

# 行政院國家科學委員會專題研究計畫 成果報告

## 二元樹之間的旋轉距離 研究成果報告(精簡版)

計畫類別：個別型  
計畫編號：NSC 100-2221-E-128-003-  
執行期間：100年08月01日至101年07月31日  
執行單位：世新大學資訊管理學系(所)

計畫主持人：劉嘉傑

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大專生-兼任助理人員：鄭琬臻  
大專生-兼任助理人員：高建中

報告附件：出席國際會議研究心得報告及發表論文

公開資訊：本計畫可公開查詢

中華民國 101 年 10 月 02 日

中文摘要：在電腦科學的領域中二元樹是非常重要的資料結構，在過去的四十年間有許多相關的研究被提出。對於度量任兩棵點數相同的二元樹之間的差異性，最常使用的方式是計算兩棵二元樹的旋轉距離。在一棵二元樹上的任一個內部節點做旋轉動作是重新建構成另一棵二元樹的一種機制，且在轉換過程中仍需維持二元樹原有的中序順序。而藉由最少次的旋轉動作將一棵二元樹轉換成另一棵二元樹，則稱之為此二棵二元樹之間的旋轉距離。到目前為止，給定任意二棵點數相同的二元樹，仍然沒有多項式時間內計算其旋轉距離的演算法。目前已知旋轉距離的上界為  $2n-6$ ，下界則為  $2n-n$ ，其中  $n$  是二元樹的節點個數。

Lucas 在 2004 年發表的期刊中限制起始二元樹內的每一個內部節點最多只能有一個子節點(degenerate tree)，而目的地二元樹則必須為一棵角樹(angle tree)，其中 angle trees 為 degenerate trees 的一個子集合。在此限制集合內，Lucas 提出了  $O(n^2)$  的演算法能準確的計算出此二棵二元樹之間的旋轉距離。我們於 2010 年針對 Lucas 的限制條件下，將時間複雜度提升至  $O(n)$ 。此外，我們亦提出另外一組與 Lucas 完全不同的限制集合 RLW-trees 且集合內的任兩棵二元樹皆能在  $O(n)$  的時間內求算其旋轉距離。

在本研究計劃的第一年，我們將求算任兩棵 degenerate trees 之間的旋轉距離。接續的第二年，我們將提出更多能具體求算任兩棵二元樹旋轉距離的限制集合，並歸納分析這些限制集合的特性，目標是提出整合性的演算法，計算所有限制集合中任兩棵二元樹的旋轉距離。我們將視這些限制集合為全部二元樹集合中的 kernels，在計劃的第三年，我們將藉由這些 kernels 降低全部二元樹中任兩棵二元樹之間的旋轉距離的上界值。

中文關鍵詞：二元樹、旋轉距離

英文摘要：Binary trees forms a fundamental data structure in computer science and have been extensively studied over the past forty years. There are a number of ways for measuring the shape difference between two binary trees with the same number of nodes. One of the most common measurements is the number of rotations required. A rotation is a local restricting that transforms one tree into another such that the in-order sequences of two trees are the same. The

rotation distance between any two  $n$ -node rooted binary trees is the minimum number of rotations needed to transform one into another. It is still an open problem to determine whether rotation distance can be computed in polynomial-time or not. For any two  $n$ -node rooted binary trees, the upper and lower bounds of rotations for any two  $n$ -node rooted binary trees are  $2n-6$  and  $2n-n$ , respectively.

In 2004, Lucas presented an  $O(n^2)$ -time algorithm for finding the rotation distance between two binary trees under the constraint that the source tree is a degenerate tree and the destination tree is an angle tree, where angle trees are subset of degenerate trees. Under this constraint, we have improved time-complexity into  $O(n)$ . Meanwhile, we defined another subset of binary trees, say RLW-set, and proposed a linear-time algorithm to construct a series of rotations for transforming  $T$  and  $T'$  with minimum rotations, where  $T$  and  $T'$  are both RLW-trees.

In the first year of this study, we will intend to propose an algorithm for finding the rotation distance between any two degenerate trees. During the second year, we will define more subsets of binary trees in which the rotation distance between any two binary trees of each subset can be found exactly. In addition, we will explore more characteristics of these subsets. Our goal is to propose an integrated algorithm for calculating the rotation distance between any two trees in these subsets. These subsets can be considered as kernels of all binary trees. It is possible to extend them to find the rotation of any two binary trees efficiently. In the last year, we will intend to reduce the upper bounds of rotations for any two  $n$ -node binary trees.

英文關鍵詞： Binary tree, rotation

行政院國家科學委員會補助專題研究計畫

☐期中進度報告

☒期末報告

二元樹之間的旋轉距離

計畫類別：☒個別型計畫 ☐整合型計畫

計畫編號：NSC 100-2221-E-128-003

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中 華 民 國 101 年 10 月 2 日

## 一、報告內容

A binary tree  $T$  considered here is a rooted, ordered tree with  $n$  internal nodes  $v_1, v_2, \dots, v_n$  where the indices are numbered according to the in-order traversal (i.e., visit recursively left subtree, root and then right subtree) of  $T$  and, thus, each internal node is restricted to having exactly two children, a left child and a right child. Such a binary tree is also called an *extended binary tree*. Binary trees form a fundamental data structure in computer science and have been extensively studied over the past forty years. There are a number of ways for measuring the shape difference between two binary trees with the same number of nodes. One of the most common measurements is the number of rotations required. Rotations are primitive steps in tree balancing for AVL-tree and splay trees, and so on. Basically, a rotation is a local restructuring that transforms one tree into another such that in-order sequence of these two trees is the same. Figure 1 illustrates the two fundamental rotation operations, the left rotation and the right rotation, applied at the node  $x$  and  $y$ , respectively, of a binary tree.

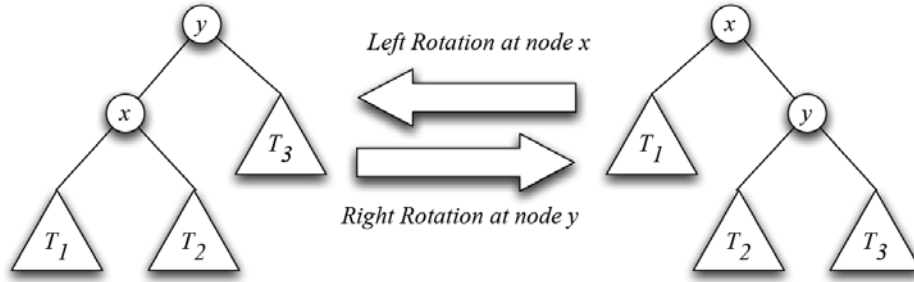


Figure 1: The left rotation and right rotation.

The studies of combinatorial properties related to rotations have been an important issue for binary trees. For example, enumerating binary trees with a Gray code with respect to rotations was studied in. In another, a well-known one to one correspondence between a binary tree with  $n$  nodes and a triangulation of a convex polygon with  $n+2$  vertices was established in. This implies that flipping an edge in a triangulation corresponds exactly to a rotation on the corresponding binary tree. See Figure 2 as an illustration.

Furthermore, Gibbons and Sant showed the coloring problem can be coupled to rotational paths between two trees. In 1986, Pallo introduced the left weight sequence for binary trees and showed that ever binary tree can be characterized by a left weight sequence. Meanwhile, Pallo also proved that the rotations on binary trees with  $n$  nodes induce a combinatorial structure called  $n$ th Tamari lattice, i.e., an  $n$ -element partially ordered set with a unique maximum element and minimum element, respectively. Consequently, coding binary trees by the left weight sequences is a valuable tool for studying the Tamari lattices.

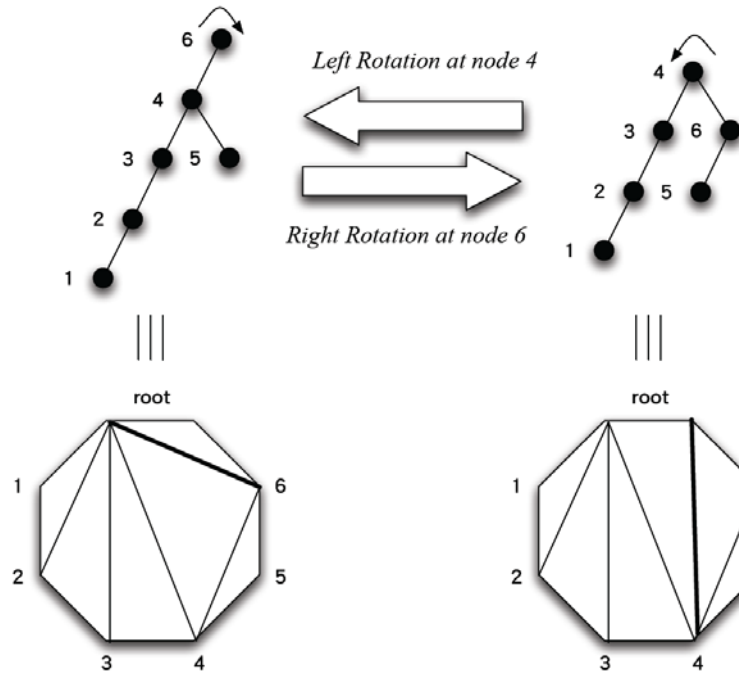


Figure 2: The relationship between an  $n$ -nodes binary tree and a  $(n+2)$ -vertices convex polygon

The rotation distance between any two  $n$ -node rooted binary trees  $T$  and  $T'$ , denoted by  $dis(T, T')$ , is the minimum number of left and right rotations needed to transform  $T$  into  $T'$ . It is still an open problem to determine whether  $dis(T, T')$  can be computed in polynomial-time. Pallo and Rogers gave an approximation algorithm to estimate the rotation distance of any two binary trees. Let  $d(n) = \max\{dis(T, T') \mid \text{for all binary trees } T \text{ and } T'\}$ . Culik and Wood showed that  $d(n) \leq 2n-2$  and this bound was improved to  $d(n) \leq 2n-6$ , for  $n \geq 11$ . Using an argument of hyperbolic geometry, they prove  $d(n) \geq 2n-6$  for  $n \geq N$ , where  $N$  is some ineffective (large) integer. A brute force argument gives  $d(n) = 2n-6$  for  $11 \leq n \leq 19$ . It is natural to conjecture  $d(n) = 2n-6$  for  $n \geq 11$ , and to predict the existence of a combinatorial proof. Recently, Dehornoy established a lower bound that  $d(n) \leq 2n - \sqrt{n}$ . Other properties of rotations on trees were studied by Hanke, Ottmann, and Schuierer, Hurtado and Noy, Hurtado, Noy and Urrutia, and Rogers and Dutton. These results were obtained based upon the equivalence between binary trees of  $n$  nodes and triangulations of an  $n+2$  vertex convex polygon.

Many researchers have focused on the rotation distances under various restrictions. Bonnin and Pallo showed that the rotation distance between two binary trees can be computed in quadratic time if rotations are restricted to nodes with leaves as left subtrees. Sundar studied transformations of trees when only right rotations can be applied. Cleary considered the situation that rotations are only allowed at the root or its right child. Using the metric properties on Thompson's group, Cleary obtained a linear upper bound and lower bound for computing the restricted rotation distance between any two binary trees. Lately, the upper bound and lower bound of such restricted rotation distance

were improved significantly by Cleary and Lucas. Pallo generalized this restriction to resolve the rotation distance under the situation that rotations are only allowed at nodes along the right arm of the trees.

We say that a binary tree  $T$  is *degenerate* if each node in  $T$  has at most one child. A degenerate tree  $T$  is called an *angle tree* if the right (respectively, left) child of the root of  $T$  is not empty and every node in  $T$  that has a non-empty right (respectively, left) child is an ancestor of every node in  $T$  that has a non-empty left (respectively, right) child. Actually, the set of restricted form contains  $2^{n-1}$  binary trees. Lucas proposed an  $O(n^2)$ -time algorithm for computing  $dis(T_0, T_f)$  with the minimum number of rotations. Under this constraint, we have improved time-complexity into  $O(n)$ . Lately, by using the coding technique of left weight sequences, we defined another set of  $2^{n-1}$  binary trees in which any two of them can be rotated with the exact rotation distance.

The weight of a binary tree  $T$ , denoted by  $w(T)$ , is  $n+1$ , i.e., the number of leaves (external nodes) in the tree. For each internal node  $v_i \in T$ , the subtree rooted at  $v_i$  is denoted by  $T_i$ . Clearly,  $T_i$  contains  $w(T_i) - 1$  internal nodes. The left subtree of  $v_i$  is the subtree rooted at the left child of  $v_i$  and is denoted by  $L_i$ . The left weight of  $v_i$  in  $T$ , denoted  $w_l(T, i)$ , is equal to  $w(L_i)$  and the integer sequence  $w_l(T) = (w_l(T, 1), w_l(T, 2), \dots, w_l(T, n))$  is called the left weight sequence (*LW*-sequence for short) of  $T$ .

We define that an *LW*-sequence  $w_l(T)$  is said to be a *restricted LW-sequence*, abbreviated *RLW*-sequence, if  $w_l(T, i)$  is either 1 or  $i$ , for  $i = 1, 2, \dots, n$ . A binary tree  $T$  is called an *RLW*-tree if  $w_l(T)$  is an *RLW*-sequence. The set containing all *RLW*-trees of  $n$  internal nodes is called an *RLW*-set. Since the first position of any *RLW*-sequence is always 1 and all of the other positions have two possible values, there are  $2^{n-1}$  binary trees in an *RLW*-set in which every binary tree has  $n$  internal nodes. In addition, the *RLW*-tree looks like an inclined curtain. That is, each node is either on the left-arm of this tree, or has no left child. Our algorithm can be done in linear time for finding the rotation distance between any two trees in the restricted set. Moreover, actual sequence of transforming rotations can also be built.

The number of binary trees with  $n$  nodes is the well-known Catalan numbers, denoted by  $B_n = \frac{1}{n+1} C_n^{2n}$ . Let  $\mathcal{L}$  and  $\mathcal{R}$  denote the set of *degenerate trees* and *RLW-trees*, respectively. Since the rotation distance between any two trees in  $\mathcal{R}$  can be found in linear time, it remains to be determining the rotation distance between any two degenerate trees  $T_0$  and  $T_f$ , that is, removing the restriction that  $T_f$  must be an angle tree. This case is significantly more complex.

In this research project, we propose an algorithm for finding the rotation distance between any two degenerate trees  $T_0$  and  $T_f$ , that is, removing the restriction that  $T_f$  must be an angle tree. Finally, we still need to use mathematical proof to ensure the correctness of our final algorithm. In addition, we also try to reduce the upper bounds of rotations for two  $n$ -node binary trees.

In the following, we prove several auxiliary lemmas.

Lemma. Given a degenerate tree  $T_0$  and a degenerate angle tree  $T_f$ , if the leaf node of  $T_0$ , say  $z$ , is equal to the angle node of  $T_f$ , say  $a$ , and  $p_{T_0}(z) \neq p_{T_f}(a)$ , then  $p_{T_0}(z) = l_f$ .

Lemma. Given a degenerate tree  $T_0$  and a degenerate angle tree  $T_f$ , if  $r_0 \neq r_f$  and the colours of  $r_0$  and  $c_{T_0}(r_0)$  are different, then  $c_{T_0}(r_0) = r_f$ .

Theorem. Given a degenerate tree  $T_0$  and a degenerate angle tree  $T_f$  with  $n$  nodes, we can transform  $T_0$  and  $T_f$  into general standard form in linear time.

Theorem. Given two degenerate trees  $T_0$  and  $T_f$  with  $n$  nodes, the rotation distance between  $T_0$  and  $T_f$  can be found in polynomial time.



## 國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

### 1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

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經由本計劃的研究，我們廣泛地收集了二元樹之間旋轉距離的相關研究，並歸納推論出許多性質，藉此找到一些限制集合並求得此限制集合之間的最短旋轉距離，並提出一個 polynomial time 的演算法計算兩顆 degenerate trees 之間的最短距離（正確性仍在最後數學證明中），而之後更進一步的研究，將可視此限制集合為一群 kernels，藉由此 kernels 能夠有效率地求算任兩顆二元樹之間的旋轉距離。

## 國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：101年03月03日

計畫編號	NSC 100-2221-E-128-003-		
計畫名稱	二元樹之間的旋轉距離		
出國人員 姓名	劉嘉傑	服務機構 及職稱	世新大學資管系助理教授
會議時間	101年2月19日至 101年2月21日	會議地點	馬來西亞吉隆坡
會議名稱	ICCSA 2010 : International Conference on Computer Science and Application		
發表論文 題目	1.The Weighted Minimum Tuple 2-Rainbow Domination on Graphs 2. Cycle Embedding in Folded Hypercubes with more Faulty Elements		

### 一、參加會議經過

「ICCSA 2010 International Conference on Computer Science and Application」為「World Academy of Science, Engineering and Technology」所舉辦之年度國際學術研討會，會議地點在馬來西亞吉隆坡的Pacific Regency Hotel飯店舉行，會議期間自2月19日至2月21日，為期共3天。與會經過如下：

2月19日：至會場完成報到手續，參加由主辦單位所舉辦的研討會並和與會之國際學者進行交流。

2月20日：參加由主辦單位所舉辦的研討會並和與會之國際學者進行交流。

2月21日：參加由主辦單位所舉辦的研討會並和與會之國際學者進行交流。

聽取和本人研究領域相關之其他論文發表。

聽取本人與顏重功教授，施朝正教授共同發表之論文「The Weighted Minimum Tuple 2-Rainbow Domination on Graphs」。

聽取本人與台北商業技術學院黃雯音同學，張肇明教授共同發表之論文「Cycle Embedding in Folded Hypercubes with more Faulty Elements」。

## 二、與會心得

此次參加會議讓本人有機會能接觸到更多Computer Science相關領域，並得以與各國的學者專家進行近距離地互動，除了增加學術視野外，更加深了對當前之研究趨勢及研究方法的瞭解，乃絕佳之學習機會。

這次是本人首次參加國際性的學術會議，藉由聆聽幾場論文報告，可以感受到不同的學者對許多問題研究的仔細與深度，及其不同的問題切入角度。此外，與會學者亦針對我們報告的論文提出許多地問題與建議也讓此次旅程獲益良多，經由相互討論的過程，更從中思考改進及後續的研究方向。

經由這趟馬來西亞的行程，除了參與此次會議而在學術上所有斬獲外，更藉此深入地體驗馬來西亞當地的文化，並大幅提升了自身的國際視野與不同的文化觀點；希望將來能有更多的機會在國際性之學術研討會進行論文發表，增加與國外學者之交流與合作。

### 三、考察參觀活動(無是項活動者略)

### 四、建議

本次出國，與顏教授及兩名博士生，兩名碩士生協同參加這次的國際研討會議，確實對本人與學生的國際觀及專業知識獲益良多，尤其是實驗設計與思考方面均有莫大助益，因此鼓勵博士班學生有機會多多參加國內或國際的大型會議，相信對自己的研究領域、熱門的研究領域、論文撰述能力與語文都有很大的幫助。應該多鼓勵研究生參與此類會議，以進一步開拓學生的國際視野、培養國際觀。

### 五、攜回資料名稱及內容

會議光碟：內容包含會議所有投稿論文

論文集：截錄部分的投稿論文

### 六、其他



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The conference is an interdisciplinary organization; the papers in each session are drawn from a number of disciplines. The main objective of this conference is to create an effective medium for academia and industries to present and share ideas, innovations and problem solving techniques, the results of their recent research activities in the field of applied science, engineering and technology, as well as social and human sciences.



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#### WASET 2012 CONFERENCE CALENDAR

Florence, IT: February 28-29, 2012  
Phuket, TH: March 12-13, 2012  
Madrid, ES: March 28-29, 2012  
Venice, IT: April 11-13, 2012  
Paris, FR: April 25-26, 2012  
Amsterdam, NL: May 13-14, 2012  
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Amsterdam, NL: July 25-26, 2012  
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Paris, FR: August 22-23, 2012  
Singapore, SG: September 12-13, 2012  
Berlin, DE: September 19-20, 2012  
Rome, IT: September 26-27, 2012

Time	Paper Title	Authors
<b>09:00 11:00</b>	<b>Chair : Muthu Poosan Moopanar, Mohammad Asif</b>	<b>HALL-A Session – I (February 19, 2012)</b>
	Recent Developments in Speed Control System of Pipeline PIGs For Deepwater Pipeline Applications	Mohamad Azmi Md Haniffa, Fakhruddin Mohd Hashim Universiti Teknologi Petronas, Malaysia
	The Effects of Roots Action of Tropical Green Roofs—Replication of German FLL in Singapore	Kian Kai Tan National University of Singapore, Singapore
	Communication Engineering Design of EDFA Gain Controller based on Disturbance Observer Technique	Seong-Ho Song, Ki-Seob Kim, Seop-Hyeong Park, Seon-Woo Lee Hallym University, Korea
	Correction of Infrared Data for Electrical Components on a Board	Seong Ho Song, Ki-Seob Kim, Seop-Hyeong Park, Seon-Woo Lee Hallym University, Korea
	Hand Gesture Recognition using Blob Detection for Immersive Projection Display System	Hasup Lee, Yoshisuke Tateyama, Tetsuro Ogi Keio University, Japan
	Steady-State Performance of a New Model for UPFC Applied to Multi-Machine Systems with Nonlinear Load	S. Ali Al-Mawsawi University of Bahrain, Bahrain
	Three-Level Converters based Generalized Unified Power Quality Conditioner	K. S. Rama Rao Universiti Teknologi Petronas, Malaysia
	Oil Palm Empty Fruit Bunch as a New Organic Filler for Electrical Tree Inhibition	M. H. Ahmad, A. A. A. Jamil, H. Ahmad, M. A. M. Piah, A. Darus, Y. Z. Arief, N. Bashir Universiti Teknologi Malaysia, Malaysia
	Concentrated Solar Power Generation	Haitham Safar Kuwait Oil Company, Kuwait
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : Elsayed Habib Elamir, Muthu Poosan Moopanar</b>	<b>HALL-A Session – II (February 19, 2012)</b>
	A Bootstrap's Reliability Measure on Tests of Hypotheses	Al Jefferson Pabelic, Dennis A. Tarepe Northern Consortium UK - Shenyang Center, People's Republic of China
	Estimating of the Renewal Function with heavy-tailed claims	Rassoul Abdelaziz High National School of Hydraulic, Algeria
	Bootstrap Confidence Interval and Parameter Estimation for Zero Inflated Strict Arcsine Model	Phang Yook Ngor, Loh Er Fu Universiti Teknologi Mara, Malaysia
	Exhaustion Numbers of 2-Subsets of Dihedral Groups	Shereen Sharmini, H. V. Chen, A. Y. M. Chin, S. Sharmini Universiti Tunku Abdul Rahman, Malaysia
	Numerical Solution of a Fluid Flow in a Non-Uniform Channel: Application to Renal Flow	Muthu Poosan Moopanar, Tesfahun Berhane National Institute of Technology, Warangal, India
	On Uses and Decomposition of Pietra Coefficient	Elsayed Habib Elamir University of Bahrain, Bahrain
<b>13:00 14:00</b>	<b>Lunch Break</b>	
<b>14:00 15:45</b>	<b>Chair : Chung-Kung Yen</b>	<b>HALL-A Session – III (February 19, 2012)</b>
	Cycle Embedding in Folded Hypercubes with more Faulty Elements	Wen-Yin Huang, Jia-Jie Liu, Jou-Ming Chang Shih Hsin University, Republic of China
	Optimizing TCP Vegas' Performance with Packet Spacing and Effect of Variable FTP Packet Size over Wireless IPv6 Network	Yew Been Seok University Malaysia Perlis, Malaysia
	Active Vibration Control of Flexible Beam using Differential Evolution Optimisation	Mohd Sazli Saad, Hishamuddin Jamaluddin, Intan Zaurah Mat Darus Universiti Malaysia Perlis, Malaysia
	A Method to Annotate Programs with High-Level Knowledge of Computation	Nobuhiko Hishinuma, Jun Igari, Rentaro Yoshioka University of Aizu, Japan
	Design and Development of Ferroelectric Material for Microstrip Patch Array Antenna	Fwen Hoon Wee, Mohd Fareq Abd. Malek Universiti Malaysia Perlis, Malaysia

	Magnetic Optimization Algorithm Approach For Travelling Salesman Problem	Mohd Muzafar bin Ismail Universiti Teknikal Malaysia Melaka, Malaysia
	OFDM and Fingerprint Authentication for Efficient Airport Security	Amrithavarshini Kannan Sri Venkateswara College of Engineering, India
	Optimizing the Number of Bits/Stage in 10-Bit, 50Ms/Sec Pipelined ADC Considering Area, Speed, Power and Linearity	Prasad Rao Perala, K. LaL Kishore Jntuh, India
	The Weighted Minimum Tuple 2-Rainbow Domination on Graphs	William Chung-Kung Yen, Jia-Jie Liu, Chao-Cheng Shih Shih Hsin University, Taiwan
<b>15:45 16:00</b>	<b>Coffee Break</b>	
<b>16:00 17:30</b>	<b>Chair : P. Palanisamy, T. Sheela</b>	<b>HALL-A Session - IV (February 19, 2012)</b>
	Minimizing Energy Consumption in Wireless Sensor Networks using Binary Integer Linear Programming	Chutima Prommak, Chompunut Jantarasorn Suranaree University of Technology, Thailand
	Evaluation of Protocol Applied to Network Routing Wcett	Nancy Yaneth Gelvez Garcia, Danilo Alfonso Lopez Sarmiento University Distrital "Francisco José de Caldas", Colombia
	A Survey: Bandwidth Management in an IP Based Network	Murizah Kassim, Mahamod Ismail, Kasmiran Jumari, Mat Ikram Yusof Universiti Kebangsaan Malaysia and Universiti Teknologi MARA, Malaysia
	Low Cost Chip Set Selection Algorithm for Multi-way Partitioning of Digital System	Jae Young Park, Soongyu Kwon, Kyu Han Kim, Hyeong Geon Lee, Jong Tae Kim Sungkyunkwan University, South Korea
	Life Time based Analysis of MAC Protocols of Wireless Adhoc Networks in WSN Applications	R. Alageswaran External Research Scholar, Sastra University, Thanjavur, Tamilnadu, India
	Analysis of Target Location Estimation in High Performance Radar System	Jinhyeok Kim KAIST, Republic of Korea
	Optimal Reactive Power Dispatch by Genetic Algorithm and Particle Swarm Optimization Considering Lost Opportunities	Dawood Talebi Khanmiri, Nasibeh Nasiri, Saeedollah Talaei Mobaraki Islamic Azad University- Bonab Branch, Iran
	Comparison Among Various Question Generations for Decision Tree Based State Tying in Persian Language	Nasibeh Nasiri, Dawood Talebi Khanmiri Azarbayjan University of Tarbiat Moallem, Iran
	Automatic Voice Controlled Wheel Chair for Challenged	Sheela Thavasi, S. Usha Sri Sairam Engineering College, Chennai, India
	A Propagator like algorithm for estimation of multiple Real-Valued Sinusoidal Signal frequencies	Sambit Prasad Kar, P.Palanisamy National Institute of Technology, India
<b>17:30 19:00</b>	<b>Chair : Yung-Tan Lee</b>	<b>HALL-A Session - V (February 19, 2012)</b>
	Determinants of Enterprise Risk Management Adopton: an Empirical Analysis of Malaysian Public Listed Firms	Nargess Mottaghi Golshan, Siti Zaleha Abdul Rasid University Technology Malaysia, Malaysia
	Apprising and Developing Strategies in Cultural and Instructional Challenges of Iranian Investment Banks	Mohammad Amin Ghalambor Shahid Beheshti University, Iran
	The Impact of Colours on Online Marketing Communications	Chai Lee Goi Curtin University, Malaysia
	Determinants of the U. S. Current Account	Shuh Liang Soochow University, Taiwan
	A Study on The Importance of Motivation among The Managers in Construction Companies in Medan	Amy Marisa, Nor'Aini Yusof Universiti Sains Malaysia, Malaysia
	A Study of Analyzing the Selection of Promotion Activities and Destination Attributes in Tourism Industry in Vietnam -from the Perspective of Tourism Industrial Service Network (TISN)	Nguyen Quang Vinh Fengchia University, Taiwan, Vietnam
	Leadership Branding for Sustainable Customer Engagement	Fauziah Sh. Ahmad, Rosmini Omar, Siti Zaleha Abdul Rasid, Muslim Amin Universiti Teknologi Malaysia, Malaysia
	Evaluation of Solid Phase Micro Extraction with Standard Testing Method for Formaldehyde Determination	Yen Li Yung University of Malaya, Malaysia
	VESMEC : A Vesmp Based Protocol for Sustainable Electronic Commerce	Irene Tiako, Thomas Djotio, Claude Tangha, Pierre Fernand Tiako Ecole Polytechnique Et Uy2 Fseg, Cameroon
	Evaluate Contribution of Starting Pitchers in Professional Baseball Team by Grey Relational Analysis	Chih-Cheng Chen, Yung-Tan Lee, Shih-Yang, Tien-Tze Chen, Mei-Jun Chen Aletheia University, Taiwan

<b>09:00 11:00</b>	<b>Chair : Emmanuelle Bernardin</b>	<b>HALL-B Session – VI (February 19, 2012)</b>
	A Hybrid Model of ARIMA and Multiple Polynomial Regression for Uncertainties Modeling of a Serial Production Line	Amir Azizi, Amir Yazid B. Ali, Loh Wei Ping, Mohsen Mohammadzadeh Universiti Sains Malaysia, Malaysia
	Trend Analysis of Ship Accident in Indonesia	Danny Faturachman University Malaysia Pahang, Malaysia
	Face Recognition using a Kernelization of Graph Embedding	Pang Ying Han, Hiew Fu San, Ooi Shih Yin; Goh Yongli, Ooi Shih Yin, Pang Ying Han Multimedia University, Malaysia
	Multi-level Metadata Integration System: XML, RDF and RuleML	Fareh Messaouda Saad Dahlab University, Blida Algeria, Algeria
	Users' Perceived Technical Service Quality and Information Satisfaction at the Ministry of Communications (MOC), Kuwait	Omar Khalil, Haitham Ghanim Kuwait University, Kuwait
	The Impact of E-Learning and E-Teaching	Mohammad Mohammad University of Western Sydney, Australia
	A New Framework to Model a Secure E-Commerce System	Youseef Alotaibi La Trobe University, Australia
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : Emmanuelle Bernardin</b>	<b>HALL-B Session – VII (February 19, 2012)</b>
	An E-learning System Architecture based on Cloud Computing	Anwar Hossain Masud Charles Sturt University, Australia
	Enhanced B2C Information Dissemination through the use of QR Codes	Michael Qugley University of Salford, UK
	A Taxonomy of Internal Attacks in Wireless Sensor Network	Muhammad R Ahmed, Xu Huang, Dharmendra Sharma University of Canberra, Australia
	A Novel Framework for Abnormal Behaviour Identification and Detection for Wireless Sensor Networks	Muhammad Raisuddin Ahmed University of Canberra, Australia
	A Systematic Review on the Integration of Project Management with Organizational Flows	Mauricio Rosito Pontifical Catholic University of Rio Grande do Sul, Brasil
	Project Management and Software Development Processes: Integrating PMBOK and Open	Mauricio Rosito Pontifical Catholic University of Rio Grande do Sul, Brasil
	Content Usage and Harmonization as Factors for LMS Adoption	Emmanuelle Bernardin Audencia Nantes, France
<b>13:00 14:00</b>	<b>Lunch Break</b>	
<b>14:00 15:45</b>	<b>Chair : Entisar Elgmati</b>	<b>HALL-B Session – VIII (February 19, 2012)</b>
	Publishing Curriculum Vitae using Weblog: an Investigation on its Usefulness, Ease of use, and Behavioral Intention to Use	Pei Eng Ch'ng, Mah, Boon Yih, Chng, Pei Cheng Universiti Teknologi MARA Penang Campus, Malaysia
	CSHARP: A Clustering using Shared Reference Points Algorithm	Mohamed Abbas, Amin A. Shoukry, Rasha F. Kashef Arab Academy for Science and Technology, Egypt
	Accessible Business Process Modelling	Daryoush Daniel Vaziri, Domingos DeOliveira University of Bonn-Rhine-Sieg, Deutschland
	The Psychological State of the Language Environment as an Indicator of Cultural Identity in a Multicultural Society	S. M. Dzhakupov, G. T. Telebayev, M. A. Perlenbetov, L. K. Komekbayeva, L. S Ilimkhanova, A. O. Mussakieva Kazakh National University, Kazakhstan
	Modelling Correlated Recurrent Events of Infant diarrhoea in Brazil	Entisar Elgmati Tripoli University, Libya
<b>15:45 16:00</b>	<b>Coffee Break</b>	
<b>16:00 17:30</b>	<b>Chair : Zainul Huda, J. Hemalatha</b>	<b>HALL-B Session – IX (February 19, 2012)</b>
	Study the Effect of Defects and H2O on the Mechanical behavior of CNT by Compression and Tension test using Atomistic Approach	Sankar Kumar Deb Nath Deb Nath Kongju National University, Republic of Korea



	Development of Rotational Smart Lighting Control System for Plant Factory	Wonsub Lee, Sung-Gaun Kim Kongju National University, Republic of Korea
	Dead-Reckoning Error Calibration using Ceiling Looking Vision Camera	Jae-Young Choi, Sung-Gaun Kim Kongju National University, Republic of Korea
	A Study on the Modeling and Analysis of an Electro-Hydraulic Power Steering system	Ji-Hye Kim and Sung-Gaun Kim Kongju National University, Republic of Korea
	Dielectric Studies on Nano Zirconium Dioxide Synthesized Through Co-Precipitation Process	K. Geethalakshmi, T. Prabhakara, J. Hemalatha Anna University of Technology Tiruchirappalli, India
	Preparation of Inorganic- Organic Hybrid Poly (Butylene Succinate)	Shuang Hu University of Science and Technology of China, PR China
	Optical and Structural Properties of Chemically deposited CdS Thin Films	Raghad Yousif Mohammed, Ali M. Mosa, Salah A. Azo University of Duhok, Iraq
	Dilatometric Behavior and Microstructure of Sintered Al <sub>2</sub> O <sub>3</sub> -SiO <sub>2</sub> -ZrO <sub>2</sub> Composite	Mebrahitom Gebremariam, O. Mamat Universiti Teknologi Petronas, Malaysia
	Acoustic Study on The Interactions of Coconut Oil Based Copper Oxide Nanofluid	M. Nabeel Rashin, J. Hemalatha National Institute of Technology, India
<b>17:30 19:00</b>	<b>Chair : Swami Naidu Gurugubelli</b>	<b>HALL-B Session - X (February 19, 2012)</b>
	Recent Advances in Energy Materials for Hot Sections of Modern Gas-Turbine Engines	Zainul Huda King Saud University, Saudi Arabia
	Using Composite Materials in Pipelines under Internal Pressure Loading and its Application in Sultanate of Oman	Hakim Samawi Sultan Aljibori College of Applied Science- Sohar, Oman
	Design Variation Effect on Saved Energy of Concentrating Solar Power Prototype at Iraqi Summertime Weathers	Miqdam Tariq C., Khalil I. A, Hussein A Kazem, Hakim S. Sultan Aljibori Sohar University, Sultanate of Oman
	Scheduling for a Reconfigurable Manufacturing System with Multiple Process Plans and Limited Pallets/Fixtures	Jae-Min Yu, Hyoung-Ho Doh, Ji-Su Kim, Dong-Ho Lee, Sung-Ho Nam Hanyang University, South Korea
	Mathematical Model and Solution Algorithm for Containership Operation/Maintenance Scheduling	Hun Go, Ji-Su Kim, Dong-Ho Lee Hanyang University, South Korea
	Simulation for Automated Visual Inspection using Robot	Hironori Hibino Technical Research Institute of Japan Society for the Promotion of Machine Industry, Japan
	Strength optimization of induction hardened splined shaft – material and geometric aspects	I. Barsoum, F. Khan The Petroleum Institute, UAE
	Structural analysis and design of a guyed telecom mast with a wind turbine	I. Barsoum, F. Barsoum The Petroleum Institute, UAE
	Variation of CONWIP systems	Joshua Prakash Universiti Sains Malaysia, Malaysia
	The Effect of Ageing on Impact Toughness and Microstructure of 2024 Al-Cu-Mg Alloy	Swami Naidu Gurugubelli JNTUK, University college of Engineering, Vizianagaram, India
<b>19:00 20:00</b>	<b>Chair : Henrik Sternberg</b>	<b>HALL-B Session - XI (February 19, 2012)</b>
	Calibration and Validation of a Dynamic Traffic Assignment Model: Case Studies	Akmal Abdelfatah American University of Sharjah, United Arab Emirates
	Modeling Capacity of Signalized Links with Sink and Source Traffic Considerations	Ghassan Abu-Lebdeh, Akmal Abdelfatah American University of Sharjah, Sharjah, United Arab Emirates
	An Overview of Issues to Consider before Introducing Performance-Based Road Maintenance Contracting	Masuda Sultana, Anisur Rahman, Sanaul Chowdhury Griffith University, Australia
	Quality Monitoring and Dynamic Pricing in Cold Chain Management	Myo Min Aung Korea Aerospace University, Republic of Korea
	Towards a Zero-System Analysis of Haulage	Henrik Sternberg Chalmers University, Sweden
	<b>Monday</b>	<b>February 20, 2012</b>
<b>09:00 11:00</b>	<b>Chair : Shailajha Sathiyaseelan, Swarnalatha Kalaiyar</b>	<b>HALL-A Session – XII (February 20, 2012)</b>
	Multiple Watermarking for Copyright Protection , Information Hiding using Visual Cryptography	Mathivadhani Dharmalingam Avinashilingam Institute for Homescience and Higher Education for Women,

		India
	An Optimal Feature Subset Selection for Leaf Analysis	N. Valliammal Avinashilingam Institute for Home Science and Higher Education for Women, India
	An Amalgam Approach for DICOM Image Classification and Recognition	J. Umamaheswari Dr. G.R.D. College of Science, India
	Assessment of Time-Lapse in Visible and Thermal Face Recognition	Sajad Farokhi, Siti Mariyam Shamsuddin, Jan Flusser, Usman Ullah Sheikh Universiti Teknologi Malaysia, Malaysia
	Offline Signature Recognition Using Radon Transform	Mehdi Radmehr Islamic Azad University, Sari Branch, Iran
	Decision Tree-based Feature Ranking using Manhattan Hierarchical Cluster Criterion	Yasmin Mohd Yacob, Harsa Amylia Mat Sakim, Nor Ashidi Mat Isa Universiti Sains Malaysia, Malaysia
	State of the Art: A Study on Fall Detection	Goh Yongli, Ooi Shih Yin, Pang Ying Han Multimedia University, Malaysia
	Active Contours with Prior Corner Detection	Uragoda Appuhamilage Aruni Niroshika Sri Lanka Institute of Information Technology, Sri Lanka
	A Proposed Information Extraction Technique in Engineering Drawing for Reuse Design	Mohd Fahmi Mohamad Amran Universiti Kebangsaan, Selangor, Malaysia
	A TRIZ-based Approach to Generation of Service-Supporting Product Concepts	Seungkyum Kim, Yongtae Park Seoul National University, Republic of Korea
	ANP-based Intra and Inter-industry Analysis for Measuring Spillover Effect of ICT Industries	Yongyoon Suh, Yongtae Park Seoul National University, Republic of Korea
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : Shailajha Sathiyaseelan, Swarnalatha Kalaiyar</b>	<b>HALL-A Session – XIII (February 20, 2012)</b>
	A Development of Home Service Robot using Omni-Wheeled Mobility and Task-Based Manipulation	Seungwoo Kim, Hijun Kim, Jungkeun Sungg Soonchunhyang University, Korea
	LQR Control for a Multi-MW Wind Turbine	Trung Kien Pham, Yoonsu Nam, Hyungun Kim, Jaehoon Son Kangwon National University, South Korea
	Multi-Rate Exact Discretization based on Diagonalization of a Linear System- A Multiple-Real-Eigenvalue Case	Takashi Sakamoto, Noriyuki Hori University of Tsukuba, Japan
	Takagi-Sugeno Fuzzy Control of a Two-Wheeled Inverted Pendulum Mobile Robot	Mustapha Muhammad Universiti Teknologi Malaysia, Malaysia
	Modelling of a Cart-Ball System Via Takagi Sugeno Fuzzy Approach	Mustapha Muhammad Universiti Teknologi Malaysia, Malaysia
	3D Sensing and Mapping for a Tracked Mobile Robot with a Movable Laser Ranger Finder	Toyomi Fujita Tohoku Institute of Technology, Japan
	A Method for Identifying Physical Parameters with Linear Fractional Transformation	Ryosuke Ito, Goro Obinata, Chikara Nagai, Youngwoo Kim Nagoya University, Japan
	Design of the Miniature Maglev Using Hybrid Magnets in Magnetic Levitation System	Jeong Min Korea Railroad Research Institute, Republic of Korea
	An Advanced Time-Frequency Domain Method for PD Extraction with Non-Intrusive Measurement	Guomin Luo, Daming Zhang, YongKwee Koh, KimTeck Ng, Helmi Kurniawan, WengHoe Leong Nanyang Technological University, Singapore
	Performance Comparison of Two Assembly Line Concepts: Conveyor Line and Box Assembly Line	Kezia Amanda Kurniadi, Emre Islamoglu, Kwangyeol Ryu Pusan National University, South Korea
	Framework and System for Supplier Scouting Enabling Web-based Collaboration	Sangil Lee, Kwangyeol Ryu, Kezia Amanda Kurniadi, Yongju Park Pusan National University, South Korea
<b>13:00 14:00</b>	<b>Lunch Break</b>	
<b>09:00 11:00</b>	<b>Chair : Muhanned Alfarras, Felix Yat-Hang Wong</b>	<b>HALL-B Session – XIV (February 20, 2012)</b>
	Mechanical Structure Design Optimization by Blind Number Theory: Time-Dependent Reliability	Zakari Yaou Beijing Institute of Technology, China

	FE Analysis of Full-scale RC Slab with Cutouts Strengthening with CFRP Sheets	Majid Mohammed Ali Kadhim, Ali Jalil Abdul kareem Chabuk , Khalid Safaa Hashim Al Khalidi Babylon University, Iraq
	Experimental and Analytical Study of Scrap Tire Rubber Pad for Seismic Isolation	Huma Kanta Mishra, Akira Igarashi Kyoto University, Japan
	Design Alternatives for Lateral Force-Resisting Systems of Tall buildings in Dubai, UAE	Mohammad AlHamaydeh, Sherif Yehia, Nader Essam, Ammar Douba, Layane Hamzeh American University of Sharjah, United Arab Emirates
	Low Complexity, High Performance LDPC Codes based on Defected Fullerene Graphs	Rakesh Sharma, Ashish Goswami NIT Hamirpur, India
	Coding of DWT Coefficients using Run-length coding and Huffman Coding for the purpose of Color Image Compression	Vinod Kumar, Varun Setia National Institute of Technology, India
	Progress Forecasting Models based on Cost and Labor in Korean Multi-family Housing Projects	Sang-Hoon Jeon, Dong-Hyun Cho, Jun-Ho Lee, Kyo-Jin Koo University of Seoul, South Korea
	Comparative Embodied Carbon Analysis of the Prefabrication Elements Compared with in-Situ Elements in Residential Building Development of Hong Kong	Felix, Yat-hang, Wong; YT Tang AECOM Asia
	Performance and QoS Analysis for SC-CAC and MC-CAC in WCDMA System	Meshal S. Alkooh, Muhanned Alfarras Gulf University, Kingdom of Bahrain
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : T.Sivasankar</b>	<b>HALL-B Session – XV (February 20, 2012)</b>
	Evaluating the Efficiency of Signalized Urban Road Network under Cluster Condition	Ali Paydar, Amir Hossein Pakshir Universiti Teknologi Malaysia, Malaysia
	Consideration of Traffic Characteristics Under Uninterrupted Flow	Amir Hossein Pakshir, Ali Paydar Universiti Teknologi Malaysia, Malaysia
	Traffic Noise under Stop and Go Conditions in Intersections – a Case Study	Nima Jahandar, Amin Hosseinpour, Mohammad Ali Sahraei Universiti Teknologi Malaysia, Malaysia
	Resource Levelling in Construction Project using Remodified Minimum Moment Approach	Abhay Tawalare, Rajesh Lalwani Visvevrya National Institute of Technology, India
	Real Time Dielectric and Water Content Measurement using Capacitance Method	M. Javadi, H.Ghasemzadeh, H. Hasibi, S. Rahimi Khaje Nasiradine Toosi University of Technology, Iran
	Tension Stiffening Parameter in Composite Concrete Reinforced with Inoxydable Steel: Laboratory and Finite Element Analysis	Sophia C. Alih, Abdel Khelil Nancy University, France
	The New Post-tensioned and Clamped Steel Solid Connector for Strengthening of Framed Structures	Ali Jahangiri STC, UTM University, Malaysia
	Effect of Ground Surface Subsidence on Piled Load Share and Settlement of Raft and Piled Raft Foundations	Van Tuan Tran Chulalongkorn University, Thailand
	Comparison of Eurocodes EN310 and EN789 in Determining the Bending Strength and Modulus of Elasticity of Red Seraya Plywood Panel	Shuk Fun Tsen University of Malaya, Malaysia
	4d Modeling and Virtual Prototyping in Construction	Gopikrishnan Seshadhri Military Engineer Services, India
	Analytical Study on a Longitudinal Joints of the Slab-Type Modular Bridges	Sang-Yoon Lee, Jung-Mi Lee, Hyeong-Yeol Kim, Jae-Joon Song Korea Institute of Construction Technology, Republic of Korea
	Artificial Neural Networks Modeling in Water Resources Engineering: Infrastructure and Applications	M. R. Mustafa, M. H. Isa, R. B. Rezaur Universiti Teknologi Petronas, Malaysia
	Development of a Support Tool for Cost and Schedule Integration Management at Program Level	H. J. Yang, R. Z. Jin, I. J. Park, C. T. Hyun University of Seoul, Korea
<b>13:00 14:00</b>	<b>Lunch Break</b>	
	<b>Tuesday</b>	<b>February 21, 2012</b>
<b>09:00 11:00</b>	<b>Chair : Abbagana Mohammed</b>	<b>HALL-A Session – XVI (February 21, 2012)</b>
	Attracting and Retaining Skilled Construction Workforce in Malaysian Construction Firms	Shazwani binti Ahmad Zaki, Sarajul Fikri Mohamed, Zakaria Mohd Yusof Universiti Teknologi Malaysia, Malaysia

	An Overview of the Factors Affecting Microbial-Induced Calcite Precipitation and its Potential Application in Soil Improvement	Wei Soon Ng Universiti Tunku Abdul Rahman, Malaysia
	Strengthening of RC Beams with Large Openings in Shear by CFRP Laminates: 2D Nonlinear FE Analysis	Siew Choo, Chin, Nasir Shafiq, Muhd Fadhil Nuruddin Universiti Teknologi Petronas, Malaysia
	Work Structuring and The Feasibility of Application to Construction Projects in Vietnam	Viet-Hung Nguyen, Luh-Maan Chang National Taiwan University, Taiwan
	Examination of Pre- Contract Budgeting Techniques for Mechanical and Electrical Services in Malaysia	Ganiyu Amuda Yusuf Universiti Teknologi Malaysia, Malaysia
	Low-Cost Eco-Friendly Building Material: A Case Study in Ethiopia	Woubishet Zewdu Taffese Ethiopian Institute of Architecture, Ethiopia
	Properties of SMA Mixtures Containing Waste Polyethylene Terephthalate	Taher Baghaee Moghaddam, Mohamed Rehan Karim University of Malaya, Malaysia
	Effects of Monetization Policy on Rental Value of Houses in Nigeria	Yahaya Ahmed Universiti Teknologi Malaysia, Malaysia
	Comparison of Polypropylene Fiber and Polyvinyl Alcohol Resin in Improving of Saturated Loose Soil	Esmail Masoumi, Farzad Abdi Nian, Farshid Shooshtarian, Hossein Meisami Isfahan University of Technology, Iran
	Lidar Sensor Matching System using Database	Hui Kim, Euntai Kim Junho Moon, Hyuk Doo Choi, Nam Hun Park, Yong Woon Park, Chong ; Yonsei University, Korea Yonsei University, Korea
	Some Factors Affecting The Compressive Behaviour of Structural Masonry at Small Scales	Abbagana Mohammed, T. G. Hughes Abubakar TafawaBalewa University, Nigeria
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : Sowa Pawel, Charlier Corinne</b>	<b>HALL-A Session – XVII (February 21, 2012)</b>
	An innovation in Brick Technology-Addition of Sludge to Red Clay Bricks and their interaction studied applying Spectroscopic techniques	Shailajha Sathiyaseelan Manonmaniam Sundaranar University, India
	Characterization and Photophysical Studies of CdS Nanoparticles Synthesized by Reverse Micelle Method	Swarnalatha K., Jency Packia Rathy P. E. Manonmaniam Sundaranar University, India
	Low-Cost Pre-Treatment of Pharmaceutical Wastewater	Ahmad Abu-Safa Royal Scientific Society, Jordan
	Treatment of Petroleum Refinery Wastewater by using UASB Reactors	H.A. Gasim, S.R.M. Kutty, M.H. Isa, M.P.M. Isa Universiti Teknologi PETRONAS, Malaysia
	Geochemistry of tektites from Rizal of Luzon, Philippine	Yung-Tan Lee, Ren-Yi Huang, Jyh-Yi Shih, Meng-Lung Lin, Yen-Tsui Hu, Hsiao-Ling Yu, Chih-Cheng Chen; Aletheia University, Taiwan
	Application of Lhrha and Dopamine Antagonist in Three Spot Gourami (Trichogaster Trichopterus)	Naji Tahereh, Hosseinzadeh. Homayon, Jazebizadeh. M. Karim Islamic Azad University, Iran
	Simulation of Population Dynamics of Aedes Aegypti using Climate Dependent Model	Nuraini Yusoff, Harun Budin, Salemah Ismail Universiti Teknologi Mara, Malaysia
	Stability Analysis of Mutualism Population Model with Time Delay	Rusliza Ahmad, Harun Budin Universiti Teknologi Mara, Malaysia
	Ultrasonic Degradation of Rhodamine B dye using Fenton's type Reagents	Ashok Babu Kurukutla, Panneerselvam Satishkumar, Sambandam Anandan, Thirugnanasambandam Sivasankar National Institute of Technology Tiruchirappalli, India
	Conversion in Chemical Reactors Using Hollow Cylindrical Catalyst Pellet	Mohammad Asif King Saud University, Saudi Arabia
	Urinary Level of Bisphenol A, Triclosan and 4nonylphenol in a General Belgian Population	Charlier, Plomteux, Dubois, Sagot, Pirard University of Liege, Belgium
	Identification of Impact of Electromagnetic Fields at Low and High Frequency on Human body	Sowa Pawel Silesian University of Technology, Poland
<b>13:00 14:00</b>	<b>Lunch Break</b>	
<b>09:00 11:00</b>	<b>Chair : Amir Al-Haddad</b>	<b>HALL-B Session – XVIII (February 21, 2012)</b>
	Two-Stage Compensator Designs with Partial Feedbacks	Kazuyoshi Mori The University of Aizu, Japan

	Petroleum System in Back Arc Basin: Majalengka Sub-Basin Indonesia	Budi Muljana, Koichiro Watanabe, Mega Fatima Rosana Kyushu University, Japan
	Evaluating Alternative Fuel Vehicles from Technical, Environmental and Economic Perspectives: Case of Light-Duty Vehicles in Iran	Vahid Aryanpur, Ehsan Shafiei Reykjavik University, Iran
	Studying of Some Parameters in Shatt Al – Hilla River During Year 2010	Ali Jalil Abdul kareem Chabuk, Majid Mohammed Ali Kadhimi, Khalid Safaa Hashim Al Khalidi Babylon university, Iraq
	Measurement of Lead Pollution in the Air of Babylon Governorate/Iraq During Year 2010	Khalid Safaa Hashim Al Khalidi, Ali Jalil Abdul Kareem Chabuk, Majid Mohammed Ali Kadhimi Babylon university, Iraq
	Solar Photo-Fenton Induced Degradation of Combined Chlorpyrifos, Cypermethrin and Chlorothalonil Pesticides in Aqueous Solution	Augustine Chioma Affam Universiti Teknologi Petronas, Malaysia
	Application of the Sludge, Produced from Water Treatment Process, in Cement Production and Agriculture (Case study of two Tehran pars Treatment Plants)	Hossein Meisami, Farzad Abdi Nian, Farshid Shooshtarian, Esmaeil Masoumi, Tayebbeh Rahimi Isfahan University of Technology, Iran
	Identification of an Appropriate Alternative Waste Technology for Energy Recovery from Waste Through Multi-Criteria Analysis	Sharmina Begum, M. G. Rasul, Delwar Akbar Central Queensland University, Australia
	An Investigation on Thermo Chemical Conversions of Solid Waste for Energy Recovery	Sharmina Begum, M. G. Rasul, Delwar Akbar Central Queensland University, Australia
	Design of a MSF Desalination Plant to be Supplied by a New Specific 42 MW Power Plant Located in Iran	Rouzbah Shafaghat, Hoda Shafaghat, Fatemeh Ghanbari, Pouya Babol Noshirvani University of Technology, Iran
	Evaluation Biofilm Sewage Treatment Plant	Shahot Khaled Almergib University, Libya
	Oil Refineries Emissions: Source and Impact: A Study using AERMOD	Amir Al-Haddad, Hisham. Ettouney, Samiya. Saqer Kuwait University, Kuwait
<b>11:00 11:15</b>	<b>Coffee Break</b>	
<b>11:15 13:00</b>	<b>Chair : Muhammad Ayyoub Tanvir</b>	<b>HALL-B Session – XIX (February 21, 2012)</b>
	Development and Verification Test of a Real-Time Infectious Waste Management System using QR Code	Takuo Ichiju, Yoshiyuki Higuchi, Kazunori Shinagawa, Chun Jin Fukushima University, Japan
	Treatment of Organic Compound of Refinery Wastewater using Bench Scale Extended Aeration Activated Sludge in Continuous Flow System	Megat A.R.M.M. Amin, Shamsul R.M. Kutty Universiti Teknologi Petronas, Malaysia
	Anaerobic Treatment of Produced Water	Fong Chee Khong Universiti Teknologi Petronas, Malaysia
	Groundwater Management - A Policy perspective	Annie Jenifer M. Anna University, India
	Domestic Workers in N'Djamena City: A case Study of Domestic from Rural de-Population and Domestic under Protection	Rititingar Appolinaire University of N'Djamena, Chad
	African Fiftieth Anniversary for Another Africa: A Contribution to Social Crises Resolution	Rititingar Appolinaire University of N'Djamena, Chad
	Consideration Factors of Moving to a New Destination for Coastland Residents	Ya-Fen Lee; Toko University, Taiwan Yun-Yao Chi; Chang Jung Christian University, Taiwan Cing-Hong Hung; Chang Jung Christian University, Taiwan
	Cultural and Anthropological Grounds of Ecology Culture of Turkic Peoples of Central Asia	Samal Kaupenbayeva, Ahmet Tashagil, Zhuldyz Suleimenova, Almagul Kanagatova ; KazNU Named after Al-Farabi, Kazakhstan
	The Cultural and Anthropological Bases of Culture Ecology of the Turkic Peoples in Central Asia	Samal Kaupenbayeva, Ahmet Tashagil, Zhuldyz Suleimenova, Almagul Kanagatova; KazNU named after Al-Farabi, Kazakhstan
	Power Flow Analysis using Power Perturbation	P. S. Bhowmik, D. V. Rajan, S. P. Bose, V. K. Chowdary National Institute of Technology Durgapur (Deemed University), India
	Germination Percentage in Albizzia procera and Leucaena leucocephala Seeds Exposed to Magnetic Field	M. Ayyoub Tanvir, Rahman Ashraf, Zia-ul-Haq, M. Tahir Siddiqui, M. Farrakh Nawaz, Irfan Ahmad University of Agriculture Faisalabad, Pakistan
<b>13:00 14:00</b>	<b>Lunch Break</b>	
<b>10:00 12:00</b>	<b>Chair : J. Nelson</b>	<b>e-Session – XX (February 19-20-21, 2012)</b>

	Corn Yield and Its Quality as Affected by Seed Bio-Priming	Bahram Mirakhouri Research Center of Agriculture, Iran
	Apyrous and Total can Play a Major Role in Chemical Weeds Control in Bread Wheat Cultivar; "Omid"	Bahloul Mirakhouri Young Research Club, Iran
	Stepwise Regression Analysis of Competition between Avena Fatua and Triticum Aestivum	Bahram Mirshekari Islamic Azad University, Iran
	CFD Modelling of Droplet Spreading Behavior on Urea Surface.	KuZilati KuShaari, Michelle Samuel Bay University Teknologi Petronas, Malaysia
	Effect of Domestic Treated Wastewater Use on Three Varieties of Amaranth (Amaranthus spp.) Under Semi Arid Conditions	El Youssfi L., Choukr-Allah R., Zaafrani M., Mediouni T., Sarr F., Hirich A. National School of Applied Science Agadir (ENSA Agadir), Morocco
	A Study on Crashworthiness Assessment and Improvement of Tilting Train made of Sandwich Composites	Hyung-Jin Jang, Kwang-Bok Shin, Sung-Ho Han Hanbat National University, Republic of Korea
	A Study on Fuzzy Adaptive Control of Enteral Feeding Pump	Seungwoo Kim, Hyojune Chae, Yongrae Jung, Jongwook Kim Soonchunhyang University, Korea
	Soyhulls as a Replacement for Ground Corn in Finishing Pigs Diets: Effects on Performances and Carcass Quality	Wisitiporn Suksombat Suranaree University of Technology, Thailand
	Port Positions on the Mixing Efficiency of a Rotor-Type Mixer – a Numerical Study	Yi-Chun Liou National Defense University, Taiwan
	Polyimides Having Thermal Curable Moieties in the Main Chain for Flexible Substrate: Synthesis and Characterization	Seung Woo Lee Yeungnam University, Republic of Korea
	Al0.3Ga0.7As Barrier Effects of InAs/GaAs based Quantum Dot Solar Cells	Seung Hyun Lee, Im Sik Han, Chang Won Sohn, Sang Jo Lee, Jae-Du Ha, Ryan P. Smith, Jong Su Kim, Sang Jun Lee, Sam Kyu Noh, Jin Soo Kim, Hyonkwang Choi, Jae-Young Leem; Yeungnam University, Korea
	Effect of Swift Heavy Ion Irradiation on Nonlinear Optical l-Valinium Picrate Single Crystals	Nagalakshmi Ramamoorthi National Institute of Technology, Tiruchirappalli, India
	Patents Analysis and Design Suggestions for the Mandibular Advancement Devices	Tsung-yin Lin National Defense University, Taiwan
	Efficient Detection using Sequential Probability Ratio Test in Mobile Cognitive Radio Systems	Yeon-Jea Cho KAIST, Republic of Korea
	H $\infty$ Approach to Functional Projective Synchronization for Chaotic Systems with Disturbances	S. M. Lee, J. H. Park, H.Y. Jung Daegu Univ/Yeungnam Univ, South Korea
	Research on The Influence of Emotional Labor Strategy used by Public Transportation Employee on Service Satisfaction	Ming-Hsiung Wu, Yu-Hsi Yuan China University of Science and Technology, Taiwan
	Analysis of the Dual-Emitter LIGBT with Improved Electrical Characteristics	Yong Seo Koo Dankook University, S.Korea
	Effect of Sintering Temperature Curve in Wick Manufactured for Loop Heat Pipe	Shen-Chun Wu China University of Science And Technology, Taiwan, R.O.C
	A Study on Predictive Controller Design for Active Cell Balancing Control	Chang-Ho Hyun Kongju National University, Republic of Korea
	Joint Design of MIMO Relay Networks Based on MMSE Criterion	Seungri KAIST, Republic of Korea
	Development of Green-BOM for Managing Green Products/Production Information	Yongju Park, Moonsoo Shin, Sungho Nam, Kezia Amanda Kurniadi, Kwangyeol Ryu Pusan National University, South Korea
	A Study on Calculation of URL Suspicion Index	Jongil Jeong, Byungik Kim, Hongkoo Kang, Hyunchel Jeong Korea Internet and Security Agency, Korea
	Design of FPGA Based Neural Network Controller for Earth Station Power System	Hanaa T. El-Madany, Faten H. Fahmy, Ninet M. A. El-Rahman, Hassen T. Dorrah; Electronic Research Institute, Egypt
	Simulated Annealing algorithm for Data Aggregation Trees in Wireless Sensor Networks and Comparison with Genetic Algorithm	Ladan Darogaran, Hossein Shahinzadeh, Hajar Ghotb, Leila Ramezanpour Seraj Higher Education Institute, Iran
	Risk Level Evaluation for Power System Facilities in Smart Grid	Sung-Hun Lee, Yun-Seong Lee, Jin-O Kim Department of Electrical Engineering, Hanyang University, Korea
	Labview Implementation and Experimental Validation of a PI Controller for dc Motor Speed	Jenica Ileana Corcau, Liviu Corcau University of Craiova, Romania
	About using PEMFC for Electrical Power Generation on More Electric Aircraft	Jenica Ileana Corcau, Liviu Dinca University of Craiova, Romania

	Developing Damage Assessment Model for Bridge Surroundings: A Study of Disaster by Typhoon Morakot in Taiwan	Jieh-Haur Chen National Central University, Taiwan, ROC
	Advances in Machine Learning and Pattern Recognition Fingerprint Identification using Discretization Technique	Wong Yee Leng Wong, Siti Mariyam Shamsuddin Universiti Teknologi Malaysia (UTM), Malaysia
	Tehran-Tabriz Intelligent Highway	Peyman Parvizi Islamic Azad University Iran
	Power System Transient Stability Improvement with SSSC Controller	P. Nagaraju Mandadi, K. Dhanvanthri J. N. T. University, Hyderabad, India
	A Maximal Covering Problem under Uncertainty on the Congested Network	Hassan Shavandi, Negar Golchin Sharif University of Technology, Iran
	An Investigation of Multi-Dimensional Knowledge Management Based on Rampersad Model- Case Study	Reza Davoodi Islamic Azad University, Iran
	Developing Marketing Strategy in Nonmetallic Mineral Industry at the business Level	Nader Gharibnavaz, Naser Gharibnavaz Shahr-e-Qods- Branch, Islamic Azad university, Tehran, Iran
	A Framework for Integrating Activity-Based Costing and Customer Relationship Management	Mahmood Shafiee, Golriz Amooee University of Qom, Iran
	Target and Kaizen Costing	Alireza Azimi Sani, Mahdi Allahverdizadeh Islamic Azad University, Iran
	Internal Accounting Controls	Alireza Azimi Sani, Shahram Chaharmahalie Islamic Azad University, Iran
	Studying the Effect of Climate Change on the Conditions of Isfahan's Province Tourism	Amir Gandomkar, Farnoush Khorasanizadeh Islamic Azad University, Iran
	Inter-Specific Competition between Chenopodium Album and Brassica Napus Cultivars	Bahram Mirshekari Islamic Azad Univ., Iran
	Stepwise Regression Analysis of Competition between AvenaFatua and Triticum Aestivum	Bahram Mirshekari Islamic Azad Univ., Iran
	The Wave Length and Height Effect of Trapezoidal Corrugated Plates on Steel Shear Walls Behavior with Corrugated Plate	Masoud Gholizadeh Islamic Azad University, Iran
	The Regression Analysis Surface Smoothness Teflon with the Effects of Cutting Speed and Feed Rate in the Milling Process	Mohammad Setareh Islamic Azad University, Iran
	T. S. D. T Method for Vibration of Functionally Graded Cylindrical Shell under Effects Boundary Conditions	Mohammad Reza Isvandzibaei Islamic Azad University, Andimeshk Branch, Iran
	Fatigue Life of An Anti-Roll Bar of A Passenger Vehicle	Aref Yadollahi, Javad Marzbanrad Iran University of Science and Technology, Iran
	Extension of a Smart Piezoelectric Ceramic Rod	Ali Reza Pouladkhan, Jalil Emadi, Hamed Habibolahian Islamic Azad University, Ardestan, Iran
	Linear Dynamic Modeling of an Open-Loop Micro Gas Turbine	Elnaz Abdollahi Iran University of Science and Technology, Iran
	Investigation the Effect of Nanoclay, Calcium Carbonate and Wood Pulp on Fusion Characteristics of Rigid PVC Compounds using Response Surface Method of Experimental Design	Mehdi Moghri Islamic Azad University, Iran
	Assessment of Steel Reinforcement Corrosion in LILW Waste Disposal facility Concretes	Ki-Beom Kim Korea Institute of Construction Technology, South Korea
	A Study for Carbonation Degree on Concrete using a Phenolphthalein Indicator and Fourier-Transform Infrared Spectroscopy	Ho Jae Lee, Do Gyeum Kim, Jang Hwa Lee, Myoung Suk Jo Korea Institute of Construction Technology, South Korea
	Application of Microstructure Analysis Technique to the Deteriorated Concrete by Environmental Factor	Dogyum Kim, Hojae Lee, Janghwa Lee, Myoungsuk Cho Korea Institute of Construction Technology, South Korea
	A Particle Swarm Optimization Approach for the Earliness-Tardiness No-Wait Flowshop Scheduling Problem	Nasser Salmasi Sharif University of Technology, Iran
	Surface Roughness and MRR Effect on Manual Plasma Arc Cutting Machining	R. Bhuvnesh, M. H. Norizaman, M. S. Abdul Manan Universiti Malaysia Perlis (UNIMAP), Malaysia
	Study the Interface Shape of Tooling and Work Piece Contact during a flow Forming Operation	Hamidreza Gharehchahi Islamic Azad University, Iran
	A Flexible Flowshop Scheduling Problem with Machine Eligibility Constraint and Two Criteria Objective Function	Nasser Salmasi Sharif University of Technology, Iran

	A Branch and Bound Algorithm for Resource Constrained Project Scheduling Problem Subject to Cumulative Resources	Ali Shirzadeh Chaleshtari, Shahram Shadrokh Sharif University of Technology, Iran
	Managing Information Systems based on a Framework with Justified Architecture of Organizational Levels	Mohamad Mahdavi Islamic Azad University, Iran
	Crisis Management Training and Planning	Saied Rasul Hosseini Baharanchi, Sepideh Sadat Hazaveh Imam Hossein University, Iran
	Offline Signature Recognition using Radon Transform	Mehdi Radmehr Islamic Azad University, Iran
	An Optimized Method for Detecting Seizures Using Electroencephalogram and Classification using Support Vector Machine with Fast LM Learning	C. S. Nandi, B. Tudu, C. Koley Avinashilingam Institute for Home Science and Higher education for Women, India
	Support Vector Machine based Maturity Prediction	C. S. Nandi, B. Tudu, C. Koley National Institute of Technology, Durgapur, India
	A Pricing Method for Urban Networks By Considering Private And External Costs	Aidin Massahi, Mansour Hadji Hosseinlou, Hamed Shagerdi Esmaeeli, Hadi Shagerdi Esmaeeli Sharif University of Technology, Iran
	Using New Technologies for Public Parking in Isfahan City	Mazaher Ahmadi Baseri, Reza Mokhtari Malekabadi, Amir Gandomkar Najafabad Branch, Islamic Azad University, Iran
	Notice Importance to Economization Methods in Building	Pezhman Nazeri Naeini, Raheleh Hekmatpanah Islamic Azad University, Iran
	Neural Network Evaluation of FRP Strengthened RC Buildings Subjected to Near-Fault Ground Motions having Fling Step	Alireza Mortezaei, Kimia Mortezaei Islamic Azad University-Semnan Branch, Iran
	Investigating Tourism Attractions and Its Development in the Desert Regions of Ardestan Township	Alireza Sharifzadeh, Mashaallah Rajabi, Seyed Ramin Ghafari, Masoud Nasri, Mehran Jamshidi Payam Nur University, Iran
	Site Selection of Public Parking in Isfahan City using AHP Model	Mazaher Ahmadi Baseri, Reza Mokhtari Malekabadi, Amir Gandomkar Najafabad Branch, Islamic Azad University, Iran
	The Effect of Silica Pretreatment Period on Salinity Resistance in Echium Amoneum	Mahshid Saadatmand Payam Noor University, Iran
	The Effect of Silicon on Cadmium Stress in Echium Amoenum	Janet Amiri Payam Noor University, Iran
	Pre Treatment with Silicon could Increase Antioxidative Compounds and Decreases Flowering Time on Echium Amoenum that Treated with NaCl	Mahshid Saadatmand Payam Noor University, Iran
	Performance Improvement of Moving Object Recognition and Tracking Algorithm using Parallel Processing of SURF and Optical Flow	Junho Choi, Youngwan Cho Seo Kyeong University, Republic of Korea
	Weeds Interference Duration Influences Soybean Yield	Bahram Mirakhoori Mahadab University, Iran
	Potential Effect of Leave+corm Extracts of Crocus Sativus in Weeds Control	Bahram Mirakhoori Mahadab University, Iran
	Studying the Trend of Drought in Fars Province (Iran) using SPI Method	Amir Gandomkar, Raziye Dehghani Islamic Azad University, Iran
	The Necessity of Optimized Management on Surface Water Sources of Zayanderood Basin	Amir Gandomkar, Katayon Fouladi Najafabad Branch, Islamic Azad University, Iran
	Design of Power System Stabilizer Based on Sliding Mode Control Theory for Multi-Machine Power System	Hossein Shahinzadeh, Ladan Darougaran, Ebrahim Jalili Sani, Hamed Yavari, Mahdi Mozaffari Legha Islamic Azad University, Iran
	Comparison of Architecture's Sustainable Areas in the Energy Efficiency in hot and Dry and Cold Regions of Iran	Farzaneh Hoseini Bagh, Mehran Jamshidi Islamic Azad University, Iran
	Stability Patterns in Iran's Traditional Architecture	Fatemeh Sadat Izadi Avani, Kazem Yazdi, Raheleh Hekmatpanah Ardestan Branch, Islamic Azad University, Ardetan, Iran
	Architectural Spaces Dependent on the Water in Iran's Deserted Areas	Jamshidi Mehran, Nasri Masoud, Moslehi Mohsen Ardestan Branch, Islamic Azad University, Ardestan, Iran
	Iranian Traditional Architecture for A Passive Cooling System, Aqueduct and Windward Combination Action	Alireza Azimi Hasanabadi, Fatemeh Sadat Izadi Avani, Kazem Yazdi, Masoud Nasri, Tayebeh Farsi Ardestan Branch, Islamic Azad University, Ardetan, Iran
	Economizing on Construction with an Approach to Constructional Technology and Knowledge of Masonry	Hassan Taheri, Shukofe Zaheri, Tayebeh Farsi Islamic Azad University, Ardestan, Iran
	Study of Solid Waste Landfill Suitability Using Regional Screening Method and AHP in Rasht City	Seyed Masoud Monavari, Pooneh Hoasami, Sannaz Tajziehchi, Nasrin Khorrami Chokami ; Islamic Azad University, Iran



	A pricing method for urban networks by considering private and external costs	Aidin Massahi, Mansour Hadji Hosseinlou, Hamed Shagerdi Esmaeeli, Hadi Shagerdi Esmaeeli K.N. Toosi University of Technology, Iran
	Notation and Explanation of the Relevance Between Job Design and Organizational Performance to Create the Optimal Model For Gob Design with an International View	Bahram Alishiri Islamic Azad University, South Tehran Branch, Iran
	An Ontology for Spatial Relevant Objects in a Location-aware System: Case Study: A Tourist Guide System	Najmeh Neysani Samani, Mahmud Reza Delavar, Nicholas Chrisman, Mohammad Reza Malek University of Tehran, Faculty of Engineering, Iran
	Programmed Cell Death in Rose ( <i>Rosa hybrida</i> cv. <i>Dolce vita</i> +) Cut Flowers as Influenced by Chemical or Physical Factors	Ramezanizadeh, R., Karimzadeh, G., Babaie, A. R. Tarbiat Modares University, Iran
	Implementation of Explicit finite Element Program for Simulation of Concrete behavior via Microplane model	Hadi Shagerdi Esmaeeli, Abolhassan Vafai, Hamed Shagerdi Esmaeeli, Aidin Massahi K. N. Toosi University of Technology, Iran
	Erosion and sedimentation assessment of Absorkh watershed (Iran) using MPSIAC model, satellite data and GIS	Fatemeh Noor, Masoud Nasri, Jamal Baninemeh Khuzestan Science and Research Branch, Islamic Azad University, Iran
	SimplexIS: Evaluating the Impact of eGov Simplification Measures in the Information System Architecture	Bruno Miguel Gomes Félix Instituto Superior Tecnico, Portugal
	Technical and Economic Assessment For Installing Micro-CHP in Residential Homes	Ladan Darougaran, Hossein Shahinzadeh, Mahdi Mozaffari Legha, Houman Gadari Seraj Higher Education Institute, Tabriz, Iran
	Study of the Effect of Project Management on Manufacturing and Production Projects	S. B. Ahmadi, Z. Moradpour, Gh. Liaghat Shahid Bahonar University, Iran
	Estimation of Thermo-Mechanical Characterisation of CuZn5 using Genetic Algorithm	M. Sharififar, A. A. Akbari Mousavi University of Tehran, Iran
	Artificial Neural Network Modeling to Evaluate and Predict the Deformation Behavior of CuZn5 Brass Alloy During Hot Tension	M. Sharififar, A. A. Akbari Mousavi University of Tehran, Iran
	The Assessment of Compaction Temperatures on Hot Mix Asphalt (HMA) Properties	Houman Saedi Tarbiat Modares University, Iran
	Stress Analysis of Non-Persistent Rock Joints under Biaxial Loading	Omer S. Mughieda Abu Dhabi University, UAE
	Mathematical Modeling and Neural Network Control for Dissolved Oxygen of Aquaculture Pond Aeration System	Doaa M. Atia, Faten H. Fahmy, Ninet M. Ahmed, Hassen T. Dorrah Electronic Research Institute, Egypt
	Overhead Estimation over Capacity of Mobile WiMAX	Saeed AL-Rashdy CRC Harbin Institute of Technology, China
	Analysis of Chloride Ion Penetration for NPP Concrete Structures by Crack	D. G. Kim, J. H. Lee, H. J. Lee, K. B. Kim, H. R. Jung Korea Institute of Construction Technology, Goyang, South Korea
	Robust Algorithms for Conflicting Scenarios of Local Landmark-Based Autonomous Navigation	Daniel N. Aloï Oakland University/iTrack LLC, Rochester, USA
	The Willingness of Business Students on Innovative Behavior within the Theory of Planned Behavior	Mei-Lan Lin, Pi-Yueh Cheng Southern Taiwan University, Taiwan
	Notice importance to economization methods in building	Pezhman Nazeri Naeini, Raheleh Hekmatpanah Dehaghan Branch, Islamic Azad University, Dehaghan, Iran
	Gasoline additives preparation using fusel alcohol	Mina Nasooti Islamic Azad University, Iran
	The Effects of Different Concentration of Phosphorus and Mycorrhizal Fungi on Aluminum toxicity in cowpea	Enteshari Shekoofeh, Delavar Kourosh, Sharifiyan Shahla, Hajhashemi Faeze; Payame Noor University, Iran
	Can 24-Epi-Brassinosteroid Decrement Adverse Effect of Drought Stress on Medicinal Borage Plant?	Enteshari Shekoofeh, Delavar Kourosh, Sharifiyan Shahla, Hajhashemi Faeze; Payame Noor University, Iran
	Electrospinning process optimization of poly (vinyl alcohol) nanofibers	A. Doustgani, E. Vasheghani- Farahani, M. Soleimani, S. Hashemi-Najafabadi, Modares University, Iran
	Physical and chemical investigation of polycaprolactone, nanohydroxyapatite and poly (vinyl alcohol) nanocomposite scaffolds	A. Doustgani, E. Vasheghani- Farahani, M. Soleimani, S. Hashemi-Najafabadi, Modares University, Iran
	New method for Performance based Seismic evaluation of Three-arch shallow tunnels with pushover analysis	Mahan pasdarpour, Shahram Vahdani University of Tehran, Iran
	Improving the Road Construction Supply Chain by Developing a National Level Performance System: The Case of Estonia	Ott Koppel, Kati K. Kaare Tallinn University of Technology, Estonia

	Providing And Collecting Of Concrete Bridges Design Criteria Based On Performance-Based Design	Hamed Shagerdi Esmaeeli, Hadi Shagerdi Esmaeeli, Aidin Massahi K.N. Toosi University of Technology, Iran
	Reproduction and Breeding Cycles of Oreochromis Niloticus and Tilapia Zilli in Gbedekere Lake, Kogi State Nigeria	Segun Adeyemi Kogi State University, Ayingba, Nigeria
	Marriages: A Social Act or Symbolic Transaction	Beenish Malik Institution University of Balochistan, Pakistan
	The Effect of Frame Geometry on the Seismic Response of Self-Centering Concentrically-Braced Frames	David A. Roke, M. R. Hasan The University of Akron, United States
	Micro-Inductors using Permalloy Thin Films	Abdelhadi Namoune, Benali Benadjemia, Asma Lakhdar University of Sciences and of the Technology of Oran Mohamed Boudiaf (USTO-MB), Algeria
	Optimization of CO2 Emissions and Cost for Composite Building Design with NSGA- II	Ji Hye Jeon, Hyo Seon Park Yonsei University, South Korea
	Dimensioning of a micro-inductor integrated in a micro-converter Buck	Benali Benadjemia, Asma Lakhdar, Abdelhadi Namoune University of Sciences and Technology of Oran, Mohamed Boudiaf (USTO-MB), Algeria
	<b>Technical Equipment</b> 1- Laptop Computer 2- LCD Data Projector 3- USB Flash Drive- Memory 4- CD/DVD-ROM Drive	5- PowerPoint Presentation Remote with Laser Pointer 6- PowerPoint Presentation/ Acrobat Reader Software 7- Each Technical Presentation is 20 Minutes including Discussions

# The Weighted Minimum Tuple 2-Rainbow Domination on Graphs

William Chung-Kung Yen, Jia-Jie Liu, and Chao-Cheng Shih

**Abstract**—Let  $G(V, E)$  be a connected and undirected graph with  $n$ -vertex-set  $V$  and  $m$ -edge-set  $E$ . Each vertex  $v$  is associated with two positive weights,  $w_1(v)$  and  $w_2(v)$ . If  $w_1(v) = 1$  and  $w_2(v) = 1$ , for all  $v \in V$ , then  $G$  is called an unweighted graph. For each  $v \in V$ , let  $N(v) = \{u | u \in V \text{ and } (u, v) \in E\}$  and  $N[v] = N(v) \cup \{v\}$ . A tuple 2-rainbow domination function of  $G$  is a function  $f$  mapping each vertex  $v$  to a Boolean string  $f(v) = f_2(v)f_1(v)$ ,  $f_1(v), f_2(v) \in \{0, 1\}$ , such that  $\bigvee_{u \in N[v]} f(u) = 11$  for all  $v \in V$ , where  $\bigvee_{u \in N[v]} f(u)$  is the result of taking bitwise OR operation on  $f(u)$ , for all  $u \in N[v]$ . The weight of  $f$  is defined as  $w(f) = \sum_{v \in V} (f_1(v)w_1(v) + f_2(v)w_2(v))$ . The objective of our problem is to identify a tuple 2-rainbow domination function  $f$  of  $G$  such that  $w(f)$  is minimized. This paper first proves that the problem is NP-Hard on unweighted planar graphs. Then, an  $O(n)$ -time optimal algorithm for the problem on trees is proposed using the dynamic programming strategy.

**Keywords**—(Tuple)  $k$ -rainbow domination function, planar graphs, trees, NP-Hard.

## I. INTRODUCTION

Domination and its variations on graphs are natural models for many location problems in Operations Research and related fields. They have been studied extensively in the literature [5], [6]. The  $k$ -rainbow domination is one of important variations which was introduced by Bresar et. al. [1]. Let  $G(V, E)$  be a connected and undirected graph, where  $V$  and  $E$  are the vertex-set and the edges-set of  $G$ , respectively. For each  $v \in V$ , let  $N(v) = \{u | u \in V \text{ and } (u, v) \in E\}$  and  $N[v] = N(v) \cup \{v\}$ . Given a positive integer  $k$ , let  $h$  denote a function mapping each vertex  $v$  of  $G$  to a  $k$ -bit Boolean string  $h(v) = h_k(v)h_{k-1}(v) \dots h_1(v)$ , i.e.,  $h_i(v) \in \{0, 1\}$ ,  $1 \leq i \leq k$ . Meanwhile, for any subset  $S$  of  $V$ ,  $\bigvee_{u \in S} h(u)$  denotes the result of taking bitwise OR operation on  $h(u)$ , for all  $u \in S$ . For convenience, we also use  $\bigvee_{u \in \{x, y\}} h(u)$  to represent  $h(x) \vee h(y)$ . Denote  $1^{(k)}$  (respectively,  $0^{(k)}$ ) as the  $k$ -bit Boolean string with exactly  $k$  1s' (respectively,  $k$  0s'). The function  $h$  is called a  $k$ -rainbow domination function of  $G$  if  $\bigvee_{u \in N[v]} h(u) = 1^{(k)}$ , for all  $v \in V$  with  $h(v) = 0^{(k)}$ . The weight of a  $k$ -rainbow domination function  $h$  of  $G$  is defined as  $w(h) = \sum_{v \in V} \sum_{i=1}^k (h_i(v))$ . The following states the formal definition of the *Minimum  $k$ -Rainbow Domination problem*.

### The Minimum $k$ -Rainbow Domination problem (The MkRD problem)

**Input:** A graph  $G(V, E)$  with  $n$ -vertex-set  $V$  and  $m$ -edge-set  $E$ .

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**Output:** A  $k$ -rainbow domination function  $h$  of  $G$  such that  $w(h)$  is minimized.

In [1], the MkRD problem was originally studied and a linear-time algorithm on trees, for  $k = 2$ , was also proposed. Later, the authors in [2] proved that the MkRD problem is NP-Hard on chordal graphs and bipartite graphs, respectively, and proposed a linear-time algorithm on trees, for all  $k$ . Recently, an improved Nordhaus-Gaddum bounds for  $k$ -rainbow domatic number of a graph was derived [7].

In this paper, we consider a new variant of the MkRD problem. The motivation of this new problem comes from the following practical resource allocation model. Consider a network modeled as a graph  $G(V, E)$ , where  $V$  represents the set of nodes and  $E$  is the set of direct links of node pairs. Two types of resources,  $R_1$  and  $R_2$ , will be allocated at some nodes to serve requests from clients all over the network. For each node  $v$ ,  $w_1(v)$  and  $w_2(v)$  denote the costs of allocating  $R_1$  and  $R_2$  at  $v$ , respectively. We require that the clients at each node  $v$  can access both  $R_1$  and  $R_2$  from  $v$  and all neighboring nodes of  $v$ , i.e., every client can access both resources via at most one direct transmission. The objective is to minimize the total allocation cost over the entire network.

Before defining our problem formally, let us introduce some terms and concepts. In the rest of this paper, each vertex  $v$  of all consider graphs  $G(V, E)$  is associated with two positive weights,  $w_1(v)$  and  $w_2(v)$ . If  $w_1(v) = 1$  and  $w_2(v) = 1$ , for all  $v \in V$ , then  $G$  is called an *unweighted graph*. Let  $f$  be a function mapping each vertex  $v$  of  $G$  to a 2-bit Boolean string  $f(v) = f_2(v)f_1(v)$ , where  $f_1(v), f_2(v) \in \{0, 1\}$ . A vertex  $v$  of  $G$  is called a 00-node if  $f(v) = 00$ . 01-nodes, 10-nodes, and 11-nodes can be defined similarly. In addition, a vertex  $v$  of  $G$  is called a 00-dominated node if  $\bigvee_{u \in N[v]} f(u) = 00$ . 01-dominated nodes, 10-dominated nodes, and 11-dominated nodes can also be defined similarly. Such a function  $f$  is called a *tuple 2-rainbow domination function* of  $G$  if every vertex  $v$  of  $G$  is a 11-dominated node. The weight of  $f$  is defined as  $w(f) = \sum_{v \in V} (f_1(v)w_1(v) + f_2(v)w_2(v))$ . The issue as stated in previous paragraph leads us to study the following new problem.

### The Weighted Minimum Tuple 2-Rainbow Domination problem (The WMT2RD problem)

**Input:** A graph  $G(V, E)$  with  $n$ -vertex-set  $V$  and  $m$ -edge-set  $E$  in which each vertex  $v$  is associated two positive weights,  $w_1(v)$  and  $w_2(v)$ .

**Output:** A tuple 2-rainbow domination function  $f$  of  $G$  such that  $w(f)$  is minimized.

This paper presents an original study about the algorithmic aspect of the WMT2RD problem. In Section 2, we will show

that the WMT2RD problem is NP-Hard on unweighted planar graphs. Then, an  $O(n)$ -time optimal algorithm for the problem on trees will be proposed using the dynamic programming strategy in Section 3. Finally, concluding remarks will be drawn in Section 4.

## II. NP-HARDNESS PROPERTY ON UNWEIGHTED PLANAR GRAPHS

A graph  $G$  is a *planar graph* if  $G$  can be drawn into the plane without edge-crossings, except the end vertices of all edges [3]. This section will show that the WMT2RD problem is NP-Hard on unweighted planar graphs. The task will be done by showing that the following NP-complete problem can be reduced to the WMT2RD problem in polynomial time.

### The Planar 3-Satisfiability problem (The P3SAT problem)

**Input:** A set  $C = \{c_1, c_2, \dots, c_p\}$  of Boolean clauses over the variable-set  $X = \{x_1, x_2, \dots, x_t\}$  such that the graph  $G(V, E)$  with  $V = C \cup X$  and  $E = \{(c_i, x_j) | c_i \text{ contains } x_j \text{ or } x'_j\}$  is planar.

**Output:** Yes iff there exists a truth assignment  $S$  of  $X$  satisfying all clauses in  $C$ .

**Theorem 1.** [4] *The P3SAT problem is NP-complete.*

**Theorem 2.** *The WMT2RD problem is NP-Hard on unweighted planar graphs.*

**Proof.** Suppose that we are given  $C = \{c_1, c_2, \dots, c_p\}$  and  $X = \{x_1, x_2, \dots, x_t\}$  of the P3SAT problem, where  $G(V, E)$  is the planar graph as stated in the above definition. The corresponding unweighted planar graph  $G^*(V^*, E^*)$  of the WMT2RD problem can be constructed as:  $V^* = C \cup X \cup X' \cup A \cup B$ , where  $X' = \{x'_1, x'_2, \dots, x'_t\}$ ,  $A = \{a_1, a_2, \dots, a_t\}$ , and  $B = \{b_1, b_2, \dots, b_t\}$ ; and  $E = \{(c_i, x_j) | x_j \text{ is a literal of } c_i\} \cup \{(c_i, x'_j) | x'_j \text{ is a literal of } c_i\} \cup \{(x_j, x'_j), (x_j, a_j), (x_j, b_j), (a_j, x'_j), (b_j, x'_j) | 1 \leq j \leq t\}$ . The planarity of  $G^*$  can be easily verified based upon the fact that  $G$  is planar. To complete the proof, the following will claim that there exists an assignment  $S$  of  $X$  satisfying all clauses in  $C$  iff there exists a tuple 2-rainbow domination function  $f$  of  $G^*$  with  $w(f) = 2t$ .

Let there exist a truth assignment  $S$  of  $X$  for  $C$ . A tuple 2-rainbow domination function  $f$  of  $G^*$  can be obtained using the following rules.

$$\begin{cases} f(x_j) = 11 \text{ and } f(x'_j) = 00, x_j = \text{TRUE}, 1 \leq j \leq t. \\ f(x_j) = 00 \text{ and } f(x'_j) = 11, x_j = \text{FALSE}, 1 \leq j \leq t. \\ f(u) = 00, \text{ for all } u \in V^* - (X \cup X'). \end{cases}$$

It is easy to verify that  $\bowtie_{u \in N[u]} f(u) = 11$ , for all  $u \in (X \cup X')$  and for each  $u \in V^* - (X \cup X')$ , there must exist  $v \in (X \cup X')$  such that  $f(v) = 11$ . This implies that  $\bowtie_{u \in N[u]} f(u) = 11$ , for all  $u \in V^*$ . Additionally, it is clear that  $w(f) = 2t$ .

Next, assume that there exists a tuple 2-rainbow domination function  $f$  of  $G^*$  such that  $w(f) = 2t$ . We claim that  $f_1(x_j) +$

$f_2(x_j) + f_1(x'_j) + f_2(x'_j) = 2$ , for all  $1 \leq j \leq t$ . For each  $1 \leq j \leq t$ , if  $f_1(x_j) + f_2(x_j) + f_1(x'_j) + f_2(x'_j) = 0$ , then we must have  $f(a_j) = 11$  and  $f(b_j) = 11$ . The definition of the tuple 2-rainbow domination functions implies that  $f_1(a_j) + f_2(a_j) + f_1(b_j) + f_2(b_j) = 4$ . Meanwhile, if  $f_1(x_j) + f_2(x_j) + f_1(x'_j) + f_2(x'_j) = 1$ , then we can easily derive that  $f_1(a_j) + f_2(a_j) + f_1(b_j) + f_2(b_j) = 2$ . This implies that  $w(f) > 2t$  if  $f_1(x_j) + f_2(x_j) + f_1(x'_j) + f_2(x'_j) \leq 1$ , for all  $1 \leq j \leq t$ . This can further imply that  $f_1(x_j) + f_2(x_j) + f_1(x'_j) + f_2(x'_j) = 2$ , for all  $1 \leq j \leq t$ . In another, we must have  $f(u) = 00$ , for all  $u \in V^* - (X \cup X')$ .

Now, let  $S$  be an assignment of  $X$  such that  $x_j = \text{TRUE}$  if  $f_1(x_j) = 1$  and  $x'_j = \text{TRUE}$  if  $f_1(x'_j) = 1$ . Verifying that  $S$  can satisfy all clauses in  $C$  is an easy task. ■

## III. THE WEIGHTED MINIMUM TUPLE 2-RAINBOW DOMINATION ON TREES

To solve the WMT2RD problem on trees, we will first propose and solve the following problem. Then, an  $O(n)$ -time algorithm for the WMT2RD problem will be designed using this result as its kernel.

### The 0/1-Component Composition problem

**Input:** A 2-bit binary string  $c_1 c_2$  and a set  $S = \{s_1, s_2, \dots, s_n\}$ , where  $s_i = (\alpha_i, \beta_i, \gamma_i, \delta_i)$  is a vector of 4 positive numbers,  $1 \leq i \leq n$ .

**Output:** A set  $\Pi = \{\pi_1, \pi_2, \dots, \pi_n\}$ , where each  $\pi_i = (x_i, y_i, u_i, v_i)$  is a vector of 4 positive numbers,  $1 \leq i \leq n$ , such

that  $z = \sum_{i=1}^n (\alpha_i, \beta_i, \gamma_i, \delta_i) \begin{pmatrix} x_i \\ y_i \\ u_i \\ v_i \end{pmatrix}$  is minimized subject to

the following conditions.

$$x_i + y_i + u_i + v_i = 1, \quad i = 1, \dots, n, \quad (1)$$

$$x_i = 0 \text{ or } 1, \quad i = 1, \dots, n, \quad (2)$$

$$y_i = 0 \text{ or } 1, \quad i = 1, \dots, n, \quad (3)$$

$$u_i = 0 \text{ or } 1, \quad i = 1, \dots, n, \quad (4)$$

$$v_i = 0 \text{ or } 1, \quad i = 1, \dots, n. \quad (5)$$

$$\bowtie_{1 \leq i \leq n} g(i) = c_1 c_2 \quad (6)$$

, where  $g(i) = 00$  if  $x_i = 1$ ,  $g(i) = 01$  if  $y_i = 1$ ,  $g(i) = 10$  if  $u_i = 1$ , and  $g(i) = 11$  if  $v_i = 1$ .

We can see from Eq. (1) that one and only one of  $x_i, y_i, u_i$ , and  $v_i$  must be 1, for  $i = 1, 2, \dots, n$ . Hereafter, we say that an element  $\alpha_i$  (respectively,  $\beta_i, \gamma_i$ , and  $\delta_i$ ) is selected if  $x_i = 1$  (respectively,  $y_i = 1, u_i = 1$ , and  $v_i = 1$ ). For ease of description, the selected elements in a feasible solution are denoted by  $S_\alpha = \{\alpha_i | x_i = 1, 1 \leq i \leq n\}$ ,  $S_\beta = \{\beta_i | y_i = 1, 1 \leq i \leq n\}$ ,  $S_\gamma = \{\gamma_i | u_i = 1, 1 \leq i \leq n\}$ , and  $S_\delta = \{\delta_i | v_i = 1, 1 \leq i \leq n\}$  such that  $\bowtie_{1 \leq i \leq n} g(i) = c_1 c_2$ . Moreover, let  $S_{\hat{\alpha}} = \{\alpha_1, \alpha_2, \dots, \alpha_n\}$ ,  $S_{\hat{\beta}} = \{\beta_1, \beta_2, \dots, \beta_n\}$ ,  $S_{\hat{\gamma}} = \{\gamma_1, \gamma_2, \dots, \gamma_n\}$ , and  $S_{\hat{\delta}} = \{\delta_1, \delta_2, \dots, \delta_n\}$ . We use  $\lambda^{c_1 c_2}(S_\alpha, S_\beta, S_\gamma, S_\delta)$  to denote the corresponding value, i.e.,  $z$ , of the feasible solution with  $S_\alpha, S_\beta, S_\gamma$ , and  $S_\delta$ .

The 0/1-component composition problem can be solved by using the dynamic programming technique as follows: Let

$\lambda_i^{d_1 d_2}$  denote the minimum value of the 0/1-component composition problem with  $S_i = \{s_1, s_2, \dots, s_i\}$  and  $d_1 d_2 = c_1 c_2$ , for  $1 \leq i \leq n$ . In the following, we describe a recurrence formula for computing  $\lambda_i^{d_1 d_2}$ . For  $i > 1$ ,

$$\lambda_i^{d_1 d_2} = \begin{cases} \lambda_{i-1}^{00} + \alpha_i, & \text{if } d_1 d_2 = 00 \\ \min\{\lambda_{i-1}^{00} + \beta_i, \lambda_{i-1}^{01} + \alpha_i, \lambda_{i-1}^{01} + \beta_i\}, & \text{if } d_1 d_2 = 01 \\ \min\{\lambda_{i-1}^{00} + \gamma_i, \lambda_{i-1}^{10} + \alpha_i, \lambda_{i-1}^{10} + \gamma_i\}, & \text{if } d_1 d_2 = 10 \\ \min\{\lambda_{i-1}^{00} + \delta_i, \lambda_{i-1}^{01} + \gamma_i, \lambda_{i-1}^{01} + \delta_i, \lambda_{i-1}^{10} + \beta_i, \\ \lambda_{i-1}^{10} + \delta_i, \lambda_{i-1}^{11} + \alpha_i, \lambda_{i-1}^{11} + \beta_i, \lambda_{i-1}^{11} + \gamma_i, \\ \lambda_{i-1}^{11} + \delta_i\}, & \text{if } d_1 d_2 = 11 \end{cases} \quad (7)$$

with initial conditions  $\lambda_1^{00} = \alpha_1$ ,  $\lambda_1^{01} = \beta_1$ ,  $\lambda_1^{10} = \gamma_1$ , and  $\lambda_1^{11} = \delta_1$ .

**Theorem 3.** The 0/1-component composition problem can be solved in  $O(n)$  time.

**Proof.** Since each value of  $\lambda_i^{00}$ ,  $\lambda_i^{01}$ ,  $\lambda_i^{10}$ , and  $\lambda_i^{11}$  can be computed in constant time, this theorem follows directly. ■

Now, we will show how to solve the WMT2RD problem on trees. For convenience, we call formula (7) for describing the 0/1-component composition problem as the 0/1-component formula. Given a tree  $T$ , we select an arbitrary vertex from  $V(T)$  as the root of tree  $T$ . We assume that the root of a tree  $T$  is with label  $r$ . For any vertex  $u \in T$ , let  $p(u)$  denote the parent of  $u$  and  $C(u)$  stand for the set of children of  $u$ . The subtree of  $T$  rooted at vertex  $v$  is denoted by  $T_v$ , and, for a tuple 2-rainbow domination function  $f$  of  $V(T)$ , let  $f_v$  denote the mapping function  $f$  of  $V(T_v)$ . The weight of  $f_v$  is denoted as  $w(f_v) = \sum_{v \in T_v} (f_1(v)w_1(v) + f_2(v)w_2(v))$ . We say  $f_v$  is a *semifinished function* if every node  $u \in T_v \setminus \{v\}$  is a 11-dominated node. Let  $\alpha(v)$ ,  $\beta(v)$ ,  $\gamma(v)$ , and  $\delta(v)$  denote the minimum weight semifinished function  $f_v$  if  $v$  is a 00-node, 01-node, 10-node, and 11-node of  $T_v$ , respectively. A semifinished function  $f_v$  is called a *00-function* (respectively, *01-function*, *10-function*, and *11-function*) if  $v$  is a 00-dominated node (respectively, 01-dominated node, 10-dominated node, and 11-dominated node) in  $T_v$ . Let  $t_{b_1 b_2}^{c_1 c_2}(v)$  denote the weight of any minimum weight semifinished function  $f_v$  in which  $v$  is a  $b_1 b_2$ -node and  $f_v$  is a  $c_1 c_2$ -function, where  $b_1, b_2, c_1, c_2 \in \{0, 1\}$ . Note that  $t_{01}^{00}(v) = \infty$  since it is impossible that  $v$  is a 01-node and  $v$  also is 00-dominated node. Similarly,  $t_{01}^{10}(v) = \infty$ ,  $t_{10}^{00}(v) = \infty$ ,  $t_{10}^{01}(v) = \infty$ ,  $t_{11}^{00}(v) = \infty$ ,  $t_{11}^{01}(v) = \infty$ , and  $t_{11}^{10}(v) = \infty$ . The following propositions hold directly.

**Proposition 4.** Let  $f$  be a minimum weight tuple 2-rainbow domination function in  $T$  and  $v$  be an internal vertex of  $T$ . The following statements are true.

- (i) If  $v$  is a 00-node, then  $f_u$  is a 11-function, for all  $u \in C(v)$ .
- (ii) If  $v$  is a 01-node, then  $f_u$  is a 10-function or 11-function, for all  $u \in C(v)$ .
- (iii) If  $v$  is a 10-node, then  $f_u$  is a 01-function or 11-function, for all  $u \in C(v)$ .
- (iv) If  $v$  is a 11-node, then  $f_u$  is a 00-function, 01-function, 10-function, or 11-function, for all  $u \in C(v)$ .

**Proposition 5.** Let  $f$  be a minimum weight tuple 2-rainbow domination function in  $T$  and  $v \neq r$  be an internal vertex of  $T$ . The following statements are true.

- (i) If  $p(v)$  is a 00-node, then  $\alpha(v) = t_{00}^{11}(v)$ ,  $\beta(v) = t_{01}^{11}(v)$ ,  $\gamma(v) = t_{10}^{11}(v)$ , and  $\delta(v) = t_{11}^{11}(v)$ .
- (ii) If  $p(v)$  is a 01-node, then  $\alpha(v) = \min\{t_{00}^{11}(v), t_{00}^{10}(v)\}$ ,  $\beta(v) = t_{01}^{11}(v)$ ,  $\gamma(v) = \min\{t_{10}^{11}(v), t_{10}^{10}(v)\}$ , and  $\delta(v) = t_{11}^{11}(v)$ .
- (iii) If  $p(v)$  is a 10-node, then  $\alpha(v) = \min\{t_{00}^{11}(v), t_{00}^{01}(v)\}$ ,  $\beta(v) = \min\{t_{01}^{11}(v), t_{01}^{01}(v)\}$ ,  $\gamma(v) = t_{10}^{11}(v)$ , and  $\delta(v) = t_{11}^{11}(v)$ .
- (iv) If  $p(v)$  is a 11-node, then  $\alpha(v) = \min\{t_{00}^{11}(v), t_{00}^{01}(v), t_{00}^{10}(v), t_{00}^{00}(v)\}$ ,  $\beta(v) = \min\{t_{01}^{11}(v), t_{01}^{01}(v)\}$ ,  $\gamma(v) = \min\{t_{10}^{11}(v), t_{10}^{10}(v)\}$ , and  $\delta(v) = t_{11}^{11}(v)$ .

In the following, we introduce how to compute  $t_{b_1 b_2}^{c_1 c_2}(v)$ , where  $b_1, b_2, c_1, c_2 \in \{0, 1\}$ , for each vertex  $v \in V(T)$ . For a subtree  $T_v$ , assume that  $C(v) = \{v_1, v_2, \dots, v_{|C(v)|}\}$ . If  $v$  is a leaf vertex of  $T$ , the values of its associated  $t_{b_1 b_2}^{c_1 c_2}(v)$ , where  $b_1, b_2, c_1, c_2 \in \{0, 1\}$ , are described in Proposition 6.

**Proposition 6.** If  $v$  is a leaf vertex of  $T$ , then  $t_{00}^{00}(v) = 0$ ,  $t_{01}^{01}(v) = w_1(v)$ ,  $t_{10}^{10}(v) = w_2(v)$ ,  $t_{11}^{11}(v) = w_1(v) + w_2(v)$ , and  $t_{b_1 b_2}^{c_1 c_2}(v) = \infty$  while  $c_1 c_2 \neq b_1 b_2$ .

**Lemma 7.** If  $v$  is an internal vertex of  $T$ , then  $t_{00}^{00}(v) = \lambda_p^{00}$  (respectively,  $t_{00}^{01}(v) = \lambda_p^{01}$ ,  $t_{00}^{10}(v) = \lambda_p^{10}$ , and  $t_{00}^{11}(v) = \lambda_p^{11}$ ) after setting  $p = |C(v)|$  and  $(\alpha_i, \beta_i, \gamma_i, \delta_i)$ , for  $1 \leq i \leq p$ , are obtained by Proposition 5 while  $v$  is a 00-node.

**Proof.** Since  $v$  is a 00-node,  $\boxtimes_{u \in C(v)} f(u) = 00$  (respectively, 01, 10, and 11) while  $f_v$  is a 00-function (respectively, 01-function, 10-function, and 11-function). Since  $z = \lambda_p^{00}$  (respectively,  $\lambda_p^{01}$ ,  $\lambda_p^{10}$ , and  $\lambda_p^{11}$ ) is the minimum solution such that  $\boxtimes_{u \in C(v)} f(u) = 00$  (respectively, 01, 10, and 11),  $t_{00}^{00}(v) = \lambda_p^{00}$  (respectively,  $t_{00}^{01}(v) = \lambda_p^{01}$ ,  $t_{00}^{10}(v) = \lambda_p^{10}$ , and  $t_{00}^{11}(v) = \lambda_p^{11}$ ). ■

**Lemma 8.** If  $v$  is an internal vertex of  $T$ , then  $t_{01}^{01}(v) = \min\{\lambda_p^{00}, \lambda_p^{01}\} + w_1(v)$  (respectively,  $t_{11}^{11}(v) = \min\{\lambda_p^{10}, \lambda_p^{11}\} + w_1(v)$ ) after setting  $p = |C(v)|$  and  $(\alpha_i, \beta_i, \gamma_i, \delta_i)$ , for  $1 \leq i \leq p$ , are obtained by Proposition 5 while  $v$  is a 01-node.

**Lemma 9.** If  $v$  is an internal vertex of  $T$ , then  $t_{10}^{10}(v) = \min\{\lambda_p^{00}, \lambda_p^{10}\} + w_2(v)$  (respectively,  $t_{11}^{11}(v) = \min\{\lambda_p^{01}, \lambda_p^{11}\} + w_2(v)$ ) after setting  $p = |C(v)|$  and  $(\alpha_i, \beta_i, \gamma_i, \delta_i)$ , for  $1 \leq i \leq p$ , is obtained by Proposition 5 while  $v$  is a 10-node.

**Lemma 10.** If  $v$  is an internal vertex of  $T$ , then  $t_{11}^{11}(v) = \min\{\lambda_p^{00}, \lambda_p^{01}, \lambda_p^{10}, \lambda_p^{11}\} + w_1(v) + w_2(v)$  after setting  $p = |C(v)|$  and  $(\alpha_i, \beta_i, \gamma_i, \delta_i)$ , for  $1 \leq i \leq p$ , are obtained by Proposition 5 while  $v$  is a 11-node.

Let  $s(T)$  denote the weight of any minimum tuple 2-rainbow domination function  $f$  of  $T$ . Thus, the computation of  $s(T)$  is equivalent to the computation of  $t_{00}^{11}(r)$ ,  $t_{01}^{11}(r)$ ,  $t_{10}^{11}(r)$ , and  $t_{11}^{11}(r)$  which will be proved in Theorem 12.

**Lemma 11.** Let  $T_r$  and  $T'_r$  be the trees rooted at  $r = v$  and  $r = u$ , respectively, and let  $f_v^*$  and  $f_u^*$  be two minimum weight tuple 2-rainbow domination functions obtained from  $T_r$  and  $T'_r$ , respectively. Then  $w(f_v^*) = w(f_u^*)$ .

**Proof.** Suppose to the contrary that  $w(f_v^*) \neq w(f_u^*)$ . We only consider the case where  $w(f_v^*) > w(f_u^*)$ . The other case, i.e.,  $w(f_v^*) < w(f_u^*)$ , can be handled similarly. Since  $w(f_v^*) > w(f_u^*)$ , after changing  $v$  as the root in  $T_u$ , we can also obtain the mapping function  $f = f_u^*$ . This contradicts that  $f_v^*$  is a minimum weighted tuple 2-rainbow domination function in  $T_r$ . This completes the proof. ■

**Theorem 12.** For a weighted minimum tuple 2-rainbow domination function  $f$  on tree  $T$ ,  $w(f) = \min\{t_{00}^{11}(r), t_{01}^{11}(r), t_{10}^{11}(r), t_{11}^{11}(r)\}$ . Furthermore, a weighted minimum tuple 2-rainbow domination function  $f$  can be found in  $O(n)$  time.

**Proof.** By Lemma 11, select any vertex in  $T$  as the root of  $T$ . Then, apply Propositions 5-6 and Lemmas 7-10 to compute  $t_{00}^{00}(v), t_{00}^{01}(v), t_{00}^{10}(v), t_{00}^{11}(v), t_{01}^{00}(v), t_{01}^{01}(v), t_{01}^{10}(v), t_{01}^{11}(v), t_{10}^{00}(v), t_{10}^{01}(v), t_{10}^{10}(v), t_{10}^{11}(v)$ , and  $t_{11}^{00}(v), t_{11}^{01}(v), t_{11}^{10}(v), t_{11}^{11}(v)$  for every vertex  $v \in V(T)$  in post-order. Note that computing  $t_{00}^{00}(v), t_{00}^{01}(v), t_{00}^{10}(v), t_{00}^{11}(v), t_{01}^{00}(v), t_{01}^{01}(v), t_{01}^{10}(v), t_{01}^{11}(v)$ , and  $t_{10}^{00}(v), t_{10}^{01}(v), t_{10}^{10}(v), t_{10}^{11}(v)$  for each vertex  $v$  takes  $O(|C(v)|)$  time by 0/1-component formula. Finally,  $s(T) = \min\{t_{00}^{11}(r), t_{01}^{11}(r), t_{10}^{11}(r), t_{11}^{11}(r)\}$  since every vertex in  $T$  should be 11-dominated node. Therefore, the total time-complexity is  $O(\sum_{v \in V(T)} |C(v)|) = O(|V(T)|) = O(n)$ .

To find out a weighted minimum tuple 2-rainbow domination function of  $T$ , traverse back the  $\lambda$  table of  $r$  from the position depending on the following 4 cases.

- (i) If  $v$  is a 00-node, then traverse back the value of  $\lambda_{|C(r)|}^{11}$ .
- (ii) If  $v$  is a 01-node, then traverse back the value of  $\min\{\lambda_{|C(r)|}^{10}, \lambda_{|C(r)|}^{11}\}$ .
- (iii) If  $v$  is a 10-node, then traverse back the value of  $\min\{\lambda_{|C(r)|}^{01}, \lambda_{|C(r)|}^{11}\}$ .
- (iv) If  $v$  is a 11-node, then traverse back the value of  $\min\{\lambda_{|C(r)|}^{00}, \lambda_{|C(r)|}^{01}, \lambda_{|C(r)|}^{10}, \lambda_{|C(r)|}^{11}\}$ .

After finding out sets  $S_\alpha^*, S_\beta^*$ , and  $S_\gamma^*$ , and  $S_\delta^*$  with respect to  $r$ , set all children  $v$  in  $S_\delta^*$  (respectively,  $S_\beta^*$ , and  $S_\gamma^*$ , and  $S_\alpha^*$ )  $f(v) = 00$  (respectively,  $f(v) = 01, f(v) = 10$ , and  $f(v) = 11$ ). Then, according to the type of  $v \in S_\alpha^* \cup S_\beta^* \cup S_\gamma^* \cup S_\delta^*$ , traverse back the  $\lambda$  table of  $v$ . Repeat the above process in a top-down approach and finally the set  $S$  contains a weighted minimum tuple 2-rainbow domination set. This establishes the theorem. ■

#### IV. CONCLUSION

This paper proposed a variant of the 2-rainbow domination on graphs, called the tuple 2-rainbow domination. The problem arisen from allocating two types of resources at some vertices of a graph. The essential requirement is that users at every vertex  $v$  must be able to access these two type of resources via at most one direct transmission cost. The problem is abbreviated as the WMT2RD problem. We first showed that the WMT2RD problem is NP-hard on unweighted planar

graphs. Then, an  $O(n)$ -time optimal algorithm for the problem on trees was designed by the dynamic programming strategy, where  $n$  is the number of the vertices of the input graph.

In summary, the WMT2RD problem is a more practical variant from the traditional minimum 2-rainbow domination on graphs. It is worth to study this new problem on other graph class such as cactus graphs, interval graphs, and so on, in the future.

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# Cycle embedding in folded hypercubes with more faulty elements

Wen-Yin Huang, Jia-Jie Liu, and Jou-Ming Chang

**Abstract**—Faults in a network may take various forms such as hardware/software errors, vertex/edge faults, etc. Folded hypercube is a well-known variation of the hypercube structure and can be constructed from a hypercube by adding a link to every pair of nodes with complementary addresses. Let  $FF_v$  (respectively,  $FF_e$ ) be the set of faulty nodes (respectively, faulty links) in an  $n$ -dimensional folded hypercube  $FQ_n$ . Hsieh et al. have shown that  $FQ_n - FF_v - FF_e$  for  $n \geq 3$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$ , under the constraints that (1)  $|FF_v| + |FF_e| \leq 2n - 4$  and (2) every node in  $FQ_n$  is incident to at least two fault-free links. In this paper, we further consider the constraints  $|FF_v| + |FF_e| \leq 2n - 3$ . We prove that  $FQ_n - FF_v - FF_e$  for  $n \geq 5$  still has a fault-free cycle of length at least  $2^n - 2|FF_v|$ , under the constraints : (1)  $|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| \geq n + 2$ , and (3) every vertex is still incident with at least two links.

**Keywords**—Folded hypercubes; Interconnection networks; Cycle embedding; Faulty elements.

## I. INTRODUCTION

**H**YPERCUBES are a powerful network that is able to perform various kinds of parallel computations and simulate many other networks [14], [15]. Hypercubes have been widely studied in interconnection networks [6], [7], [8], [20]. A number of other topologies, such as paths, trees, rings, and meshes, can be embedded into a hypercube. There are also many related results in hypercubes with faulty vertices or link [2], [3], [5], [13], [16]. One of the most popular variants is the *folded hypercube*, which is an extension of the hypercube and can be constructed by adding a link to every pair of nodes with complementary address. The folded hypercube has been shown to be able to improve the system's performance over a regular hypercube in many measurements [1], [17].

Since faults may happen on both nodes and edges in a network, it is practically meaningful and important to consider faulty networks. A node is *fault-free* if it is not faulty. A link is *fault-free* if the communication link between end-nodes is not faulty. A path (cycle) is *fault-free* if it contains neither faulty nodes nor faulty links. Previously, the problem of fault-tolerant embedding on an  $n$ -dimensional folded hypercube  $FQ_n$  has been studied in [9], [10], [17], [18], [19]. Let  $FF_v$  (respectively,  $FF_e$ ) be the set of faulty nodes (respectively, faulty links) in an  $n$ -dimensional folded hypercube  $FQ_n$ . Hsieh et al. [12] have shown that  $FQ_n - FF_v - FF_e$  for

$n \geq 3$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$ , under the constraints that (1)  $|FF_v| + |FF_e| \leq 2n - 4$  and (2) every node in  $FQ_n$  is incident to at least two fault-free links. In this paper, we further consider the constraints  $|FF_v| + |FF_e| \leq 2n - 3$ . We prove that  $FQ_n - FF_v - FF_e$  for  $n \geq 5$  still has a fault-free cycle of length at least  $2^n - 2|FF_v|$ , under the constraints : (1)  $|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| \geq n + 2$ , and (3) every vertex is still incident with at least two links.

The rest of this paper is organized as follows. In Section 2, we describe some important properties in folded hypercubes. We present our main result in Section 3. Concluding remarks are given in Section 4.

## II. PRELIMINARIES

An  $n$ -dimensional hypercube  $Q_n$ , also called an  $n$ -cube, can be modeled as a graph with vertex set  $V(Q_n)$  and edge set  $E(Q_n)$ . In  $Q_n$ , there are  $2^n$  vertices and  $n2^{n-1}$  links. Each vertex  $u$  of  $Q_n$  can be distinctly labeled by an  $n$ -bit string  $b_n b_{n-1} \cdots b_2 b_1$ . For any  $i$ ,  $1 \leq i \leq n$ , we use  $u^{(i)}$  to denote the binary string  $b_n b_{n-1} \cdots \bar{b}_i b_{i-1} \cdots b_1$ . Thus, if vertices  $u$  and  $v$  are adjacent, then  $u = v^{(i)}$  and  $v = u^{(i)}$  for some  $1 \leq i \leq n$  and we call the edge  $uv^{(i)}$  an  $i$ -dimensional edge. We will also refer to the edge  $uv^{(i)}$  as  $d^i(u)$ . Thus, if  $v = u^{(i)}$ , then  $v^{(j)} = (u^{(i)})^{(j)}$  is simplified as  $u^{(i)(j)}$ . Let  $E_i = \{d^i(u) | u \in V(Q_n)\}$ , i.e., the set containing all  $i$ -dimensional edges of  $Q_n$ . It is clear that  $|E_i| = 2^{n-1}$  for every  $1 \leq i \leq n$ .

An  $n$ -dimensional folded hypercube  $FQ_n$  can be constructed from an  $n$ -dimensional hypercube by adding a link to every pair of nodes with complementary addresses, e.g., node  $x = b_n b_{n-1} \cdots b_2 b_1$  and node  $\bar{x} = \bar{b}_n \bar{b}_{n-1} \cdots \bar{b}_2 \bar{b}_1$ . Thus  $FQ_n$  has  $2^{n-1}$  more links than a regular hypercube. We call these extra links *skips* to distinguish them from regular links. Let  $E_s$  be the set of skips in  $FQ_n$ . Figure 1 illustrates a 2-dimensional and a 3-dimensional folded hypercubes.

A *path*  $\mathcal{P}$  of length  $k$  from vertex  $x$  to vertex  $y$  in  $FQ_n$  is a sequence of distinct vertices  $v_0, v_1, \dots, v_k$  in which  $x = v_0$ ,  $y = v_k$ , and  $v_i v_{i+1} \in E(FQ_n)$ , for  $i = 0, 1, \dots, k-1$ , where  $k \geq 1$ . We also use  $\langle v_0, \mathcal{P}, v_k \rangle$  as another representation of  $\mathcal{P}$  in order to indicate the two endpoints  $v_0$  and  $v_k$  of  $\mathcal{P}$ . For consistency, an edge  $uv$  can also be represented as a path  $\langle u, v \rangle$ . For two paths  $\langle x, \mathcal{P}, y \rangle$  and  $\langle u, \mathcal{Q}, v \rangle$  in which  $y$  and  $u$  are adjacent, we use  $\langle x, \mathcal{P}, y, u, \mathcal{Q}, v \rangle$  to denote the concatenation of paths  $\mathcal{P}$  and  $\mathcal{Q}$ . A *cycle* is also a sequence of distinct vertices  $v_0, v_1, \dots, v_k$  except  $v_0 = v_k$ . In the following, we introduce some previous results that will be employed later.

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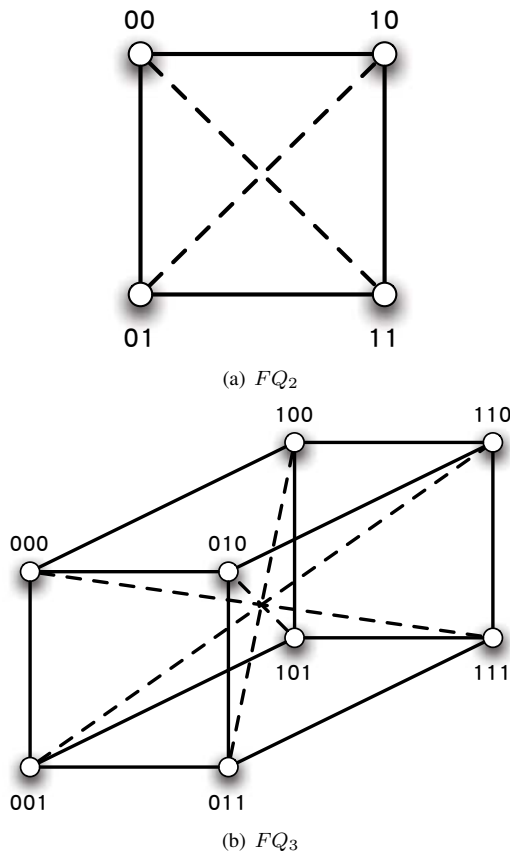


Fig. 1. Graphs of  $FQ_2$  and  $FQ_3$ , in which complementary links are drawn by dashed lines.

**Lemma 1** ([19]). *There is an automorphism  $\delta$  of  $FQ_n$  such that  $\delta(E_i) = E_j$  for  $i, j \in \{1, 2, \dots, n\} \cup \{s\}$ .*

It directly derives the following corollary.

**Corollary 2.**  *$FQ_n - E_i$  is isomorphic to  $Q_n$  for  $i \in \{1, 2, \dots, n\} \cup \{s\}$ .*

In an  $n$ -dimensional faulty hypercube  $Q_n$ , let  $F_v$  and  $F_e$  be the sets of faulty nodes and faulty links of  $Q_n$ , respectively. On the problem of finding the lower bound of longest fault-free cycle in  $Q_n$ , Du et al. [4] have shown the result as Lemma 3.

**Lemma 3** ([4]).  *$Q_n - F_v - F_e$  for  $n \geq 3$  contains a fault-free cycle of length at least  $2^n - 2|F_v|$  if (1)  $|F_v| + |F_e| \leq 2n - 4$  and  $|F_e| \leq 2n - 5$  and (2) every node in  $Q_n$  is incident to at least two fault-free links.*

**Lemma 4** ([11]). *Every edge of  $Q_n - F_v - F_e$  lies on a cycle of every length from 4 to  $2^n - 2|F_v|$  even if  $|F_v| + |F_e| \leq n - 2$ , where  $n \geq 3$ .*

### III. FAULT-FREE CYCLE IN THE FAULTY FOLDED HYPERCUBES

In this section, we present our main result on considering the constraints that (1)  $|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| \geq n + 2$ , and (3) every vertex in  $FQ_n$  is incident with at least two links, as shown in Theorem 6. In an  $n$ -dimensional faulty

folded hypercube  $FQ_n$ , we call a non-faulty node  $k$ -free if it is incident to at most  $k$  fault-free links.

**Lemma 5.** *If  $|FF_v| + |FF_e| \leq 2n - 3$ , there are at most two 2-free nodes contained in  $FQ_n$ .*

**Proof.** By the definition of  $k$ -free node, a 2-free nodes is adjacent to at least  $n - 1$  faulty elements, included faulty links and faulty nodes. Since  $|FF_v| + |FF_e| \leq 2n - 3$ , there is at most two 2-free nodes contained in  $FQ_n$  and these two nodes are adjacent with a common faulty link, say  $(u, v)$  (see Figure 3 as an example). ■

**Theorem 6.**  *$FQ_n - FF_v - FF_e$ , for  $n \geq 5$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$  if (1)  $|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| \geq n + 2$ , and (3) every vertex is incident with at least two links.*

**Proof.** We consider the following three cases according to the number of 2-free nodes:

**Case 1:**  $FQ_n$  contains no 2-free node.

Since  $|FF_e| \geq n + 2$ , there exists a dimension  $i$  such that  $F(E_i) \geq 2$ , for  $i \in \{1, 2, \dots, n\} \cup \{s\}$ . By Corollary 2,  $FQ_n - E_i$  is isomorphic to  $Q_n$ . Thus,  $|FF_v| + |FF_e| \leq 2n - 5$  in  $Q_n$ . Since every node in  $FQ_n$  is  $k$ -free for some  $k \geq 3$ , every node in  $Q_n$  is incident at least two fault-free links. By Lemma 3, there exists a fault-free cycle of length  $2^n - 2|F_v|$  ( $= 2^n - 2|FF_v|$ ) in  $Q_n - F_v - F_e$  since  $|F_v| + |F_e| \leq 2n - 4$ ,  $|F_e| \leq 2n - 5$ , and every node in  $Q_n$  is incident to at least two fault-free links. Therefore, we obtain that  $FQ_n - FF_v - FF_e$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$ .

**Case 2:** There is a unique 2-free node  $u$  in  $FQ_n$  and every node in  $FQ_n - \{u\}$  is  $k$ -free for some  $k \geq 3$ .

Assume without loss of generality that  $d^1(u)$  and  $d^2(u)$  are two non-faulty links and either  $d^1(u)$  is faulty link or  $u^{(i)}$  is a faulty node, for  $i \in \{3, 4, \dots, n\} \cup \{s\}$ . Since  $|FF_e| \geq n + 2$ , there exists a dimension  $j$  such that  $F(E_j) \geq 2$ , for  $j \in \{1, 2, \dots, n\} \cup \{s\}$ . If  $j \notin \{1, 2\}$ ,  $FQ_n - E_j$  is isomorphic to  $Q_n$ . With the same arguments as Case 1, we have that  $FQ_n - E_j$  also satisfies the constraints in Lemma 3. It derives that  $FQ_n - FF_v - FF_e$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$ .

Now, we consider the case that  $j \in \{1, 2\}$ . There are two subcases to consider.

**Subcase 2.1:** There exists a faulty link  $d^a(u)$  such that  $d^1(u^{(a)})$  is a non-faulty link and  $u^{(a)}$  and  $u^{(a)(1)}$  are non-faulty nodes, where  $a \in \{3, 4, \dots, n\} \cup \{s\}$  (see Figure 2(a)).

Hence,  $FQ_n - E_k$  is isomorphic to  $Q_n$ , where  $k \in \{3, 4, \dots, n\} \cup \{s\} - \{a\}$ . Furthermore,  $Q_n$  can be decomposed to  $Q_{n-1}^L$  and  $Q_{n-1}^R$  at dimension 1 and  $u \in Q_{n-1}^L$ . Assume that  $d^a(u)$  is a non-faulty link. Let  $F_v^L$  and  $F_e^L$  (respectively,  $F_v^R$  and  $F_e^R$ ) denote the set of faulty nodes and faulty links in  $Q_{n-1}^L$  (respectively,  $Q_{n-1}^R$ ), respectively. Since  $u$  is a 2-free node,  $F(E_1) \geq 2$ ,  $F(E_k) \geq 1$ , and  $d^a(u)$  is a non-faulty link,  $|F_v^L| + |F_e^L| \geq n - 1$  and  $|F_v^L| + |F_e^L| \leq 2n - 3 - 4 = 2n - 7$ . Let  $F^L(w)$  denote the set of faulty elements adjacent to node  $w$ , where  $w \in Q_{n-1}^L$ . Since  $F^L(u) = n - 3$  and  $|F_v^L| + |F_e^L| \leq 2n - 7$ ,  $F^L(j) \leq n - 3$  for all  $j \in Q_{n-1}^L$  except  $u$ . Thus, every node in  $Q_{n-1}^L$  is incident at least two fault-free



links. By Lemma 3, there exists a fault-free cycle  $\mathcal{C}^L$  of length  $2^{n-1} - 2|F_v^L|$  in  $Q_{n-1}^L - F_v^L - F_e^L$  since  $|F_v^L| + |F_e^L| \leq 2n - 6$ ,  $|F_e^L| \leq 2n - 7$ , and every node in  $Q_{n-1}^L$  is incident to at least two fault-free links.

If  $u, u^{(a)} \in \mathcal{C}^L$ , then we denote  $u^{(1)}$  and  $u^{(a)(1)}$  by  $x$  and  $y$ , respectively; otherwise, we choose any link  $(p, q) \in \mathcal{C}^L$  such that  $d^1(p)$  and  $d^1(q)$  are two non-faulty links and denote  $p^{(1)}$  and  $q^{(1)}$  by  $x$  and  $y$ , respectively. Since  $u$  is a 2-free node,  $F(E_1) \geq 2$ , and  $|FF_v| + |FF_e| \leq 2n - 3$ ,  $|F_v^R| + |F_e^R| \leq n - 4$ . By Lemma 4, edge  $d^a(x)$  lies on a fault-free cycle  $\mathcal{C}^R$  of length  $2^{n-1} - 2|F_v^R|$  in  $Q_{n-1}^R - F_v^R - F_e^R$  since  $|F_v^R| + |F_e^R| \leq (n - 1) - 2$ . Therefore, we can obtain a fault-free cycle  $\langle u, \mathcal{C}^L, u^{(a)}, y, \mathcal{C}^R, x, u \rangle$  (respectively,  $\langle p, \mathcal{C}^L, q, y, \mathcal{C}^R, x, p \rangle$ ) of length  $2^{n-1} - 2|F_v^L| - 1 + 2^{n-1} - 2|F_v^R| - 1 + 2 = 2^n - 2|FF_v|$ . **Subcase 2.2:** If  $d^a(u)$  is a faulty link, then  $d^1(u^{(a)})$  is also a faulty link, for  $a \in \{3, 4, \dots, n\} \cup \{s\}$  (see Figure 2(b)).

Since  $|FF_v| + |FF_e| \leq 2n - 3$  and  $|FF_e| \geq n + 2$ ,  $|FF_v| \leq n - 5$ . If  $|FF_v| = 0$ , then  $|FF_e| \geq 2n - 2$  since every faulty link  $d^a(u)$  is adjacent to another faulty link  $d^1(u^{(a)})$ , for  $a \in \{3, 4, \dots, n\} \cup \{s\}$ . Therefore,  $|FF_v| > 0$ . Since  $u$  is a 2-free node in  $FQ_n$  and  $|FF_v| \leq n - 5$ , there exists at least four faulty links, say  $d^3(u)$ ,  $d^4(u)$ ,  $d^5(u)$ , and  $d^6(u)$ , such that  $d^1(u^{(3)})$ ,  $d^1(u^{(4)})$ ,  $d^1(u^{(5)})$ , and  $d^1(u^{(6)})$  are also fault. Hence,  $FQ_n - E_3$  is isomorphic to  $Q_n$  and  $Q_n$  can be decomposed to  $Q_{n-1}^L$  and  $Q_{n-1}^R$  at dimension 4 and  $u \in Q_{n-1}^L$ . Note that,  $d^1(u^{(3)})$ ,  $d^1(u^{(5)})$ , and  $d^1(u^{(6)})$  are in  $Q_{n-1}^L$  while  $d^1(u^{(4)})$  is in  $Q_{n-1}^R$ . Thus,  $|F_v^L| + |F_e^L| \leq 2n - 3 - 3 = 2n - 6$ . Since  $|FF_v| > 0$  and  $|F_v^L| + |F_e^L| \leq 2n - 6$ ,  $|F_e^L| \leq 2n - 7$ . Since  $F^L(u) = n - 3$ ,  $|F_v^L| + |F_e^L| \leq 2n - 6$ , and  $d^1(u^{(3)})$ ,  $d^1(u^{(5)})$  and  $d^1(u^{(6)})$  are in  $Q_{n-1}^L$ ,  $F^L(j) \leq n - 4$  for all  $j \in Q_{n-1}^L$  except  $u$ . Thus, every node in  $Q_{n-1}^L$  is incident at least two fault-free links. By Lemma 3, there exists a fault-free cycle  $\mathcal{C}^L$  of length  $2^{n-1} - 2|F_v^L|$  in  $Q_{n-1}^L - F_v^L - F_e^L$  since  $|F_v^L| + |F_e^L| \leq 2n - 6$ ,  $|F_e^L| \leq 2n - 7$ , and every node in  $Q_{n-1}^L$  is incident to at least two fault-free links.

Choose any link, say  $d^a(x)$ , in  $\mathcal{C}^L$  such that  $x^{(4)}$  and  $d^4(x^{(a)})$  are non-faulty nodes in  $Q_{n-1}^R$  and  $d^4(x)$  and  $d^4(x^{(a)})$  are non-faulty links. Since  $u$  is a 2-free node, both  $d^1(u^{(3)})$  and  $d^1(u^{(5)})$  are in  $Q_{n-1}^L$ , and  $|FF_v| + |FF_e| \leq 2n - 3$ ,  $|F_v^R| + |F_e^R| \leq n - 5$ . By Lemma 4 again, edge  $d^a(x^{(4)})$  lies on a fault-free cycle  $\mathcal{C}^R$  of length  $2^{n-1} - 2|F_v^R|$  in  $Q_{n-1}^R - F_v^R - F_e^R$  since  $|F_v^R| + |F_e^R| \leq (n - 1) - 2$ . Therefore, we can obtain a fault-free cycle  $\langle x, \mathcal{C}^L, x^{(a)}, x^{(a)(4)}, \mathcal{C}^R, x^{(4)}, x \rangle$  of length  $2^{n-1} - 2|F_v^L| - 1 + 2^{n-1} - 2|F_v^R| - 1 + 2 = 2^n - 2|FF_v|$ .

**Case 3:** There are two 2-free nodes  $u$  and  $v$  in  $FQ_n$ .

Since  $|FF_v| + |FF_e| \leq 2n - 3$  and there are two 2-free nodes  $u$  and  $v$  in  $FQ_n$ ,  $u$  and  $v$  are adjacent,  $|FF_v| + |FF_e| = 2n - 3$ . Assume without loss of generality that link  $(u, v) = d^1(u) = d^1(v)$ . Assume that  $d^a(u)$ ,  $d^b(u)$ ,  $d^c(v)$ , and  $d^d(v)$  are four non-faulty links with respect to  $u$  and  $v$ , where  $a \neq b$ ,  $c \neq d$ , and  $a, b, c, d \in \{2, 3, \dots, n\} \cup \{s\}$ . Since  $n \geq 5$  and  $|FF_e| \geq n + 2$ , there exists a dimension  $k$  such that  $d^k(u)$  and  $d^k(v)$  are faulty links, where  $k \in \{2, 3, \dots, n\} \cup \{s\} - \{a, b, c, d\}$ . By Corollary 2,  $FQ_n - E_k$  is isomorphic to  $Q_n$ . Thus,  $|FF_v| + |FF_e| \leq 2n - 5$  in  $Q_n$  and every node in  $Q_n$  is incident at least two fault-free links. By Lemma 3, there exists a fault-free cycle of length  $2^n - 2|F_v|$  ( $= 2^n - 2|FF_v|$ ) in  $Q_n - F_v - F_e$  since  $|F_v| + |F_e| \leq 2n - 4$ ,  $|F_e| \leq 2n - 5$ ,

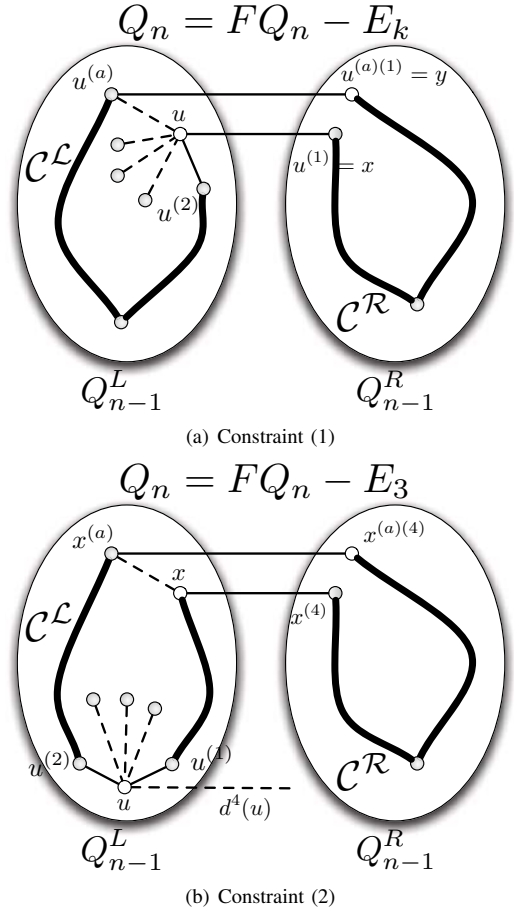


Fig. 2. An illustration of Constraints (1) and (2).

and every node in  $Q_n$  is incident to at least two fault-free links. Therefore, we obtain that  $FQ_n - FF_v - FF_e$  contains a fault-free cycle of length at least  $2^n - 2|FF_v|$ .

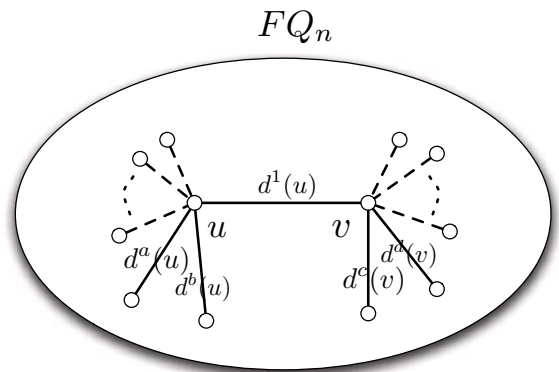


Fig. 3. There are two 2-free nodes  $u$  and  $v$  in  $FQ_n$ .

#### IV. CONCLUSION

In this paper, we consider the  $n$ -dimensional folded hypercube with some faulty elements with the constraints that (1)

$|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| \geq n + 2$ , and (3) every vertex is still incident with at least two links. We proved that  $FQ_n - FF_v - FF_e$  for  $n \geq 5$  has a fault-free cycle of length at least  $2^n - 2|FF_v|$ . In the further work, we interest to consider whether  $FQ_n - FF_v - FF_e$  for  $n \geq 5$  still has a fault-free cycle of length at least  $2^n - 2|FF_v|$  under the constraints : (1)  $|FF_v| + |FF_e| \leq 2n - 3$ , (2)  $|FF_e| < n + 2$ , and (3) every vertex is still incident with at least two links.

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# 國科會補助計畫衍生研發成果推廣資料表

日期:2012/09/25

國科會補助計畫	計畫名稱：二元樹之間的旋轉距離	
	計畫主持人：劉嘉傑	
	計畫編號：100-2221-E-128-003-	學門領域：計算機理論與演算法
無研發成果推廣資料		

100 年度專題研究計畫研究成果彙整表

計畫主持人：劉嘉傑

計畫編號：100-2221-E-128-003-

計畫名稱：二元樹之間的旋轉距離

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	1	4	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	3	3	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

<p>其他成果</p> <p>(無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)</p>	<p>研究成果仍在撰寫並做最後數學證明驗證中，而與本研究相關的期刊論文計有一篇已接受發表於 TOCS，另三篇審稿中，三篇分別發表於 ICCSA, ICS, 及組合數學研討會。</p>
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	成果項目	量化	名稱或內容性質簡述
<div> 科 教 處 計 畫 加 填 項 目 </div>	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

# 國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

## 1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

☒ 達成目標

☐ 未達成目標（請說明，以 100 字為限）

☐ 實驗失敗

☐ 因故實驗中斷

☐ 其他原因

說明：

## 2. 研究成果在學術期刊發表或申請專利等情形：

論文：☐ 已發表 ☐ 未發表之文稿 ☒ 撰寫中 ☐ 無

專利：☐ 已獲得 ☐ 申請中 ☒ 無

技轉：☐ 已技轉 ☐ 洽談中 ☒ 無

其他：（以 100 字為限）

## 3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

經由本計劃的研究，我們廣泛地收集了二元樹之間旋轉距離的相關研究，並歸納推論出許多性質，藉此找到一些限制集合並求得此限制集合之間的最短旋轉距離，並提出一個 polynomial time 的演算法計算兩顆 degenerate trees 之間的最短距離（正確性仍在最後數學證明中），而之後更進一步的研究，將可視此限制集合為一群 kernels，藉由此 kernels 能夠有效率地求算任兩顆二元樹之間的旋轉距離。