb{N}$ be defined as $f(v) = d(v)/k$ for each $v \in V$, where k divides g. If $f(v)$ is odd for an odd number of vertices, then $G \in C_f2$.*

Let G and H be two graphs with n and m vertices, respectively. The *corona product* of a graph G with a graph H, denoted by $G \odot H$, is a graph obtained by taking one copy of an n-vertex G and n copies of H, namely H_1, H_2, ..., H_n, and then for $i = 1,2,...,n$, joining the i-th vertex of G to every vertex of H_i. Here G is called the *center* of $G \odot H$, denoted by G^1, and H_i is called the *outer* of $G \odot H$, denoted by H_i^2.

Let C_n be a cycle on n vertices, S_n be a star on $n+1$ vertices, W_n be a wheel on $n+1$ vertices, and K_n be a complete graph on n vertices. We showed in [3] that the corona product of a cycle with either the complement of a complete graph, or a path, or another cycle is in C_f1. In [2] we gave a characterization of some graphs containing wheels, namely the corona product of either the complement of a complete graph, or a path, or a star with a cycle, based on f-coloring.

As well-known, the corona product is not commutative. Hence, in this paper, we are interested in considering the corona product of C_n with S_m. In Theorem 4, we show that it is in C_f1 for any f. Besides that, we consider the corona product of C_n with either W_m or K_m. By using Theorem 3, we give a characterization of the corona product of C_n with W_m based on its f-chromatic index as we state in Theorem 5. In Theorem 6, we give a necessary and sufficient condition of the corona product of C_n with K_m to be in C_f2.

MAIN RESULTS

Let $G = C_n \odot S_m$ be the corona product of a cycle with a star. We label all vertices of C_n^1 by $v_1, v_2, ..., v_n$, respectively. Next, for $i = 1,2,...,n$ and $j = 1,2,...,m$, we label the center of i-th star S_m^2 by u_i and the other vertices of the i-th star S_m^2 by $w_{i,j}$. In the following theorem, we show that the corona product of a cycle with a star is in C_f1 for any f.

Theorem 4. *Let $n \geq 3$, $m \geq 3$, $G = C_n \odot S_m$, and f be a function from $V(G)$ to a subset of positive integers, then $G \in C_f1$.*

Proof.

If $\Delta_f(G) = 1$, then we can define an f-coloring of G with one color. For $\Delta_f(G) \geq 2$, we divide the proof into two cases as follows.

Case 1. $\Delta_f(G) = 2$

For $i = 1,2,...,n$ and $j = 1,2,...,m$, we color all edges u_iv_i by c_1, $v_iw_{i,j}$ by c_1 and c_2 alternately, and $w_{i,j}u_i$ by c_2 and c_1 alternately such that $w_{i,j}$ is incident with two different colored edges. Next, we color all edges in $E(C_n^1)$ by c_2.

Case 2. $\Delta_f(G) \geq 3$

For $i = 1,2,...,n$ and $j = 1,2,...,m$, we color all edges $u_iw_{i,j}$ by $c_1, c_2, ..., c_{\Delta_f}$ alternately, $v_iw_{i,j}$ by $c_2, c_3, ..., c_{\Delta_f}, c_1$ alternately, and u_iv_i by c_{Δ_f}. Next, we color all edges in $E(C_n^1)$ by c_1 and c_2 alternately. Finally, for odd n and for $i = 1,2,...,n$, we have to replace the color on $v_iw_{i,m}$ by c_2.

So, all edges of G have been colored by using $\Delta_f(G)$ colors and every vertex $v \in V(G)$ has at most $f(v)$ edges with a same color. □

Let $G = C_n \odot W_m$ be the corona product of a cycle with a wheel. We label all vertices of $V(C_n^1)$ by $v_1, v_2, ..., v_n$, respectively. Next, for $i = 1,2,...,n$ and $j = 1,2,...,m$, we label the center of i-th wheel W_m^2 by u_i and the other vertices of the i-th wheel W_m^2 by $w_{i,j}$. In the following theorem, we give a necessary and sufficient condition of the corona product of C_n with W_m to be in C_f2.

Theorem 5. *Let $n \geq 3$, $m \geq 3$, and $G = C_n \odot W_m$. If n is odd and*

$$f(v) = \begin{cases} \frac{m+3}{2}, & v \in V(C_n^1), \\ \frac{m+1}{2}, & v = u_i, \\ 2, & v = w_{i,j}, \end{cases}$$

then $G \in C_f2$. Otherwise, $G \in C_f1$.

Proof.

If the premise of the theorem is fulfilled, then $\Delta_f(G) = 2$ and $d(v) = 2f(v)$ for every $v \in V(G)$. Meanwhile, there exists odd $f(v)$ for odd number of vertices $v \in V(G)$. Hence, by Theorem 3, then $G \in C_f2$.

If the premise of the theorem is not fulfilled, we divide the proof into two cases as follows.

Case 1. For even n

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If $f(v)$ is as given above, we can construct an f-coloring by using Δ_f colors as follows. For $i = 1,2,...,n$ and $j = 1,2,...,m$, we color all edges $u_iw_{i,j}$ by $c_1, c_2, ..., c_{\Delta_f}$ alternately and $v_iw_{i,j}$ by $c_{\Delta_f}, c_1, ..., c_{\Delta_f-1}$ alternately, and u_iv_i by c_{Δ_f}. Next, for $i = 1,2,...,n$ and $j = 1,2,...,m-1$, we color all edges $w_{i,j}w_{i,j+1}$ and $w_{i,m}w_{i,1}$ by c_{Δ_f-1}, c_{Δ_f}, c_1,... c_{Δ_f-2} alternately. Finally, for $i = 1,2,...,n-1$, we color all edges v_iv_{i+1} and v_nv_1 by c_1 and c_2 alternately. Meanwhile, if $f(v)$ does not satisfy the above conditional, then it becomes more easy to construct an f-coloring by using Δ_f colors.

Case 2. For odd n

For $i = 1,2,...,n$ and $j = 1,2,...,m$, we color all edges $u_iw_{i,j}$ by $c_1, c_2, ..., c_{\Delta_f}$ alternately, and u_iv_i and $v_iw_{i,1}$ by c_1. For $i = 2,3,...,n$ and $j = 1,2,...,m$, we color $v_iw_{i,j}$ by $c_{\Delta_f-1}, c_{\Delta_f}, c_1, ..., c_{\Delta_f-2}$ alternately. Next, we color all edges v_iv_{i+1} and v_nv_1 by c_{Δ_f}. Finally, for $i = 1,2,...,n$ and $j = 1,2,...,m-1$, we color edge $w_{i,j}v_{i,j+1}$ and $w_{i,m}w_{i,1}$ by $c_{\Delta_f}, c_1, ..., c_{\Delta_f-1}$ alternately.

Hence, $G \in C_f1$. □

In Theorem 6, we give a characterization of the corona product of C_n with K_m based on f-chromatic index. All vertices of C_n^1 are labeled by $v_1, v_2, ..., v_n$, and for $i = 1,2,...,n$ and $j = 1,2,...,m$, all vertices of i-th K_m^2 are labeled by $w_{i,j}$. In the following theorem, we characterize the corona product of a cycle with a complete graph based on its f-chromatic index.

Theorem 6. *Let $n \geq 3$, $m \geq 2$, and $G = C_n \odot K_m$. If n is odd, m is even, and*

$$f(v) = \begin{cases} \frac{m}{2}+1, & v \in V(C_n^1), \\ \frac{m}{2}, & v \in V(K_m^2), \end{cases}$$

then $G \in C_f2$. Otherwise, $G \in C_f1$.

Proof.

For $i = 1,2,...,n$, let L_i be a subgraph of G which is induced by all vertices of i-th K_m^2 and v_i.

If the premise of the theorem is fulfilled, we have $\Delta_f(G) = 2$ and $d(v) = 2f(v)$ for every $v \in V(G)$. Meanwhile, there exists odd $f(v)$ for odd number of vertices $v \in V(G)$. Hence, by Theorem 3, we get $G \in C_f2$.

If the premise of the theorem is not fulfilled, we can construct an f-coloring on G by using $\Delta_f(G)$ colors. We divide the proof into two cases as follows.

Case 1. $\Delta_f(G) = m$

If $f(v) = 1$ for every $v \in V(G) \setminus V(C_n^1)$, then we divide proof into two subcases.

Subcase 1.1. For odd m

Since every L_i is a complete graph with even order, then L_i can be decomposed into m edge–disjoint matchings with $(m+1)/2$ edges each. Give a different color to each class. Next, we color all edges in $E(C_n^1)$ by using two different colors alternately. So, all edges of G have been colored by using $\Delta_f(G)$ colors and every vertex $v \in V(G)$ has at most $f(v)$ edges with a same color.

Subcase 1.2. For even m

In this case, we color all edges in $E(C_n^1)$ by using one color, namely t. Next, for $i = 1,2,...,n$ and $j = 1,2,...,m$, we color all edges which joining v_i with every vertex $w_{i,j}$ by using $m/2$ colors (except t) such that the number of colors on edges which is incident with v_i is equal to 2 for every color. Hence, every $L_i \setminus \{v_i\}$ can be decomposed into m edge-disjoint matchings. We color each *matching* by using one class of color such that the number of colors on edges which is incident with $w_{i,j}$ is equal to 1 for every color. So, we have constructed an f-coloring on G by using Δ_f colors.

If there exist $f(v) \neq 1$ for some vertices $v \in V(G) \setminus V(C_n^1)$, then we can construct an f-coloring easier than both of two subcases above.

Case 2. $\Delta_f(G) < m$

Every subgraph K_m^2 contains a complete graph K_{r+1} with $r = max\{s \leq m : s \text{ is divided by } 2\Delta_f\}$. Based on Lucas Theorem [6], a complete graph with odd order can be decomposed into some edge-disjoint Hamiltonian cycles. Hence, we decompose every K_{r+1} into $r/2$ edge-disjoint Hamiltonian cycles. Next, we partition this Hamiltonian cycles into Δ_f classes with cardinality of each is r/Δ_f. Give a different color to each class. We obtain an f-coloring on every K_{r+1} by using Δ_f colors such that every vertex is joining with r/Δ_f edges for every color.

If $m \neq 0 \pmod r$, then some edges in $E(K_m^2)$ are not colored yet. For $i = 1,2,...,n$, let $W_{i,j} = \{w_{i,m-r+1}, \ldots, w_{i,m-r+\Delta_f}\}$ be a subset of vertices of $K_m^2 \setminus K_{r+1}$ which are incident with edges in K_{r+1}. Next, for $i = 1,2,...,n$, we partition vertices of i-th K_{r+1} into Δ_f subsets, namely $U_{i,1}, \ldots, U_{i,\Delta_f}$. For $i = 1,2,...,n$ and $j = 1,2,...,\Delta_f$, we color the edges which is joining every vertex $w_{i,m-r+j} \in W_{i,j}$ with $U_{i,l}$ with color $(j+l) \pmod{\Delta_f}$. In case $(j+l) \equiv 0 \pmod{\Delta_f}$, we color the edges by Δ_f. It implies every vertex in $U_{i,l} \cup W_{i,j}$ has at most $(m+1)/\Delta_f$ edges with a same color. Next, for

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$i = 1,2,...,n$ and $j = 1,2,...,\Delta_f$, we can color all edges which is joining vertices in $W_{i,j}$ such that the number of colors on edges which are incident with $w_{i,m-r+j}$ at most $f(w_{i,m-r+j})$.

If $m \equiv 0 \pmod{r}$, then $L_i \setminus \{v_i\}$ $(1 \leq i \leq n)$ is a complete graph with even order. This means that the L_i can be decomposed into $m/2$ edge-disjoint Hamiltonian cycles. Next, we recollect the Hamiltonian cycles into Δ_f classes and for every class, we color all edges by using different colors. Finally, we color all edges in $E(C_n^1)$ by using a color such that every vertex $v \in V(C_n^1)$ has at most $f(v)$ edges with a same color. □

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