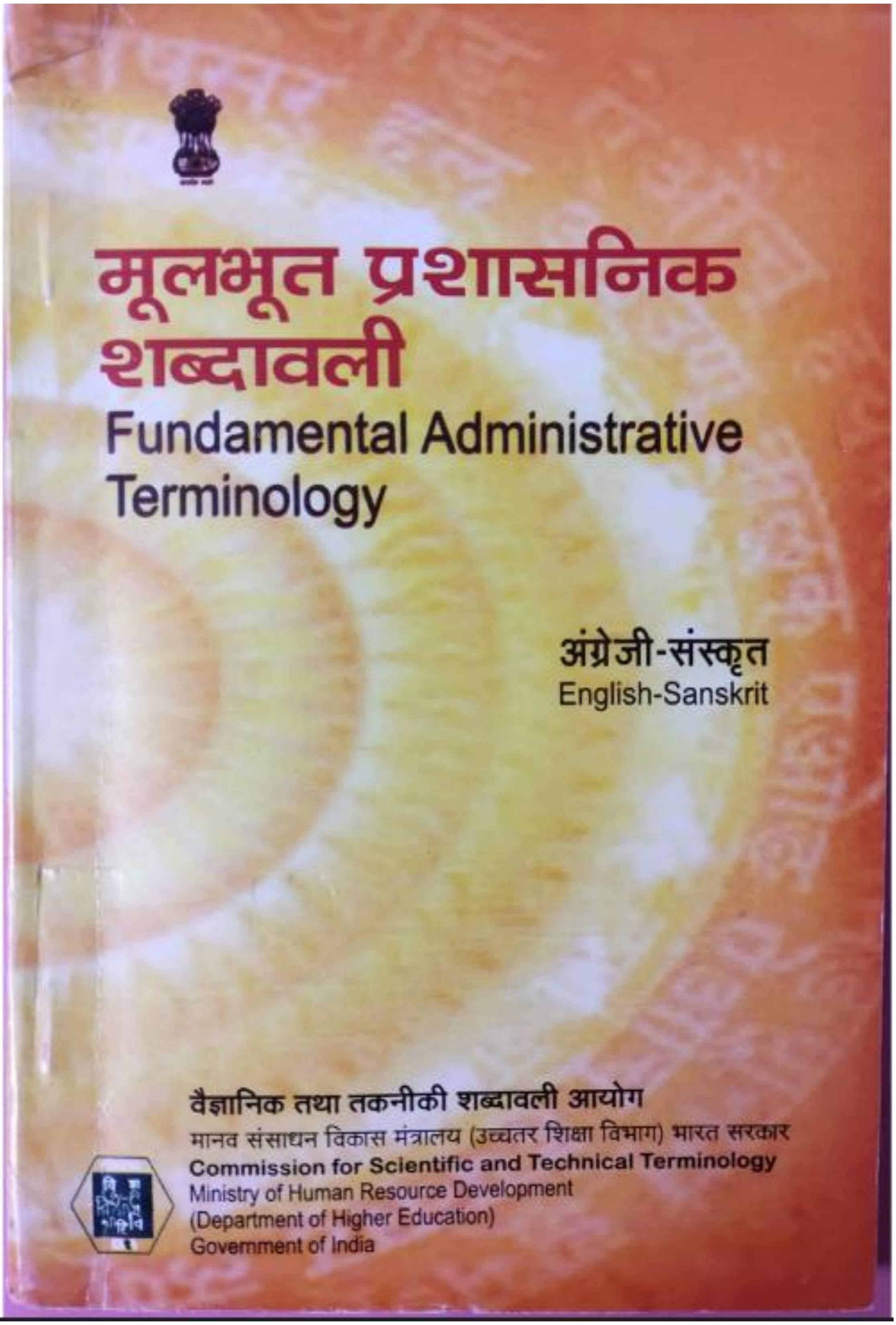
Fundamental Administrative Terminology – By Dr.Suman K S (Editorial Member)



Fundamental Administrative Terminology – By Dr.Suman K S (Editorial Member)

मूलभूत प्रशासनिक शब्दावली

(अंग्रेजी–संस्कृत)

(भारतीय भाषाओं में प्रशासनिक शब्दावली श्रृंखला के अंतर्गत)

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(Series under Administrative Terminology in Indian Languages)

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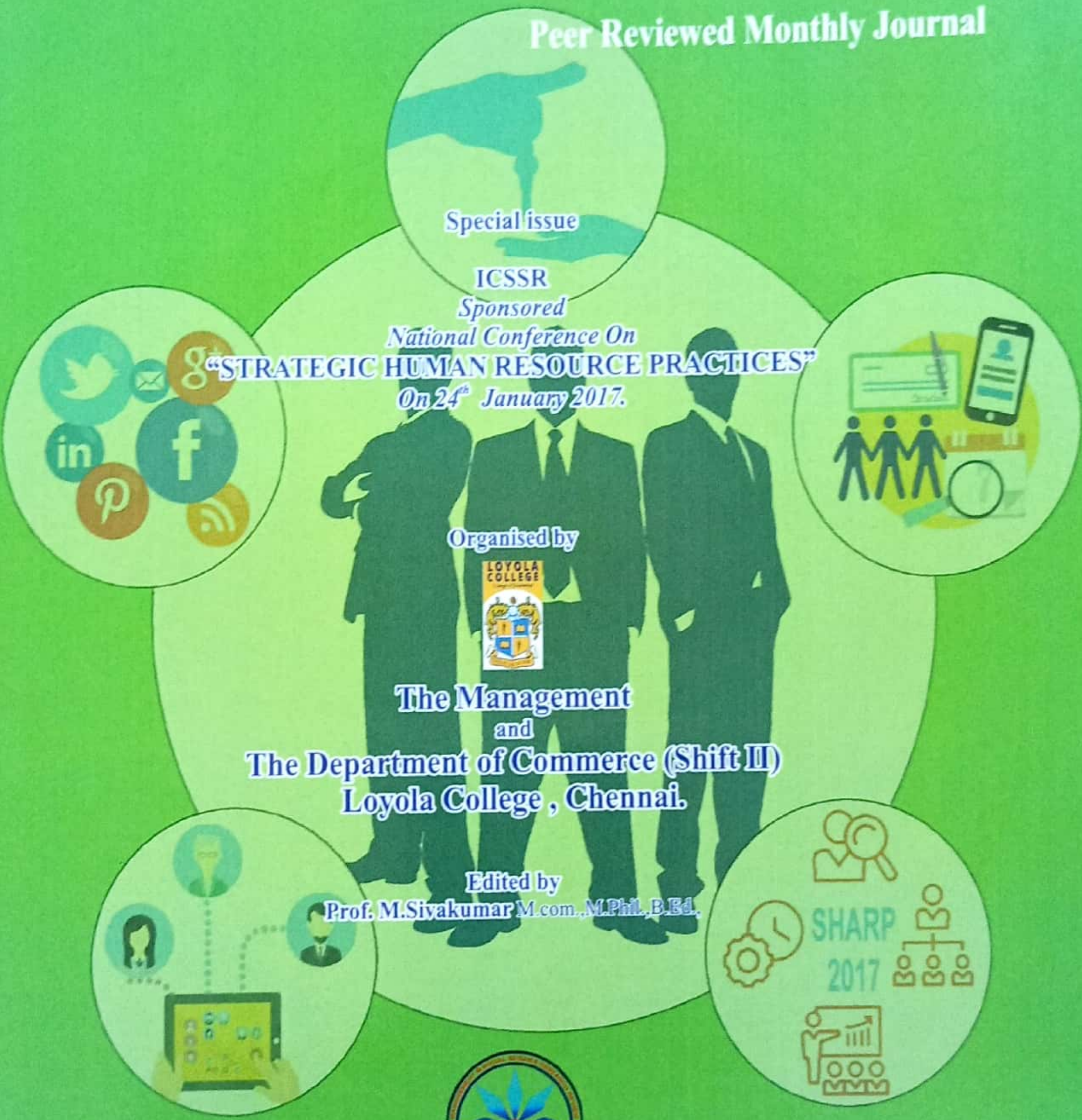

Special issue

ICSSR
Sponsored
National Conference On
"STRATEGIC HUMAN RESOURCE PRACTICES"
On 24th January 2017.

Organised by

The Management
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Loyola College , Chennai.

Edited by
Prof. M.Sivakumar M.com.,M.Phil.,B.Ed.,

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Message

It is a privilege for the Commerce department to host the conference of **NATIONAL CONFERENCE ON STRATEGIC HUMAN RESOURCE PRACTICES** on 24thJanuary, 2017. The objective of the conference isbringing together the faculty and students of the various colleges in India to have a healthy discussion on the topic of human resources and to bridge the gap between theoretical knowledge and practical implementation of human resources management strategies and to explore the conventional practices in human resources management and to provide an insight into the advancements in the same. This conference is meant to stimulateconsciousness among the students and faculties of the need to consider human resources as a valuable asset to every organization.

I offer my felicitations and congratulations to the convener and the student representatives for conducting this conference a priority area of the Jesuits of the Madurai Province.

Best wishes

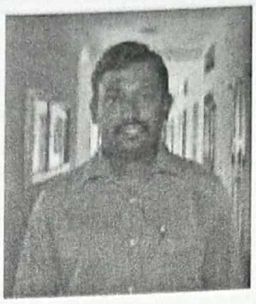
International Journal of Management and Social Science Research Review (IJMSRR)

About the Editor

Prof.M.Sivakumar is a professor of commerce in Loyola College. He has over 7 years of teaching and research experience. His primary expertise is Management, Human Resources Management and Accounting. He is presentlydoing a research under the University of Madrasin the field of Succession Planning an extensive module in human resources. He has a master's degree in from Presidency College, Chennai as well as a master's degree in philosophy from Pachaiappa's CollegeChennai. He developed an interest in teaching which made him to do other Bachelors in Education from Annamalai University, Chidambaram. He has cleared the National Eligibility Test(NET) with JRF. He has submitted and published Research papers in various topics in reputed Journals. He has been an active participant in various national and international conferences.He has a solid track record of being an active member in National Institute of Personal Management, Chennai Chapter and Human Resource Sangam, Chennai. He has shown keen interest in helping the less fortunate people through the Department of Service learning.

About the Organizing Secretaries

Prof. HerminaCorera is a professor in the Department of Commerce (Shift-II), Loyola College. She has more than 24 years of teaching and research experience. Her primary expertise is in the field of Accounting and Management Studies. She is presently doing a research in the field of Human Resource Management. She completed her Bachelors and Masters degree in Commerce from St. Mary's College, Tuticorin (Affiliated to Madurai Kamaraj University). She developed an immense interest in teaching which made her complete Masters in Education from Annamalai University, Chidambaram. Moreover, she has completed Masters in Philosophy from Madurai Kamaraj University and MBA from Madras University. She has cleared the National Eligibility Test (NET). She has been an active participant in various National and International conferences. Her primary field of interest isaccounting.



Dr D John Benedict is an Assistant Professor of Commerce Loyola College. He has over four years of teaching and research experience. His primary expertise is in the field of Finance. He was awarded Ph.D in the field of finance from Pondicherry University, Puducherry.His dissertation was "Implications Sectorial Indices of National Stock Exchange on CNX Nifty Index". He has cleared the State Eligibility Test (SET) on 2012 and National Eligibility Test (NET) on 2014. He has pursed his Master's Degree in Commerce from Pondicherry University, Puducherry. He completed his MBA from the Pondicherry University, Puducherry. He has also done Bachelors in Education from Pope John Paul II College of Education, Puducherry. Presently he is the Coordinator for Entrepreneurial Development Cell in Loyola. He has published four research papers and presented many papers in National and International conferences. His areas of interest are Investment and Portfolio Management, Management Accounting, Banking and Financial Institution.

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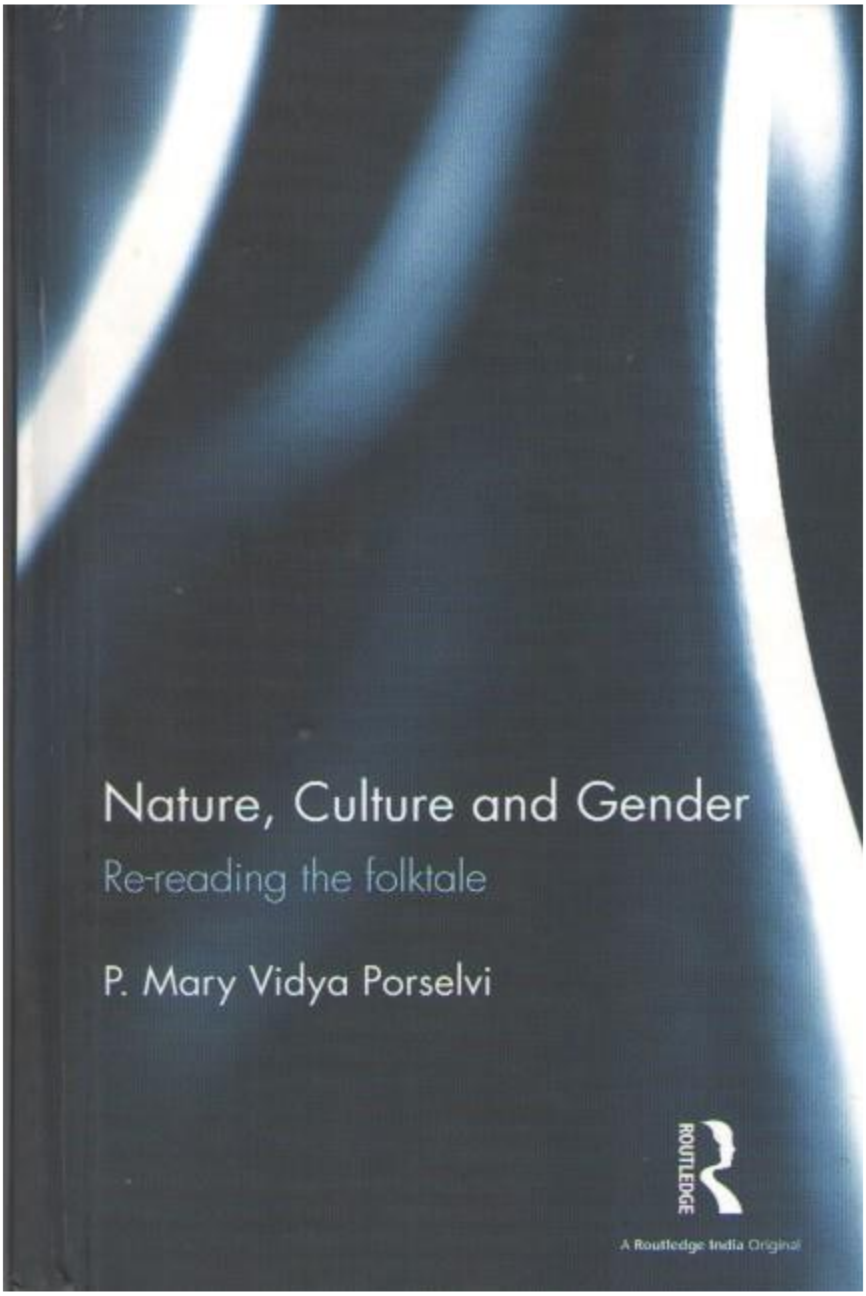
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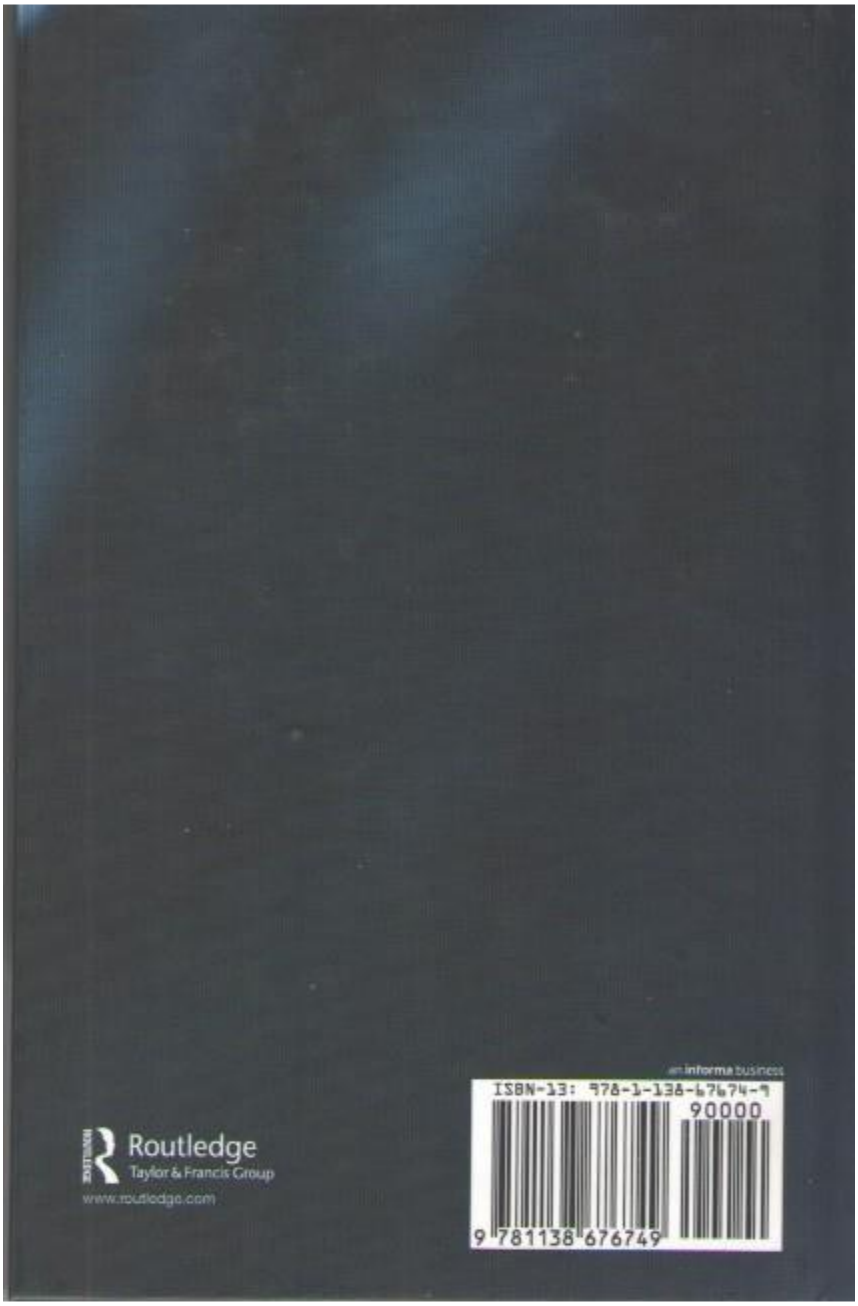
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Critical Essays on English Language Teaching: New Perspectives
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CRITICAL ESSAYS ON ENGLISH LANGUAGE TEACHING

NEW PERSPECTIVES

Edited by Dr. K. Balachandran

Contents

Developing Reading Skills through Internet

Pearline Paulraj & Lily Arul Sharmila

English is an International language and is one of the most popular languages in the world. It is estimated that around two billion people in the world communicate in English. The rapid changes in business, media and communication have made English a global language. Apart from being the dominant business language, it has almost become inevitable for those who aspire to enter the global work force. It is the official language in most of the countries in the world. Many of the world's best books, films, documentaries etc., are in English. Although learning English can be time consuming and challenging, it is indeed valuable and important. In India, a multilingual country, English is taught as a second language. It serves two purposes. Firstly, it provides a linguistic tool for administrative cohesiveness of the country, bringing the population that speaks different languages together. Secondly, it serves as a language of wider communication, including a large number of people living in different states in India.

English is a link language in India and it is the first language for the creamy layer of the society. It binds us together and functions as a bridge that connects India to the rest of the world. It has an extraordinary role to play in the parliament, judiciary, English is no more the native language of the British. It has become a world language because of its broad-mindedness; it borrows words from almost all other languages. Though some may hate English in this country, it has been playing the role of a national link language; a unifying force between State Governments and the Central Government, on the one hand, and between States on the other. English has become the language of intellectuals and business alike, and therefore, it has to be learnt and taught with a great deal of involvement for the enlightenment and progress of everyone.

ELT: New Perspectives is a collection of 21 research articles from researchers and teachers of English to inform, inspire and initiate students, researchers and teachers to recognize the need for English learning and ELT. The articles are on a wide range of subjects such as Approaches to ELT, Spoken English course, Second Language Acquisition, Attitude of English Teachers, E-learning, Reading Skills, Techniques in ELT, Meta-cognition, and Preparation of Teaching Materials. These 21 articles on the various aspects of English language and ELT highlight the importance of English Teaching.

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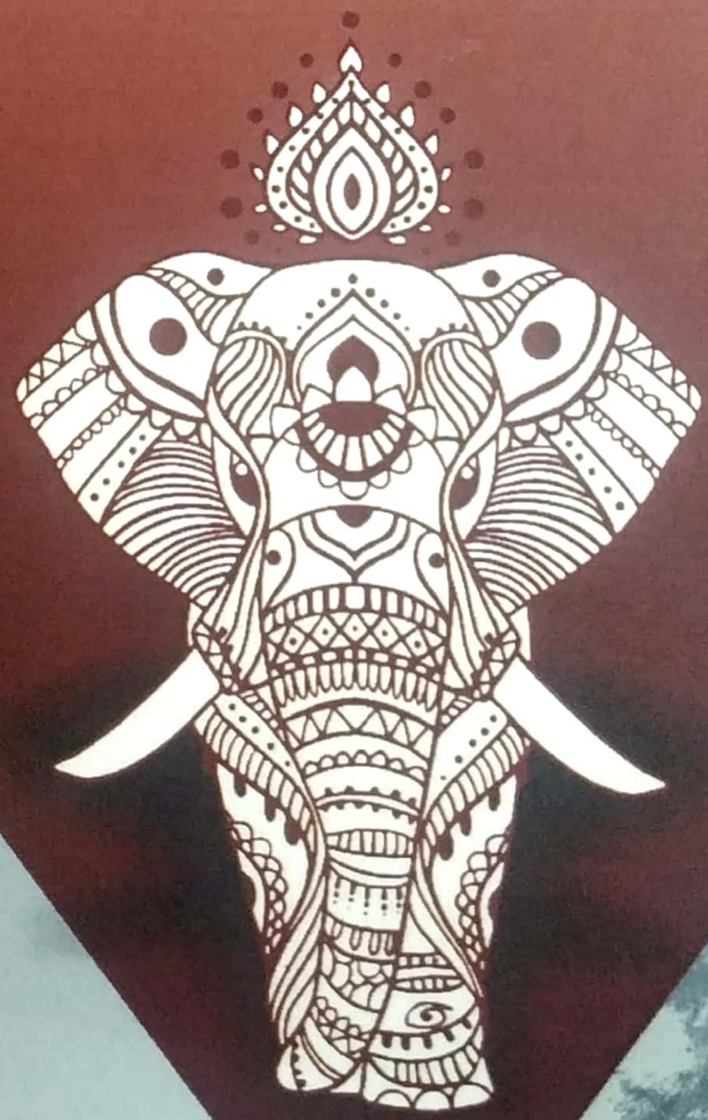
SOUTH ASIAN LITERATURE IN ENGLISH

New and Emerging Trends

Edited by

Marie Josephine Aruna



Losing to Gain – A Study on Identity Crisis with Reference to Shashi Deshpande's *In the Country of Deceit*

Prof. Pearline Paulraj

The portrayal of women in postcolonial fiction has witnessed an immense transformation. Women novelists have been portraying traditional, social and cultural values in the contemporary India. With the progress of years, there is a pronounced difference in the depiction of women, by women writers. The new generation of women writers are ready to grapple with the crisis encountered by their women counterparts. They are aware of the silent suffering that Indian women have undergone in the past. Hence they are competent in handling the themes relating to women's sufferance, search for identity, journey to selfhood, shifting the self and how they strive to strike a balance between tradition and modernity.

Shashi Deshpande is a prominent novelist in the Indian literary arena. Her novels depict the conflicts and dilemmas encountered by women. The women in her novels are entangled in a plethora of relationships. When the web stifles them they withdraw into silence and review their relationships to reconcile to what life has in store for them, but with a better outlook towards life. *The Country of Deceit* is the story of Devayani, a

Contents

Dr. M. J. Aruna is Assistant Professor at the Department of English, Bharathidasan Govt. College for Women, (Autonomous), Puducherry. She has authored a book titled *Patriarchal Myths in Postmodern Feminist Fiction*. Her area of specialization is feminist literary theory and postmodern feminist literature. She has to her credit a number of research articles published in peer reviewed journals and books. She is a life member of Indian Association for Women's Studies, and member, Indian Association for Commonwealth Literature and Language Studies and Indian Association for American Studies.

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Book Titled: ***Facets of Contemporary India***

Chapter Titled: ***A Visual Ethnographic Study on Mutharamman Dasara Festival in Kulasekarapattinam***

Chapter Author: Dr. J. Vijay Ratna Kumar

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ABOUT THE EDITORS

Dr.M.Thilakavathy, is teaching in the Department of History Tourism and Travel Management, Ethiraj College for Women, Chennai. She did her doctorate from the Department of Indian History, University of Madras, Chennai. She has been serving the academic world for the past 32 years. She has written two Books. She has many publications in international and national journals/ Books to her credit. She has been invited as a resource person for the international conference on Tourism in Srilanka. She has been invited by the Gwalior University to deliver a lecture on Heritage Sites in Tamil Nadu. She has contributed a lot in the pursuit of research. Dr. M. Thilakavathy has successfully completed UGC major project. She is a member of different Academic Bodies, Organizations and Boards. Her areas of interest include History of Tamil Nadu, Tourism and Women Studies.

Dr R.K.Maya is teaching in the Department of History Tourism and Travel Management, Ethiraj College for Women, Chennai. She has publications in international and national journals/ Books to her credit. She obtained her doctorate in History from the Department of Humanities, IIT Madras. She has been an academician for over a decade and more. Her areas of interest include, labour history, women studies and human rights.

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Chapter 17

A VISUAL ETHNOGRAPHIC STUDY ON MUTHARAMMAN DASARA FESTIVAL IN KULASEKARAPATTINAM

J. Vijay Ratna Kumar

Research Scholar

Manonmaiyam Sundaranar University

INTRODUCTION

In the developing world, people's culture and arts are persistently shifting and people forget their cultural identity. In today's context many folk deities have been converted to *saivism* and *vaishnavism*. With dominant ideology of spiritualism, Sanskritization were deployed in temples in the district of Tuticoirn of Tamil Nadu. In Kulasekarapattinam in the temple dedicated to the the goddess *Muthuramman* the *Dasara* festival is celebrated with gusto. This paper deals with the God's worships, beliefs, rituals and performance at *Mutharamman Dasara* Festival Kulasekarapattinam in Kanyakumari District. This paper deals with the temple's contemporary history, beliefs, worships, and performance.

The aim of the research paper is to analyses the phenomena of worshippers undertaking face painting, wearing masks and makeup offering at, *Dasara* festival. Such activities are done in order to calm down the ferocious goddess.

The devotees perform various rituals, following are *Vel Kambu Kuthuthal*(piercing the cheeks with needles), taking the fire pot with bare hands, goat sacrifice, tonsure ceremony, fire walking, fasting, sacred thread tying. But in Kulaisekarapattinam *Dasara* festival the devotees worship the goddess with special vows by applying mask and painting the face with Hindu epic characters and modern day life characters. Then they go to different villages to get offertory.

Book Titled: ***Arab Muslims of Pazhaverkadu - Photo Essay***

Author: Dr. J. Vijay Ratna Kumar

ISBN: 9788193278109

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Publisher: All India Deprived Community Support Centre, Chennai.

About the Book

This photo essay features the history, lifestyle and socio-economic status of the Arab descendent Muslims of Pazhaverkadu. It encapsulates the changing face of this lost (or lesser known) community.

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THE ARAB MUSLIMS OF PAZHAVERKADU

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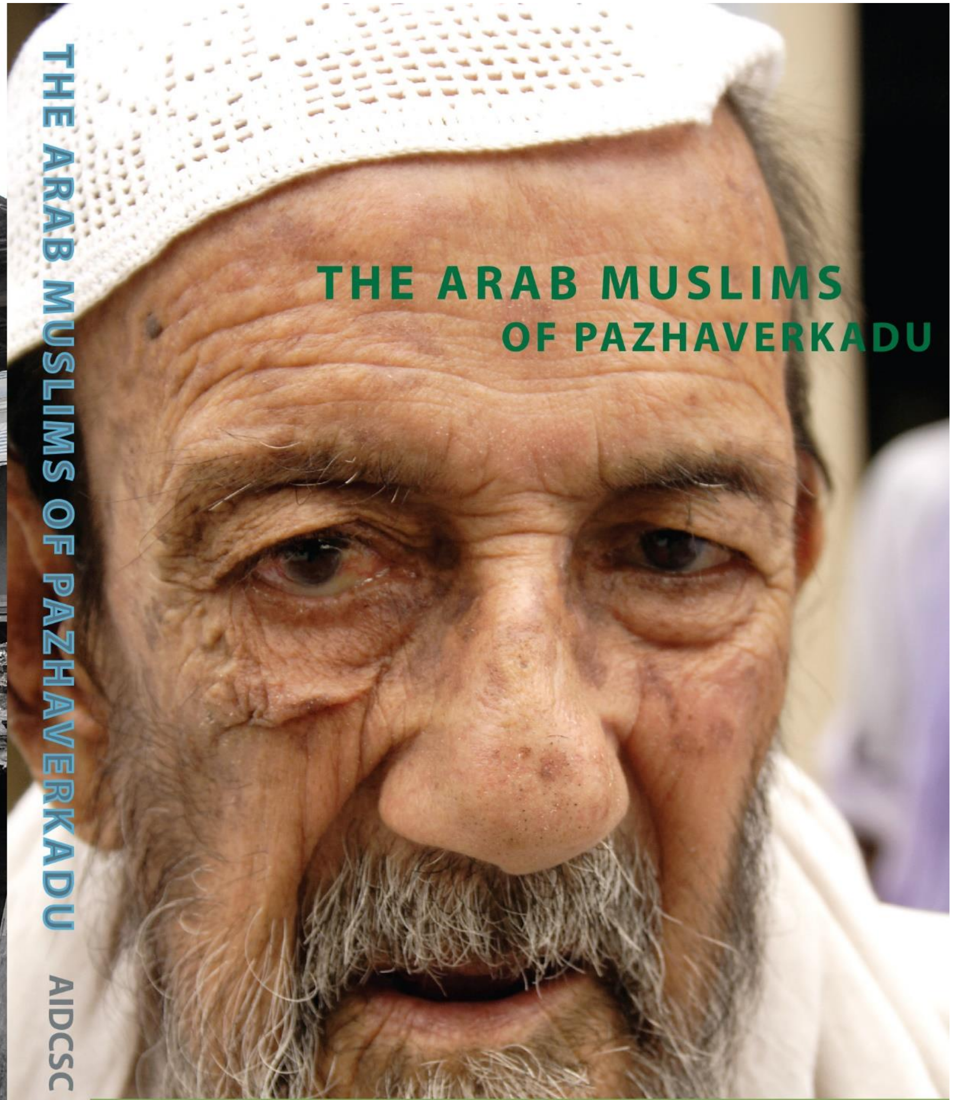

THE ARAB MUSLIMS
OF PAZHAVERKADU

Photo Essay by
B. Jishamol
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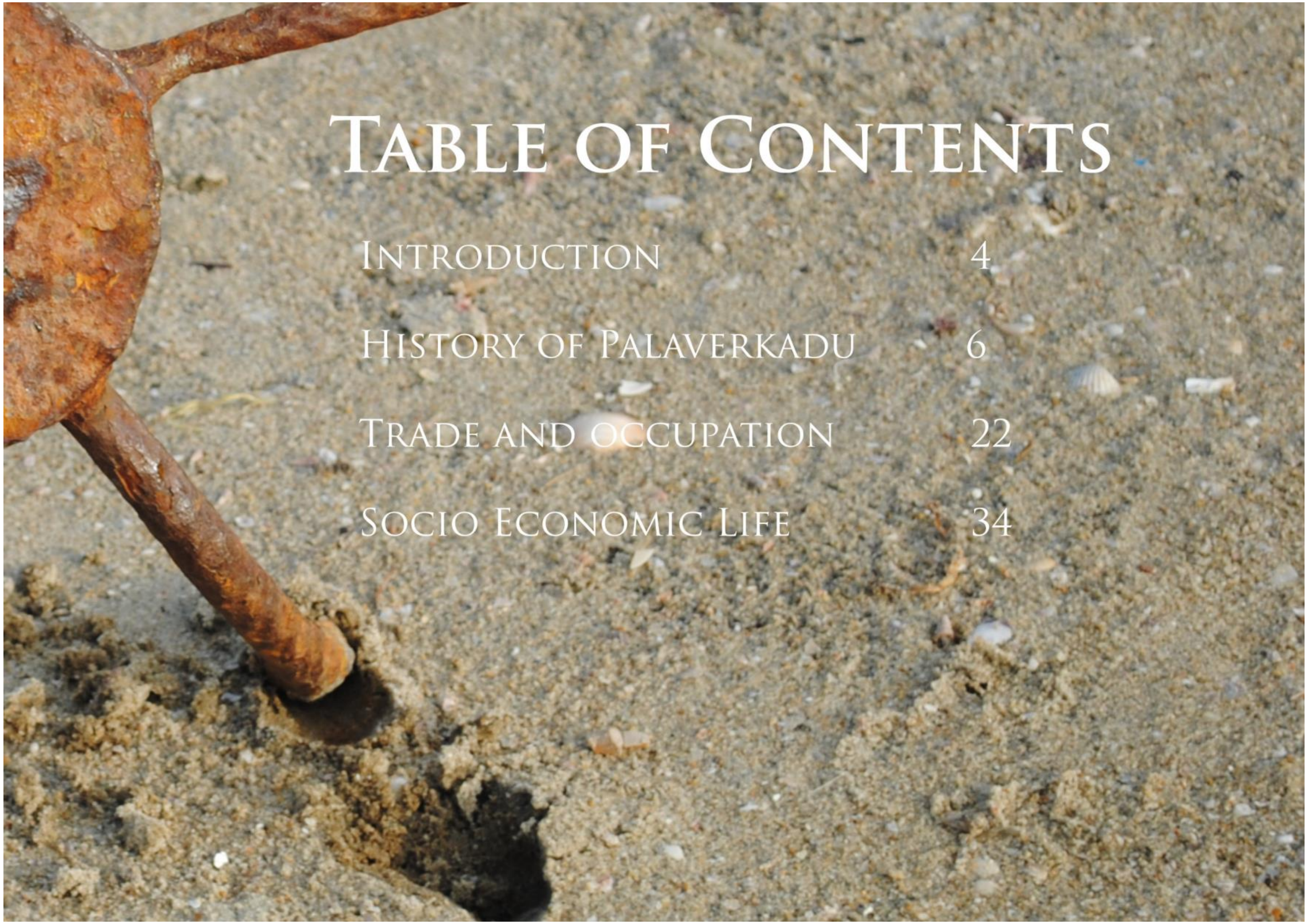

Table of Contents

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இந்நூல்...

சமகால நிகழ்வுகளை சமூக, பொருளாதார, அரசியல், பண்பாட்டுப் பின்புலத்தில் அலசுகிறது. அனுபவங்களை விவாதத்திற்குரிய மையப் பொருளாக மாற்றி, ஊடறிவு மற்றும் கூர்மையான விமர்சனப் பார்வையோடு அர்த்தமுள்ள கேள்விகளை எழுப்புகிறது.

இந்தப் படைப்பு சமூக மாற்றத்திற்காக ஒரு சிறு துளி அளவாவது பங்களிப்புச் செய்ய நம்மைத் தூண்டுகிறது.

- இருதயராஜ்,சே.ச. அவர்கள் ஓர் ஊடக விமர்சகர்.
- சென்னைப் பல்கலைக்கழகத்தில் வெகுசன தொடர்பியல் மற்றும் இதழியல் பாடத்தில் முதுகலைப் பட்டம் பெற்றவர்.
- தினமணி,சிலம்பம்,கணையாழி,காலச்சுவடு,தாமரை,புதிய கோடங்கி, தலித் முரசு, தீக்கதிர், **Deep Focus** ஆகிய இதழ்களில் இவரது படைப்புகள் வெளிவந்துள்ளன.
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வைகறை பதிப்பகம்

உள்ளடக்கம்

S. Arumugam · Jay Bagga
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Contents

Minimum Layout of Circulant Graphs into Certain Height Balanced Trees

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Abstract. A graph embedding comprises of an ordered pair of injective maps $\prec f, p \succ$ from a guest graph $G = (V(G), E(G))$ to a host graph $H = (V(H), E(H))$ which is formulated as follows: f is a mapping from $V(G)$ to $V(H)$ and p assigns to each edge (a, b) of G, a shortest path $p(a, b)$ in H. The minimum layout problem is to find an embedding $\prec f, p \succ$ from a graph G into a graph H such that $\sum_{e \in E(H)} EC_{\prec f,p \succ}(e) = \sum |(a, b) \in E(G) : e \in E(p(a, b))|$ is minimized. In this paper we develop an algorithm to find the minimum layout of embedding the circulant graph into certain height balanced trees like Fibonacci tree and wounded lobster.

Keywords: Height balanced tree · Layout · Circulant graph · Fibonacci tree

1 Introduction

Graph embedding has been an integral tool in efficient implementation of parallel algorithms on parallel computers with minimal communication overhead. A graph embedding comprises of an ordered pair of injective maps $\prec f, p \succ$ from a guest graph $G = (V(G), E(G))$ to a host graph $H = (V(H), E(H))$ which is formulated as follows: f is a mapping from $V(G)$ to $V(H)$ and p assigns to each edge (a, b) of G, a shortest path $p(a, b)$ in H [1,7]. Figure 1 illustrates a graph embedding. The edge congestion of an embedding is defined by $EC_{\prec f,p \succ}(e) = |(a, b) \in E(G) : e \in E(p(a, b))|$ [6].

The layout $L_{\prec f,p \succ}(G, H)$ of an embedding is defined as the sum of edge congestion of all the edges of H [3,5]. The minimum layout of G into H is given by $L(G, H) = \min L_{\prec f,p \succ}(G, H)$. The minimum layout problem is to find the embedding that induces $L(G, H)$. When the host graph is a tree, the layout problem finds application in graph drawing, data structures and representations and networks for parallel systems [5,10].

Maximum Induced Subgraph Problem [3]: Let $G = (V(G), E(G))$ and $S \subseteq V(G)$. Let $I_G(S) = \{(u, v) \in E(G) : u \in S \text{ and } v \in S\}$ and for $1 \le k \le |V(G)|$, let $I_G(k) = \max_{S \subseteq V,\ |S|=k} |I_G(S)|$. Then the problem is to find $S \subseteq V(G)$ with

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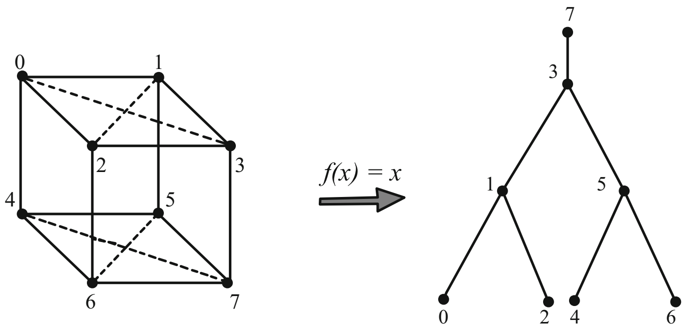


Fig. 1. Embedding of an enhanced hypercube G into rooted complete binary tree H

$|S| = k$ such that $I_G(k) = |I_G(S)|$. Such a set S is called an optimal set with respect to the maximum induced subgraph problem.

Min-cut Problem [3]: Let $G = (V(G), E(G))$ and $S \subseteq V(G)$. Let $\Theta_G(S) = \{(u, v) \in E : u \in S$ and $v \notin S\}$ and for $1 \leq k \leq |V(G)|$, let $\Theta_G(k) = \min_{S \subseteq V,\ |S|=k} |\Theta_G(S)|$. Then the problem is to find $S \subseteq V(G)$ with $|S| = k$ such that $\Theta_G(k) = |\Theta_G(S)|$. Such a set S is said to be optimal with respect to the min-cut problem. For any graph G, $\Theta_G(V - S) = \Theta_G(S)$ for all $S \subseteq V(G)$. If G is an r-regular graph, then $\Theta_G(k) = rk - 2I_G(k)$ for every $k \in \{1, 2, \ldots, |V(G)|\}$.

The following results provide a method for partitioning the edges of the host graph which in turn can be effectively used to solve the minimum layout problem.

Lemma 1 (Congestion Lemma) [6]. *Let G be an r-regular graph and $\prec f, p \succ$ be an embedding of G into H. Let S be an edge cut of H such that the removal of edges of S splits H into 2 components H_1 and H_2 and $EC_{\prec f,p \succ}(S)$ denote the sum of edge congestion over all the edges in S. Let $G_1 = G[f^{-1}(H_1)]$ and $G_2 = G[f^{-1}(H_2)]$. Suppose the following conditions hold.*

1. *For every edge $(a, b) \in G_i$, $i = 1, 2$, $p(a, b)$ has no edges in S.*
2. *For every edge (a, b) in G with $a \in G_1$ and $b \in G_2$, $p(a, b)$ has exactly one edge in S.*
3. *G_1 is optimal with respect to the maximum induced subgraph problem.*

Then $EC_{\prec f,p \succ}(S)$ is minimum and $EC_{\prec f,p \succ}(S) = \Theta_G(|V(G_1)|) = \Theta_G(|V(G_2)|)$.

Lemma 2 [6]. *Let $\prec f, p \succ$ be an embedding from G into H. Let $\{S_1, S_2, \ldots, S_p\}$ be a partition of $E(H)$ such that $EC_{\prec f,p \succ}(S_i)$ is minimum for all i. Then $L_{\prec f,p \succ}(G, H)$ is minimum and $L_{\prec f,p \succ}(G, H) = \sum_{i=1}^{p} EC_{\prec f,p \succ}(S_i)$.*

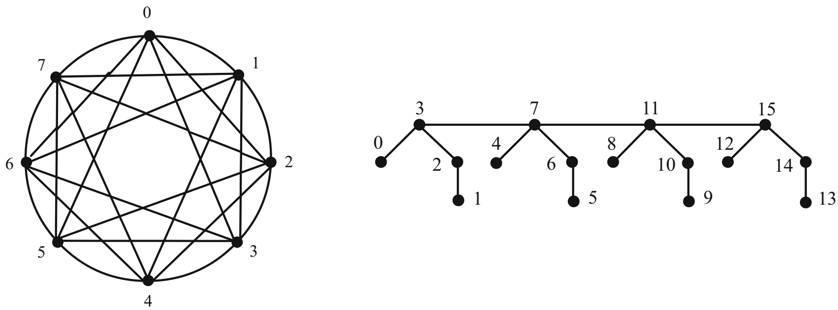
Definition 1 [10]. *A circulant undirected graph $G(n; \pm S)$, $S \subseteq \{1, \ldots, \lfloor n/2 \rfloor\}$, $n \geq 3$ is defined as a graph consisting of the node set $V = \{0, 1, \ldots, n-1\}$ and the edge set $E = \{(i, j) : |j - i| \equiv s (mod\ n),\ s \in \pm S\}$.*

In this paper, we confine our work to the circulant graph $G(n; \pm S)$, where $S = \{1, 2, ..., j\}$, $1 \leq j < \lfloor n/2 \rfloor$. For $n \geq 3$, $1 \leq j < \lfloor n/2 \rfloor$, $G(n; \pm\{1, 2, ..., j\})$ is a $2j$-regular graph. Figure 2(a) illustrates a circulant graph.

Lemma 3 [8]**.** *A set of k consecutive nodes induces an optimal set with respect to the maximum induced subgraph problem in $G(n; \pm S)$ on k nodes.*

Lemma 4 [8]**.** *Let G be the circulant graph $G(n; \pm S)$, $n \geq 3$. Then for $1 \leq k \leq n$,*

$$I_G(k) = \begin{cases} k(k-1)/2 & ; k \leq j+1 \\ kj - j(j+1)/2 & ; j+1 < k \leq n-j \\ \frac{1}{2}\{(n-k)^2 + (4j+1)k - (2j+1)n\} & ; n-j < k \leq n \ . \end{cases}$$



(a) **(b)**

Fig. 2. (a) Circulant graph $G(8; \pm\{1, 2, 3\})$ (b) Wounded lobster L_4

A height balanced tree T is a rooted binary tree in which for every node v, the difference between the heights of the left and right child denoted as v_1 and v_2 respectively is at most one [2].

Fibonacci trees are a type of height balanced trees which are built recursively in one of the following two ways.

Fibonacci Tree f_h [4]: The trees f_1 and f_2 consists of only the root node. For $h \geq 3$, f_h is constructed by taking a new root node and attaching f_{h-1} on the left side and f_{h-2} on the right side of the root node by an edge as shown in Fig. 3(a).

Fibonacci Tree $f_h^{'}$ [2]: The tree f_1^1 consists of only the root node and $f_2^{'}$ is formed by attaching a pendant node to the root node. For $h \geq 3$, the left subtree of $f_h^{'}$ is $f_{h-1}^{'}$ and its right subtree is $f_{h-2}^{'}$. Figure 3(b) illustrates $f_h^{'}$ for $h = 1, 2, \ldots 5$.

Let $|V(f_h)| = m_h$ and $|V(f_h^{'})| = m_h^{'}$. Then, $m_h = 2F_h - 1$ and $m_h^{'} = F_{h+2} - 1$, where F_h denotes the Fibonacci number.

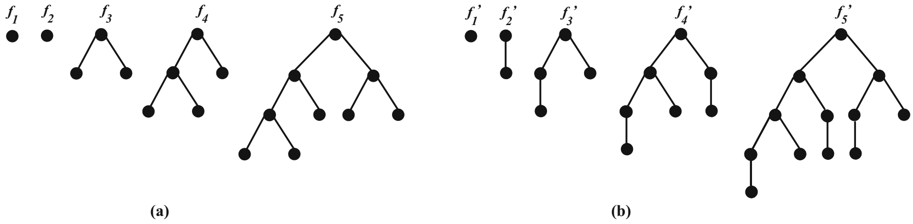


Fig. 3. (a) f_h type Fibonacci trees (b) $f_h^{'}$ type Fibonacci trees

Definition 2 [9]**.** *A lobster is a tree with the property that the removal of pendant nodes leaves a caterpillar. A wounded lobster L_n is a lobster satisfying the following conditions:*

(i) There are 2^{n-2} spine nodes and every spine node is adjacent to exactly one node of degree 2 and one node of degree 1.
(ii) Removal of pendant nodes incident at nodes of degree 2 leaves a caterpillar.

Figure 2(b) illustrates a wounded lobster.

There are several techniques for traversing the nodes of a tree according to the order in which the nodes are visited. In this paper we confine our study to postorder.

Algorithm 1. Postorder Tree Traversal Algorithm

Do the following recursively until all nodes are traversed:
Step 1 - Traverse left subtree.
Step 2 - Traverse right subtree.
Step 3 - Visit root node.

2 Main Results

In this section we embed the circulant graph into Fibonacci trees and wounded lobster to minimize their layouts.

Theorem 1. *The minimum layout of circulant graphs $G = G(m_h; \pm S)$ and $G^{'} = G(m_h^{'}; \pm S)$ into the Fibonacci trees is given by (a) $L(G, f_h) = F_{h-2}.\Theta_G(m_3) + F_{h-3}.\Theta_G(m_4) + \ldots + F_2.\Theta_G(m_{h-1}) + 2|S|$ and (b)$L(G', f_h^{'}) = F_{h-1}.\Theta_{G'}(m_2^{'}) + F_{h-2}.\Theta_{G'}(m_3^{'}) + \ldots + 2\Theta_{G'}(m_{h-2}^{'}) + \Theta_{G'}(m_{h-1}^{'}) + 2|S|$.*

Proof. We split the proof into three parts comprising of labeling the guest and host graphs, followed by the proposal of embedding and layout computation.

Guest and Host Labeling: Label the circulant graph and the two types of Fibonacci trees as in the pattern given in Table 1.

Table 1. Labeling algorithm

Labeling I	Labeling II
Guest Graph: Label the consecutive nodes of $G(m_h; \pm S)$ as $0, 1, 2, \ldots, m_h - 1$ in the clockwise direction	**Guest Graph:** Label the consecutive nodes of $G(m_h^{'}; \pm S)$ as $0, 1, \ldots, m_h^{'} - 1$ in the clockwise direction
Host Graph: Label the nodes of f_h by postorder tree traversal from 0 to $m_h - 1$	**Host Graph:** Label the nodes of $f_h^{'}$ by postorder tree traversal from 0 to $m_h^{'} - 1$

Proposed Embedding: Define an embedding $\prec f, p \succ$ from $G(m_h; \pm S)$ into f_h and $G(m_h^{'}; \pm S)$ into $f_h^{'}$ such that $f(x) = x$.

Layout Computation: We split the proof into two cases.

Proof for (a): For $1 \leq i \leq m_h - 1$, let S_i be an edge cut of f_h such that its removal disengages f_h into two components X_i and $\overline{X}_i$ as shown in Fig. 4(a), with the node set V_i of X_i being as follows.

For $1 \leq i \leq m_{h-1}$,

$$V_i = \begin{cases} \{0, 1, \ldots, i-1\}, & if\ i = m_g, 1 \leq g \leq h-1 \\ \{m_a, m_a + 1, \ldots, i-1\}, & if\ i = m_a + m_b, 1 \leq b < a \leq h-1 \\ \{i-1\}, & otherwise. \end{cases}$$

For $m_{h-1} + 1 \leq i \leq m_h - 1$,

$$V_i = \begin{cases} \{m_{h-1}, m_{h-1} + 1, \ldots, i-1\}, if\ i = m_{h-1} + m_g, 1 \leq g \leq h-1 \\ \{m_{h-1} + m_a, m_{h-1} + m_a + 1, \ldots, i-1\}, if\ i = m_{h-1} + m_a + m_b, \\ \qquad 1 \leq b < a \leq h-1 \\ \{i-1\}, \quad otherwise. \end{cases}$$

Let G_i be the graph induced by $\{f^{-1}(u) : u \in V_i\}$. It can be noted that X_i is consecutively labeled for all i and hence by Lemma 3, V_i is an optimal set with respect to the maximum induced subgraph problem. S_i also satisfies conditions (i) and (ii) of Lemma 1. In addition, $\{S_i\}_{i=1}^{m_h - 1}$ forms a partition of $E(f_h)$. Hence by Lemma 2, $L_{\prec f,p \succ}(G, f_h)$ is minimum.

Let $m_h - 1 = F_h + F_{h-2} + F_{h-3} + F_{h-4} + \ldots F_2$, where $m_h - 1$ represents the number of edge cuts of f_h and $F_h, F_{h-2}, F_{h-3}, \ldots, F_3, F_2$ denote the number of node sets V_i of cardinality $m_2, m_3, \ldots, m_{h-2}$ and m_{h-1} respectively.

Layout: $L(G, f_h) = \sum_{i=1}^{m_h - 1} EC_{\prec f,p \succ}(S_i) = \sum_{i=1}^{m_h - 1} \Theta_G(|V_i|) = \sum_{i=1}^{F_h} \Theta_G(m_2) + \sum_{i=1}^{F_{h-2}} \Theta_G \ (m_3) + \sum_{i=1}^{F_{h-3}} \Theta_G(m_4) + \ldots + \sum_{i=1}^{F_3} \Theta_G(m_{h-2}) + \sum_{i=1}^{F_2} \Theta_G(m_{h-1}) = F_{h-2}.\Theta_G(m_3) + F_{h-3}.\Theta_G(m_4) + \ldots + F_2.\Theta_G(m_{h-1}) + 2|S|$.

Proof for (b): Let $S_i^{'}$, $1 \leq i \leq m_h - 1$ be an edge cut of $f_h^{'}$ such that removal of $S_i^{'}$ disconnects $f_h^{'}$ into two components Y_i and $\overline{Y}_i$ as depicted in Fig. 4(b) where the node set $V_i^{'}$ of Y_i is defined by replacing m_g, m_a, m_b and m_{h-1} in V_i of case (a) by $m_g^{'}, m_a^{'}, m_b^{'}$ and $m_{h-1}^{'}$ respectively.

Let $G_i^{'}$ be the graph induced by $\{f^{-1}(a) : a \in V_i^{'}\}$. Clearly X_i is labeled consecutively for all i and hence by Lemma 3, $V_i^{'}$ is an optimal set with respect to the maximum induced subgraph problem. $S_i^{'}$ also satisfies the remaining two conditions of Lemma 1. In addition, $\{S_i^{'}\}_{i=1}^{m_h^{'}-1}$ forms a partition of $E(f_h^{'})$. Hence by Lemma 2, $L_{\prec f,p \succ}(G, f_h^{'}) = L(G, f_h^{'})$.

Let $m_h^{'} - 1 = F_h + F_{h-1} + F_{h-2} + \ldots F_2$, where $F_h, F_{h-1}, F_{h-2}, \ldots, F_3, F_2$ denote the number of nodes sets $V_i^{'}$ of cardinality $m_1^{'}, m_2^{'}, \ldots, m_{h-2}^{'}$ and $m_{h-1}^{'}$ respectively.

Layout: $L(G^{'}, f_h^{'}) = \sum_{i=1}^{m_h^{'}-1} EC_{\prec f,p \succ}(S_i^{'}) = \sum_{i=1}^{m_h^{'}-1} \Theta_{G^{'}}(|V_i^{'}|) = \sum_{i=1}^{F_h} \Theta_{G^{'}}(m_1^{'}) + \sum_{i=1}^{F_{h-1}} \Theta_{G^{'}}(m_2^{'}) + \ldots + \sum_{i=1}^{F_3} \Theta_{G^{'}}(m_{h-2}^{'}) + \sum_{i=1}^{F_2} \Theta_{G^{'}}(m_{h-1}^{'}) = F_{h-1}.\Theta_{G^{'}}(m_2^{'}) + F_{h-2}.\Theta_{G^{'}}\ (m_3^{'}) + \ldots + 2\Theta_{G^{'}}(m_{h-2}^{'}) + \Theta_{G^{'}}(m_{h-1}^{'}) + 2|S|$.

Theorem 2. *The minimum layout of* $G = G(2^n; \pm S)$ *into the wounded lobster* L_n *is given by* $L(G, L_n) = \frac{1}{3}\{2^{n-1}(12j(2^{n-4}+1) + 2^{n-3}(3-2^n) - 7)\}$.

Proof. **Guest and Host Labeling:** Label $G(2^n; \pm S)$ in the clockwise direction as described in Table 1. Label L_n using postorder tree traversal order from 0 to $2^n - 1$.

Proposed Embedding: Define an embedding $\prec f, p \succ$ from $G(2^n; \pm S)$ into L_n such that $f(x) = x$.

Layout Computation: Table 2 gives three sets of edge cuts covering $E(L_n)$ and the node set of the components obtained by the removal of these edge cuts as depicted in Fig. 4(c).

Let G_r, $G_r^{'}$ and $G_r^{''}$ be the inverse image of Y_r, $Y_r^{'}$ and $Y_r^{''}$ respectively under $\prec f, p \succ$. By Lemma 3, the node set of all the three inverse images are optimal in G with respect to the maximum induced subgraph problem. All three edge cuts S_r, $S_r^{'}$

Table 2. Edge cuts of L_n

Edge Cuts	Components	V(Component)
$S_r\ r = 1, 2, \ldots, 2^{n-1}$	Y_r, $\overline{Y}_r$	$V(Y_r) = \begin{cases} \{4(r-1)\} & if\ r\ is\ odd \\ \{2(r-2)+1\} & if\ r\ is\ even \end{cases}$
$S_r^{'}\ r = 1, 2, \ldots, 2^{n-2}$	$Y_r^{'}$, $\overline{Y}_r^{'}$	$V(Y_r^{'}) = \{4(r-1)+1, 4(r-1)+2\}$
$S_r^{''}\ r = 1, 2, \ldots, 2^{n-2}-1$	$Y_r^{''}$, $\overline{Y}_r^{''}$	$V(Y_r^{''}) = \{4(r-1)+0, \ldots, 4(r-1)+3\}$

and $S_r^{''}$ also satisfy the remaining two conditions of Lemma 1. In addition, $\{S_r, r = 1, 2, \ldots, 2^{n-1}\} \cup \{S_r^{'}, r = 1, 2, \ldots, 2^{n-2}\} \cup \{S_r^{''}, r = 1, 2, \ldots, 2^{n-2} - 1\}$ forms a partition of $E(L_n)$. Hence by Lemma 2, the layout induced by the embedding $\prec f, p \succ$ is minimum.

From Lemmas 2 and 4, $L(G, L_n) = \sum_{r=1}^{2^{n-1}} EC_{\prec f,p\succ}(S_r) + \sum_{r=1}^{2^{n-2}} EC_{\prec f,p\succ}(S_r^{'}) + \sum_{r=1}^{2^{n-2}-1} EC_{\prec f,p\succ}(S_r^{''}) = \sum_{r=1}^{2^{n-1}} \Theta_G(|V(Y_r)|) + \sum_{r=1}^{2^{n-2}} \Theta_G(|V(Y_r^{'})|) + \left\{ \sum_{r=1}^{2^{n-3}} \Theta_G (|V(Y_r^{''})|) + \sum_{r=2^{n-3}+1}^{2^{n-2}-1} \Theta_G(|V(Y_r^{''})|) \right\} = \frac{2^{n-1}}{3} \{ 12j\,(2^{n-4}+1) + 2^{n-3}(3-2^n) - 7 \}$.

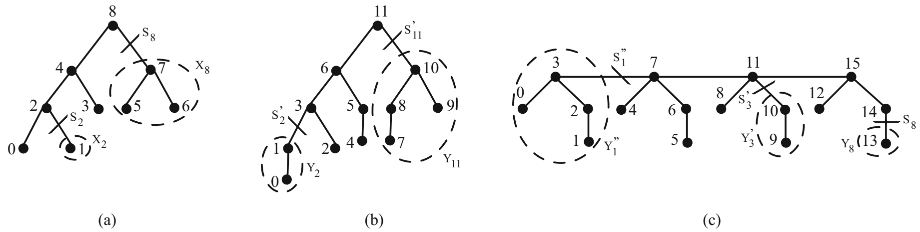


Fig. 4. Edge cuts of (a) f_5 (b) $f_5^{'}$ (c) L_4

3 Conclusion

In this paper we have embedded and found the minimum layout of the circulant graph into certain classes of height balanced trees like Fibonacci trees and wounded lobster by using edge partitioning techniques and isoperimetric methods.

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Contents

Optimal Embedding of Locally Twisted Cubes into Grids

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Abstract. The hypercube has been used in numerous problems related to interconnection networks due to its simple structure and communication properties. The locally twisted cube is an important class of hypercube variants with the same number of nodes and connections per node, but has only half the diameter and better graph embedding capability as compared to its counterpart. The embedding problem plays a significant role in parallel and distributed systems. In this paper we devise an optimal embedding of the n-dimensional locally twisted cube onto a grid network. AQ1

Keywords: Locally twisted cube · Embedding · Edge congestion · Optimal set

1 Introduction

In a parallel distributed system, the execution of parallel algorithms devised for a particular network on other networks in such a way that communication overhead could be minimized when they are run concurrently, can be modeled as a graph embedding problem.

Let $G = (V(G), E(G))$ and $H = (V(H), E(H))$ be undirected connected graphs on n nodes each known as a *guest graph* and *host graph*, representing the network underlying the algorithm and the network on which it is to be embedded respectively. A *graph embedding* is an ordered pair $\prec f, p \succ$ of injective maps where f maps $V(G)$ onto $V(H)$ and p maps the edges of G into simple paths of H such that if $e = (a, b) \in E(G)$, then $p(e)$ is a simple path in H with $f(a)$ and $f(b)$ as endpoints [11].

The *edge congestion* $EC_{\prec f,p\succ}(e)$ [3,10] of an edge $e \in H$ denotes the maximum number of edges of the guest graph that are embedded on e and is denoted as

$$EC_{\prec f,p\succ}(e) = |\{(u, v) \in E(G) : e \in E(p(u, v))\}|.$$

For any set $S \subseteq V(G)$, let $I_G(S) = \{(u, v) \in E(G) : u \in S \,\&v \in S\}$ and for $1 \le k \le |V(G)|$, let $I_G(k) = \min_{S \subseteq V(G), |S|=k} |I_G(S)|$. The *maximum subgraph problem* is to find $S \subseteq V(G)$ with $|S| = k$ such that $I_G(k) = |I_G(S)|$. Such a set S is called an optimal set [8].

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Lemma 1 *(Congestion Lemma). [10] Let G be an r-regular graph and $\prec f, p \succ$ be an embedding of G into H. Let S be an edge cut of H such that the removal of edges of S splits H into 2 components H_1 and H_2 and let $G_1 = f^{-1}(H_1)$ and $G_2 = f^{-1}(H_2)$. The following conditions are sufficient for $EC_{\prec f,p \succ}(S)$ to be minimum where $EC_{\prec f,p \succ}(S)$ denotes the sum of edge congestion over all the edges in S.*

1. *For every edge $(a, b) \in G_i$, $i = 1, 2$, $p(a, b)$ has no edges in S.*
2. *For every edge (a, b) in G with $a \in G_1$ and $b \in G_2$, $p(a, b)$ has exactly one edge in S.*
3. *G_1 or G_2 is an optimal set.*

Let $\{S_i\}_{i=1}^{m}$ be a partition of $E(H)$ such that $EC_{\prec f,p \succ}(S_i)$ is minimum over all embeddings for every i. An embedding $\prec f, p \succ$ from G into H for which such a partition can be determined is known as an *optimal embedding* [10]. Finding an optimal embedding helps in solving the layout problem [12–14], which finds application in VLSI circuit design [4], graph drawing [2], crossing number problem [5] and structural engineering [9].

The rest of the paper is organized as follows. Some fundamental definitions and preliminary results for locally twisted cube and grid are given in the next section. In Sect. 3, we devise a labeling algorithm and prove that it yields the optimal embedding for locally twisted cubes into grids. In Sect. 4, we conclude the paper.

2 Basic Definitions and Terminologies

The binary hypercube is one of the most popular, versatile and efficient topological structures of interconnection networks having simple deadlock-free routing, a small diameter, bounded link traffic density and a good support for parallel algorithms.

Definition 1. *[8] For $n \geq 1$, the node set of an n-dimensional hypercube Q_n is made up of n-bits binary strings labeled in order using $\{0, 1, \ldots, 2^n - 1\}$ beginning with 0 at $\underbrace{00\ldots00}_{n\ times}$ and ending at $\underbrace{11\ldots11}_{n\ times}$ with $2^n - 1$. Two nodes $x, y \in V(Q_n)$ are adjacent if and only if their corresponding binary strings differ in exactly one bit. An* incomplete hypercube *on i nodes of Q_n is the subgraph induced by $L_i = \{0, 1, \ldots, i-1\}$, $1 \leq i \leq 2^n$, and is denoted by $Q_n[L_i]$.*

Theorem 1. *[7] For $1 \leq i \leq 2^n$, L_i is an optimal set in Q_n.*

Definition 2. *[15] For $n \geq 2$, an n-dimensional locally twisted cube is defined recursively as follows:*

1. *LTQ_2 is a graph consisting of four nodes labeled with $00, 01, 10, 11$ respectively, connected by four edges $(00, 01)$, $(00, 10)$, $(01, 11)$ and $(10, 11)$.*

2. *For $n \geq 3$, LTQ_n is built from two disjoint copies of LTQ_{n-1} as follows: Let $0LTQ_{n-1}$ denote the graph obtained by prefixing the binary representation of each node of one copy of LTQ_{n-1} with 0. Let $1LTQ_{n-1}$ denote the graph obtained by prefixing the binary representation of each node of another copy of LTQ_{n-1} with 1. Connect each node $0x_2x_3 \ldots x_n$ of $0LTQ_{n-1}$ to the node $1\,(x_2 \oplus x_n)\,x_3 \ldots x_n$ of $1LTQ_{n-1}$ by an edge, where $\oplus$ denotes addition modulo 2.*

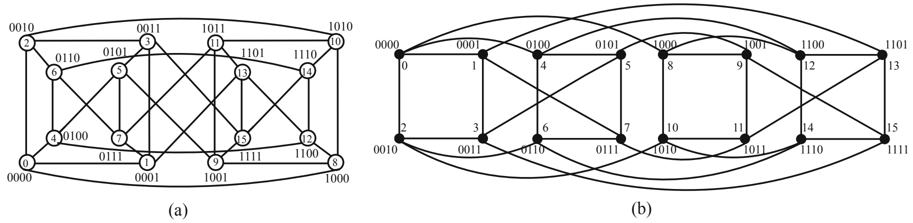

Fig. 1. Isomorphic 4-dimensional locally twisted cubes with decimal and binary labeling

Figure 1 depicts a 4-dimensional locally twisted cube. LTQ_n can be equivalently defined non-recursively as follows.

Definition 3. *[15] For $n \geq 2$, an n-dimensional locally twisted cube is a graph with node set of the form $\{0,1\}^n$. Two nodes $x = x_1x_2x_3 \ldots x_n$ and $y = y_1y_2y_3 \ldots y_n$ of LTQ_n are adjacent if and only if either of the following conditions is satisfied.*

1. *(a) There is an integer i with $1 \leq i \leq n-2$ such that $x_i = \overline{y}_i$ and $x_{i+1} = y_{i+1} \oplus x_n$.*
   (b) All remaining bits of x and y are identical.
2. *There is an integer $i \in \{n-1, n\}$ such that x and y differ only in the i^{th} bit.*

For $1 \leq i \leq 2^{n-1}$, let $E_i = \{0, 2, \ldots, 2i-2\}$ and let $(TO)_i = \{a_t : 1 \leq t \leq i\}$ where $a_1 = 1$, $a_2 = 3$ and for $2 \leq k \leq n-1$, $1 \leq j \leq 2^{k-1}$,

$$a_{2^{k-1}+j} = \begin{cases} a_j + 2^k + 2^{k-1} : & 1 \leq j \leq 2^{k-2} \\ a_j + 2^{k-1} \quad : & 2^{k-2} < j \leq 2^{k-1}. \end{cases}$$

Lemma 2. *[1] For $1 \leq i \leq 2^n$,*

$$(ETO)_i = \begin{cases} E_i & : \ 1 \leq i \leq 2^{n-1} \\ E_{2^{n-1}} \cup (TO)_{i-2^{n-1}} & : \ 2^{n-1} < i \leq 2^n. \end{cases}$$

is an optimal set in LTQ_n.

In what follows, $A \simeq B$ represents an isomorphism between A and B.

Lemma 3. *[1] For* $1 \leq i \leq 2^{n-1}$, $LTQ_n[E_i] \simeq LTQ_n[(TO)_i] \simeq Q_n[L_i]$.

Definition 4. *[6] An* $n \times m$ *grid* $G[n \times m]$ *is a graph with node set* $V(G[n \times m]) = \{\alpha_{ij} \mid 1 \leq i \leq n, 1 \leq j \leq m\}$ *and edge set* $E(G[n \times m]) = \{(\alpha_{ij}, \alpha_{i(j+1)}) \mid 1 \leq i \leq n, 1 \leq j \leq m-1\} \cup \{(\alpha_{kp}, \alpha_{(k+1)p}) \mid 1 \leq k \leq n-1, 1 \leq p \leq m\}$. *A* $2^a \times 2^b$ *grid is of the form* $G[2^a \times 2^b]$, *where* $a \leq b$, $a + b = n$.

3 Optimal Embedding Methodology

The optimal embedding proof comprises of three steps namely, node labeling, embedding proposal and proof of optimization for the proposed embedding.

3.1 Node Labeling Algorithm

In this section we label the nodes of LTQ_n and $G[2^a \times 2^b]$ in a particular pattern and prove that this labeling pattern gives the optimal embedding of LTQ_n into $G[2^a \times 2^b]$.

***LTQ_n* Labeling:** Label the nodes of LTQ_n by lexicographic order [10] using $\{0, 1, \ldots, 2^n - 1\}$ starting with 0 at $\underbrace{00\ldots\ldots00}_{n\ times}$ and ending at $\underbrace{11\ldots\ldots11}_{n\ times}$ with $2^n - 1$. A clear illustration for this decimal labeling is given in Fig. 1(b).

Grid Labeling: For $1 \leq k \leq 2^a$, $1 \leq l \leq 2^b$, let $g(k, l)$ denote the node located in the k^{th} row and l^{th} column of the grid $G[2^a \times 2^b]$. We shall split the grid labeling into two cases.

Case 1. For $1 \leq k \leq 2^a$, $1 \leq l \leq 2^{b-1}$,

$$g(k, l) = 2^b(k-1) + 2(l-1).$$

Case 2. For $1 \leq k \leq 2^a$, $2^{b-1} < l \leq 2^b$, labeling $g(k, l)$ is divided into three sub-cases.

Sub-case 2(a). When $l = 2^{b-1} + 1$, let

$$g(k, l) = \begin{cases} 2^b(k-1) + 1 & : k = 1 \\ 2^b(k-1) + 2^{b-1} + 1 & : k = 2. \end{cases}$$

For $3 \leq k \leq 2^a$, let p be a positive integer such that $2^{p-1} < k \leq 2^p$. Then

$$g(k, l) = \begin{cases} 2^b(k-1) + 1 & \& : g(k - 2^{p-1}, l) = 2^b(k - 2^{p-1} - 1) + 2^{b-1} + 1 \\ 2^b(k-1) + 2^{b-1} + 1 & \& : g(k - 2^{p-1}, l) = 2^b(k - 2^{p-1} - 1) + 1. \end{cases}$$

Sub-case 2(b). When $l = 2^{b-1} + 2$,

$$g(k, l) = g(k, 2^{b-1} + 1) + 2.$$

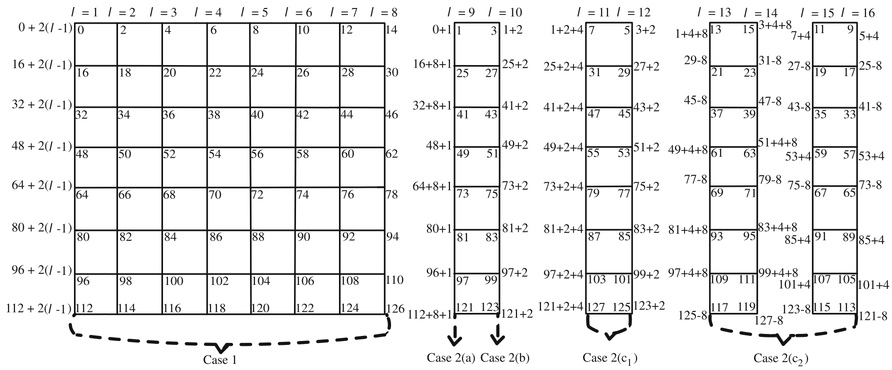

Fig. 2. The different cases of node labeling of $G[2^3 \times 2^4]$

Sub-case 2(c). For $2^{b-1} + 3 \le l \le 2^b$, we shall represent l in the form $l = 2^{b-1} + 2^{i-1} + j$, where $2 \le i \le b-1, 1 \le j \le 2^{i-1}$. The labeling of $g(k,l)$ for this case is subdivided into two cases.

Case 2c_1: Suppose $l = 2^{b-1} + 2^{i-1} + j$, $1 \le i \le b-2$, $1 \le j \le 2^{i-1}$,

$$g(k,l) = \begin{cases} g(k, 2^{b-1} + j) + 2^{i-1} + 2^i : & 1 \le j \le 2^{i-2} \\ g(k, 2^{b-1} + j) + 2^{i-1} & : 2^{i-2} < j \le 2^{i-1}. \end{cases}$$

Case 2c_2: Suppose $l = 2^{b-1} + 2^{b-2} + j$, $1 \le j \le 2^{b-2}$,

$$g(k,l) = \begin{cases} g(k, 2^{b-1} + j) + 2^{b-2} + 2^{b-1} : g(k, 2^{b-1} + 1) = 2^b(k-1) + 1 \\ \qquad \& \ j \le 2^{b-3} \\ g(k, 2^{b-1} + j) + 2^{b-2} : g(k, 2^{b-1} + 1) = 2^b(k-1) + 1 \ \& \ j > 2^{b-3} \\ g(k, 2^{b-1} + 2^{b-2} - j + 1) - 2^{b-1} : g(k, 2^{b-1} + 1) = 2^b(k-1) \\ \qquad + 2^{b-1} + 1. \end{cases}$$

Figure 2 illustrates the node labeling pattern of a $2^3 \times 2^4$ grid.

3.2 Embedding Optimization

The following results are used to obtain the proof of optimization for the embedding.

For $1 \le i \le 2^a$, let $D_i = \{(i-1)2^b, (i-1)2^b + 1, \ldots, (i-1)2^b + (2^b - 1)\}$ and $R_i = \{D_1, D_2, \ldots, D_i\}$.

Lemma 4. *For $1 \le i \le 2^a$, R_i is an optimal set in LTQ_n.*

Proof. We prove this result by induction on i. By the recursive definition of locally twisted cubes, $LTQ_n[R_1] \simeq LTQ_b$ and hence $|E(LTQ_n[R_1])| = b.2^{b-1}$.

By Lemmas 2 and 3, R_1 is an optimal set in LTQ_n. Assuming that the result is true for $i = k-1$, we prove that R_k is optimal in LTQ_n.

We first show that $LTQ_n[D_k] \simeq LTQ_b$ for every k, $1 \leq k \leq 2^a$. We have that $LTQ_n[D_1] \simeq LTQ_b$. We prove the hypothesis for every other k by showing that $LTQ_n[D_k]$ is isomorphic to $LTQ_n[D_{k-2^{p-1}}]$, where $1 \leq p \leq a$ and $2^{p-1} < k \leq 2^p$. Define a mapping $\varphi : V(LTQ_n[D_{k-2^{p-1}}]) \to V(LTQ_n[D_k])$ such that $\varphi(x) = x + 2^{b+p-1}$.

Let the binary representation of x be $\underbrace{00\ldots00}_{(a-p)\ times}\ 0x_{a-p+2}\ldots x_n$. Then the binary representation of $\varphi(x)$ is $\underbrace{00\ldots00}_{(a-p)\ times}\ 1x_{a-p+2}\ldots x_n$.

For $j \in \{a-p+2, \ldots, n-2\}$, the bits variation of $(x,y) \in E(LTQ_n[D_{k-2^{p-1}}])$ and the corresponding $(\varphi(x), \varphi(y)) \in E(LTQ_n[D_k])$ is as follows.

$$x = \underbrace{000\ldots\ldots00}_{(a-p)\ times} 0x_{a-p+2}\ldots x_j \ldots x_{n-1}x_n \text{ and}$$

$$y = \begin{cases} \underbrace{00\ldots00}_{(a-p)\ times}\ 0\ldots\overline{x}_j(x_{j+1}\oplus x_n)\ldots x_{n-1}x_n & : j \in \{a-p+2,\ldots,n-2\} \\ \underbrace{00\ldots00}_{(a-p)\ times}\ 0x_{a-p+2}\ldots\overline{x}_j x_n & : j = n-1 \\ \underbrace{00\ldots00}_{(a-p)\ times}\ 0x_{a-p+2}\ldots x_{n-1}\overline{x}_j & : j = n \end{cases}$$

then the binary representations of $\varphi(x)$ and $\varphi(y)$ are

$$\varphi(x) = \underbrace{000\ldots\ldots00}_{(a-p)\ times} 1x_{a-p+2}\ldots x_j \ldots x_{n-1}x_n \text{ and}$$

$$\varphi(y) = \begin{cases} \underbrace{00\ldots00}_{(a-p)\ times}\ 1\ldots\overline{x}_j(x_{j+1}\oplus x_n)\ldots x_{n-1}x_n & : j \in \{a-p+2,\ldots,n-2\} \\ \underbrace{00\ldots00}_{(a-p)\ times}\ 1x_{a-p+2}\ldots\overline{x}_j x_n & : j = n-1 \\ \underbrace{00\ldots00}_{(a-p)\ times}\ 1x_{a-p+2}\ldots x_{n-1}\overline{x}_j & : j = n \end{cases}$$

Hence $(x,y) \in E(LTQ_n[D_{k-2^{p-1}}]) \Leftrightarrow$ for $j \in \{a-p+2, a-p+3, \ldots, n-2\}$, the binary representations of x and y differ in the j^{th} bit and have either identical or different $(j+1)^{th}$ bit depending on x_n, the remaining bits being identical or their binary representations differ only in the $(n-1)^{th}$ or n^{th} bit $\Leftrightarrow$ the binary representations of $\varphi(x)$ and $\varphi(y)$ differ in the j^{th} bit and have either identical or different $(j+1)^{th}$ bit depending on x_n, the remaining bits being identical or their binary representations differ only in the $(n-1)^{th}$ or n^{th} bit $\Leftrightarrow$ $(\varphi(x), \varphi(y)) \in E(LTQ_n[D_k])$. Therefore φ is an isomorphism and hence $LTQ_n[D_k] \simeq LTQ_b$.

Let $E(LTQ_n[D_k] \wedge LTQ_n[R_{k-1}]) = \{(x,y) : x \in V(LTQ_n[D_k])\ and\ y \in V(LTQ_n[R_{k-1}])\}$. Let k be represented as $k = 2^{r_1} + 2^{r_2} + \ldots + 2^{r_q} + 1$ such that $r_1 > r_2 > \ldots > r_q \geq 0$. Each node in $LTQ_n[D_k]$ is adjacent to q nodes in $LTQ_n[R_{k-1}]$. For $m \in \{1, 2, \ldots, a\}$, the binary representation of x and y such that $(x, y) \in E(LTQ_n[D_k] \wedge LTQ_n[R_{k-1}])$ are of the form $x = x_1x_2 \ldots x_{m-1}x_m \ldots x_{n-1}0$ and $y = x_1x_2 \ldots x_{m-1}\overline{x}_m x_{m+1} \ldots x_{n-1}0$, when $x \in \{(k-1).2^b, (k-1).2^b+2, \ldots, (k-1).2^b+(2^b-2)\}$, $y \in \{0, 2, \ldots, (k-2).2^b+(2^b-2)\}$ and $x = x_1 \ldots x_{m-1}1x_{m+1} \ldots x_{n-1}1$ and $y = x_1 \ldots x_{m-1}0\overline{x}_{m+1} \ldots x_{n-1}1$, when $x \in \{(k-1).2^b + 1, (k-1).2^b + 3, \ldots, (k-1).2^b + (2^b - 1)\}$, $y \in \{1, 3, 5, \ldots, (k-2).2^b + (2^b - 1)\}$. Clearly, there is no edge (x, y) where $x \in \{(k-1).2^b, (k-1).2^b + 2, \ldots, (k-1).2^b + (2^b - 2)\}$ and $y \in \{1, 3, 5, \ldots, (k-2).2^b + (2^b - 1)\}$ and vice versa. Therefore, $|E(LTQ_n[R_k])| = |E(LQ_n[R_{k-1}])| + |E(LTQ_n[D_k])| + |E(LTQ_n[D_k] \wedge LTQ_n[R_{k-1}])| = |E(LTQ_n[(ETO)_{k-1.2^b}])| + |E(LTQ_b)| + q(2^b) = |E(LTQ_n[(ETO)_{(k).2^b}])|$ and hence by Lemma 2, R_k is an optimal set in LTQ_n. □

For $1 \leq j \leq 2^{b-1}$, let $S_j = \{o_{1j}, o_{2j}, \ldots, o_{2^a j}\}$ be the set of all nodes in the $(2^{b-1} + j)^{th}$ column of $G[2^a \times 2^b]$ taken in a distinct order, where o_{ij} is defined as follows.

1. For $i = 1, 2$, $1 \leq j \leq 2^{b-1}$,

$$o_{ij} = \begin{cases} a_j & : i = 1 \\ a_{2^{b-1}+j} & : i = 2. \end{cases}$$

   where a_k denotes the k^{th} element of $(TO)_{2^{b-1}}$.
2. For $3 \leq i \leq 2^a$, $1 \leq j \leq 2^{b-1}$, let t be a positive integer such that $t \leq n$ and $2^{t-1} < i \leq 2^t$. Then

$$o_{ij} = \begin{cases} o_{(i-2^{t-1})j} + 2^{b+t-1} + 2^{b+t-2} & : 2^{t-1} < i \leq 2^{t-1} + 2^{t-2} \\ o_{(i-2^{t-1})j} + 2^{b+t-2} & : 2^{t-1} + 2^{t-2} < i \leq 2^t. \end{cases}$$

Let $CO_j = \{S_{2^{b-1}}, S_{2^{b-1}-1}, \ldots, S_{2^{b-1}-j+1}\}$.

Lemma 5. *For $1 \leq j \leq 2^{b-1}$, CO_j is an optimal set in LTQ_n.*

Proof. The proof consists of two parts. First we prove that for $1 \leq j \leq 2^{b-1}$, $LTQ_n[S_j]$ is isomorphic to a copy of Q_a. In the second part we prove that $|E(LTQ_n[CO_j])| = |E(Q_n[L_{j.2^a}])|$ for all j, which asserts the optimality of CO_j, according to Lemma 3.

For $1 \leq j \leq 2^{b-1}$, let $C^j_{2^1} = \{o_{1j}, o_{2j}\}$. For $2 \leq r \leq a$, $1 \leq j \leq 2^{b-1}$, let $C^j_{2^r} = C^j_{2^{r-1}} \cup X$, where $C^j_{2^{r-1}} = \{o_{ij} : 1 \leq i \leq 2^{r-1}\}$ and $X = \{o_{ij} : 2^{r-1} < i \leq 2^r\}$. We prove the first part by induction on r. By verification, $LTQ_n[C^j_{2^1}] \simeq Q_1$. Assuming that the result is true for $r = k - 1$, we show that $LTQ_n[C^j_{2^k}] \simeq Q_k$. For this we first prove that $LTQ_n[X] \simeq LTQ_n[C^j_{2^{k-1}}]$.

Define a function $f : V(LTQ_n)[C^j_{2^{k-1}}] \to V(LTQ_n[X])$ such that

$$f(x) = \begin{cases} x + 2^{b+k-1} + 2^{b+k-2} : x \in C_{2^{k-2}j} \\ x + 2^{b+k-2} : x \in C_{2^{k-1}j} \setminus C_{2^{k-2}j}. \end{cases}$$

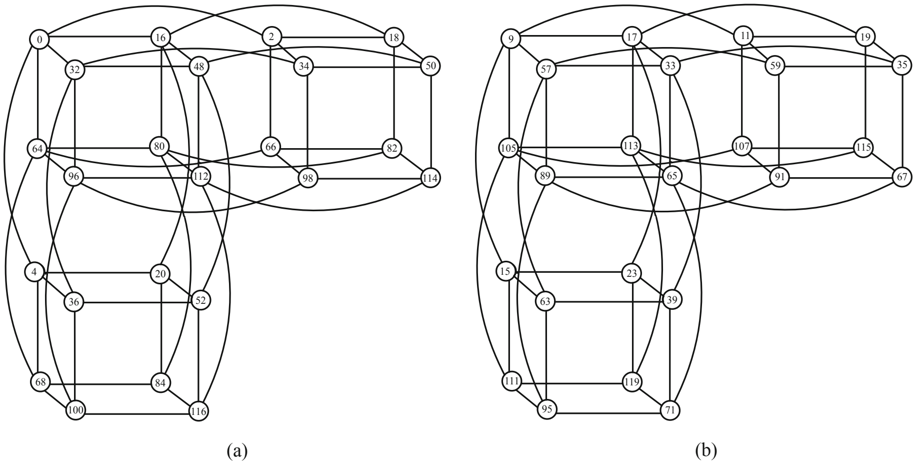

Fig. 3. (a) $LTQ_7[CE_3]$ (b) $LTQ_7[CO_3]$ both isomorphic to $Q_7[L_{24}]$

If the binary representation of x is $\underbrace{00\ldots00}_{(a-k)times}0x_{a+k+2}\ldots x_{n-1}1$, then the binary representation of $f(x)$ is $\underbrace{00\ldots00}_{(a-k)times}1\overline{x}_{a+k+2}x_{a+k+3}\ldots x_{n-1}1$. The bits variation of $(x,y)\in E(LTQ_n[C^j_{2^{k-1}}])$ and the corresponding $(f(x),f(y))\in E(LTQ_n[X])$ for $i\in\{a-k+3,a-k+4\ldots,n-3\}$ is as follows.

The binary representations of x and y are

$$x=\underbrace{00\ldots00}_{(a-k)times}0x_{a-k+2}\ldots x_ix_{i+1}\ldots x_{n-1}1 \text{ and}$$

$$y=\underbrace{00\ldots00}_{(a-k)times}0x_{a-k+2}\ldots x_{i-1}\overline{x}_i\overline{x}_{i+1}x_{i+2}\ldots x_{n-1}1.$$

Then the binary representations of $f(x)$ and $f(y)$ are

$$f(x)=\underbrace{00\ldots00}_{(a-k)times}1\overline{x}_{a-k+2}\ldots x_ix_{i+1}\ldots x_{n-1}1 \text{ and}$$

$$f(y)=\underbrace{00\ldots00}_{(a-k)times}1\overline{x}_{a-k+2}\ldots x_{i-1}\overline{x}_i\overline{x}_{i+1}x_{i+2}\ldots x_{n-1}1.$$

Hence $(x,y)\in E(LTQ_n[C^j_{2^{k-1}}])\Leftrightarrow$ there exists an $i\in\{a-k+3,a-k+4,\ldots,n-3\}$ such that the binary representations of x and y differ only in the i^{th} and $(i+1)^{th}$ bits $\Leftrightarrow$ the binary representations of $f(x)$ and $f(y)$ differ only in the same i^{th} and $(i+1)^{th}$ bits $\Leftrightarrow (f(x),f(y))\in E(LTQ_n[X])$. Therefore f is an isomorphism.

Next we prove that there is a perfect matching between $LTQ_n[C^j_{2^{k-1}}]$ and $LTQ_n[X]$. For any $o_{ij}\in V(LTQ_n[X])$ and $o_{(i-2^{k-1})j}\in V(LTQ_n[C^j_{2^{k-1}}])$, let the binary representation of o_{ij} be

$$o_{ij} = \alpha_1\alpha_2 \ldots \alpha_{a-k}\alpha_{a-k+1} \ldots \alpha_{n-1}1$$

Then the binary representation of $o_{(i-2^{p-1})j}$ is

$$o_{(i-2^{k-1})j} = \alpha_1\alpha_2 \ldots \alpha_{a-k}\overline{\alpha}_{a-k+1}\overline{\alpha}_{a-k+2}\alpha_{a-k+3} \ldots \alpha_{n-1}1.$$

The binary representations of o_{ij} and $o_{(i-2^{k-1})j}$ differ only in the $(a-k+1)^{th}$ and $(a-k+2)^{th}$ bits. Hence $(o_{ij}, o_{(i-2^{k-1})j})$ is an edge in LTQ_n for $2^{k-1} < i \leq 2^k$, implying that there is a perfect matching between the two isomorphic components, similar to a hypercube connectivity. Therefore $LTQ_n[C^j_{2^k}] \simeq Q_k$ and $LTQ_n[S_j]$ is isomorphic to Q_a for all $j \in \{1, 2, \ldots, 2^{b-1}\}$.

We prove the second part by induction on j. Clearly $LTQ_n[CO_1] \simeq Q_a$. Hence $|E(LTQ_n[CO_1])| = |E(Q_n[L_{1.2^a}])|$. By Lemma 3, it is optimal. Assuming that the postulate is true for $j = q-1$, we prove that $|E(LTQ_n[CO_q])| = |E(Q_n[L_{q.2^a}])|$.

$V(LTQ_n[CO_q])$ can be represented as $V(LTQ_n[CO_q]) = V(LTQ_n[CO_{q-1}]) \cup V(LTQ_n[S_{2^{b-1}-q+1}])$. Let $E(LTQ_n[CO_{q-1}] \wedge LTQ_n[S_{2^{b-1}-q+1}]) = \{(u,v) : u \in V(LTQ_n[CO_{q-1}]), v \in V(LTQ_n[S_{2^{b-1}-q+1}])\}$. Let q be represented as $q = 2^{s_1} + 2^{s_2} + \ldots + 2^{s_m} + 1$ such that $s_1 > s_2 > \ldots > s_m \geq 0$. For any q, there are $m.2^a$ edges in $E(LTQ_n[CO_{q-1}] \wedge LTQ_n[S_{2^{b-1}-q+1}])$.

For $t \in \{a+1, a+2, \ldots, n-1\}$, the binary representations of u and v such that (u,v) is an edge in $E(LTQ_n[CO_{q-1}] \wedge LTQ_n[S_{2^{b-1}-q+1}])$ are of the form

$$u = u_1u_2 \ldots u_tu_{t+1} \ldots u_{n-1}1 \textit{ and}$$

$$v = \begin{cases} u_1u_2 \ldots \overline{u}_t\overline{u}_{t+1} \ldots u_{n-1}1 : t \in \{a+1, a+2 \ldots, n-2\} \\ u_1u_2 \ldots u_{t-1}\overline{u}_t1 \qquad\qquad : t = n-1. \end{cases}$$

Hence the number of edges in $LTQ_n[CO_q]$ is given by $|E(LTQ_n[CO_q])| = |E(LTQ_n\ [CO_{q-1}])| + |E(LTQ_n[S_{2^{b-1}-q+1}])| + |E(LTQ_n[CO_{q-1}] \wedge LTQ_n[S_{2^{b-1}-q+1}])| = |E(Q_n[L_{q-1.2^a}])| + |E(Q_a)| + m.2^a = |E(Q_n[L_{q.2^a}])|$. Figure 3(b) depicts $LTQ_7[CO_3]$. ◻

Lemma 6. *For* $1 \leq j \leq 2^{b-1}$,

$$CE_j = \begin{array}{l} \{\ 0,\quad 1 \times 2^b, \quad \ldots \quad, (2^a-1) \times 2^b, \\ \quad 2,\quad 1 \times 2^b + 2, \quad \ldots \quad, (2^a-1) \times 2^b + 2, \\ \qquad\qquad \ldots \\ \qquad\qquad \& \ldots \\ \qquad\qquad \& \ldots \\ 2(j-1), 1 \times 2^b + 2(j-1), \ldots, (2^a-1) \times 2^b + 2(j-1)\ \} \end{array}$$

is an optimal set in LTQ_n.

Proof. We have to prove that $LTQ_n[CE_j]$ is isomorphic to $LTQ_n[(ETO)_{j.2^a}]$. But $j.2^a \leq 2^{n-1}$ and hence by Lemma 3, it is enough to show that $LTQn[CE_j]$ is isomorphic to $Q_n[L_{j.2^a}]$. Define a function $\pi : V(LTQ_n[CE_j]) \to V(Q_n[L_{j.2^a}])$ such that for $0 \leq g \leq 2^{a-1}, 0 \leq h \leq j-1, \pi(g \times 2^b + 2h) = h \times 2^a + g$. Let the binary representation of $g \times 2^b + 2h$ be $\alpha_1\alpha_2 \ldots \alpha_{b-1}\beta_1 \ldots \beta_{a+1}$. Then the binary representation of $h \times 2^a + g$ is $\beta_1\beta_2 \ldots \beta_{a+1}\alpha_1\alpha_2 \ldots \alpha_{b-1}$.

Two nodes $x = x_1x_2 \ldots x_n$ and $y = y_1y_2 \ldots y_n$ are adjacent in $LTQ_n[CE_j]$ $\Leftrightarrow$ there exists an integer $i \in \{1, 2, \ldots, n-1\}$ such that $x_i = \overline{y}_i \Leftrightarrow \pi(x)$ and $\pi(y)$ differ only in the i^{th} bit $\Leftrightarrow (\pi(x), \pi(y)) \in E(Q_n[L_{j.2^a}])$. Hence $LTQ_n[CE_j]$ is isomorphic to $Q_n[L_{j.2^a}]$. Figure 3(a) illustrates this result. □

Proposed Embedding. Define an embedding f from LTQ_n into $G[2^a \times 2^b]$ such that $f(x) = x$, together with $p(u, v)$, a shortest path irrespective of choice in $G[2^a \times 2^b]$ between $f(u)$ and $f(v)$ for every $(u, v) \in E(LTQ_n)$.

Theorem 2. *The embedding $\prec f, p \succ$ from LTQ_n into $G[2^a \times 2^b]$ is optimal.*

Proof. Table 1 gives a list of certain edge cuts covering the entire edge set of $G[2^a \times 2^b]$ and the node set of the components obtained by the removal of these edge cuts, which is illustrated in Fig. 4.

Table 1. Edge cuts of $G[2^a \times 2^b]$

Edge Cuts	Type of Cuts	Components	V(Component)
X_i $i = 1, 2, \ldots, 2^a - 1$	Horizontal cut	A_i, $\overline{A}_i$	$V(A_i) = R_i$
Y_{ej} $j = 1, 2, \ldots, 2^{b-1} - 1$	Left to middle vertical cut	B_{ej}, $\overline{B}_{ej}$	$V(B_{ej}) = CE_j$
Y_{oj} $j = 1, 2, \ldots, 2^{b-1} - 1$	Right to middle vertical cut	B_{oj}, $\overline{B}_{oj}$	$V(B_{oj}) = CO_j$
Z	Middle vertical cut	P_1, P_2	$V(P_1) = E_{2^{n-1}}$

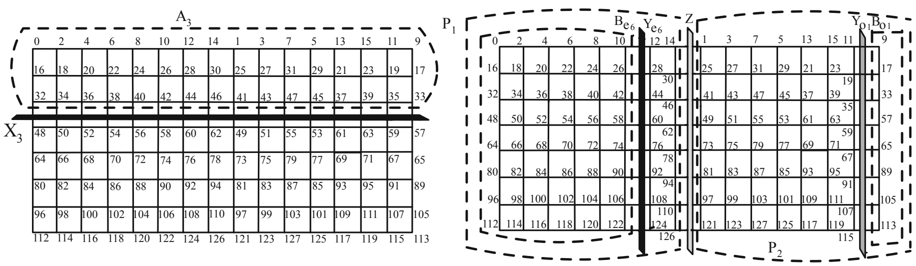

Fig. 4. Edge cuts along the rows and columns of $G[2^3 \times 2^4]$.

All the edge cuts satisfy conditions $(i) - (iii)$ of Lemma 1. In addition, $\{X_i : i = 1, 2, \ldots, 2^a - 1\} \cup \{Y_{ej} : j = 1, 2 \ldots, 2^{b-1} - 1\} \cup \{Y_{oj} : j = 1, 2, \ldots 2^{b-1} - 1\} \cup Z$ is a partition of $E(G[2^a \times 2^b])$. Therefore by the definition of optimal embedding, $\prec f, p \succ$ is optimal. □

Author Proof

Author Queries

Chapter 1

Query Refs.	Details Required	Author's response
AQ1	Please confirm if the corresponding author is correctly identified. Amend if necessary.	

4 Conclusion

In this paper we have devised a rigorous node labeling algorithm and proved that this labeling gives the optimal embedding of an n-dimensional locally twisted cube into a $2^a \times 2^b$ grid structure, where $a \leq b < n$, using Congestion Lemma and edge partitioning techniques. It would be an interesting line of research to find another elegant and simple node labeling pattern which induces an optimal embedding.

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A STUDY ON TECHNOLOGY READINESS FOR POINT OF SALE (POS) USAGE AMONG FEMALE GARMENT FACTORY WORKERS IN BENGALURU, KARNATAKA, INDIA

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Abstract: Technology Readiness refers to an individual's positive and negative attitude and experiences with regard to technology usage. This paper has discussed the present scenario of femal garment factory workers in Bengaluru on the usage of POS (Point of Sale), in the absence of non working of ATM (Automated Teller Machine), due to demonetization. Those plastic cards which used to fetch money from kiosks, seem to be useful no more. A three point Likert scale was used in order to prepare the questionnaire. A pilot study was conducted with 15 respondents. Later, the questionnaire was rectified. 384 respondents were surveyed. Cronbach's Alpha was used to test the reliability of the data which was collected. Pearson's Chi Square Test was used to analyze demographic variables. Pearson's Chi Square Test was used to analyze the factors. The study concludes by saying that there are enough and more opportunities available to raise the optimism and innovativeness of these workers, if they are to use these technology in a hassle free manner.

Keywords: Technology Readiness, ATM, Garment workers, Bengaluru

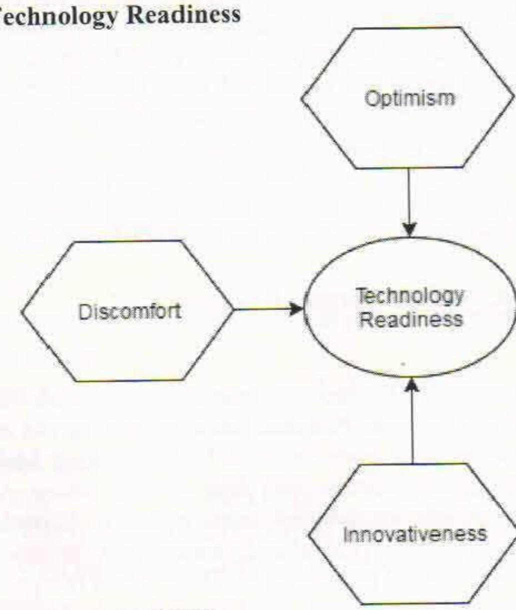
1. Introduction

The demonetization announcement made by the Government of India on November 8th, 2016 had changed the payment transaction scenario in India. Lack of cash in the economy had opened up a wide array of possibilities to go even more cashless. Mobile Wallet, Mobile Banking and Internet Banking needed Internet to operate together with host of other issues. As per World Bank Data, in 2014-15, 26 out of 100 people are internet users in India. A readily available opportunity was making use of plastic money. Banks had already armed their customers with debit and credit cards, due to which common man started possessing it. There was a fair growth of credit cards in the economy from 23.78 million in January 2016 to 26.38 million in August 2016 and a steady growth of debit cards in the economy from 653.4 million in January 2016 to 712.5 million in August 2016 as per Reserve Bank of India. But, the past data posts a feeble growth in terms of transactions made out of these cards. There were only 18 out of 100 debit card users who conducted a transaction, in the month of August 2016 and 3 out of 100 credit card users who conducted a transaction, in the month of August 2016. Even though demonetization had greatly spurred up cashless means of payment transactions, a change in the usage of cards for POS (Point of Sale) transactions had not picked up due to following reasons: POS machines were in usage only in urban areas (70% of it concentrate in only 15 cities in India as per 'Ernst and Young's Accelerating financial inclusion - The role of payment systems', 2014). Their penetration towards rural areas were rare or nil. Hence, this study focuses only on the urban parts of Bengaluru. Federation of Indian Chambers of Commerce and Industry (FICCI) and Indian Banks' Association (IBA) and Boston Consulting Group (BCG) in 2014 reported on digital channels. Out of total transaction in banks, 26% were cash, 19% cheque, 37% ATM (Automated Teller Machine), and rest 18% were digital channels like EFT-POS, including mobile, internet, NEFT (National Electronic Fund Transfer) and ECS (Electronic Clearing Services). But, on the brighter side, digital channels are growing at a healthy rate of 67% in the latest report of 2016. Still, India remains on the backburner when compared with a developing country such as Brazil which has got 32,995 POS terminals per million people compared to 693 POS terminals per million people in India as per Ernst and Young's 'Accelerating financial inclusion- The role of payment systems', in 2014.

The report of India Committee of the Netherland says that eighty percent of these female work forces are migrants. They earn between Rs. 3,000 and Rs. 10,000 per month (based on skill and hierarchy) and work in around 800 factories in Bengaluru. There are around 5 Lakhs of workers as per 19th April, 2016 reports of the Times of India.

Technology Readiness was chosen to find out the acceptance level among such workers who were forced to undergo salary cuts due to low sales caused by demonetization. They were stopped paying in cash and rather they started getting their salary in bank accounts. Living in a Metropolitan area like Bengaluru, this is a study to identify the change in the attitude towards payment transactions among these workers.

Table 1.1: Technology Readiness



Source: Parasuraman, A. (2000)

Table 1.1 shows the factors used in this study. The factors are explained below:-

a) Optimism (OP): This factor exhibits an individual's opinion on how useful technology is going to be for her or him. It tells us that they appreciate it's effectiveness, efficiency and the role that technology is going to play in their day to day lives.

b) Innovativeness (IV): This factor points at the individual's attitude towards change. Technology changes every now and then. Hence, it keeps creating disruption. Are these changes accepted or averted is the question here.

c) Discomfort (DI): This factor is an effect of innovativeness. The rapid changes make the individual think whether to stick on with the changes or leave.

d) Insecurity (IN): This is a factor experienced in users who experienced bad situations due to technology downtime or hardware problem. They doubt the role that technology could play and thus may downplay it's usage completely.

2. Literature Review

This paper is based on the term technology readiness, defined by Parasuraman(2000). He defines it as "an individual's natural tendency to adopt new technology for fulfilling daily needs". Many other studies followed after that. This paper has considered only select articles post 2014, in order to keep up with the current scenario in this field, in recent studies.

A Structured Equation Modeling (SEM) analysis done by Koivisto & Et Al., (2016) noted that Technology Readiness Index (TRI) and Technology Acceptance Model (TAM) was better than Personal Innovativeness in Information Technology (PIIT) and Technology Acceptance Model (TAM),in describing user's intention to use a technology and ease of use and usefulness of a technology to a user. Boon-itt (2015) study notes that there is a positive relationship between Technology Readiness and Service Quality of Self- Service Technology. The study stresses that technology is not merely about infrastructure availability, but it is beyond it. He says that there is an element of e-satisfaction that must be increased by studying the user's perceived value of any transaction. On an organization level, Ramaseshan et al., (2015) maintains that Technology Readiness is not related to users alone, but rather it is collaborative and it involves the management, channel operators, employees and users. Technology Readiness may bring easiness to users, but it will not create any drive to use a Self- Service Technology (SST).

Technology Readiness was used in different arenas. Joo (2015) combined Technology Readiness (TR), TAM (Technology Acceptance Model), and TPB (Theory of Planned Behavior), in order to study social commerce behavior. It was stated that Technology Readiness is the apt model that could predict people's social behavior in social networking websites and the studied behavior could later be applied to understand people's e commerce websites behavior. Lin et al., (2016) observes that without self directed learning from the individual's side, he is not going to adopt a Self- Service Technology. They further add that Optimism developed out of self learning makes users to appreciate a particular technology. Ricardo et al., (2016) used Technology Readiness Index (TRI) in order to study Columbians. The study had few mentions on how Technology Readiness needs to be studied on three levels viz.,- Demography, Attitude and Personality. Demographically, the study stated that there is gender inequality, since men use Technology more than women. As far as attitude was concerned, Columbians were open to innovation, but had inherent fears about technology uncertainty. The Personality of Columbians showed that they were collective and not individualistic and thus the authors suggested for a Self-Service Technology (SST) system which was developed keeping all these in mind. Focusing on the Indian Context of E-Governance, a study by Supriya et al., (2014) found that India lagged behind other developed countries in terms of Technology Readiness in using Information and Communication Technology for Development (ICT4D) due to lack of technology utility awareness and aversion to innovativeness. A study conducted by Florestiyanto (2015) among the participants in Gadjah Mada University, Indonesia, where they were enquired about the usage of any Information system in managing finance, the study concluded by stating that technology readiness is influenced by discomfort (which had the highest ranking), innovation and insecurity. Optimism was considered to have no influence. Discomfort, low income and female participants were found to lacking Technology Readiness. McDonough (2016) study among the elderly directly points at age being a stimulant in creating discomfort and lack of innovation among the elderly people. Croatian retail customers were studied and the results of Kovač et al., (2016) points that users are ready to embrace technology based on two fronts- Maximum gain attained and through awareness of minimizing fear about technology frauds. Behavioral study of Abbade (2014) among undergraduate students of a private university for technology readiness found that neither income nor gender have any significant impact on technology readiness, but unpreparedness can be an obstruction towards attaining Technology Readiness.

This paragraph will deal with studies already done on banking field, specifically with regard to Technology Readiness. Shin & Lee (2014) focused on usage of Near Field Communication (NFC) Mobile Payments using both Technology Acceptance Model (TAM) and Technology Readiness (TR) and observed that the elements found in Technology Readiness (TR) did influence perceived ease of use. This perceived ease of use would propel perceived usefulness. In turn, this would predict user's intention to use Near Field Communication (NFC) Mobile Payments. Kamaludin & Purba (2015) conducted a survey among bank employees in Indonesia in order to test their Technology Readiness. On the optimism and innovation fronts, they appreciated technology usefulness. But, on the discomfort and insecurity fronts, they were overwhelmed when technology downtime was seen. In a conceptual paper by Illia et al., (2015) all the elements of Technology Readiness was attributed to a factor known as 'Trust'. Trust was seen as the product of Optimism, Innovativeness, Insecurity and Discomfort.

3. Research Methodology

A three point Likert scale was used in order to prepare the questionnaire. A pilot study was conducted with 15 respondents. Later, the questionnaire was rectified. 384 respondents were surveyed. Cronbach's Alpha was used to test the reliability of the data which was collected. Pearson's Chi Square Test was used to analyze demographic variables. Pearson's Chi Square Test was used to analyze the factors.

4. Results and Discussions

a. Data Reliability

High reliability of 0.927 was found when the data was tested using Cronbach's Alpha.

Reliability Statistics

Cronbach's Alpha	N of Items
0.927	7

b. Descriptive Analysis

40% of the respondents came under the age range between 21 and 30. 80% of the respondents had studies only upto 7th standard. 50% of the respondents were semi- skilled.

c. Inferential Analysis

i. Demographic variables of the respondents

The demographic independent variables were related with technology readiness factors using Pearson's chi-square to identify the association. The results were illustrated in Table 1.2.

Table 1.2 Relationship of demographic statuses of respondents with technology readiness factors using Pearson's chi-square

Independent variables	Dependent variables	Value	df	Asymp. Sig. (2-sided)
Age of the respondent	Optimism	348.61	8	0.000
	Innovativeness	259.52	8	0.000
	Discomfort	371.25	8	0.000
	Insecurity	295.85	8	0.000
Highest Educational Qualification	Optimism	66.6.1	6	0.000
	Innovativeness	23.35	6	0.000
	Discomfort	69.54	6	0.000
	Insecurity	54.03	6	0.000
Worker Category	Optimism	367.86	4	0.000
	Innovativeness	139.97	4	0.000
	Discomfort	384	4	0.000
	Insecurity	298.37	4	0.000

In Table 1.2, all the demographic variables had no significant association with other factors ($p<0.05$). All the respondents irrespective of their socioeconomic status had equal opinion on Optimism, Compulsive Usage, Technology Availability and Insecurity.

A. Hypothesis relating to Optimism

$H_0 1$: Optimism has no significant evidence of relationship with insecurity

Table 1.3: Hypotheses testing relating to Optimism

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	627.973	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.3, it was inferred that Optimism had significant evidence of relationship with insecurity.

B. Hypothesis relating to Optimism

$H_0 2$: Optimism has no significant relationship with discomfort

Table 1.4: Hypotheses testing relating to Optimism

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	702.032	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.4, it was inferred that Optimism had significant evidence of relationship with discomfort.

C. Hypothesis relating to Optimism

$H_0 3$: Optimism has no significant relationship with innovativeness

Table 1.5: Hypotheses testing relating to Optimism

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	303.158	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.5, it was inferred that Optimism had significant evidence of relationship with innovativeness.

D. Hypothesis relating to Innovativeness

$H_0 4$: Innovativeness has no significant relationship with discomfort

Table 1.6: Hypotheses testing relating to Innovativeness

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	320.732	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.6, it was inferred that Innovativeness had significant evidence of relationship with discomfort.

E. Hypothesis relating to Innovativeness

$H_0 5$: Innovativeness has no significant relationship with optimism

Table 1.7: Hypotheses testing relating to Innovativeness

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	320.732	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.7, it was inferred that Innovativeness had significant evidence of relationship with optimism.

F. Hypothesis relating to Insecurity

$H_0 6$: Insecurity has no significant relationship with innovativeness

Table 1.8: Hypotheses testing relating to Insecurity

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	303.158	4	0.000

Since $p < 0.05$, the hypothesis was rejected. From Table 1.8, it was inferred that Insecurity had significant evidence of relationship with innovativeness.

4. Conclusion

An appreciation of technology helps to reduce insecurity. These workers were found to be having insecurity over technology usage. With the pessimism around, there was discomfort attached with it. Innovativeness comes as a result of optimism. The workers were found to be averse to innovation. These workers were used to opting ATMs (Automated Teller Machines) for all their transactions. Such a change was unprecedented. Lack of innovativeness also caused discomfort apart from optimism. Since the workers had no bent over innovation, there was pessimism. Insecurity stops the willingness to be innovative in approach.

The above study was done among a sample which is low on technology readiness factors. However, a phenomenon like demonetization is an opportunity to try the unchartered waters for these workers. Such an opportunity might not bring innovativeness for them, but might produce optimism or insecurity or discomfort, depending on individual experiences. Though the workers seemed to be lacking on the innovation and optimism factors, one is sure that they are currently undergoing discomfort and insecurity. Concrete measures from the Business Correspondents, Government, Unions, NGOs (Non Governmental Organizations) and Banks can help ease the transition pain.

5. Limitations, Implications and Future research

The study was conducted within a short time frame of one month. It has taken only one model and not a mixture of many. It implies for the immediate attention of the government for uplifting such workers from the mental trauma that demonetization has caused them. Future researchers can focus on the family members that are dependent on these workers, whose life gets affected with the way these workers suffer.

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