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PARITANTRA

Journal of Systems Science and Engineering

Aims and Scope

This journal publishes original research and advancement in the field of theory and applications of systems science and engineering. The journal is primarily devoted to unification of themes, cross fertilization of ideas, identification and characterization of underlying quantitative and qualitative features of problem formulation and general solution; and solution of multi-level interdisciplinary socio-economic, engineering-economic and real-world problems in the context of national/global development. The journal has a very wide scope which includes applied systems research, systems modelling methodology, socio-economic and environmental systems, operational research and management, informatics, artificial intelligence and soft systems including literary systems and theology ("Better Worldliness").

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Editorial

This issue of PARITANTRA contains two original contributed papers and five selected papers from forty-sixth (Inter) National Systems Conference (NSC-2023). The first contributed paper titled “Interpretive Structural Modelling of the Film System *Slumdog Millionaire*: An Interdisciplinary Perspective” by Dr Bani Dayal Dhir provides an excellent exposition of the intersection of film studies and Systems Methodologies, in particular, the Interpretive Structural Modelling (ISM) approach. The second contributed paper “Evolution, Meditation and the Causality of Consciousness” by Dr Priti Gupta, Geeta D Chandoo and Prof C M Markan explains the process of meditation in simple scientific and relatable terms and builds a case that the ability to wilfully raise our level of consciousness through meditation, like any other cognitive ability, has an evolutionary purpose.

The selected five papers from forty-sixth (Inter) National Systems Conference (NSC-2023) received the best paper award in oral sessions in five different categories– Agroecology-cum-Precision Farming Systems; Engineering Systems; Environmental Systems; Healthcare and Education Systems; and Information and Communication Systems. The papers were reviewed by experts and were duly revised for the publication in this issue. The forty-sixth (Inter) National Systems Conference (NSC 2023) was co-organized with the fifth International Dayalbagh Science of Consciousness Conference (DSC 2023) on 27 – 29 June 2023 at Dayalbagh Educational Institute in partnership with the Systems Society of India. The conference was organized in hybrid mode on the theme “Evolution of Homo Sapiens to Homo Spiritualis for Better Worldliness”.

We are eternally grateful for the inspiration, blessings, guidance and direction received from Revered Prof PS Satsangi Sahab, Founding President of the Systems Society of India; Chairman of the Advisory Committee on Education for Dayalbagh Educational Institutions (a non-statutory body constituted to serve as a think-tank to suggest inter-alia steps necessary for achieving highest levels of excellence); and the Chief Patron for the 46th (Inter) National Systems Conference, 2023.

We sincerely appreciate the efforts of all authors in contributing to this issue. We would also like to express our deep gratitude to the Editorial Board of the journal PARITANTRA for supporting and sponsoring this issue. We also gratefully acknowledge competent assistance from Dr Priti Gupta, for copy editing and proofreading and Mrs Aruna Sharma for design and layout.

Chief Editor and NSC-2023 Program Committee

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Contents

CONTRIBUTED PAPERS

Interpretive Structural Modelling of the Film System *Slumdog Millionaire*: An Interdisciplinary Perspective

Bani Dayal Dhira 1

Evolution, Meditation and the Causality of Consciousness

Priti Gupta, Geeta D Chandoo and CM Markan 11

SELECTED PAPERS FROM NSC - 2023

Smart Crop Health Monitoring System: An AI-powered Approach to Enhance Agricultural Productivity and Sustainability

Rohit Singh, Rishabh Kumar, Shikhar Pathak, Satyam Sharma and Priya Asthana 19

Applying Systems Approach to Engineering Pedagogy for a Sustainable Future

Shradha Kishore, Kushal Kishore and Kushagra Kishore 30

The Impact of Biomass Burning on the Oxidative Potential of PM_{2.5} at Dayalbagh, Agra

Muskan Agarwal, Isha Goyal, Gunjan Goswami, Simran Bamola and Anita Lakhani 41

Mediating Role of Consciousness in the Relationship between Resilience and Happiness among Healthcare Professionals

Preet Kumari and Jincy Cherian 54

Optical Character Recognition of Text in Textured and Newspaper Images

Sarika Singh, C Vasantha Lakshmi and C Patvardhan 63

Interpretive Structural Modelling of the Film System *Slumdog Millionaire*: An Interdisciplinary Perspective

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The research paper examines the intersection of film studies and Systems Methodologies, particularly John N. Warfield's Interpretive Structural Modelling (ISM), to explore the intricate layers of socio-economic exploitation depicted in the award-winning film system Slumdog Millionaire. The study employs ISM to unravel the hierarchical relationships among characters and themes within the film system. Through an analysis of the narrative structure and character dynamics, the paper uncovers the pervasive themes of power, control, resilience, and love embedded within the storyline. The application of Interpretive Structural Modelling (ISM) to the film system adds an interdisciplinary perspective to film studies blending scientific analysis with artistic interpretation. The paper underscores the universal relevance of Slumdog Millionaire as a poignant cultural text that resonates with the human narrative across diverse socio-cultural contexts.

Keywords – Interpretive Structural Modelling, Slumdog Millionaire, Hierarchy of exploitation

I. INTRODUCTION

Literary/film systems are perceived intuitive systems which largely belong to the typology of human activity systems rather than other types such as natural systems, designed physical systems or designed abstract systems. Among various types of systems, human activity systems constitute the social arena in which real problems abound [1].

Film is a potential art form as significant and profound as painting or music. Films, operating on a two-fold principle: to delight, aesthetically recreate society, culture and human experience. “Cinema’s dynamism, its capacity to arrange and rearrange time and motion, thus reveals its dimensions that are deeply social, historical, industrial, technological, philosophical, political, aesthetic, psychological, personal, and so forth. The aggregate of these multiple dimensions indeed is cinema” [2].

Film studies is a rapidly growing interdisciplinary domain of study that encompasses a critical analysis, interpretation, and appreciation of films as cultural artefacts and works of art. In today's digital age, media literacy is crucial. Film studies help individuals develop critical thinking skills to analyze and evaluate the messages conveyed through visual media.

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As a pioneering attempt, the paper situates the award-winning film system *Slumdog Millionaire* within the interpretative framework of John N Warfield's Interpretive Structural Modelling (ISM), a methodology of Interactive Management (IM) widely used in the domains of science, engineering, management, law etc. The researcher puts forth through the applicational case study of the fictional film system that the transdisciplinary concepts of Systems Methodologies can be applied with equal efficacy in the field of film studies to add the much-needed scientific and interdisciplinary correctives to this discipline.

II. FILM SYSTEM *SLUMDOG MILLIONAIRE*: A POLYSEMIC NARRATIVE

In the twenty-first century, Indian cinema has become a global enterprise. A 2008 British Drama, *Slumdog Millionaire* which won widespread acclaim was directed by Danny Boyle and written by Simon Beaufoy. It was co-directed in India by Loveleen Tandan. The film fused the elements of crime and adventure. In February 2009, *Slumdog Millionaire* won eight Academy Awards, including Best Picture, Best Director, and Best Screenplay. Foregrounding the theme of the victory of good over evil, the film is an adaptation of Indian author Vikas Swarup's novel Q & A published in 2005.

Slumdog Millionaire chronicles Jamal Malik's extraordinary odyssey from the impoverished slums of Mumbai, India. The narrative revolves around Jamal and his brother Salim. It portrays Jamal as compassionate, optimistic, and romantically inclined and Salim as aggressive and easily swayed by wealth and power. Latika, an orphan, serves as both Jamal's love interest and a source of conflict between the brothers. Jamal ascends from the slums through honest but meagre employment, while Salim descends into criminality, ultimately aligning with a ruthless gangster.

Jamal's participation in India's "Who Wants to Be a Millionaire?" provides the framework for the central narrative, wherein he astonishingly answers each question correctly, drawing upon his impoverished past. In the final moments of the film as Jamal reaches the last question of the game show, the host, suspecting Jamal is cheating to know the answers, gets him arrested and tortured by the police.

However, through a series of flashbacks, the spectators are told how Jamal comes to know the correct answers through experiences in his life. Eventually, the police officer while interrogating Jamal realizes the truth and lets him go. Jamal returns to the game show's set, successfully answers the final question, wins the grand prize of twenty million rupees and reunites with Latika. The film's powerful narrative showcases the triumph of the human spirit over adversity and the enduring power of love. It is a film in which 'Human Rights' are explicitly or implicitly the key concerns. Narrated by the survivor-victim, it presents a socio-cultural condition of the present day. The observation of Jean Jacques Derrida, the renowned French philosopher, is worth quoting:

"We must more than ever stand on the side of human rights. We need human rights. We are in need of them and they are in need, for there is always a lack, a shortfall, a falling short, an insufficiency; human rights are never sufficient" [3].

As a cultural text of the human narrative, *Slumdog Millionaire* implicitly touches upon the notion of cultural trauma. The characters Jamal and Salim are representatives of several other victims, displaced and marginalized in the society whose plight is very much similar. Their experiences are shared by many downtrodden across India. Cultural trauma, *"occurs when members of a collective feel they have been subjected to a horrendous event that leaves an indelible mark upon their group consciousness"* [4].

The film system is an illustration of how social inequalities produce suffering humans such as Jamal, Salim and Latika whose trauma is rooted in the stratified social structure. Latika's victimization puts the film within the taxonomy of 'atrocities narrative' which depicts how women are abused and deprived of dignity,

happiness and independence. In most of the ‘atrocity narratives’, the child – the victim is central to the theme. This aspect is best illustrated in *Slumdog Millionaire*. The suffering of the protagonist can be located within a larger trauma narrative. *“The abuse victim’s story is simultaneously an individual and a general”* [5].

The film system *Slumdog Millionaire* can be called a slum subaltern narrative. *“In the South Asian context the term ‘subaltern’ may be applied to those groups that have been subordinated in terms of class, caste, age, gender, and the like. Gramsci considered the subaltern as a historically determined category that exists within particular historical, economic, political, social, and cultural contexts”* [6]. According to Subaltern theory, norms are established by those in power and imposed on the ‘other’ who has had no voice because of race, class, or gender.

The fiction and the film have been acclaimed as well as criticized by critics. The slum dwellers may be the poorest of the poor, but they are to be respected as persons in a world. Amitabh Bachchan rightly reacted *“if SM projects India as [a] third-world, dirty, underbelly developing nation and causes pain and disgust among nationalists and patriots, let it be known that a murky underbelly exists and thrives even in the most developed nations”* [7].

III. INTERPRETIVE STRUCTURAL MODELLING: A BRIEF OVERVIEW

The American Systems Scientist John Nelson Warfield (1925-2009) is best known as the inventor of Interpretive Structural Modelling (ISM), Interactive Management and Generic Design Science. John N. Warfield in his book *Introduction to System Science* discusses two types of processes – neutral and specific. The neutral ones are readily identifiable as those which contain no carry-forward mathematics other than the mathematics of logic. The specific ones will contain some type of mathematics associated with numerical spaces from which the quantitative data such as time, intensity, mass, standard deviation, weight and reaction factor enter quantitatively. Specific processes are applicable to some kinds of systems only. The neutral processes of Nominal Group Technique (NGT) and Interpretive Structural Modelling (ISM) are sufficient for system science. The context for all systems applications is the problematic/ambiguous/complex situation. A problematic situation is polysemic in nature. For instance, in a literary/film system, a word/phrase/sentence can have multiple meanings, and an event/situation can have multiple connotations and can abound in structural complexity.

Warfield developed the methodology of Interpretive Structural Modelling (ISM) to analyze and represent the relationships among elements within a complex system. He developed it to decode the elements' hierarchical structure and their interdependencies within a system. ISM as a methodology specifically falls under the umbrella of Systems Analysis. *“The Interpretive Structural Model process transforms complex mental models of systems into visible, well-defined models useful for many purposes”* [8].

The first step in the formulation of Interpretive Structural Modelling involves the identification of the elements or factors within a system that need to be analyzed. These elements can be variables, factors, components, or any relevant entities. From a literary/film perspective, the elements can be characters and their complex relationships, diverse thematic strands and their interconnections or stylistic elements. In the system under consideration, we identify the elements and establish pairwise comparisons to establish relationships between the identified elements. The Structural Self-Interaction Matrix (SSIM) helps in making a graphical representation of these comparisons to help determine which elements influence or are influenced by others. Based on the pairwise comparisons, a Reachability Matrix is constructed. The matrix represents the reachability relationship among different elements, indicating whether one element can directly or indirectly influence another. The reachability matrix is used to create a directed graph or network

that visually represents the hierarchical structure and relationships among the elements. This graph is often referred to as the "ISM Digraph." In Level Partitioning, the ISM Digraph is partitioned into levels based on the relationships and dependencies identified. This helps in understanding the hierarchical structure of the system. The final step involves interpreting the ISM Digraph and analyzing the relationships to gain insights into the structure of the system.

IV. INTERPRETIVE STRUCTURAL MODELLING OF FICTIONAL FIM SYSTEM *SLUMDOG MILLIONAIRE*

The interactive management techniques, particularly the neutral processes of Nominal Group Technique (NGT) and Interpretive Structural Modelling (ISM) transform unclear, poorly articulated mental models of a system, from the fictional literary/movie field, into a visible well-defined hierarchical model, which assumes particular importance in managing complexity in highly complex situations. The process of Structural Modelling consists of several phases. An object system, the film system *Slumdog Millionaire*, a complex and ambiguous system, has to be described and depicted as a well-defined representation system.

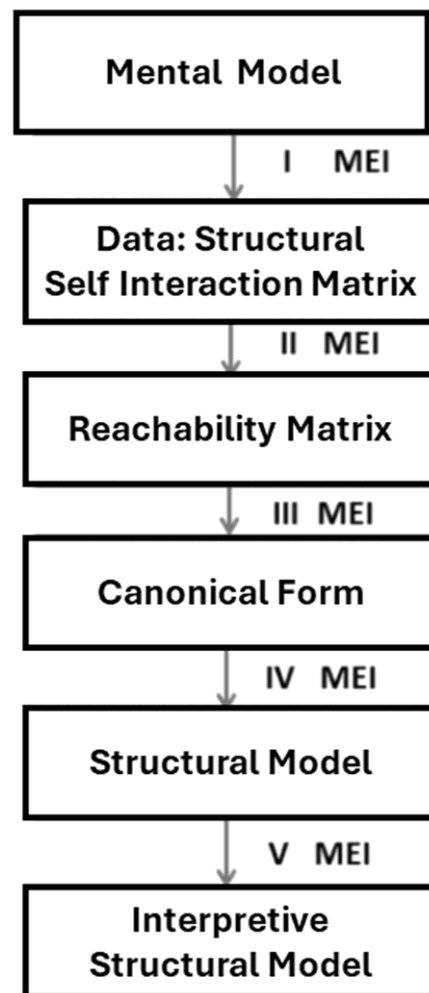


Fig. 1. Model Exchange Isomorphisms (MEIs)

Five Model Exchange Isomorphisms (MEIs) are readily identified from the mental model through data; Structural Self Interaction Matrix, Reachability Matrix, Canonical Form, Structural model to Interpretive Structural Model (Fig. 1). The perspective adopted in this study is of a researcher of English literature and systems science, and the model used is descriptive, rather than normative or prescriptive. Primitives employed in this modelling study consist of an appropriate contextual relationship given by R: exploit(s) socio-culturally-economically; and the element set given by S: Jamal Malik, Latika, Salim Malik, Maman, Javed (Boss of a criminal gang), Prem Kumar (host of the game show), Police Inspector, Head Constable, Arvind the blind child and the other children in Maman's gang, Jamal's mother, Adele (the American Tourist), and the Religious Fanatics and the rioters.

The first model exchange isomorphism (MEI 1) of ISM transforms the mental model into a data set: Structural Self Interaction Matrix(SSIM). This is accomplished using the following interrogation format:

Element i

Relation R

Element j

Is element i connected by relation R with element j?

Participant responses, individual or group, reflect judgement as to the existence of a relation between any two elements and the associated direction of the relation. If the relation R holds from element i to element j and is not in both directions, the modeller or group leader responds with a V as symbolic of the direction from the upper element i to the lower element j. If the group perceives that the relation holds from element j to element i but not in both directions, entry A is made as symbolic of the direction from the lower displayed element j upto the upper displayed element i. If the relation is perceived by the group as valid in both directions, the group leader responds with an X as symbolic of a valid relationship in both directions between elements i and j. If the relation between the elements does not appear valid, the appropriate response is a zero (0). A possible Structural Self Interaction Matrix (SSIM) of the embedded object system (or representation system) of *Slumdog Millionaire* under consideration is given in Fig. 2.

A	0	0	A	A	A	0	A	A	0	1 Jamal Malik
0	0	0	0	0	0	A	A	A		2 Latika
A	0	0	0	0	0	A	A			3 Salim Malik
0	0	V	0	0	0	0				4 Maman
0	0	0	0	0	0					5 Javed (Boss of a criminal gang)
0	0	0	0	0						6 Prem Kumar (host of the game show)
0	0	0	0							7 Police Inspector
0	0	0								8 Head Constable
0	0									9 Arvind the blind child and the other children in Maman's gang
A										10 Jamal's mother
										11 Religious Fanatics and Rioters

Fig.2. Structural Self Interaction Matrix

The transformation from the SSIM format to the Reachability Matrix format is accomplished by transforming information in each entry of the SSIM into 1s and 0s in the Reachability Matrix. If the (i,j) entry of SSIM is a 0, then both the (i,j) and (j,i) entries of the Reachability Matrix become 0. Likewise, if the (i,j) entry of the SSIM is an X then both (i,j) and (j,i) entries of the Reachability Matrix become 1. If the (i,j) entry in the SSIM is a V, the (i,j) entry in the Reachability Matrix becomes 1 and the (j,i) entry becomes 0. Likewise, if the (i,j) entry in the SSIM is an A the (i,j) entry in the Reachability Matrix becomes 0 and the (j,i) entry becomes 1.

The resultant Reachability Matrix for this representation system is given in Fig. 3. To transform the reachability matrix into a canonical form, it is first converted into a lower triangular format simultaneously identifying strong relationships between pairs of elements as cycles.

0	1	2	3	4	5	6	7	8	9	10	11
1	1	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	0	0	0
4	1	1	1	1	0	0	0	0	1	0	0
5	0	1	1	0	1	0	0	0	0	0	0
6	1	0	0	0	0	1	0	0	0	0	0
7	1	0	0	0	0	0	1	0	0	0	0
8	1	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0
10	0	0	0	0	0	0	0	0	0	1	0
11	1	0	1	0	0	0	0	0	0	1	1

Fig. 3. Reachability Matrix

The intermediate modified reachability matrix with lower triangularization (LTP) and identification of cycles if any is shown in Fig. 4.

0	1	2	3	4	5	6	7	8	9	10	11
1	1	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	0	0	0
4	1	1	1	1	0	0	0	0	1	0	0
5	1	1	1	0	1	0	0	0	0	0	0
6	1	0	0	0	0	1	0	0	0	0	0
7	1	0	0	0	0	0	1	0	0	0	0
8	1	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0
10	0	0	0	0	0	0	0	0	0	1	0
11	1	1	1	0	0	0	0	0	0	1	1

Fig. 4. Modified Reachability Matrix LTP: Lower Triangularization and Cycle Identification

Minimum Edge Adjacency Matrix (Canonical Form) MEP is then obtained as shown in Fig. 5 by reducing to zero all diagonal entries as well as those which can be inferred through transitivity in Matrix LTP of Fig. 5.

0	1	2	9	10	3	6	7	8	4	5	11
1	1	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	0	0	0
3	1	1	0	0	1	0	0	0	0	0	0
6	1	0	0	0	0	1	0	0	0	0	0
7	1	0	0	0	0	0	1	0	0	0	0
8	1	0	0	0	0	0	0	1	0	0	0
4	1	1	1	0	1	0	0	0	1	0	0
5	1	1	0	0	1	0	0	0	0	1	0
11	1	1	0	1	1	0	0	0	0	0	1

Fig. 5. Minimum Edge Adjacency Matrix (Canonical Form) MEP

Structural Model as Digraph G, as shown in Fig. 6, is now determined from the connectivity information contained in the foregoing Minimum Edge Adjacency Matrix (Canonical Form) MEP of Fig. 5.

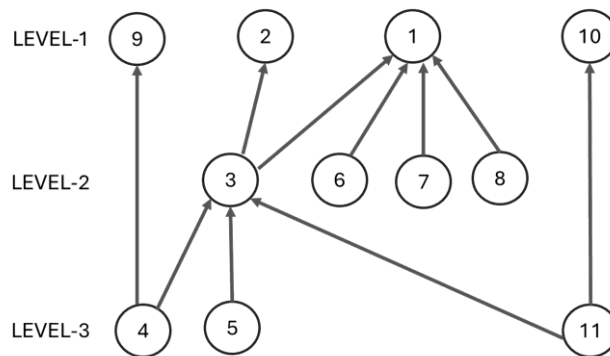


Fig. 6. Structural Model as a Digraph G

Finally, the Interpretive Structural Model (ISM) of Fig. 7 is obtained by superimposing the subjective contextual material on the Structural Model as Digraph shown in Fig. 6.

The paper amply demonstrates how the unclear and complex initial model of the film system *Slumdog Millionaire* has been progressively transformed through the use of the ISM of Fig. 7 which is substantially close to normality and within easy human comprehension. The film system is a poignant portrayal of the exploitation and marginalization of individuals by societal structures and power dynamics.

The formal ISM (Fig. 7) clearly shows three hierarchical levels depicting degrees of exploitation among the eleven 'major' identified elements or characters or actors in the fictional film system. The top level represents the miserably exploited characters represented by the Protagonist Jamal Malik who is the most exploited character/element in the film system followed by three important characters viz, Latika, Arvind and other children and Jamal's mother. Jamal is victimized by Mamman, Salim Malik, Prem Kumar, the Police Inspector and Head Constable. Jamal is also indirectly exploited by religious rioters by whom his mother got killed and he and his brothers became orphans.

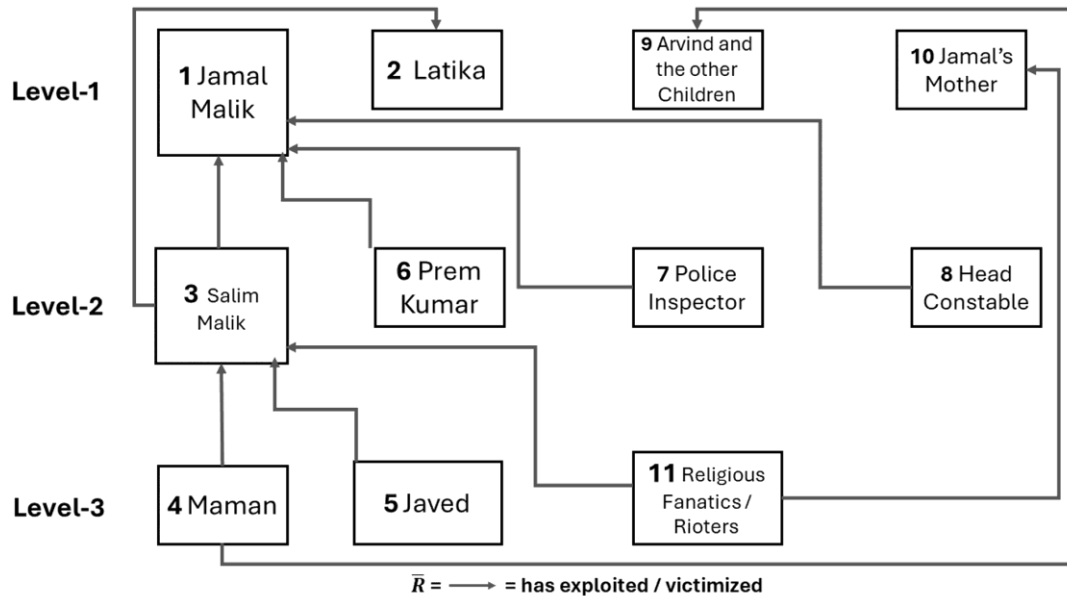


Fig. 7. Interpretive Structural Model of the Film System *Slumdog Millionaire*

The second level represents less exploited characters such as Salim Malik who is both victimizer as well as victimized. If Salim Malik exploits Jamal Malik and Latika, he is also victimized by Mamman, Javed and religious rioters. At this level, we also have other characters/elements viz., Prem Kumar, Police Inspector and Head Constable who exploit Jamal.

The third level represents ruthless exploiters - Mamman and Javed. Mamman victimizes the majority of characters in the film system including Jamal Malik, Latika, Arvind and other children and Salim Malik. Javed is the slum lord and also the gangster who exploits Salim Malik who joined Javed's gang.

The precise formal ISM (Fig 7) depicts differences in the degree of exploitation and also brings out various forms of exploitation prevalent in Indian society, particularly in the context of the slums of Mumbai. The film system highlights economic exploitation through the experiences of Jamal and Salim. Their exploitation as children by criminals like Mamman illustrates the harsh realities faced by many children living in poverty in the world. Apart from socio-economic exploitation, the film system also depicts sexual and media exploitation. Latika, the female protagonist, is trafficked and forced into prostitution which symbolically brings out the vulnerability and abuse of women and children living in poverty. The film system also showcases how the binary opposition of exploiter/ exploited comes into play with transformation in the characters of Salim and Police Inspector.

V. CONCLUSION

Literary theory and Film studies are domains which would certainly benefit from the use of transdisciplinary Systems Methodologies like Interpretive Structural Modelling (ISM) which not only help coherent representation of complex films and literary systems but also enable literary researchers to blend artistic sensibility with scientism. The domain of film studies is inundated with several approaches such as Auteur theory, Genre Theory, Cognitive Theories, Marxist Theory, Psychoanalytic approaches, Postcolonial theories among others. However, the application of Systems Methodologies needs to be encouraged in sync

with the contemporary intellectual spirit of collaboration and interdisciplinarity.

Application of Interpretive Structural Modelling (ISM) to the film system *Slumdog Millionaire* allows a systematic analysis and depiction of the hierarchical relations among characters highlighting themes of power, control, and social stratification. It also unravels the themes of resilience, exploitation and love.

The film system *Slumdog Millionaire* is universal and relevant as a cultural text of human narrative. It has captivated the attention of a global audience as it depicts the slum reality of the metropolitan cities of the world today. Slum-Subaltern has got its voice heard to some extent, seeking redressive measures. The rags-to-riches story of Jamal finally climaxing in emotional union with Latika affirms human values of love and compassion in a consumerist society, providing some consolation to the disillusioned audience of today, where only one relationship matters that is of buyers and sellers.

As a footnote, the researcher would like to mention the emergent pattern of transitions in consciousness levels of the “three musketeers”, viz. Jamal, Salim and Latika, in the cinematic-literary creation *Slumdog Millionaire*. Subjected to the maximum degree of exploitation/victimization and therefore suffering, Jamal succeeds in making a transition from material/physical consciousness through cognitive/mental consciousness to the level of almost spiritual consciousness propelled by the force of true love. Latika being the next most victimized/exploited musketeer with no role as exploiter shows the emergence of transition from material consciousness to almost spiritual consciousness as a result of reciprocating the true love of Jamal. The middle musketeer Salim while also considerably exploited/victimised has a dual role of occasional exploiter showing the emergence of transition from material consciousness to almost spiritual consciousness as a result of reciprocating the true love of Jamal. The middle musketeer Salim while also considerably exploited/victimised has a dual role of occasional exploiter/victimizer of both the other musketeers and others, and therefore shows emergence in transition between consciousness levels from material/physical level to mental/cognitive level only.

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Evolution, Meditation and the Causality of Consciousness

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Over the past decade there is a renewed curiosity about meditation in the scientific community. The scope of the scientific discussion on meditation however is very constricted. While the benefits of meditation such as enhanced cognition, improved health and brain plasticity, regulated emotions and general well-being are widely talked about, the subjective aspects of meditation are still considered 'mystical' and outside the purview of scientific investigation. Through this paper we attempt to bridge this gap and highlight why it is important to look beyond the obvious positive effects of meditation towards addressing the more foundational question of why meditation is a vitally important aspect of the human system and why should everyone embrace this practise. Evolution endowed the human system with the capacity to control attention and thereby enabled us to consciously/wilfully raise our levels of awareness/consciousness. These raised levels of consciousness in turn have causal effects on our being, leading not just to a better-quality life but to an overall acceleration of the human evolutionary process. This brief note is our attempt as scientists to understand what exactly happens during meditation in contemporary scientific terms and raise some important questions. We also highlight the current challenges in studying meditation scientifically and point to some directions in which the science of meditation should proceed in order that all aspects of the meditational process can be brought into mainstream scientific discussions.

Keywords: evolution, causality, consciousness, science of meditation

I. MEDITATION THROUGH HUMAN EVOLUTION

Meditation is an umbrella term for different contemplative practices that absorb our attention, and which require us to focus inwards using a variety of techniques [1], [2]. Over the last decade or so, meditation has garnered a lot of interest from the scientific community. Primarily because of its positive effects on health and well-being. Historically speaking, meditation seems to have emerged as a natural human capacity based on introspection at some point during evolution [1]. Even though the precise origins of meditation have been hard to determine, given their ancient roots in orally transmitted practices, the earliest written records of meditation come from the Hindu Vedas around 1500 BCE [3]. There is a common misconception in the contemporary and secular Western world that meditation as primarily an Eastern practice. This view, however, is far from the truth. Much like how cooking practices emerged as a universally human method for transforming raw ingredients into food to nourish the body, various practices that qualify as meditation emerged almost simultaneously in different cultures at different locations at similar points in time [4]. In fact, many indigenous forms of Western meditation have existed since the ancient Greeks [5]. The European people, that populate much of the West have practiced a variety of indigenous meditational forms [6]. Given

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that the ability to meditate developed in humans at a distinct evolutionary stage, there are reasons to believe that there might be an underlying common reason or purpose among all these seemingly distinct meditational practices across the world. Even though the techniques and practices may appear different on the periphery, they might all eventually be leading to the same inner states of experience or posit a similar evolutionary advantage.

From a neuro-biological standpoint, the development of the parietal lobes was a major transformational stage in Humans and Neanderthals. It was a key evolutionary progression that awakened the capacity to pay attention and live in the moment. Humans (*Homo sapiens*) went on to expand the advantage to the point where individuals could consciously control their attention and their minds. The study of the evolution of the parietal lobes, an important part of the attention network, allowed researchers to determine their impact on the ability to stay focused on one objective over time in the face of internal and external distractions. Considering the close relationship between attention and meditation, it could be inferred that the capacity to meditate emerged around this evolutionary stage [7]. Another significant evolutionary change in the human brain was the development of the association cortex. As the brains got bigger, their motor and sensory cortices barely expanded. Rather it was the regions in between them that expanded. These regions came to be known as the association cortex. The association cortices are crucial for the kinds of thought that humans excel at e.g. making decisions, retrieving memories and reflecting on ourselves [8]. They are also unusual in their wiring, unlike other cortices association cortices link to one another with wild abandon allowing for some amazing feats. e.g. these new brain regions can communicate without any input from the outside world, discovering new insights about our environment and ourselves [9]. It is possible that the evolution of the parietal lobes together with the association cortex were a turning point in humans as they equipped the human body with the hardware needed for partaking meditational practices.

Over the past decade meditation has received a lot of attention from medical experts, cognitive scientists and neurobiologists alike. Several studies focussed around the positive effects of meditation such as enhanced cognition, improved health and brain plasticity, emotional regulation and well-being have given valuable insights about meditation. However, the foundational question of what is the purpose of meditation for a human being is still treated as ‘mystic’ and kept outside of scientific discussions. Humans are at the apex of the evolutionary tree and it is only the human system that is equipped with the neural structure to engage in meditational practise, speaks to the fundamentality of this process for us. Many intriguing questions about the practise of meditation remain open: Why should anyone meditate? What happens during meditation? What could be the possible evolutionary advantage of meditation? Are different meditations really different or is there a grand ladder or hierarchy of consciousness that each of these forms of meditation allow us to traverse? As scientists we are urged by our natural curiosity to understand this. This article is a step towards finding answers to some of these questions and articulating them in simple scientific terms. The main problem with the current research on meditation is that more than often meditation is just treated like a black box process, and the internal phenomenon that arise during the meditational process are simply regarded as scientifically incomprehensible. The reason why these aspects of meditation have not been scientifically questioned is not because they are incomprehensible in nature, but because of the limitations of science itself. If the evolutionary significance of meditation is indeed beyond just good health, this knowledge should be disseminated to all and therefore the scientific curiosity to understand all aspects of meditation needs to be encouraged.

II. MEDITATION AND THE HIERARCHY OF CONSCIOUSNESS

Meditation is an internal journey of awareness that begins when one blocks off the external senses and focusses attention inwards. In some sense how perception leads to awareness of the outside world, meditation allows us to be aware of our internal world. During this inward journey individuals gradually

ascent to experience varying levels of consciousness or awareness, each offering its own unique characteristics and benefits. Through seemingly different practices, the underlying common principle in meditation seems to be to develop mastery of self-observation or self-awareness. Like in any other journey, to mark the distance that has been covered or to measure the internal progress that has been made, there are internal milestones. These milestones are internal experiences that are hierarchically organized and that are common across different practices and are reproducible [10]. The subjective experience of these internal milestones comprises vivid images or internal sounds (meditators often describe these experiences as something like they have never seen before or relate the sounds to those of some known musical instruments). For a more objective analysis one can examine the dominant brain frequencies during meditation. Many studies have shown that as practitioners progress in their internal journey, the dominant frequencies in their brain during the meditation practise and also in the restful state progressively becomes higher [11], [12]. The higher the state of consciousness achieved, the larger is the brain area involved and the higher is the dominant frequency [13], [14]. Studies have even tried to localize the source of these high frequencies and have found that most high frequency activity during meditation arises at different nodes in the association cortex [9]. Regular practise of meditation must therefore be wiring the association cortex in different ways. As discussed earlier, these association cortices are unique to the human brain. They liberate us from making rapid responses like other mammalian brains and allow us to consciously respond to any situation. Thus, it is possible that the positive effect of meditation on creative thinking and decision making has its roots in the way regular practise of meditation affects the wiring in the association cortex.

If meditation is indeed an internal journey of self-observation and self-awareness, how does one gauge one's progress in the inward journey? The eastern philosophical view offers a plausible explanation. As explained in the eastern Vedic scriptures and very eloquently articulated using modern systems theory and graph theoretic techniques [27], [28], there are three fundamental layers/divisions in the human system. The material layer or the body, the layer of the mind and the layer of the subtle aspect of our existence, the source of consciousness, the subtle-mind [15]. Each of these three grand divisions is further subdivided into sublevels each with hierarchically increasing levels of consciousness [27], [28]. While the sublevels of the material body are well known 'Six Chakras' described in Eastern Philosophy. The lower sublevels of the second grand division of Universal Mind transcend through regions of Shiva-Brahma-Vishnu upto Trikuti as described in the Indian Philosophy. The higher sublevels of the second grand division beyond these have been mystical and are grossly summarized as 'thousand petal lotus' or Sahas-dal-kamal. Some practitioners of transcendental meditation who continued to strive to unravel higher sublevels revealed these elusive levels experienced by them. The details of the sublevels of the three grand division have been very eloquently articulated using modern systems theory and graph theoretic techniques in [27], [28].

In line with these three divisions, meditation also happens at three different levels. The first level of meditation is when our mind observes the body. If we take the example of meditational practises in most Hindu or Buddhist traditions the first level involves focussing one's attention onto certain nerve centres called 'chakras' that allow us to gain awareness of the body. Even though the human body functions autonomously, by practising this regularly we slowly gain control over some of the body processes. It is at this level that the various benefits of meditation on our physical health become manifest. The second level of meditation is when the subtle mind observes the grosser mind. At this level of meditation, the practitioner is able to observe his mind and is able to gain control over several mental phenomenon leading to benefits on mental health such as enhanced cognition, regulated emotions etc. At the third level of meditation there is no concept of observation but this is the level of absolute awareness and is difficult to describe in current scientific terms. However, the known manifestations of this level of awareness are feelings of absolute love, compassion, awareness of one's purpose and oneness with the universe. Within these three broad divisions, there are other finer divisions each corresponding to a different level of consciousness or awareness each with its unique properties or subjective experiences. As the practitioner progresses in his internal journey,

he experiences different levels of awareness when there is a frequency match or ‘resonance’ between the frequency associated with that level of awareness and the dominant operating frequency of the practitioner’s brain. Some recent experiments undertaken at the Dayalbagh Educational Institute have unraveled the underlying Power Law of Meditational Consciousness that attempts to associate the experiential sublevels of upper two grand divisions of meditational consciousness [29] with experimentally measurable dominant frequency correlates associated with some of these sublevels. Since during meditation one is self-absorbed and it is impossible to indicate the sublevel of consciousness one is experiencing at any point in time, a novel methodology has been adopted by the researchers called the Analytical Hierarchy Process (AHP) to associate experiential self-reports with experimentally measurable dominant frequency correlates. Power Law of Meditational Consciousness clearly reveals the hierarchical association between increased frequency ‘resonating’ with higher meditational consciousness.

An abstract way to understand these complex dynamics would be to consider the sampling theorem, a very compelling theorem in physics which says that to capture the properties of any signal and to be able to reconstruct it, one needs to sample it with a frequency that is at least twice the frequency of the signal itself [16], [17]. We can roughly use this as an analogy to explain what happens during meditation. The three divisions in the human system (the body, the mind and the subtle mind) operate at different frequencies. According to the *Spanda* principle of Kashmir Shaivism or the philosophy of vibration, the body operates at lower frequencies than the mind which in turn operates at frequencies lower than the subtle mind [18]. The mind that operates at frequencies much higher than the body, is this able to observe (and perhaps causally influence) the body, the subtle-mind that works at an even higher frequency than the mind is able to observe and influence the mind and the body and this creates an internal hierarchy of observers within the human system.

III. THE CAUSALITY OF CONSCIOUSNESS

Another important aspect of meditation worth some consideration is its ability to create lasting structural changes in the brain. The question of how meditation, a seemingly introspective mental phenomenon, causally influences the brain is quite an intriguing one. Through meditation we experience different levels of consciousness, but, since western science regards consciousness or awareness as simply an epiphenomenon of an active brain (with no causal role), it is difficult to correlate how meditation might be bringing about these physical changes in the brain. However, let us consider the following argument about the nature of our experiences. If our experiences were not conscious or they were outside of our awareness, would they still have the same effect on our brains? Put in other words, would a person in an unconscious state, experience the world and have similar memories as a conscious person, even if their environments were exactly the same? Is there anything like an unconscious experience? It seems quite intuitive, that it is the ‘conscious’ nature of our experiences that allows them to get imprinted on our brains and we cannot be wrong in saying that experiences are implicitly ‘conscious’. The different levels of consciousness that we explore during meditation practice might be deciding the depth of our conscious experience, with each new level opening up some new dimensions to our awareness.

Interestingly, considerable scientific evidence has accumulated over the years that suggests that our experiences do have a direct role in wiring our brains. Early experiences in life are particularly very vivid and have lasting impressions on our life. Even for the development of the brain, early experience has been shown to be vital for sensory organization in the brain. The concept of critical learning periods put forth by Hubel and Weisel has its roots in the importance of early experience [19]. Hubel and Weisel experimented with kittens and showed that by artificially blocking one of their eyes in the very early weeks of development, kittens do not develop critical neural circuits required for normal vision even when they are allowed to see

from that eye later in life. Similar lack of early experience has been shown to have detrimental effects for the normal development of brain circuits involved in language processing, social integration, audition and many other modalities. Also, our experiences throughout our life continue to shape our brains. If an experience is not conscious (or not in our awareness), irrespective of whether it is early or late in the developmental timeline, it does not have any significant effect on the brain.

Another important evidence towards the causal nature of consciousness is that raised levels of consciousness have been shown to affect even our genetic fabric. E.g. the regular practise of raising levels of consciousness through meditation has been found to alter the genetic expression of the immune system [20] and also the ageing process [21]. In another rather unusual recent study, researchers have (perhaps unintentionally) used the causal nature of consciousness in treating Amblyopia. Amblyopia or Lazy eye is a common disorder of the eye in children where the connection of one eye to the brain becomes weak due eye misalignment, an imbalanced refractive state, or obstruction to form vision. Researchers showed that vision can be restored in the weak eye, even after the critical learning periods have passed, by using therapy that involves anesthetizing the healthy eye (or making the healthy eye unconscious) thereby allowing the weaker, but conscious, eye to reinstate its connections with the brain [22]. Therefore, there are already several examples of how different levels of consciousness causally influence the brain. This just needs to be viewed with a new perspective.

In order to understand the underlying mechanisms that lead to all the meditation induced changes in the brain, one needs to dig deeper to appreciate what exactly happens during meditation. As a person progresses in his internal journey reaching higher states of consciousness, three things happen. First, large parts of the brain seem to get activated, second, the dominant brain frequencies increase and third, through focused attention, one is required to hold these states. By regularly practicing this, the state becomes hardwired and can be easily achieved repeatedly with lessor effort. This is very similar to how the brain adapts to or learns different skills involving multiple brain regions e.g. playing a musical instrument or driving a car. When one is learning these skills, it takes immense focus of attention to synchronize the different parts of the brain involved. With regular practice, the task becomes easier and requires much less effort. This hardwiring of brain states that regular practitioners experience, reflects as structural changes in the brain, similar to how complex skills are acquired externally. Some higher meditative states, however, cannot be hardwired and need immense focus of attention to achieve every time. Very similar to, for example, how one needs immense focus of attention to solve a novel mathematical problem. Another way to understand this is to look at meditation as a process that is analogous to perception, but in our internal environment. How the perception of external or environmental sensory experiences shapes our brain, internal experiences too possess a similar causal capacity to wire and rewire our brains. The main point therefore is, that our conscious experiences have the causal capacity to shape our brains, whether they are internal or external. If an experience is not conscious or does not reach the threshold of awareness, it doesn't leave an imprint on the brain. As the depth of our awareness increases, at different levels of consciousness during meditation, the brain gets wired in new and unexpected ways. These novel connections possibly underly the cognitive and creative enhancements that are observed in regular practitioners.

The question of how something non-physical like a 'conscious' experience, interfaces with the physical brain however still remains open. There needs to be something that lies at the interface of the physical and non-physical that facilitates the continuous wiring and rewiring of the brain based on experience. While such a mechanism is yet to be found, electrical synapses or gap junctions could be a potential candidate. In our previous work we had discussed a 'Quantum Hebbian' model of learning in the brain that explained how the brain operates in two different regimes, a very fast quantum regime and a slow classical regime and this helps us understand how conscious experiences possibly lead to the formation of neural assemblies [23]. Gap junctions are abundantly found in the developing brain and at the location of the chakras [24].

They have been implicated in synchronizing brain activity with great temporal precision and also seem to have an important role in brain plasticity [25].

Coming to the much-overlooked aspect of meditation i.e. the evolutionary role of raised consciousness for human beings. Humans acquired the ability to focus attention and to meditate at some point during evolution. The very reason that evolution brought about this change in the human system, it must have had some survival advantage or at least a role to play. But what is the evolutionary significance of the practise of meditation? The answer to this question lies in understanding evolution itself. Humans as a race are continuously evolving. However, the direction that evolution takes and the forces that govern it keep changing with time. If one looks at the way evolution has shaped over the past million years, natural selection was always the prime shaper of the human population and DNA sequence analysis has revealed just how powerful the force had been since the dawn of civilization. However, owing to the tremendous advances in medical science humans have now almost transcended natural selection. Additionally, we have evolved new physical and mental capabilities, particularly through the use of science and technology. While the natural process of evolution is definitely moving towards better survival, human beings have practically taken over their evolution in their own hands. While this is an extremely empowering situation, it is also worrisome because unknowingly humans are drastically moving away from nature's design. Even though urbanization has brought in several physical comforts, our physical and mental health levels are at an all-time low. This is because our lives are not aligned with nature. It is here that meditation fits in. Meditation not only allows us to recalibrate and connect with our inner self, thereby creating a peaceful inner environment that leads to good health and better cognition, but it also allows us to accelerate our evolution in the natural direction. Practicing meditation by raising levels of consciousness lead to more evolved human beings who can function at their highest potential physically, cognitively and emotionally. By regularly practicing meditation and internally raising our level of consciousness, we not only alter our brain circuits to achieve highest physical and cognitive benefits, but also change our DNA in such a way that even future generations can reap these benefits. If evolution takes a natural course, these changes would still happen, but would take hundreds of years to manifest. Therefore, Meditation, a seemingly insignificant practice, in reality has the power to accelerate the evolution of entire human kind.

IV. EDUCATION AS A PRECURSOR FOR MEDITATION

To build a case for why meditational practises should be embraced as a cultural change by everyone, let's take the example of education. Recent research has shown that culture appears to hold greater adaptive potential than even genetic inheritance in driving human evolution [26]. It is hard not to appreciate the transformational role education has played in human civilization. Ever since education became formalized and culturally accepted and movements for free education began springing up in different parts of the world, tremendous social developments began to happen around the globe. These social developments ensured that education appropriate for their particular developmental stage was made available to all. The push for universal education also encouraged the efforts to extract poorer children from the farms and factories where they were put to work in often inappropriate conditions with few protections. Higher education shaped the skills, attitudes, and beliefs of people and played a role in shaping the norms and values of a particular society. These values eventually defined the community structures people built, the goals they strived for, and how they help advance global development. In a nutshell, education demonstrated the power to bring individuals and communities together, equipping them with the abilities and knowledge to greatly enhance their lives and overcome pressing challenges. Institutionalizing education thus greatly benefited the human civilization in unimaginable ways.

The challenges that the world faces today are of a different kind. In a literal sense, we've extended our natural capabilities with technology. Education and modernization have made lives very comfortable, yet people are unhealthy, stressed and unhappy. This is because while humans evolved, they did not learn to use their consciousness in the best possible way and therefore to create this awareness, institutionalizing

meditation is the need of the hour. The ability to meditate, that is unique to our species aligns us with nature and is designed to get us in touch with our inner being, bringing back our bodies and mind to a state of homeostasis with the internal and external environments, in a manner similar to sleep, but with benefits much beyond a healthy body or mind. Regular practise of raising our levels of consciousness through meditation has the capacity to transform the inner workings of our body and mind to work at their most optimum capacity thereby creating human beings who can work at their maximum potential. By regularly practising meditation we also change our DNA in a way that even the future generations would bear the fruit of our practise. Therefore, if like education, the practise of meditation can be institutionalized, the positive impact of that on the evolution of humankind would be tremendous, almost unimaginable.

V. DISCUSSION AND CONCLUSION

This article explains the process of meditation in simple scientific and relatable terms and builds a case that the ability to wilfully raise our level of consciousness through meditation, like any other cognitive ability, has an evolutionary purpose. By practising meditation and raising our level of consciousness, not only can we improve our physical and mental health but we can enable our body and mind to reach their highest potential. Regular practise of meditation, has the capacity to alter our brain structure and our DNA with benefits that would be carried even beyond our generation and create humans with superior physical, mental and emotional faculties. Therefore, meditation should not just be looked at as an exercise for holistic health, it is an evolutionary tool that only humans possess, which if effectively used can accelerate evolution itself.

The scientific challenge of understanding meditation is a significant one. Not because it is not comprehensible, but because contemporary science lacks the tools and terminology to explain all aspects of meditation. But, if given enough thought, like any other physical or mental ability, this too can be put through rigorous scientific investigation. A promising way forward in the endeavour to understand the meditational process in greater depth would be to create models that can then be verified through carefully designed experiments. Significant modelling efforts in this direction have been made [27], which stimulate the need for further experimental studies to be undertaken. But even before that, scientists across the world need to embrace the idea that the ability to meditate or focus attention inwards and wilfully experience states of higher consciousness is an inherently important aspect of human existence, and therefore, deserves much more attention.

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Smart Crop Health Monitoring System: An AI-Powered Approach to Enhance Agricultural Productivity and Sustainability

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Agriculture's productivity and sustainability heavily depend on crops' health. However, monitoring the health of crops can be a daunting task for farmers, as it requires continuous surveillance of crops and interpretation of data. In recent years, advances in technology have led to the development of smart crop health monitoring systems that leverage the power of Artificial Intelligence (AI) to automate the process of monitoring and analyzing crop health data. This paper presents an overview of a smart crop health monitoring system that uses AI algorithms to analyze the collected data and identify any anomalies or diseases affecting the crops. The proposed system can alert farmers in real-time about any crop health issues and provide them with actionable insights to take preventive measures. Additionally, the system can generate crop health reports to help farmers make informed decisions regarding crop management practices, such as irrigation, fertilization, and pesticide application.

Keywords— Crop health, Android application, Machine learning, Rover, Disease detection

I. INTRODUCTION

The agricultural sector provides a living for almost 58% of Indians. India is the second-largest producer of the two main staple foods in the world—rice and wheat. Several dry fruits, agriculturally based textile raw materials, roots, tuber crops, pulses, coconut, sugarcane, and a range of vegetables are among the goods produced in India that are currently rated second globally. At a time when the nation wants to increase agricultural production but also assure food security and nutrition for its expanding consumption needs, it is estimated that 15–25% of India's potential crop production is lost to pests, weeds, and diseases.

The objective behind developing the rover is to overcome the problem of crop destruction by pre-determining diseases in the crops and providing essential nutrients to the plants.

The development of the rover is done in two phases.

- a) Maneuver the rover in the agriculture field using an Android application that is interfaced by Bluetooth.
- b) Detection and classification of the disease found in different crops.

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A. Mobility

This rover is made up of an Arduino UNO, which is referred to as the rover's brain. With the aid of smartphones, a motor driver and DC motors are utilized to freely move the rover. A Bluetooth device serves as a communication channel between the Arduino UNO board on the smartphone and the motor driver. The design of the rover is based on the six-wheel framework that enables the rover to drive easily through the uneven terrain of the agricultural fields. This rover is using a 2200 mAh lithium polymer battery to provide 11.1 volts of power.

B. Android Application

The Android application provides an interface between an Android device and an Arduino UNO. This code enables the Raspberry Pi4 to collect the image data necessary for disease diagnosis and also allows the user to give the commands to the rover which requires moving around the field. All rover operations are completely controlled by Android Application.

C. Disease Detection

The Raspberry Pi 4 and camera module will be used for plant disease detection. The camera module is used to capture a photo using the Android app and sends it to the Raspberry Pi, which classifies and detects the diseases before sending a message to the mobile device that is linked to the server. SVM (Support Vector Machine), is a machine learning classifier used for the classification of diseases in plants based on the symptoms in plants.

II. RELATED WORK

Bluetooth technology has risen substantially over the past few months. The technology is needed to address the demands of numerous needs nowadays with the help of Bluetooth-enabled remote-controlled robotic cars. Therefore, with the aid of straightforward architecture, a robotically controlled car was designed and developed using open-source hardware [1]. For conducting an in-situ scientific study of goals that are distant by many meters to tens of kilometers, rocker bogies are crucial. Many wheels or legs are used in the complex mobility designs of today. The hostile Martian environment exposes them to mechanical breakdown. a four-wheeled rover with an effective suspension system was developed with a high degree of mobility that can travel through uneven terrain [2]. Low-level picture segmentation problems have been resolved using the well-known K-Means clustering method. Using a user-defined initial set of clusters that is updated with each iteration, initially identify the pixels that are primarily green in color. Following that, these mostly green pixels are muted based on predetermined threshold values computed with Otsu's method. The pixels on the edges of the infected cluster (object) and those with red, green, and blue values of zero were completely deleted as an additional step. The experimental findings show that the suggested method is a reliable method for the detection of plant leaves [3]. To distinguish between healthy and diseased leaves from the generated data sets, Random Forest Classifier is used. The phases of implementation included training and classification. To categorize the photos of sick and healthy leaves, the produced datasets of sick and healthy leaves are combined and trained using Random Forest. For feature extraction Histogram of an Oriented Gradient (HOG) is used. The model was trained using 160 images of papaya leaves and it achieves around 70% accuracy in the classification task [4]. Producing enough food to meet societal demand is now possible due to the growth of developed technologies. The food's and the crops' safety and security, however, remained unachieved. Climate change, a decline in pollinators, plant diseases,

and other problems put farmers in a difficult position. To maximize the quality and segment the leaf samples, K-means clustering is first used. The K-means clustering response can be used to predict whether a leaf is infected or not at an early stage of operation. Second, the informative regions and features of the samples are extracted using various machine learning-based classifiers to predict the disease in the plants [5]. The creation of a tracking device that can be remotely controlled to carry out cadastral measurements. To obtain real-time kinematic (RTK) corrections via the internet, a Raspberry Pi Zero W module that receives position data from a VBOX 3iSR GNSS receiver and a particular modem was combined to create a Bluetooth-controlled rover. A cloud platform receives position and inertial data, allowing for remote monitoring and storage. Additionally, the power supply section was built to power the various acquisition section components, providing 2 hours of energy independence. A mobile application was created to control the rover and track its progress in real-time [6].

III. PROPOSED METHODOLOGY

A. Data Collection

The collection of data is done by taking pictures of five crops that are wheat, rice, potato, corn, and tomato. This dataset consists of 24 classes. These classes consist of all diseased plant images and healthy plant images. As mentioned in Fig.1, the classes of various plants are shown. The dataset contains 18,427 images which are further divided into 5 plant categories and 24 classes. The machine learning model classifies the diseased and non-diseased plants based on the features extracted from the image. The testing dataset contains 2,135 images which are used to test the performance of the developed system.

TABLE I. CROPS AND THEIR DISEASE, CATEGORISED
AS CLASSES FOR MACHINE LEARNING MODEL

PLANTS	DISEASE
WHEAT	Wheat healthy, wheat stripe rust, wheat septoria
RICE	Rice healthy, rice bacterial leaf blight, rice brown spot, rice leaf smut
POTATO	Potato healthy, potato late blight, potato early blight
CORN	Corn healthy, corn common rust, corn gray leaf spot, corn blight
TOMATO	Tomato healthy, Tomato bacterial spot, Tomato early blight, Tomato late blight Tomato leaf Mold, Tomato spider mites, Tomato Septoria leaf spot, Tomato target spot, Tomato mosaic virus, Tomato yellow leaf curl virus



Fig. 1. Sample Images of Dataset

B. Core components

i) Raspberry Pi4

A compact single-board computer with 4GB of RAM, the Raspberry Pi 4 Model B is intended for several applications, including research, education, and hobby projects. It is the most capable and feature-rich Raspberry Pi to date, and it has vastly improved over earlier models. The quad-core ARM Cortex-A72 CPU found in the Raspberry Pi 4 offers considerable performance gains over earlier models. It operates at 1.5 GHz. It also has dual-band 802.11ac wireless connectivity, built-in Bluetooth 5.0, and Gigabit Ethernet, making it simple to connect to a range of networks and gadgets. More demanding programs, like data processing and machine learning, can operate without any issues thanks to the 4GB of RAM. Additionally, it has two micro-HDMI ports that can support two 4K displays at a frame rate of 60. The board contains several ports, including a USB-C port for power, two USB 3.0 ports, two USB 2.0 ports, and two USB 2.0 ports. Additionally, it has an audio jack for audio output and a microSD card slot for storage. It also features GPIO pins for attaching to external devices.

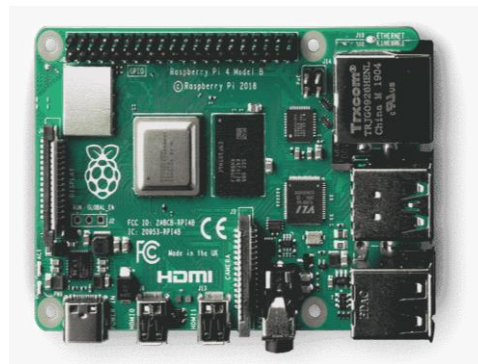


Fig. 2. Raspberry Pi4 (Source: raspberry pi 4 images)

ii) Motor Driver (L298N)

Robotics and mechatronics frequently use the twin H-bridge motor driver integrated circuit (IC) known as the L298N. Stepper motors and DC motors' direction and speed are intended to be controlled. With a maximum current of 2A per channel and a peak current of up to 3A per channel, the L298N can drive up to two motors concurrently. Pulse width modulation (PWM) signals can be used to control it, and it is compatible with several microcontrollers, including Arduino and Raspberry Pi. Additionally, the IC has integrated protection circuits for thermal shutdown, overvoltage defense, and under-voltage lockout. This guarantees that in the event of a problem, the L298N and the linked motors are protected from harm. The L298N is appropriate for a wide range of applications because of its broad operating voltage range of 5V to 46V. Additionally, it has an internal voltage regulator that can output 5V to power external devices. The L298N may control solenoids, relays, and other high-current devices in addition to controlling motors. Due to its adaptability, both professionals and hobbyists favor it.

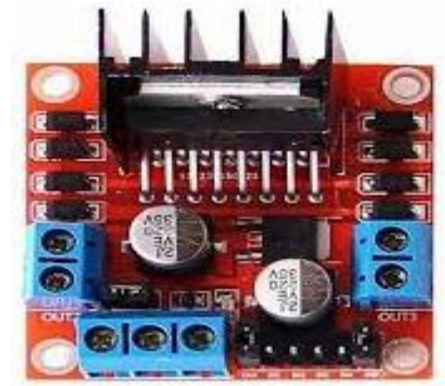


Fig. 3. Motor Driver (Source: motor driver l2989)

iii) Arduino UNO

An open-source microcontroller board called Arduino Uno is made to be user-friendly and adaptable. It is a well-liked option for studies in robotics, automation, and other related topics. A set of digital and analog input/output pins on the board, which is based on the Atmel ATmega328P microcontroller, can be used to connect to different sensors, actuators, and other parts. The Arduino Uno's simplicity and ease of use are two of its key advantages. The Arduino Integrated Development Environment (IDE), a user-friendly software platform that makes it easier to write, upload, and debug code, can be used to program it. The Arduino Uno is not only straightforward to use but also quite adaptable. Shields, which are add-on boards that offer more functionality like Ethernet connectivity, wireless communication, or motor control, can be used to expand it. Due to its adaptability, it serves as a platform for a variety of research applications.

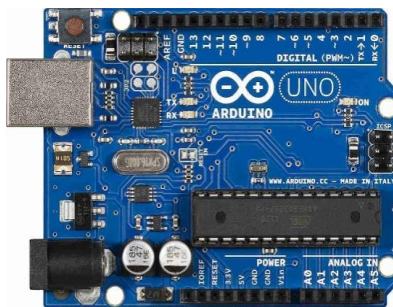


Fig. 4. Arduino UNO (Source: Arduino uno r3)

iv) Bluetooth Module

A wireless communication module called the HC-05 Bluetooth can be utilized for a variety of tasks, including research projects. It is a compact module that offers wireless communication capabilities across close ranges and is simple to integrate into electronic circuits and devices. The majority of Bluetooth-enabled devices, including laptops, tablets, and smartphones, are compatible with the HC-05 module because it adheres to the Bluetooth 2.0 protocol. The HC-05 module's simplicity of usage is one of its main benefits. straightforward AT commands that are exchanged over a serial connection between the module and a microcontroller or computer make configuration straightforward. This makes it a well-liked option for researchers and amateurs who might not have a lot of background in wireless communication protocols. The HC-05 module can be used with several microcontrollers and other electronic devices since it supports a range of baud rates. It is appropriate for a variety of applications, including data logging, remote control, and sensor monitoring because it can transport data at speeds of up to 2.1 Mbps.



Fig. 5. Bluetooth Module HC-05 (Source: [Bluetooth module hc05](#))

v) Camera Module

A compact camera module called the OV5647 is made for a range of electronic gadgets and research purposes. It's produced by Omni Vision and has a 5-megapixel image sensor in addition to several cutting-edge features that make it appropriate for a variety of research projects. The OV5647 camera module's tiny size, which makes it simple to integrate into electronic gadgets and other applications, is one of its primary benefits. Additionally, it has a built-in auto-focus mechanism that enables it to automatically change the image's focus. Additionally, the OV5647 module includes several sophisticated image processing capabilities, such as automatic gain control, automatic white balance, and noise reduction. It may therefore be used in a range of settings and lighting circumstances. I2C, SPI, and MIPI are just a few of the interfaces that the OV5647 module can use to connect to a variety of microcontrollers and other electrical devices. It can record video at resolutions as high as 1080p and capture photos up to 2592 x 1944 pixels.



Fig. 6. Camera Module OV5647 (Source: Camera Module OV5647)

vi) LiPo Battery

A common high-capacity rechargeable battery utilized in several electrical products and research purposes is the 11.1V 2200mAh lithium polymer battery. This particular form of lithium-ion battery is more versatile and can be produced in a range of shapes and sizes since it employs a polymer electrolyte rather than a liquid electrolyte. The battery can be used in a variety of electrical equipment because of its nominal voltage of 11.1V. Additionally, it has a capacity of 2200mAh, meaning it can supply a lot of power for a long time. Because of its high energy density, which allows it to store a lot of energy, lithium polymer batteries are well-known.



Fig. 7. LiPo Battery (Source: [LiPo Battery](#))

vii) Motors

A compact, excellent motor with a 12-volt direct current power supply is the 150 RPM - 12V Centre Shaft DC Geared Motor. The motor has a gearbox installed, which increases its torque and allows it to deliver a maximum speed of 150 revolutions per minute (RPM). A circular wheel component with a 10 cm diameter and a 6 mm hole, called the Wheel - 10 cm Diameter - 6 mm Hole - Big size, is made for usage in a variety of machinery, robotics, and automation projects. The wheel is rather huge in size, measuring 10cm, or roughly 3.94 inches, in diameter. The wheel's big size enables it to travel swiftly and cover more ground with each turn, making it appropriate for uses requiring high speed or a wide range of movement. The wheel features a 6mm hole in the center that makes it simple to connect it to a motor shaft or other parts. It is simple to integrate the wheel into a variety of motor shafts since the hole is compatible with a wide range of motor shafts.

IV. WORKING PRINCIPLE

The 6-wheeled rover, which is programmed in Arduino and powered by an 11.1 volts LiPo battery, can be easily controlled through an Android application that is connected to it via a Bluetooth device, and all the commands are provided through the same Android application. A Raspberry Pi 4 is used to detect diseases in plants. The process is straightforward: the user approaches the plant with the rover and issues a command via an Android device using an Android application. Upon pressing a button in the Android application, the Arduino board sends a serial command to the Raspberry Pi to execute a machine-learning sketch that can detect diseases. Once a disease is detected, a message is sent to the concerned person on WhatsApp.

A. Role of Raspberry Pi 4

The Raspberry Pi 4 is employed to detect diseases in crops and suggest appropriate solutions via WhatsApp. The model is trained using the SVM algorithm, which involves the utilization of a vast dataset encompassing five crops, namely Potato, Tomato, Rice, Wheat, and Corn, along with their corresponding diseases. Upon completion of training, the machine learning model is tested and saved as a sketch. When a serial command is issued to the sketch by the Arduino board, supplied by the Android application, the attached camera on the Raspberry Pi captures an image of the crop, which is then processed by the program. The model performs a classification task on the image to detect any potential diseases or to confirm whether the plant is healthy or not. Based on the result obtained, a message is sent accordingly. The message is provided in both languages Hindi and English.

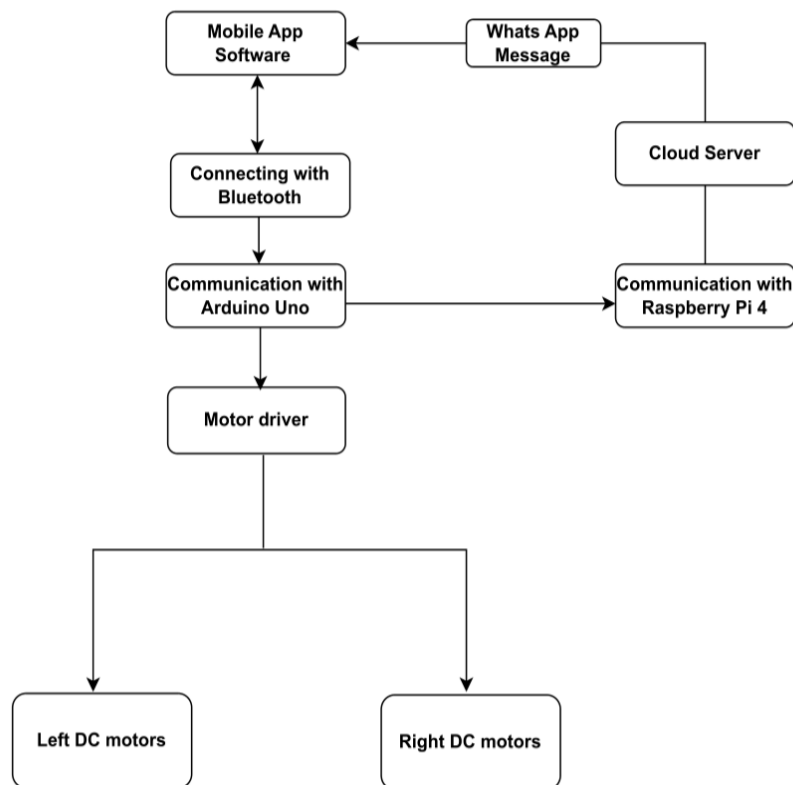


Fig. 8. Working of Raspberry Pi4

i) Arduino Board

The Arduino board is responsible for the mobility of the rover. The L298N Motor driver and HC-05 Bluetooth module are controlled by the Arduino board. All 6 motors are connected to the motor driver and the motor driver is connected to the Arduino through a digital pin. The working of the three components is very simple as illustrated in Fig. 10. The Bluetooth Module sends commands to the Arduino and Arduino sends commands to the motor driver through which motors move according to the command.

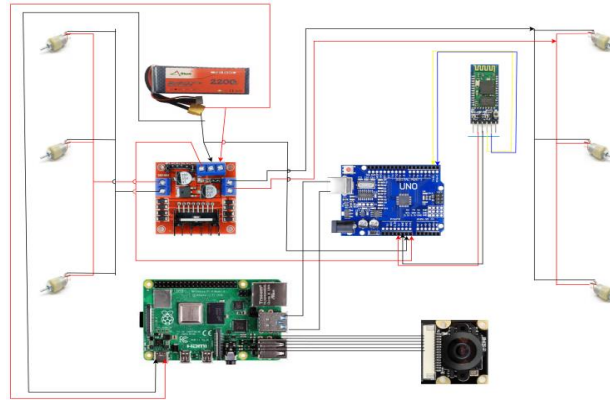


Fig. 9. Circuit Diagram

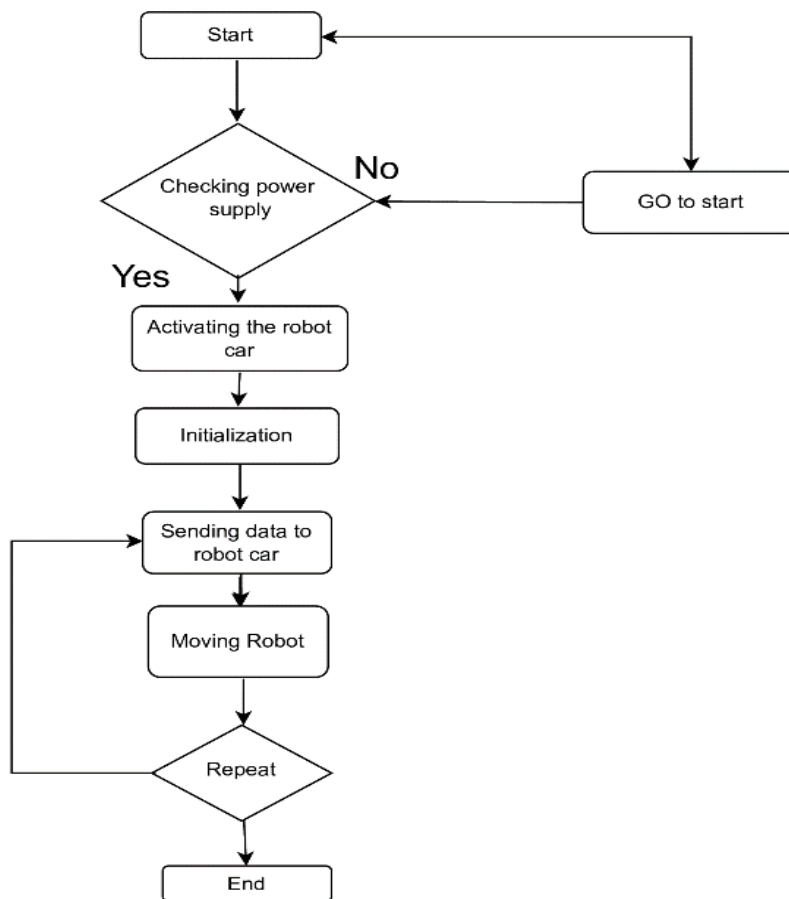


Fig. 10. Process Check-Up

V. EXPERIMENTATION AND RESULTS

To evaluate the performance of the developed rover, we conducted experiments in a real-world scenario. The rover was deployed in a field of tomato plants infected with three different types of diseases: Early Blight, Late Blight, and Leaf Spot. The rover collected images of the infected plants, and the images were processed using our AI-based algorithm. Thus, the other plants are seasonal crops they also have been tested by using the testing dataset. After the model receives the image, it categorizes it and uses a sample image to identify the ailment. The testing dataset of five plant categories is used to test the other plants because only tomato plants were accessible at the time of the testing. The results of our experiments show that our developed rover is capable of accurately detecting the presence of diseases on plant leaves along with it sends a message to the user on WhatsApp about the health status of a plant and also suggests possible remedies to cure the disease (Fig. 12) otherwise a congratulations message is sent to the concerned person if the plant is disease free. The architecture of the developed rover is shown in Fig. 11.



Fig. 11. Structure of Rover

VI. CONCLUSION AND FUTURE SCOPE

Various subsystems were integrated to construct a fully functional rover to solve the problem faced by farmers all over the globe. The monitoring of plant health in huge agricultural fields can be time-consuming well as needs human effort. To overcome the certain problem and save human effort which can be diverted for better purposes. This system successfully provides the solution for the affected crops by sending WhatsApp messages to the person, which identifies the disease as well as provides several possible solutions to cure the disease from the present stage. The operation of the rover in the agriculture field is also tested and can tackle pretty rugged surfaces.

In the future this system could incorporate a different camera for navigational purposes, allowing it to move independently and do the necessary tasks. The process of farming could also be made simpler in the future by the introduction of features like plowing and seed sowing. The bot can also be changed so that it can recognize diseases in a wider variety of plant species. Additionally, weeds can be removed automatically utilizing cutters and blades, saving the farmers from having to do it by hand.



Fig. 12. Screenshot of the message sent by Raspberry Pi

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Applying Systems Approach to Engineering Pedagogy for a Sustainable Future

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The goal of engineering education should be focused on imparting a solid knowledge foundation, inculcating understanding, developing skills to apply theoretical knowledge to practical use, researching and then procreating something useful to mankind. The current curriculum design has created a gap between textual knowledge and real-world practical demands due to a fragmented learning approach. The application of a systems approach helps in modeling and visualizing engineering as a horizontal part/sub-system of a whole/super-system of holistic education as well as an individual vertical sub-system composed of the further sub-systems of pedagogy, instructors, and learners. It also models the engineering system as an interconnected network of multidisciplinary systems based on a “Many to Many” relationship with other systems. The aim of the proposed system model is to create a flexible education structure to induce an ability to create better awareness and understanding of real-life problems and the skills to solve them based on critical thinking and analytical abilities, using multiple horizontal subsystems, leading to meaningful and sustainable technological growth in the future. In order to attain this objective of the proposed model, modifications are required in each sub-system, such as in the engineering pedagogy, with a broad, stable theoretical base and with research and design contribution aspects at the apex, based on Bloom’s taxonomy.

Keywords – Engineering education, Theoretical knowledge, Curriculum design, Many to many, Systems approach

I. INTRODUCTION

Infrastructure development is a true representation of the social, economic and political growth of any nation and engineers play a crucial role in this segment. Engineering education has transformed from a rudimentary individual skill level to an organized and systematic pedagogy over a considerable period. The current pedagogy is based on Grinter’s report of building a solid theoretical foundation but as technological growth has evolved over the ages, the mindset and requirements of the society too have evolved and this has necessitated modifications in the training of engineers with foresightedness for a sustainable future. The pyramidal hierarchical approach of Benjamin Bloom has turned the focus of education to a multidimensional expansion of an individual’s humane capabilities. The process of evolution and transformation has now escalated to an exponential scale, which requires further modifications and a systems approach in education, taking into consideration interconnectedness of its multiple subsystems on a horizontal plane, and its further three vertical subsystems i.e., pedagogy, instructors, and learners. The

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goal of education has transformed from a mere skill-based focus to value, satisfaction, wellness, happiness, and spiritual quotients.

A lot of existing problems have arisen out of a faulty implementation of Bloom's model of the education system, with too much weightage given to the first stage of memorizing theoretical knowledge, and that too in watertight pipeline mode compartments. A significant transformation can be achieved if an interconnected systems approach is applied to build a comprehensive understanding by giving more weightage to the higher levels of the model, which focus on the application, design and creation of new, enhanced, and multifunctional technologies which can improve the quality of life. The goal of engineering education is not only to solve hypothetical problems at the end of textbooks or perform some pre-designed laboratory experiment in the curriculum as a requirement for obtaining the degree but to inculcate an ability to solve real-life challenges that are occurring in the current state or might occur in the future. This ability to apply theoretical knowledge to practice and develop foresightedness cannot be developed in a pseudo-real, artificial, closed-door static environment but in a real day-to-day dynamically changing environment for tackling future threats and building a sustainable environment [1]. Till now, the modifications in this regard have been done with the assumption that the subsystems of the education tree are individual components and the impact of modifications in one subsystem on another subsystem is negligible, resulting in ineffective and lopsided growth. Real-life situations require the knowledge and application of more than one subsystem, and this discretion of selecting subsystems depends on the mental ability and training of individuals who presently specialize in water-tight single domains and execute tasks without any collaborative effort. Some classic examples are climatic changes (which require the knowledge of multiple subsystems of Geology, Climatology, Agroecology, Industrial production, Space Science, living patterns of humans based on technological growth, and various other systems), Biotechnology (which requires the knowledge of multiple subsystems of Science, Medicine, Engineering, Technology and Ecology), and Transportation (which requires Civil, Mechanical, and Electrical engineering along with Arts and Design).

The curriculum design needs to be universal for the general well-being of society and yet cater to individual student's interests and abilities, which are widely varied and cross-disciplinary. The current pedagogy lacks in this aspect on many fronts as it is still stagnant, rigid, and generic for all learners. The best multidimensional potentials of any individual have neither been tapped nor trained to get to a level of superior, resilient and sustainable homo sapiens, which might become a necessity in the near future.

A. Problem Identification

The interconnectedness and impact of multiple subsystems on a horizontal level have been grossly neglected and not analyzed. The action taken by one subsystem (like the faulty handling of industrial pollutants) disturbs other subsystems (like ecology, habitat, physiological and psychological development) at both the micro and macro levels.

The current scenario of the execution of imparting engineering education on a vertical plane demarcates the theoretical and practical curriculum as two separate entities due to which there is a fragmentation of knowledge. Most of the time the theory and the laboratory classes are taught by different instructors, held in different time zones, and that too focused on only one or two segments of the syllabus. Also, the theory teacher focuses on solving the problems of the textbook in the class without dealing with their practical aspects or application, and simultaneously, the teacher engaging the laboratory class is not able to demonstrate the theoretical objective of all the experiments being conducted. The laboratory teacher presumes that the student knows all the theoretical aspects. This demarcation and lop-sided approach create a break in learning and the learners are not able to correlate textual knowledge to discrete laboratory

performance. This lack of coherence between theory and experiments in institutions has no intellectual impact on the minds of the learners and the executions of the experiments go unregistered on their minds. It does not motivate them or create curiosity for further knowledge or for seeking research prospects on innovative topics at a cross-subsystem level. The learners get disconnected from the problems being faced by the people of society at the local, national, or international levels. They come from different sets of ethical values and do not have a unified vision for the greater goal of solving the existing problems and growth of the nation, and for a healthier and peaceful universal environment in general.

In order to solve these problems, the curriculum must be redesigned for complete and meaningful cross-disciplinary learning and to enhance research. This paper presents an integrated pyramidal approach for enhanced and effective learning with constructive modifications in the existing set-up, along with the proposed model.

B. Novel Contribution

This paper presents a novel methodology to tackle the existing problem and give thrust to critical thinking and the creation of sustainable technology design by the horizontal and vertical correlational approach. By applying a systems approach in the horizontal plane, engineering education has to be modelled as a part of a whole concept where multiple subsystems of education like Science, Technology, Engineering, Arts, Medicine, Ecology, Design, and Spirituality (STEAMEDS) shown in Fig. 1 are inter-related and integrated as a consolidated many-to-many system and not a standalone system [2].

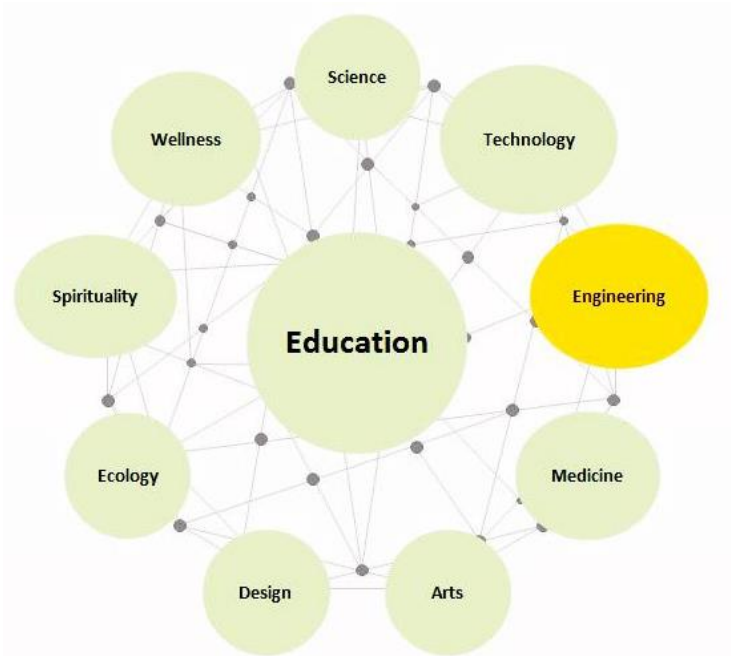


Fig. 1. Interconnectedness of Subsystems at a Horizontal level.

Secondly, to enrich, inculcate and enhance an individual's ability to gain a complete perspective, a vertical structure within the subsystem, consisting of pedagogy, instructor, and learner, must also be modelled. The modifications must be done with the objective of building a wide knowledge base, promoting critical analysis, and creating sustainable solutions for future needs, as shown in Fig. 2 [3].

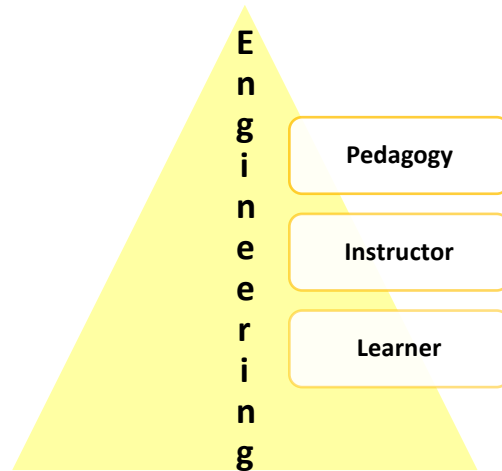


Fig. 2. Vertical Structuring of the Engineering Subsystem.

C. Organization of the Paper

The existing pattern of engineering education has been discussed in Section II. Some modifications and suggestions have been made to improve the quality of knowledge-based understanding in the horizontal level model in Section III and the vertical level model in Section IV. A modified structured model to obtain the unified objective has been proposed in Section V and conclusions in Section VI.

II. EXISTING PATTERN OF ENGINEERING EDUCATION

The pattern of engineering education varies from university to university, unlike medical education which is more or less uniform across the world. The general pattern is a 3 or 4 credit theory paper with or without a supporting laboratory, an industrial internship and/or a project in the final semester.

A. Selection of Discipline

The education system at the kindergarten and matriculation level is too restrictive and static, leading to fixed mental development of learners due to which they are unable to figure out their strengths and interests. The selection of discipline at the intermediate level is hardly done by the learners, who are confused and not sure of their future prospects. At times, the parents force their progeny to take up a discipline which would fulfil their unachieved dreams irrespective of the inclination of the ward. Such a student is not self-driven by his own interest and learns the subject forcefully leading to no meaningful learning or subsequent growth of the discipline. Also, since the allocation of the discipline is hierarchical, depending on the academic marks obtained, availability of seats and demand by the learners and industry, there are a majority of cases in which the learners do not get a subject of their choice at their desired institutions, leading to them opting for a different choice of discipline.

B. Pedagogy

The subject teaching distribution is done at the level of the department and not at the institute level, resulting in the engagement of multiple instructors from different departments for a common interdisciplinary theory paper. As a result, in order to balance the load, other theory papers may be either allotted to a teacher who has lesser specialization or lesser interest in the paper, leading to lower output of

the pedagogy. The low teacher-student ratio and the lack of adequate facilities in the classrooms also weigh down the quality of actual impartation of knowledge of the subject. The lack of any uniform guideline for the syllabus plan results in a deviation from the desired topic to be discussed in a particular class or the percentage of the syllabus to be covered by different instructors engaging the same subject in the institute. This situation leads to a pressure build-up on the learners, who resort to memorizing the content without much understanding, purely for the sake of getting good academic grades for placement requirements. They forget the contents as soon as they clear the semester, without any attempt to climb the upper levels of Bloom's taxonomy. As memorizing is a time-consuming process, they overlook the conditions or problems prevailing in society. Even within a particular discipline, there is no coherence between different theoretical papers and the question of inter-disciplinary collaboration is out of bounds.

In the case of software-based labs, the codes are not available in older versions of the textbooks and the instructors from general streams of engineering are not able to provide accurate codes for the experiments. The recent licensed versions of the software are not purchased by some institutions due to high costs and as a result, both instructors and learners face difficulties. The hardware experimental setup is not modified or upgraded most of the time, so the learners do not take an interest in getting accustomed to the age-old rusted equipment. They do not apply their knowledge skills and perform experiments in a mechanized, routine way. In some cases, the number of learners conducting a particular experiment is more than two, so the task gets divided and some of the learners do not get to do the actual connections individually. The connections are done without understanding the logic, with the mere intention to perform the experiment somehow.

The current curriculum requires a single summer internship after the completion of the sixth semester and a project of choice in the eighth semester. There is no organized structure for conducting industrial training, either at the institute or industrial level. An internship opportunity instead depends on the personal contacts of individuals. The project too is unstructured, with no focus on solving the problems faced by industries and with no correlation to either the industrial training done or current academic research. These activities too are done with an intention to somehow get the bachelor's degree without any meaningful contribution.

C. The Placement Race

The road to higher post-graduation education is unstructured, time-consuming, and low-paid. The brightest learners do not go for higher education and research but opt for managerial skills and highly-paid software coding jobs. Some of them have to support their families and some have societal pressure to get the highest package or foreign placement, leading to a brain drain from the research and innovation sector.

III. MODIFICATIONS AND SUGGESTIONS FOR THE HORIZONTAL LEVEL

Several modifications and suggestions in the existing curriculum are required to improve the learning and understanding of concepts and their application to solving real-world problems, which require a fundamental and in-depth knowledge of multiple disciplines, as shown in Fig. 1. As one subsystem has the capacity to cause an effect on another subsystem, each transformative step must be taken with due consultation with experts from other subsystem domains. The classic example of technological development in the wide use of polythene bags was taken up without much discussion on its disposal and non-biodegradability effects, leading to environmental pollution and ecological and human health hazards. The collaboration of generalists and specialists of different subsystems is required for problem solutions and sustainable development.

A. Theoretical Foundation

- a. Primary education at the grassroots level must be given utmost importance and the selection of trained instructors with varied interests, maturity and patience must be strictly monitored as it influences the learning pattern in the minds of young individuals who need to explore various fields without much restriction and develop interests based on their inherent talents.
- b. Collaborative project-based learning must be encouraged with a proper structure, where bigger projects allow the hiring of young interns from schools and universities.
- c. The mushrooming growth of single-domain colleges must be discouraged or they should be merged with other colleges in a university structure so that learners can avail the facility of opting for cross-disciplinary subsystems, say, for example, a major in Electrical Engineering with minors in Design, Music or Language.
- d. A database of experts of subsystems, available for conducting workshops and training with the collaboration of industrial houses to bridge learning gaps between academic institutions and technological needs, must be created.
- e. The huge repository of educational materials available on e-platforms should be utilized for more effective learning. Links to topic-relevant videos on free platforms made by reputed institutes should be shared with learners or screened in class for further enhanced learning [4].

B. Hands-on Practical Training

- a. Educational institutes must compulsorily tie up with industrial or training institutes so that student training is more systematic and can be held in systematic multilevel tiers with an adequate frequency in multiple subsystem domains and not as a one-time opportunity at the final graduation level.
- b. There should be a collaboration between industrial houses and institutional establishments with properly designed faculty exchange programs and consultancy opportunities to bridge the gap in the knowledge and prevailing skill levels of both sides.
- c. A project, however small, based on a real-world experiential problem from another subsystem domain must be enforced in the curriculum. Such a kind of exposure would make learners acquainted with the existing problems of society and develop an ability to find solutions to problems that may arise in the future. Learners would get to know the current demands of the industry and can upgrade their skills for better employment opportunities [5].
- d. Access to remote interactive laboratories established by prestigious institutes of the world should be made available to earnest learners, with an open platform for discussion on difficulties and challenges faced by the users. This activity would inspire learners to search for solutions to problems currently faced by other research enthusiasts across the world and form a strong network of experts.
- e. The weekend schedule/semester break of learners should be effectively planned to conduct multiple internships/projects/industrial training at off-campus locations with adequate entertainment to create interest and not be a forceful burden. Their natural talents and interests can be tapped once the learners are themselves able to figure out which field attracts them the most.

These modifications might help learners to understand their strengths and weaknesses and choose a career option or a field of their own choice. Such motivated individuals would be naturally focused on research and development in their chosen domain of trained expertise and self-driven interest as well as have a capacity to participate in cross-subsystems collaboration.

IV. MODIFICATIONS AND SUGGESTIONS FOR THE VERTICAL LEVEL

Most existing instructors and learners are inept at facing real-life challenges and either give up or resort to unethical ways to overcome situations. The humane aspect of society must be instilled in engineers to be more responsible in the execution of technology for a sustainable future.

A. Pedagogy

- a. The delivery of theoretical classes should be in hybrid mode in smart classes. At the very least, interdisciplinary theory papers should compulsorily be held in online mode to reduce the teaching load of instructors, who can spare time to mentor the learners [6].
- b. There should be provision by institutional libraries for the greater availability of free e-textbooks, updated with proper numerical/experimental problems at the end of each chapter, which can be performed either on software or hardware-based platforms to create a uniformly biased laboratory performance.
- c. There should be overlapping of theory and practical classes [7]. Instead of a separate and independent lab schedule, a mix of software and hardware-based experiments should be performed along with each module of the theory class, in a continuum by the same instructor. This would help in getting more knowledge and understanding, leading to a greater interest in further research.
- d. Universal human values must be incorporated not only in the curriculum but also in true spirit and practice.
- e. Each course of a semester must necessarily have a small project which must be executed after a full cross-examination of its viability, utility to society and impact on other subsystems, thus training learners about the methodology to execute a task.
- f. A free, fair, and unbiased learning environment must be created at the temples of knowledge.

B. Instructor

- a. Consistent upgradation of skills to keep abreast with recent advances in the industry must be taken up by instructors.
- b. Faculty development programs and exchange programs must be promoted.
- c. The mentor-mentee bond should be strengthened for real, mutual/symbiotic growth.
- d. A time-bound career advancement scheme must be implemented to keep the instructors motivated to give their best.
- e. The teaching fraternity should also be given due respect for their efforts in transforming individuals.

C. Learner

- a. Time management skills must be taught to the learners so that they can take up multitasking and multidisciplinary work.
- b. They should be consistent in their performance and ethically strong for genuine research and should not resort to cut-and-paste methods for selfish monetary gains.
- c. They should have a genuine desire to learn and expand their knowledge as responsible citizens of not only their local land but a greater universe [8].

V. PROPOSED PYRAMIDICAL DIAGRAM FOR UNIFIED GROWTH

In order to bridge the gap, the curriculum has to be redesigned incorporating the above-mentioned modifications for complete and meaningful learning and to enhance research [9]. The pyramidal model of the proposed structure has been shown in Fig. 3 below.

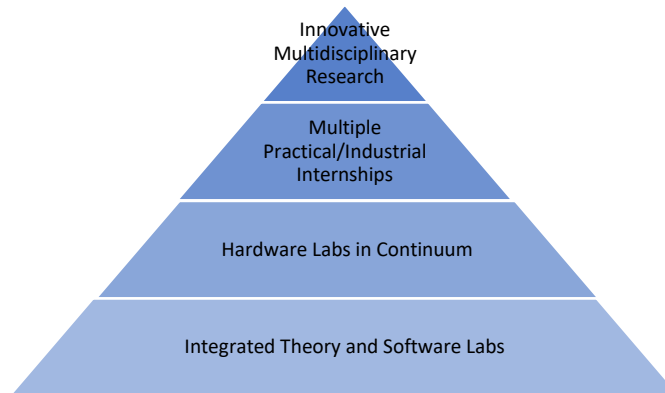


Fig. 3. Proposed Pyramidal Model of Curriculum Design

A. *Level 1: Integrated Theory and Software Labs*

- a. Each semester should be designed in a way that gives prime importance to incorporating multidisciplinary papers from other subsystems.
- b. The hierarchy of pre-requisite papers for a particular course must be taken care of for the correlation of the parts to the whole structure and to prevent a fragmented learning approach.
- c. Each theory paper should be accompanied by an integrated software laboratory. Even subjects like the mathematics taught in the initial semester should be redesigned with their focus on engineering application and not from the aspect of the regular graduation syllabus.
- d. Any theory and its corresponding laboratory should necessarily be in the same semester to give a clear understanding of fundamental concepts.

B. *Level 2: Hardware Labs in Continuum*

- a. Each module of the theoretical syllabus should necessarily have a hardware-based experiment setup.
- b. There should be freedom of designing the nature and number of experiments for the faculty members to effectively demonstrate the theoretical concepts.
- c. The laboratories should be continuously upgraded in collaboration with industrial houses and training institutes.
- d. 3D cut-outs of models, especially of motors and generators which are normally enclosed in safe casings, should be installed in laboratories for a better impact on young minds. This would allow learners to view the internal cross-sections of these models, as taught in their textbooks.
- e. Interactive and safe pseudo-real or virtual experimental setups should also be introduced for venturing out into the creative research domain.

C. Level 3: Multiple Practical/ Industrial Internships

- a. Instead of a single internship, there should be an organized multilevel internship and training schedule throughout the course period for multiple subject papers, as done in most medical institutes.
- b. Each educational institute must tie up with multiple industrial houses where the learners can get trained in different departments and batches for shorter/flexible durations.
- c. Both software and hardware-based training institutes must be structured to impart training to both learners and faculty members according to current industrial demands.
- d. Premier institutions must open their resources and repositories for the benefit of those desirous of enhancing their skills.
- e. Student/faculty exchange programs and summer/winter schools must be designed in a hybrid mode for the exchange of knowledge and an equitable world of technology.

D. Level 4: Innovative Multidisciplinary Research

- a. The selection of a research project topic in the final semester must be the pinnacle of all the internship projects and not a hurriedly done work without any meaningful contribution.
- b. The research methodology must be taught as a subject in the pre-final semester, along with the soft skills required for presentation and research paper writing.
- c. Access to world-class research literature and a discussion forum would lead to a more relevant collaborative contribution to real-world problems. Premier institutes must realize that talent can be nurtured if given the right training and exposure at the right level.
- d. Research and innovation must be at the top of the integrated learning pyramid even at the graduate level and not only a one-time requirement at the doctorate level.
- e. Education must go beyond textbook skills and focus on qualities like values, happiness, health and mental wellness and spirituality to make a complete man [10].
- f. Focus on independent and self-reliant execution of physical tasks and manual labour must be a part of the education pedagogy to enhance experiential learning, which is the best form of holistic knowledge and establishes a healthy connection with mother nature.
- g. Group projects must also be a part of the pedagogy for the development of psychological adjusting capabilities of a collaborative nature [11].

VI. CONCLUSION

The existing structure of engineering education has a fragmented approach, as the current pedagogy is designed on the assumption that it is an independent, standalone, static system. Due to this structure, learners are not able to develop a proper understanding of the integrated, meaningful, and sustainable education system that also provides for out-of-the-box innovation. Most of the learners are textbook specialists in a single domain and have not been able to properly exploit their other multidimensional talents and needs like finances, entertainment, health, wellness etc. The recent trend of misuse of technology for human greed, overexploitation of natural resources and their harmful effects on other subsystems requires a change in the engineering pedagogy. The different fields of specialization in multiple subsystems are actually correlated and often necessary in solving real-world problems. The visualization of the education system as composed of the vertical and horizontal subsystem models, as presented in this work, helps in understanding the impact of the development of one subsystem on other subsystems and

opens an avenue for modification and restructuring of the current pedagogy. This approach to the application of systems modelling can lead to the growth of sustainable research and technological development of society, as well as that of individual members of society. The evolutionary dynamics of the current transformation process require individuals to be generalists of a good level and then become specialists for collaborative research and innovation in this ever-changing scenario.

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The Impact of Biomass Burning on the Oxidative Potential of PM_{2.5} at Dayalbagh Agra

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Biomass burning (BB) emissions are the major contributor to the gradually deteriorating air quality. Thus, the objective of the present study is to investigate the impact of biomass burning during both the haze and non-haze period in the winter season. The meteorological parameters like relative humidity (RH), temperature (T), solar radiation (SR) and wind speed (WS) were studied to determine the effect of long range transported biomass burning aerosols during the study period. Furthermore, the satellite retrievals for the estimation of burning period were also taken. The PM_{2.5} samples were collected on quartz filters during winter (1st January to 30th January, 2019 and 5th November to 31st December, 2019) season at a suburban site of Agra. The elemental composition of PM_{2.5} samples was analyzed using ICP-OES, and the associated oxidative potential was assessed through the Dithiothreitol (DTT) assay. Total PM_{2.5} mass concentration was found higher in haze period ($236.6 \pm 19.9 \mu\text{g m}^{-3}$) than non-haze period ($137.1 \pm 45.7 \mu\text{g m}^{-3}$). Among the metals, K was recorded leading trace metal in PM_{2.5} during the study period as it is an important marker of biomass burning activities. The linear correlation analysis reveals a strong correlation between metals such as Cr ($r=0.6$), Cd ($r=0.5$), and Ni ($r=0.5$) and the DTT activity of PM_{2.5}, indicating risk to the human respiratory tract as a result of their contribution to the increased toxicity of PM_{2.5}. Positive matrix factorization identified agricultural dust and BB (46.9%) as the major contributors to PM_{2.5}. Thus, it is necessary to implement effective mitigation policies to reduce these emissions.

Keywords - Biomass burning, Haze period, Metals, Oxidative potential, Positive matrix factorization

I. INTRODUCTION

Biomass burning (BB) has significant regional and global effects on the chemical composition of the atmosphere and the radiative balance of earth. Open burning of agricultural residues, slash-and-burn practices, and forest fires continue to contribute to atmospheric particle accumulation. These particles scatter and absorb sunlight, resulting in a significant decrease in atmospheric visibility and a radiance imbalance [1], [2]. Particulate pollution from the burning of biomass is a serious environmental problem due to the presence of hazardous chemicals such trace metals and polycyclic aromatic hydrocarbons (PAHs) [3]. These particles are either emitted directly or indirectly through atmospheric chemical reactions during biomass burning into the air. Anthropogenic activities such as combustion of fossil fuels, wood and agricultural burning, high temperature industrial processes produce particle bound metals such as arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), zinc (Zn), vanadium (V), potassium (K), sodium (Na), mercury

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(Hg) and lead (Pb) into the atmosphere (4). Many past studies reported K as a biomass tracer among these metals due to its abundance in the plant cells [5], [6].

According to [7], metal-containing particles are particularly concerned about the harmful health impacts of airborne PM due to their solubility and ability to change their oxidation state in biological fluids. However, the physiological availability of PM also depends on the likelihood of these particles penetrating deeper to the alveoli as independent entities or as carriers of other particles. According to the World Health Organization (WHO) report [8], excessive exposure to PM_{2.5} can lead to arteriosclerosis, preterm births, and respiratory diseases in children. In biological systems, excessive concentrations of trace metals have been reported to affect cellular organelles and metabolic enzymes. It has been discovered that metal ions interact with cell components such as DNA and nuclear proteins, resulting in DNA damage and conformational change that may contribute to modulation in cell cycle that results to carcinogenesis [9], [10]. Therefore, information on structural influences between metal, particles, and other airborne entities, such as carbonaceous aerosols, is essential for enhancing our understanding of metal toxicity in humans and animals [11]. Several studies provide convincing evidence that PM-bound metals have adverse health effects, with the severity varying by age group. According to recent studies, metals are crucial in the toxicity of PM because of their redox activity [12], [13]. Among other hypotheses for PM-induced toxicity, oxidative stress is the most widely acknowledged. In this context, the oxidative potential (OP) is a measurement of the ability of PM to oxidize a target molecule or generate reactive oxygen species catalyzed by metals. Thus, as an accompaniment to mass concentration, OP can be used to account for the impacts on human health.

India, being an agricultural country with rich biodiversity, experiences excessive biomass burning episodes and trans-boundary haze. The northwestern Indo-Gangetic Plain (IGP), which encompasses the majority of northern and western India, is a region with intense anthropogenic emissions that contribute to wintertime haze. As a part of the IGP region, Agra is impacted by the long-distance transport of aerosols caused by trans-boundary haze pollution, including the combustion of fossil fuels and biomass burning, which causes severe regional air pollution issues. Thus, this study focuses on analyzing trace metal concentration bound to PM_{2.5} along with the estimation of OP during biomass burning in haze period at a sub-urban site of Agra.

II. METHODOLOGY

A. Sampling Site

The samples were collected on the rooftop of the Science Faculty Building at Dayalbagh Educational Institute in Agra. The location of this site is in Dayalbagh, which is encompassed by agricultural land within a 5 km radius. Its geographical coordinates are 27°10' N and 78°32' E, and its altitude is 169 meters above sea level. The climate of Agra is characterized by high temperatures and low humidity during the summer season, with temperature fluctuations ranging from 25 to 46°C and relative humidity levels between 25 and 40%. The temperature in winter ranges from 10 to 20 °C during the day and can drop to 3 °C at night, and relative humidity ranges from 80 to 85% and wind speed ranges from 0.3 to 0.5 m s⁻¹.

B. Sampling Procedure

In this study, 24 aerosol samples were collected from January 1 to January 30, 2019, and November 5 to December 31, 2019, in Agra. Of these, 10 samples were collected during haze periods on specific dates: November 28 and 29, 2019 (two samples), December 13, 24, 25, 29, 30, and 31, 2019 (six samples), and January 23 and 24, 2019 (two samples). The remaining samples were collected every fifth day. Each sample was collected for duration of 24 hours using an Envirotech APM 550 High Volume Sampler, with a flow rate of 16.6 L/min, on pre-combusted 47 mm quartz microfiber filters (Pallflex, Tissue quartz). Prior to chemical

analysis, the exposed filters were kept in a refrigerator at a temperature of about 4°C. The gravimetric method was employed to determine PM mass concentrations, utilizing an electronic microbalance (Mettler ME204). Before and after sampling, the filters were weighed to determine the net mass calculation, calculated as the difference between the two weights.

C. Extraction and Analysis

Trace Metals: A quarter of the exposed filter paper was subjected to 10 ml of HPLC-grade HNO₃ (65%, Merck Supra pure) in a microwave digester. The digested sample was filtered through a microporous membrane filter (Sartorius 393) and stored in polytetrafluoroethylene (PTFE) bottles. The resulting solution was subsequently adjusted to a volume of 50 ml using distilled water. The samples were then analyzed by ICP-OES (Agilent Technologies) for metals (K, Mg, Na, Ca, Al, Ba, Fe, Cr, Cd, Mn, Zn, Co, Pb, Cu, Ni, and Se).

Dithiothreitol (DTT) Assay: A quarter of the filter was extracted using an ultrasonicator (model: USB 3.5 L H DTC, PCi Analytics), in 30 ml of MilliQ water that was ultrasonicated for 45 minutes. The extract was filtered using a microporous membrane filter, eliminating insoluble suspended particles from the sample (Sartorius 393). Furthermore, the filtered sample was reacted with 100 M dithiothreitol (DTT) (98%, SRL Chem) in a 0.1 M phosphate buffer solution (Thermo Fisher, pH 7.4) in amber-colored glass vials and incubated at a temperature of 37 °C. Samples were extracted from the reaction mixture at time intervals of 0, 10, 20, and 30 minutes, and subsequently treated with a solution containing 10% (w/v) trichloroacetic acid (TCA, Thermo Fisher), 0.4 M Tris-HCl (LOBA Chemie, 20 mM EDTA, pH 8.9), and 10 mM 5, 5'-dithiobis-2-nitrobenzoic acid (DTNB, SRL Chem) to halt the reaction. The residual DTT present in this particular sample transforms 5,5'-dithiobis(2-nitrobenzoic acid) (DTNB) into its yellow-colored derivative and 2-nitro-5-thiobenzoic acid (TNB), which remains stable at ambient temperature for a duration of two hours [14]. The concentration of the residual DTT is directly correlated to the quantity of TNB produced. Thus, the measurement of the TNB product was conducted through UV-Vis spectrophotometer (UV-1800, Shimadzu) at a wavelength of 412 nm. The outcomes of the assay is reported in two measures: volume-normalized DTT (DTTv) and mass-normalized DTT (DTTm). These measures respectively indicate the intrinsic and extrinsic concentrations of PM [15].

Satellite Data: The Fire Information for Resource Management System (FIRMS) delivered active fire locations and brightness derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) [16].

Meteorological Data: The haze periods are defined as days with low atmospheric visibility (10 km) and high relative humidity (RH>90%), whereas non-haze periods are days with impaired visibility (>10 km) [17]. Hourly data was retrieved from the Continuous Ambient Air Quality Monitors on the Agra-UPPCB website [18] for meteorological parameters, including wind speed (WS), wind direction (WD), relative humidity (RH), and ambient temperature (AT). The visibility data retrieved from the Weather Underground website [19]. Using the HYSPLIT model [20], the reverse air mass trajectories were retrieved as well.

Source Apportionment: Positive Matrix Factorization (EPA PMF v5.0) was used to quantify the contribution of various emission sources to PM_{2.5} mass. PMF is a multivariate factor analysis tool that decomposes a matrix of speciated sample data into two matrices: factor contributions and factor profiles.

III. RESULTS & DISCUSSION

A. Mass concentration of PM_{2.5} and Meteorology

The average mass concentration of PM_{2.5} was 236.6±19.9 µg m⁻³ during the haze period, whereas it was

$137.1 \pm 47.5 \mu\text{g m}^{-3}$ during the non-haze period (Table 1). The aforementioned values were found to be 3.9 and 2.3 times greater than the National Ambient Air Quality Standards (NAAQS) of India ($60 \mu\text{g m}^{-3}$) [21].

TABLE1. AVERAGE MASS CONCENTRATION OF $\text{PM}_{2.5}$ AND MEAN VALUES OF METEOROLOGICAL PARAMETERS DURING HAZE AND NON-HAZE PERIOD

Parameters	Haze Period			Non-Haze Period		
	Mean	SD	Range	Mean	SD	Range
$\text{PM}_{2.5} (\mu\text{g m}^{-3})$	236.6	19.9	190 -260	137.1	45.7	74- 182
Temperature ($^{\circ}\text{C}$)	11.9	2.2	6.1-15.3	16.0	2.9	12.3-21.6
Relative Humidity (%)	91	2	90-94	66	11	54-82
Visibility (km)	0.9	0.5	0.5-1.6	1.4	1.1	0.3-3.2
Wind speed (m s^{-1})	1.1	0.4	0.6-1.6	1.3	0.9	0.4-2.3
Wind Direction	N-NW			N-NW		

During the study period, the average conditions included low visibility (0.9 km), a wind speed of 1.1 m s^{-1} , and high relative humidity (RH) at 91%. The presence of these relatively humid atmospheric conditions significantly contributed to the notable increase in PM concentrations, leading to the suspension of atmospheric particles [22]. The elevated mass of PM during haze episodes is associated with stagnant meteorological conditions, facilitating the accumulation of pollutants in the atmosphere [23], [24]. Fig. 1 illustrates the backward trajectories of air masses for both non-haze and haze periods. In India, haze periods are predominantly observed post-monsoon and during winter when northwest winds prevail. Specifically, during non-haze periods, long-range wind transport leads to greater dispersion of pollution (Fig. 1a). Conversely, during haze, predominant winds originate from the north western states of India, Punjab and Haryana indicating the transporting aerosols primarily from the regions where post-harvest burning dominantly occur (Fig. 1b and Table 1) [5].

The higher concentration of $\text{PM}_{2.5}$ during haze period in winter could be a result of combustion activities which is supported by MODIS fire counts data. The spatial distribution of the fire counts across the country during the studied months is shown in Fig. 2. It has been observed that in the month of January, November, and December 2019, a total number of 15,611 fire events were detected in India using TERRA and AQUA model. The fire counts during study period found higher in November, followed by December and January. The post-harvest burning in India during post-monsoon season can be a reason for the dominant number of fire counts in November [25], [26], [27].

B. Elemental Composition

Fig. 3 and Table 2 illustrates the variations in average concentrations of fifteen metals present in $\text{PM}_{2.5}$ during haze and non-haze period. Metals may be classified into three distinct categories based on their quantified concentration. The first category of contains metals like Al, Ca, Fe, K, Mg, and Na with concentrations exceeding $1 \mu\text{g m}^{-3}$. The second group contains Cu, Mn, Pb, Se and Zn whose concentration varied from 0.1 to $1 \mu\text{g m}^{-3}$, while the remaining group contains other trace metals like Ba, Cd, Cr and Ni that were mostly between 0.01 and $0.1 \mu\text{g m}^{-3}$. The total concentration of the fifteen metals was $18.2 \pm 7.4 \mu\text{g m}^{-3}$ during haze period, varying from 0.01 to $5.3 \mu\text{g m}^{-3}$ while during non-haze period the concentration was $17.0 \pm 5.1 \mu\text{g m}^{-3}$, varying from 0.01 to $4.7 \mu\text{g m}^{-3}$.

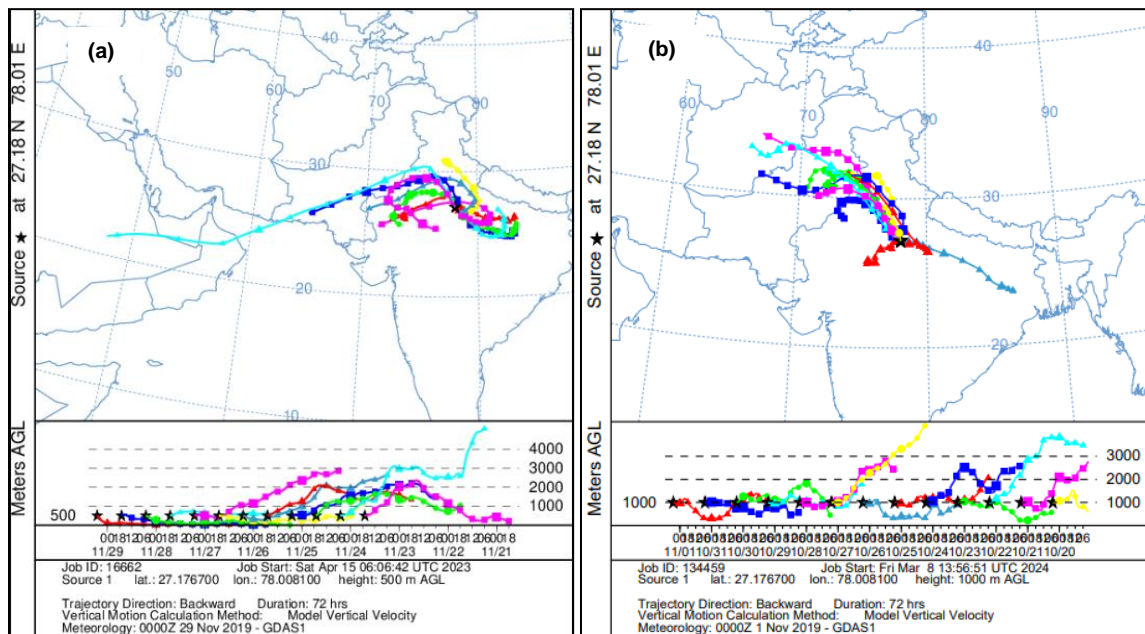


Fig. 1. Air Mass Backward Trajectories on (a) Non-Haze Period (b) Haze Period.

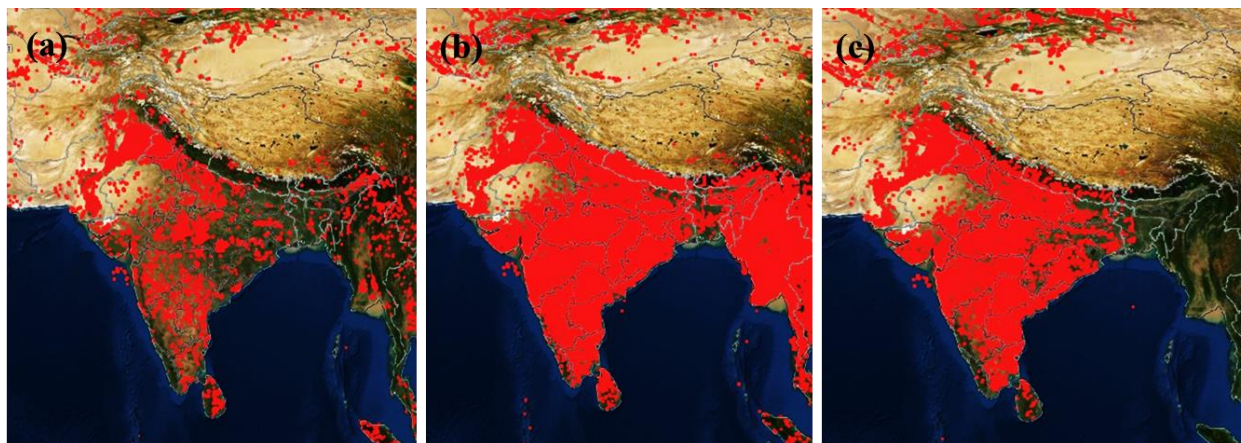


Fig. 2. Total Fire Pixels in India during (a) January 2019 (b) November 2019 (c) December 2019.

With the predominance of more stagnant conditions and prevailing biomass burning activities throughout the study period, there is less variation in the concentration of metals over both periods. Previous studies conducted in India and various other countries have also documented a comparable rise in various metal concentrations (both crustal and anthropogenic) during haze period in contrast to non-haze period [23], [24]. Furthermore, the obtained results show that K had the highest contribution with the average concentration of $4.9 \pm 1.2 \mu\text{g m}^{-3}$, while Ba had the lowest. The higher concentrations of K indicate that the combustion activities are attributed to the biomass or crop-residue burning. According to the majority of studies, potassium is abundantly associated with particles generated from combustion of wood and plants.

TABLE 2. AVERAGE CONCENTRATION OF METALS DURING HAZE AND NON_HAZE PERIODS

Metals	Haze Period ($\mu\text{g m}^{-3}$)	Non-Haze Period ($\mu\text{g m}^{-3}$)
Ca	4.0 \pm 3.6	3.6 \pm 0.8
Fe	1.7 \pm 0.8	2.8 \pm 0.2
Na	2.5 \pm 0.8	2.0 \pm 0.4
Mg	1.7 \pm 0.8	1.3 \pm 0.2
K	5.2 \pm 1.8	4.7 \pm 0.6
Al	1.4 \pm 0.8	1.1 \pm 0.5
Ba	0.01 \pm 0.003	0.01 \pm 0.005
Cd	0.03 \pm 0.008	0.02 \pm 0.005
Cr	0.05 \pm 0.01	0.05 \pm 0.006
Cu	0.08 \pm 0.02	0.07 \pm 0.01
Mn	0.1 \pm 0.02	0.1 \pm 0.04
Ni	0.03 \pm 0.02	0.03 \pm 0.006
Pb	0.3 \pm 0.1	0.3 \pm 0.04
Se	0.3 \pm 0.1	0.2 \pm 0.1
Zn	0.4 \pm 0.1	0.6 \pm 0.05

As a result, it has been widely used as a tracer for biomass burning. Nonetheless, potassium has been detected in soil dust [28], [29], coal combustion particles [6], and salt [30].

C. Oxidative Potential of $\text{PM}_{2.5}$: Role of trace metals in PM-related toxicity

The results show that average DTTv values during haze and non-haze period were 11.1 \pm 8.5 nmolmin⁻¹m⁻³ and 7.8 \pm 7.1 nmolmin⁻¹m⁻³, respectively, based on the cell-free DTT assay. The mean DTTm values per unit PM mass were 28.5 \pm 13.7 pmolmin⁻¹ μg^{-1} and 20.6 \pm 14.8 pmolmin⁻¹ μg^{-1} during haze and non-haze periods, respectively. The higher DTT activity during haze periods indicates more health-related issues during haze. As depicted in Fig. 4, the higher DTTv during the study period was attributed to the higher $\text{PM}_{2.5}$ mass concentration and subsequently higher concentration of metals during haze periods. In addition, these depicted results were found to be several times higher than those reported at various locations in the United States [31], Europe [32], and China [33]. In Bangalore, India, it was reported that the DTTv for ambient particles was 0.8 \pm 0.1 nmolmin⁻¹m⁻³ [34] which is substantially lower than that observed during the study period for both haze and non-haze period. During period of haze, it is anticipated that samples with a high $\text{PM}_{2.5}$ mass concentration will contain a relatively high concentration of oxidizing species, which could be a possible reason for the high OP.

D. Correlation between metals and DTT activity

Table 3 shows the linear correlation coefficient results between metal concentration and DTTv values during the study period. A significant correlation has been observed between the oxidative potential of PM and water-soluble metals such as Na (r=0.8), Mg (r=0.6), K (r=0.8), Ba (r=0.5) as well as Cr (r=0.6), Ni (r=0.5)

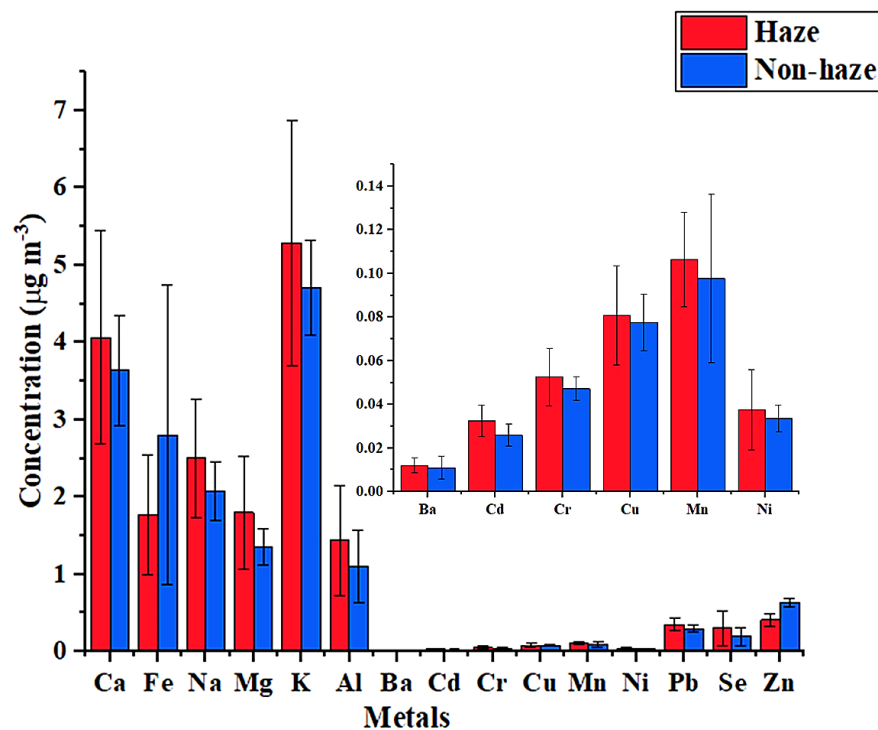


Fig. 3. Concentration of Metals during Haze and Non-Haze Periods.

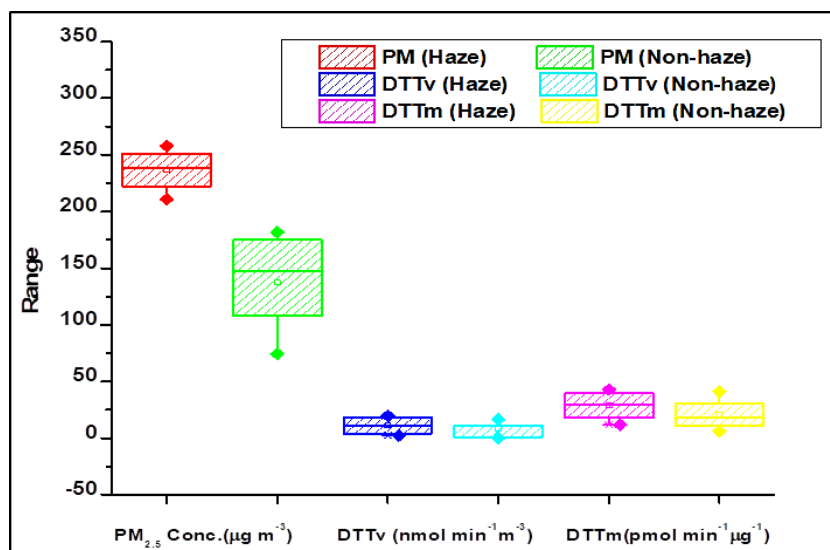


Fig. 4. $\text{PM}_{2.5}$ Concentration and DTT Activity of Trace Metals during Haze and Non-Haze Period.

TABLE 3. LINEAR CORRELATION COEFFICIENT BETWEEN METALS AND DTT_v ACTIVITY

Metals	Correlation Coefficient (r)
Na	0.91
Mg	0.81
Al	0.17
K	0.90
Ca	0.17
Cr	0.81
Mn	0.59
Fe	0.65
Ni	0.70
Cu	0.78
Zn	0.41
Cd	0.72
Ba	0.74
Pb	0.24
Se	0.57

and Cd ($r=0.5$). According to the USEPA report [35], metals such as Cr, Ni, and Cd are carcinogens, being a hazard to the human respiratory tract due to their contribution to the increased toxicity of PM_{2.5}. Similar investigations report the health risks associated with these metals using either a health risk model or OP [12], [36].

E. Source Apportionment: Positive Matrix Factorization

Mass fraction distribution of chemical species (Fig. 5) enabled source identification, revealing contributions from agricultural dust, vehicular emissions, biomass burning, and combustion activities associated with cooking and heating during the study period at the site. PMF analysis further delineated source profiles and their respective contributions to total PM_{2.5} mass concentration which are discussed as following.

Resuspended Road Dust: PMF analysis in our study revealed that traffic-induced resuspended road dust near the sampling site contributed a substantial 24.9% to the mass of fine PM_{2.5} aerosols. This finding emphasizes the significant role of vehicles in polluting urban and semi-urban environments apart from the direct emission in the form of vehicular exhausts. Brake wear plays a key role in this process, not only generating metal-laden particles through direct abrasion but also by triggering resuspended road dust and Cu, Zn, Mn, Sb, Sn, Mo, Ba and Fe are markers of brake wear and can serve as indicators of traffic re-suspension [37], [38]. In this study, this particular source contributes to the atmospheric presence of crustal metals like Fe, Al, Na, K, Mg and Ca along with the another set of metals, including Mn, Ni, Cd, Zn, and Cu that serve as indicators of traffic re-suspension [39], [40]. Other factors that influence metal concentration due to the road dust re-suspension are vehicle type and technology, fuel quality, traffic volume and density and road conditions.

Agricultural Dust and Biomass Burning: Notably, PMF analysis in this study reveals that the combined factor of agricultural dust and biomass burning contributes 49.4% to PM_{2.5} mass, highlighting their joint significance as pollution sources. Previous studies like Sharma et al. (2016) identified crustal dust as a major

source of Si, Na, Mg, Ca, Ti, and Al in PM [41] but the study site (Dayalbagh) is surrounded by agricultural fields that adds agricultural dust as a potential contributor to "crustal metals" Al, Ca, Mg, Na, K along with elements like Mn, Zn, Cu, and Ba. Interestingly, the observed increase in K content suggests an additional influence of biomass burning. This aligns with studies, where K serves as a marker for biomass burning in source apportionment studies across Europe and Asia [6], [42]. Furthermore, the use of different types of biomass as a fuel during biomass burning practices could explain the presence of other metals like Cd and Pb.

Combustion Activities: The complex interplay of local and potentially regional combustion sources is reflected in the 16% contribution of combustion activities to PM_{2.5} mass revealed by PMF analysis. Elevated concentration of Al, Fe, Zn, K, Ca, and Mg at the Dayalbagh sampling site suggest a significant influence of combustion activities on PM_{2.5} composition. However, the specific contribution of various combustion sources requires further scrutiny. While Cr and Cd often originate from high-temperature combustion of coal, oil, and waste, their presence could stem from diverse sources beyond just local cooking and heating [43]. Nearby commercial activities, using these fuels, or even open waste burning like scrap, garbage, wood, coal burning practices for cooking and heating purposes are observed in some residential areas could be potential culprits. Furthermore, elements like Ni and V, known markers for fuel combustion [44], [45], point towards both domestic and commercial burning. The prevalence of domestic and commercial cooking and heating practices during winters, likely contributes to the dominance of these metals.

Vehicular Emissions: PMF analysis revealed that vehicular emissions contributed 9.6% to PM_{2.5} at study site with the metals Cu, Zn, Mn, Ni, and Pb as indicators of vehicle emissions. Vehicle exhaust primarily comprises elemental carbon, with metals like Cu, Zn, Ba, Sb, Pb, Mn, Mo, and Ni serving as key markers of vehicular sources [46]. This also aligns with established knowledge that vehicular emissions are a major source of PM in urban environments, with research indicating their contribution ranging from 10 to 80% across Indian cities. However, direct comparison of these estimates can be challenging due to variations in how different studies quantify vehicular sources.

IV. CONCLUSION

The average PM_{2.5} mass concentrations during the haze and non-haze period were $236.6 \pm 19.9 \mu\text{g m}^{-3}$ and $137.1 \pm 47.5 \mu\text{g m}^{-3}$ that were approximately 3.9 and 2.3 times higher than the National Ambient Air Quality Standards (NAAQS) of India ($60 \mu\text{g m}^{-3}$), respectively. These increased values of PM_{2.5} during winter season could be a result of local and regional combustion activities during the study period. The contribution of combustion activities like biomass burning has been evident by the MODIS fire counts that were observed higher during the post-monsoon and winter seasons in India. The local meteorology such as higher relative humidity (91%) and lower visibility (0.9 km) indicate that haze prevailed during the study period. As a result of the haze, the atmosphere becomes more stagnant, enhancing the impact on local and regional pollution and health. A higher concentration of trace metals has also been observed in haze periods, with K ($4.9 \pm 1.2 \mu\text{g m}^{-3}$) having the greatest contribution. As a biomass tracer in the atmosphere, the maximum concentration of K among the PM-bound metals indicates the impact of local biomass burning. The OP of PM_{2.5} is a crucial indicator to assess the toxicity and its association with metals showed that water soluble metals K ($r=0.9$), Na ($r=0.9$) Mg ($r=0.8$), Ba ($r=0.7$) and trace metals Cr ($r=0.6$), Cd ($r=0.5$), and Ni ($r=0.5$) have a significant correlation with the DTT activity of PM_{2.5} and, consequently, are associated with toxicity of PM and health risks. To mitigate these conditions the source of the respective metals should be known which was suggested by PMF analysis that indicates the agricultural dust and biomass burning (49.4%) as the potential source for the enhanced metal concentration apart from these, traffic-induced resuspended road dust (24.9%), local combustion activities (16%) and vehicular emissions (9.6%) also play significant role.

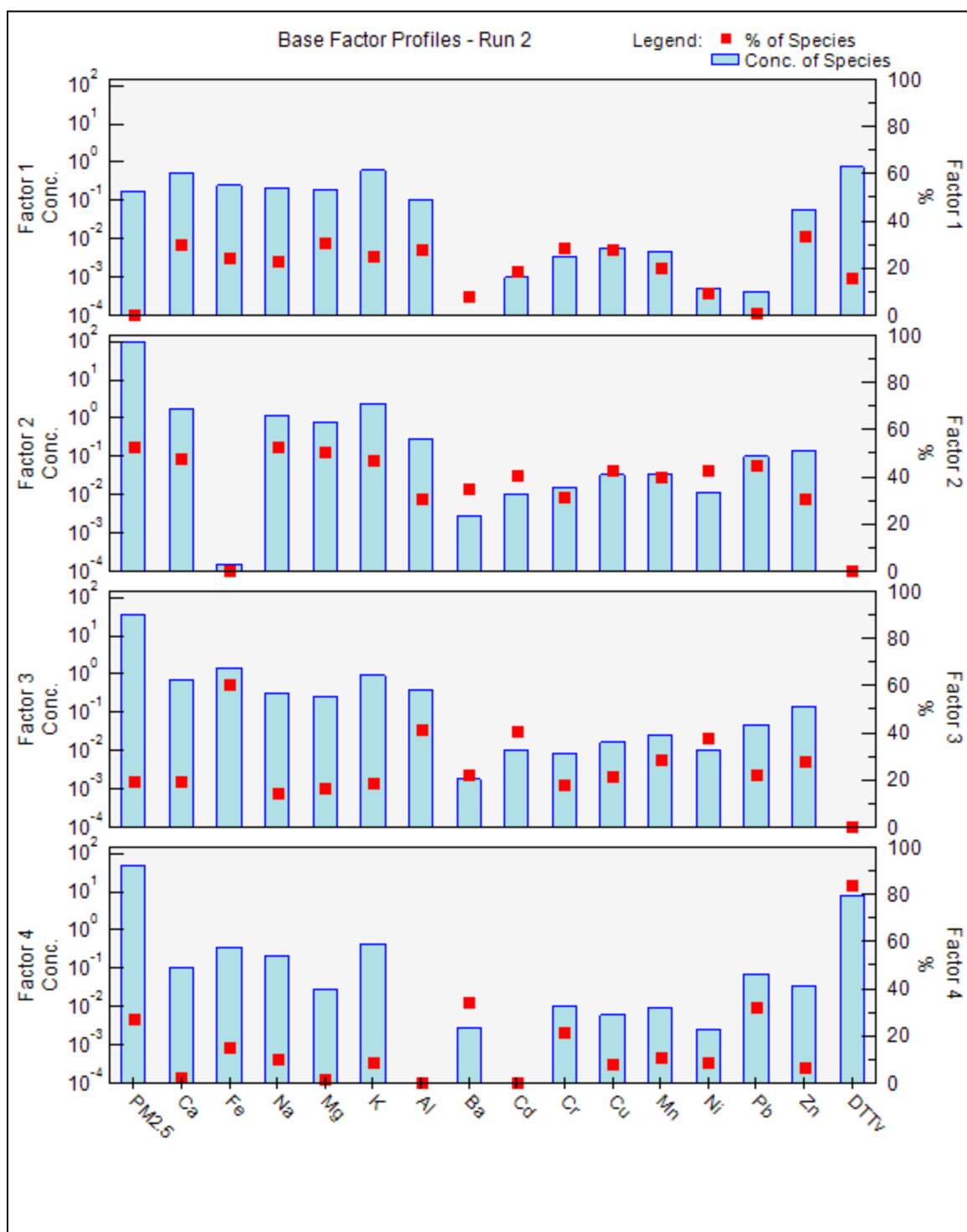


Fig. 5. PMF source profile of Traffic-induced Resuspended Road Dust (Factor 1), Agricultural Dust and Biomass Burning (Factor 2), Local Combustion Activities (cooking and heating) (Factor 3) and Vehicular Emissions in Dayalbagh for PM_{2.5} Mass.

Thus, this study enhances our understanding of aerosol toxicity during haze periods in terms of OP, investigating the contribution of metals to oxidative stress, and exploring the role of biomass burning in the context of haze periods at this specific site in the Indo-Gangetic Plain (IGP) region. Consequently, there is an urgent need for mitigation policies and their implications in order to reduce the impacts of biomass burning.

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Mediating Role of Consciousness in the Relationship between Resilience and Happiness among Healthcare Professionals

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Happiness is an emotional state characterized by feelings of joy, satisfaction, contentment, and fulfilment. Resilience is the process and outcome of successfully adapting to difficult or challenging life experiences. Consciousness describes our awareness of internal and external stimuli. The present correlational study aimed to understand the relationship between resilience and happiness and how consciousness mediates this link. The sample included 320 healthcare professionals who were assessed with the Oxford Happiness Scale, The Brief Resilience Scale, and a self-constructed consciousness scale. The data was analyzed with SPSS 20, and regression analysis was done. The results revealed a significant positive relationship between resilience and happiness and consciousness partially mediating the link. Thus, revealing the importance of being conscious to attain happiness through resilience.

Keywords – *Consciousness, Resilience, Happiness, Healthcare professionals, Mediation analysis*

I. INTRODUCTION

Modern healthcare sector has become demanding and complex [1] as they are required to be competent in understanding, diagnosing, and treating patients. Healthcare professionals are highly exposed to not only the ever-present stress, but as well as to the principles of perfectionism. Thus, they are in greater need of the tools to achieve a balance in their lives in order to effectively provide help to the patients [2]. Thus, in order to improve the overall wellbeing of our healthcare professionals, efforts including the practices to evoke consciousness are being taken up [3]. Happiness is defined as the feeling of joy, serenity, or positive wellbeing, along with a sense and understanding that life is good, meaningful and valuable [4]. Happiness is a state of a person's emotional well-being which can be either a narrow sense when general good things happen at specific moments or a positive understanding of one's life achievements and wellbeing. Research advancements have given us an insight about the relationship between happiness and life satisfaction [5-9]. In general, due to the lengthy work hours, healthcare providers experience lower amounts of happiness [10]. Evidence exists highlighting the importance of happiness among healthcare providers in strengthening the healthcare force and systems [11].

Resilience is defined as the ability to bounce back in life after adversities. It exists when an individual uses the mental processes and acts into advancing personal assets and protect self from the possible negative

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effects of life stressors [12]. Psychologically individuals develop mental and behavioural abilities in order to stay calm during crisis and move on from the situation without incurring the long-term consequences of the incident [13]. Kim and Chang [14] explored the experiences of resilience among nurses at their workplace. The results of the qualitative research revealed the importance of fostering resilience towards life by developing strategies to overcome adversities and become a better nurse. Cusack, et al. [15] mentioned resilience as a positive ability that helps nurses to overcome stressful life events. And adapting to life events with this positive concept results in maintaining happiness, psychological wellbeing and their mental health [16]. Consciousness refers to being aware of oneself and the surroundings one is in- the state of being mindful. Consciousness may foster resilience as high levels of mindfulness in individuals make them capable of responding to difficult situations instead of reacting in a non-adaptive way. Consciousness also helps people in better coping with difficult emotions and thought processes without being overwhelmed and tend to be creative [17].

Thus, measuring happiness and the variables contributing to it like consciousness and resilience among healthcare providers would be beneficial in understanding the important determinants to the creation of positive work environment, reduced work-related burnout, enhancing patient care and building their overall wellbeing.

II. CONCEPTUAL FRAMEWORK AND METHODS

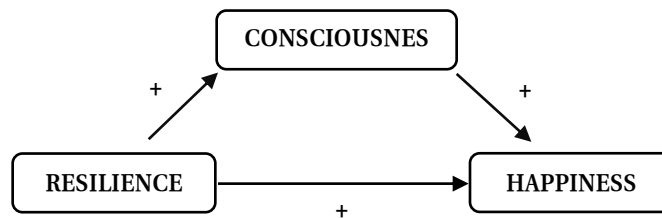


Fig. 1: Conceptual framework of the relationship among resilience, consciousness, and happiness.

A. Problem

To study the inter-relationship among resilience, consciousness, and happiness among healthcare professionals.

B. Objectives

- To study the association of resilience with happiness among healthcare professionals.
- To study the association of resilience with consciousness among healthcare professionals.
- To study the association of consciousness with happiness among healthcare professionals.
- To study the mediating role of consciousness in the link between resilience and happiness among healthcare professionals.

C. Hypotheses

- Resilience will be positively associated with happiness among healthcare professionals.
- Resilience will be positively associated with consciousness among healthcare professionals.
- Consciousness will be positively associated with happiness among healthcare professionals.

- Consciousness will mediate the link between resilience and happiness among healthcare professionals.

D. Design

Correlational Design was used to understand the relationship among resilience, consciousness, and happiness among healthcare professionals.

E. Sample

320 healthcare professionals (112 nurses, 110 doctors and 98 paramedics), with 194 Females, 126 Males, belonging to the age group 21 to 35 years of age from various hospitals of Agra, Mathura and NCR were included in the sample. Convenient Sampling technique was used.

F. Variables

- INDEPENDENT VARIABLE
Resilience
- DEPENDENT VARIABLE
Happiness
- MEDIATING VARIABLE
Consciousness

G. Tools

- The Oxford Happiness Questionnaire (OHQ): developed by Hills and Argyle (2002) [18]. The Questionnaire consists of 29 items, to be scored on a six-point Likert scale ranging from 1-strongly disagree to 6- strongly agree. The negative items (1,5,6,10,13,14,19,23,24,27,28,29) were scored in reverse. Cronbach's alpha was calculated to be .92 and the inter item correlations ranged from .03 to .58.
- The Brief Resilience Scale (BRS): developed by Smith et al., (2008) [19]. The scale consists of 6 items to be scored on a five-point Likert scoring (strongly disagree- 1, disagree- 2, neutral- 3, agree- 4 & strongly agree- 5). There are 3 positive questions (1,3, &5) and 3 negative questions (2, 4 & 6). Reverse scoring was done for the negative questions. The Cronbach's alpha was equal to .80 and the internal consistency ranged from .84 to .91.
- The Consciousness Scale: developed by Kumari & Cherian (2021) [20]. The scale included 25 items divided into 5 dimensions of consciousness namely- Emotional Consciousness (1-5), Moral Consciousness (6-10), Cognitive Consciousness (11-15), Social Consciousness (16-20), Spiritual Consciousness (21-25). The scale is scored on a three-point Likert scoring- Agree (3), Sometimes (2), Disagree (1). The reliability of the scale was estimated through Cronbach's Alpha which was calculated to be equal to .721. The internal consistency of the scale was estimated by correlating the dimension totals with the grand total, having a range of .663 to .756.

H. Statistical Techniques

The relationship among the three variables (resilience, consciousness and happiness) was tested using Pearson Product Moment Correlation Coefficient and Mediational Analysis.

III. RESULTS

Table 1 shows the inter-correlation among resilience, consciousness, and happiness.

TABLE I. CORRELATIONAL MATRIX

	Mean	SD	RESILIENCE	CONSCIOUSNESS	HAPPINESS
RESILIENCE	20.39	5.04	1	.245**	.508**
CONSCIOUSNESS	84.72	15.28	.245**	1	.667**
HAPPINESS	108.06	9.17	.508**	.667**	1

** $p < 0.01$

The correlation matrix in table 1 shows the inter-relationship among resilience, consciousness and happiness. There is a positive relationship between resilience and consciousness ($r = .245$) revealed. This relationship is found significant at 0.01 level. This indicates that an increase in the scores of resilience have a tendency of increasing the scores of consciousness.

A positive relationship was observed between resilience and happiness ($r = .508$) among the sample. This relationship was found significant at 0.01 level. This indicates that an increase in the scores of resilience will intend a rise in the scores of consciousness.

The relationship between consciousness and happiness ($r = .667$) was found to be positive and significant at 0.01 level. This indicates that an increase in the scores of consciousness will induce an equal increase in the scores of happiness among the sample.

Mediation Analysis: The mediation model represents the mediation analysis that illuminates as how and why a relationship exists among the variables and where the mediating variable, M, acts like a mediator in the link between the independent variable- X and the dependent variable- Y, hypothetically [21].

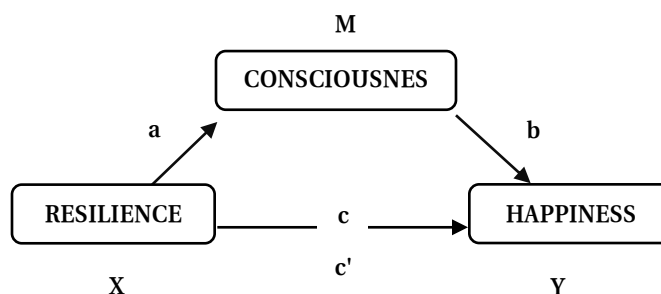


Fig. 2: Research design and the method for single-mediator model.

The figure above explains the design of research and the procedural action for a single-mediator model that is being used to understand the inter-relationship among the variables, by the steps for mediation formula. The first step includes Path C, which requires the understanding of the relationship between the independent variable (X)- Resilience and the dependent variable (Y)- Happiness. The second step includes Path A, where the relationship between the independent variable (X) and the mediating variable (M)- Consciousness is to be established. The next step includes Path B, where the knowledge of the relationship between the mediating variable (M) and the dependent variable (Y) is essentially established. The final step

(Path C') in mediation formula includes applying hierarchical regression analysis would be applied in order to understand which predictor variable among resilience and consciousness predicts Happiness the best.

Testing the Mediating role of Consciousness in the link between Resilience and Happiness

TABLE 2. RESILIENCE (X) AND HAPPINESS (Y)

Variables	B	SE	Beta	t	r	R Squared	F
Resilience	.925	.088	.508	10.525**	.508	.250	110.779**

**p < 0.01

On following the steps required in the mediation formula, where resilience is the predictor variable and happiness is the criterion variable, a positive relationship was established between resilience and happiness ($\beta = .508$, $t = 10.525$). This relationship was found significant at 0.01 level. This indicates that resilience significantly predicts happiness. The b value ($b = .925$) explains the variation that occurs when 1 unit change happens in the scores of resilience a change of .925 occurs in the scores of happiness. Thus, the hypothesis stating “Resilience will be positively associated with Happiness” was accepted.

TABLE 3. RESILIENCE (X) AND CONSCIOUSNESS (M)

Variables	B	SE	Beta	t	R	R Squared	F
Resilience	.742	.165	.245	4.504**	.245	.060	20.283**

**p < 0.01

The next step, where resilience is the predictor variable and consciousness is the mediating variable, a positive relationship was established between resilience and consciousness ($\beta = .245$, $t = 4.504$). This relationship was found significant at 0.01 level. This indicates that resilience significantly predicts consciousness. The b value ($b = .742$) explains the variation that occurs when 1 unit change happens in the scores of resilience a change of .742 occurs in the scores of happiness. Thus, the hypothesis stating “Resilience will be positively associated with consciousness” was accepted.

TABLE 4. CONSCIOUSNESS (M) AND HAPPINESS (Y)

Variables	B	SE	Beta	t	R	R Squared	F
Consciousness	.400	.025	.667	15.947**	.667	.444	254.319**

**p < 0.01

The next step, where consciousness is the mediating variable and happiness is the mediating variable, a positive relationship was established between consciousness and happiness ($\beta = .667$, $t = 15.947$). This relationship was found significant at 0.01 level. This indicates that resilience significantly predicts consciousness. The b value ($b = .400$) explains the variation that occurs when 1 unit change happens in the scores of resilience a change of .667 occurs in the scores of happiness. Thus, the hypothesis stating “Consciousness would be positively associated with happiness” was accepted.

TABLE 5. RESILIENCE (X), CONSCIOUSNESS (M) AND HAPPINESS (Y)
MEDIATION OF CONSCIOUSNESS IN THE LINK BETWEEN RESILIENCE AND HAPPINESS.
HIERARCHICAL REGRESSION ANALYSIS WITH HAPPINESS AS DEPENDENT VARIABLE.

Variables	B	SE	Beta	t	R	R Squared	F
Step 1							
Resilience	.925	.088	.508	10.525**	.508	.250	110.779**
Step 2							
Consciousness	.346	.023	.577	15.200**	.756	.571	210.988**
Resilience	.668	.069	.367	9.675**			

**p < 0.01

Table 5 shows the results of the hierarchical regression analysis, where resilience and consciousness were included as the predictor variables and happiness as the criterion variable. First consciousness entered the equation and is seen accounting for about 44% of variance caused in predicting happiness among the sample. In the next step resilience and consciousness enter the equation and an additional 13% of change is observed in the value of R Squared. This indicates that resilience and consciousness calculate to about 57% of variance in predicting the criterion variable-Happiness. The last model with resilience and consciousness stands evidence with the standardized beta coefficients, that a statistical, significant relationship occurs between the independent variables and the dependent variable. Consciousness was found to be the strongest predictor of Happiness.

The results of the hierarchical regression analysis verify that resilience and consciousness are positively associated with happiness. Resilience was found to predict happiness significantly, however when resilience and consciousness enter the equation together, a decrease in the beta value of resilience is observed, from .508 to .367. The relationship between resilience and happiness was still found to be significant at 0.01 level. This indicates a partial mediation [22]. This means that consciousness partially mediates the link between resilience and happiness among healthcare professionals. As a result, the hypothesis stating “Consciousness would mediate the link between resilience and happiness” was accepted.

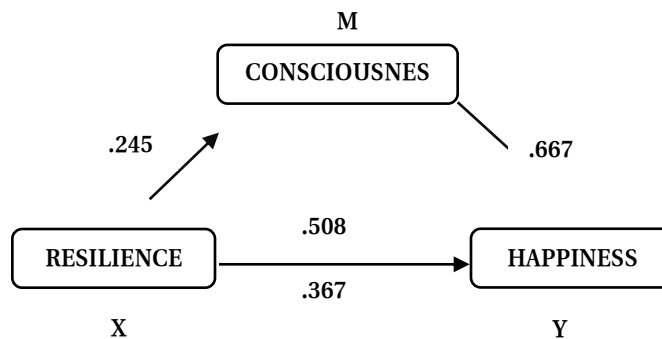


Fig. 3: Mediating role of consciousness in the link between resilience and happiness.

The findings of the hierarchical regression analysis that was used to test the mediating role of consciousness in the link between resilience and happiness is represented in Fig. 3. As presented the beta value of resilience alone (path c) in predicting happiness was equal to .508. The beta value is observed to drop by .141 to .367 when consciousness is added into the equation. Hence, a partial mediating role of consciousness in the link between resilience and happiness is recorded.

IV. FINDINGS AND DISCUSSION

The analysis of data and the interpretation of the results calculated from the present study directs to the findings below:

- Resilience was found to have a significant positive association with happiness among healthcare professionals.
- Resilience was found to have a significant positive association with consciousness among healthcare professionals.
- Consciousness was found to have a significant positive association with happiness among healthcare professionals.
- Consciousness was found to be partially mediating the link between resilience and happiness among healthcare professionals.

Sharma [23] attempted to examine the relationship between resilience and happiness among students in Haryana, India. The researcher included a sample of 60 individuals for the correlational study. The Pearson Product Moment correlation revealed a positive relationship between resilience and happiness. Bajaj [24] aimed to explore the association of mindfulness and resilience among 462 undergraduates. The correlational research revealed a positive significant relationship between the two variables and that both play an important role in influencing mental health among young adults. Wavle and Singh [25] in their study aimed to explore the influence of consciousness on happiness and predict happiness among young adults. The data included 172 young adults included in the study through convenient sampling technique. Pearson Correlation revealed a significant positive relationship between consciousness and happiness and the linear regression analysis revealed consciousness to be a significant predictor of happiness among the sample. Aldahadha [26] aimed to explore the relationship of mindfulness and its predicting ability towards happiness and wellbeing. A strong relationship was uncovered between mindfulness and happiness. A positive relationship was revealed between mindfulness and wellbeing. This indicated that mindfulness is much more effective and advantageous in living a happy life with health benefits.

V. CONCLUSION

The wellbeing of our healthcare providers should be the utmost important concern in order to deliver remarkable patient care. In order to achieve the optimum results for the patients and their families, the functioning of these healthcare providers must be at the highest level of health- physical and psychological both. Highlighting resilience, the encouraging positive force to overcome adversities to the healthcare providers would play a very crucial role in enhancing the quality of treatment care. Both their professional and personal lives will be benefitted with a little resilience.

On the other hand, consciousness practices can be extensively implemented by our healthcare warriors, thus enhancing their wellbeing and the quality of care they provide to the ones in need. Practicing consciousness will help them in being aware and mindful about their surroundings and their role as healthcare providers. This will give them clarity and enhance their decision making and critical thinking- which is an important ability needed in their profession. The findings of the present study suggest that increases in consciousness skills mediate the resilience of an individual in order to achieve happiness in life. This can be considered as classifications for the resilience of medical warriors and offer an outline to guide the understanding and development of an intervention program directing in improving their resilience and consciousness levels. Thus, based on the findings of the study it can be concluded that varied intervention programs could be developed in order to enhance the inter strengths of the healthcare providers.

Programs based on mindfulness can prove helpful to the healthcare providers to develop the essential skills to manage the medical stress and enhance their health conditions; increase their overall attention, devotion, empathy, helpfulness, and presence with the patients and their families. It would help them experience the joy of work satisfaction, peacefulness and reduce burnout at the workplace.

Further explorations and research with larger sample sizes, with arduous research methods would prove useful in extending the work.

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Optical Character Recognition of Text in Textured and Newspaper Images

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Most of the work reported in the literature for Optical Character recognition (OCR) assumes the background to be clean or white and works for one or two fonts. Real documents can range from simple plain backgrounds to complex uneven illuminated backgrounds. OCR of such documents is further complicated due to text written in a variety of fonts and sizes. In this paper, an OCR system is proposed for extraction and OCR of text for Newspaper layouts and textured backgrounds. The proposed system has been tested on a variety of images taken from different newspapers, old books and synthetic images on textured backgrounds. It works on several unknown fonts even in the presence of complicated backgrounds although the database consists of only four fonts. The recognition accuracies obtained are 98-100% in most cases. Thus, the proposed approach for Telugu OCR performs well for extracted text images from a larger variety of sources than the previous attempts which were more restrictive and domain specific.

Keywords – Histogram, Wavelet transform, Edge direction feature, Jeffrey divergence distance measure; Telugu OCR

I. INTRODUCTION

Text images to be recognized using OCR are basically of three types

- Images in which text is written on plain background,
- Images in which text is written on textured background and
- Images in which text and images are juxtaposed in any possible order as in Newspaper layouts.

Newspapers, magazines, advertisement boards, cards, and credit cards are examples of such images. Some of these are shown in Fig. 1. The success of OCR of such documents is directly related to how well the text regions are segmented and separated from their backgrounds for facilitating downstream OCR operations. Once the text is separated it has to be accurately recognized. The task of recognizing text from such images is complicated because the process of background removal may also inadvertently affect the text portion. Furthermore, like in any OCR problem, recognition of text written in different sizes and fonts presents its own difficulty. A good OCR system should work over a variety of backgrounds, combinations of text and images portions, and multiple fonts and sizes of characters. Commercial OCR software is available for Roman script that provides reasonable performance over a wide range of such images.

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OCR of Indian scripts has proven to be more difficult to handle due to the presence of vowel and consonant modifiers resulting in compound characters consisting of several connected entities even in relatively “clean” backgrounds. Coupled with noisy, textured and variety of backgrounds the OCR of Indian scripts becomes even more challenging.

Telugu is a popular South Indian language. The basic alphabet of Telugu script consists of 16 vowel modifiers (matras) and 38 consonant modifiers resulting in 54 symbols. The combinations of these alphabets run into lakhs of Akshars or compound characters which in many cases may have 3 to 4 connected entities. Lakshmi et al. [1] reported the development of a Telugu OCR System for Printed text (TOSP) based on identification of basic symbols which is a single connected entity in Telugu script. They identified 386 basic symbols. Jayaram et al. [2] discussed the state of the art of machine printed Telugu OCR. Most of the reported work can handle only one or two fonts for images with simple backgrounds [3, 4, 5, 6 and 7]. OCR of Telugu script on textured backgrounds is relatively less studied although it is commonly required.

An attempt is made in this paper to fill this gap. The text regions from Telugu text embedded on textured backgrounds and Telugu newspaper images are identified and isolated. The background is then removed to yield a cleaner text image which is then processed through OCR. The background removal process is designed to leave the characters untouched as far as possible so that the recognition accuracy of the extracted text remains high being 100% for database fonts and in the range of 95 – 100% for unknown fonts from images of newspapers and images with textured backgrounds.

The rest of the paper is organized as follows. A literature review of the work done in separation of text from background is given in Section 2. Our proposed method for the same is briefly explained in Section 3. The methodology adopted for Telugu OCR is explained in Section 4. Experimental results and conclusions are derived in Sections 5 and 6.

II. RELATED WORK

Garg et al. [8] proposed an approach for simple newspaper layouts. They detected a pseudo-periodic pattern that discriminates text from graphics and could correctly segment 39 images out of 45 images. Negi et al. [9] extracted Telugu text from Newspaper layouts. They used the Hough Transform on Sobel gradient magnitude approach for identification of text regions and reported an accuracy of 100%. A segmentation technique for ancient Telugu document images is proposed by Rao [10]. They segmented line by taking the convolution of the Horizontal profile and Gaussian kernel and reported an accuracy of 73.5%. Kaur et al. [11] extracted text for Gurumukhi script by using candidate text region and their algorithm did not perform well for extracting very small text or text with poor contrast. Nagabhushan et al. [12] identified candidate text regions by connected component analysis on edge pixels using Canny edge detector. Saluja et al. [13] proposed an approach which is based on adaptive thresholding, detecting connected components, generating blobs and finally extraction of only those blobs which consist of textual part. Gupta et al. [14] proposed an approach using discrete wavelet transform (DWT) for extracting text information from complex images. Sumathi et al. [15] presented an effective combined edge based approach using compass operators, edge map, and morphological operations for feature extraction for text region extraction in document images. Niblack [16] proposed an algorithm that calculates pixel-wise threshold in a chosen rectangular window of the image. Sauvola et al. [17] proposed an approach for stained and badly illuminated document images which is improved version of Niblack method. Kim et al. [18] proposed a rain fall model which is obtained by applying global Otsu method on the difference image of original image and water filled image.

algorithm with some well-known algorithms such as Otsu, Niblack and Sauvola and showed that their method is better or comparable to Sauvola's.

The Wavelet based approach works well for extracting text from images on textured backgrounds. However, the text region is not well extracted from newspaper images. The algorithm leaves black spots and the text is also removed at some places adjacent to the text – image borders as shown in Fig. 3.



Fig. 3. (a) Original Image (b) Extracted text Image.

A histogram based approach is adopted for extracting text from newspaper images prior to application of the background removal scheme to remedy this problem. This step is done as follows. Text regions can be identified by uniformly distributed alternate peaks and valleys. The valleys are deep i.e. all near 0, as they indicate line gaps. They may not be exactly 0 because of the presence of modifiers that appear below a character. Image regions if any can be traced easily as the valleys become shallow or may even disappear. Thus, the variations of heights of peaks in the horizontal histogram provide information for identification of image region. A similar exercise with the vertical histogram completes the process of isolating the image region. The pseudo-code of the algorithm is as follows.

- The input image is colored or gray scale image.
- Find the binarized image using Otsu method [20].
- Find the horizontal histogram of the image (Fig. 4)
- Find the regions where valleys become shallow or disappear in the horizontal histogram.
- Find the vertical histogram of that region (Fig. 5)
- Find the sub-region where valleys become shallow or disappear in the vertical histogram.
- Remove the recognized region from the image.

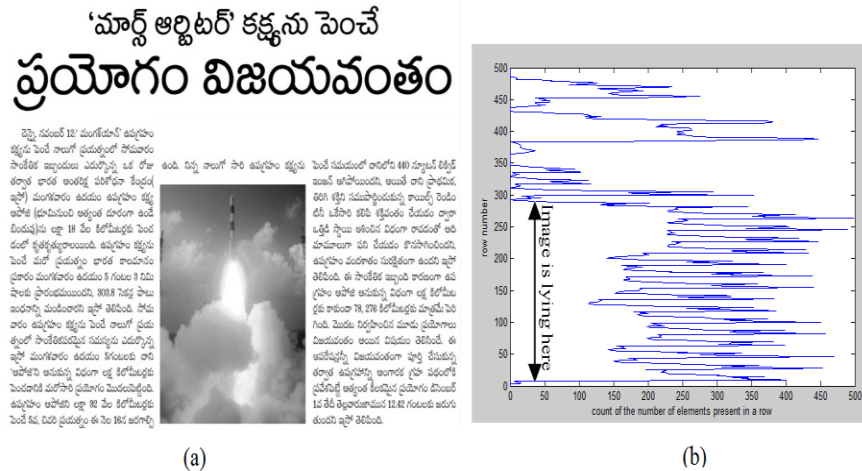


Fig. 4. (a) Original Image (b) Horizontal histogram.

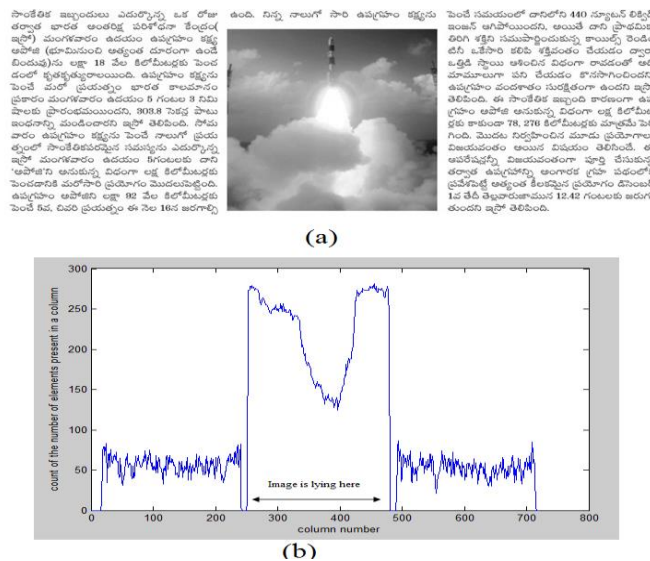


Fig. 5. (a) Original Image (b) Vertical Histogram of that region identifying the image portion.

IV. PROPOSED OCR SYSTEM

The methodology adopted for Telugu OCR system is presented as a block diagram given below in Fig. 6.

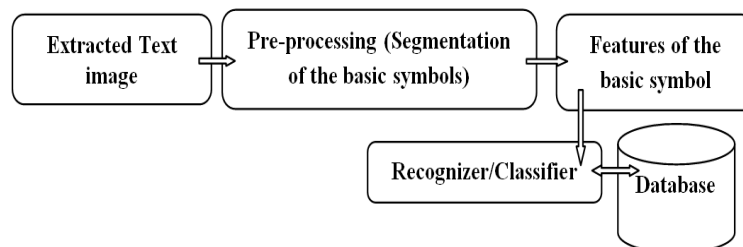


Fig. 6. Block Diagram of the proposed OCR system

D. Edge Direction Histogram Features

Edge Direction Histogram features [6] are used for each of the 386 basic symbols. The features of all the basic symbols of different fonts and sizes are stored in the database and basic symbols are recognized on the basis of these features.

E. Database Creation

For creating a database, Telugu samples are prepared using four fonts i.e. Harshapriya, Godavari, Hemalatha and Gautami and three different sizes i.e. 25, 30 and 35 resulting in $386 \times 4 \times 3 = 4632$ basic symbols. The basic symbols are normalized by maintaining the aspect ratio. Each basic symbol is converted to size 36 while maintaining its aspect ratio. They are then skeletonised using algorithm in [21]. Edge Direction Histogram features are extracted for the skeletonised basic symbols. The features of all the basic symbols of different fonts and sizes are stored in the database. Recognition is by identifying the nearest neighbor in the feature space of the unknown symbol in the database. The recognizer uses a Jeffrey distance measure scheme for this purpose. If 'a' is the feature vector of unknown basic symbol to be classified and 'b' the feature vector of a basic symbol in the database, Jeffrey Divergence Distance measure between a and b is

$$D_{ab} = \sum_{n=1}^{81} \left(a_n \log \left(\frac{a_n}{m_n} \right) + b_n \log \left(\frac{b_n}{m_n} \right) \right) \quad (1)$$

where $m_n = \frac{(a_n + b_n)}{2}$.

Increased database size slows down the recognition process as the distance has to be computed with each feature vector. To make the process faster, the database size is reduced using a clustering technique to retain only one representative of each cluster containing similar symbols. Further iterations are performed to add the symbols that cause mis-recognitions till no further symbols need to be added and 100% recognition is obtained with the testing set. These are essentially the outliers in the clusters. The reduced database size is thus 691.

F. Recognition

The flow chart depicting the steps in OCR of the extracted text image is given in Fig. 7. The features of the unknown to be recognized are computed and sent to the kNN recognizer. The kNN recognizer determines the k-nearest neighbors in the features space from the database of features using the Jeffrey Distance measure. In this work k is taken to be 2. The final step for completing the recognition is to select one symbol out of these two candidates. This is done using aspect ratios and selective template matching as follows. The aspect ratios of the two candidate neighbors determined by the kNN are computed and matched with the unknown symbol. If one of these two matches much more closely with the unknown symbol the recognition is over. However, if both the candidates are roughly equally close template matching is performed to identify the better match. This two-step process saves the computation involved in template matching in many of the cases as the decision is arrived by merely looking at the aspect ratios. The process is repeated till all the basic symbols are recognized.

G. Confusion Logic

Although the kNN recognizer with subsequent post processing is able to provide correct recognition in most cases, some basic symbols are sometimes confused with other very similar ones causing incorrect

recognition. The sets of similar looking basic symbols are given in the form of a table which is referred to as the Confusion Table given in Table 1. The confusion is resolved using structural properties of the candidate characters e.g. presence or absence of holes and loops and their location, number of zero crossings, whether the '√' modifier is connected to the main symbol or disconnected etc.

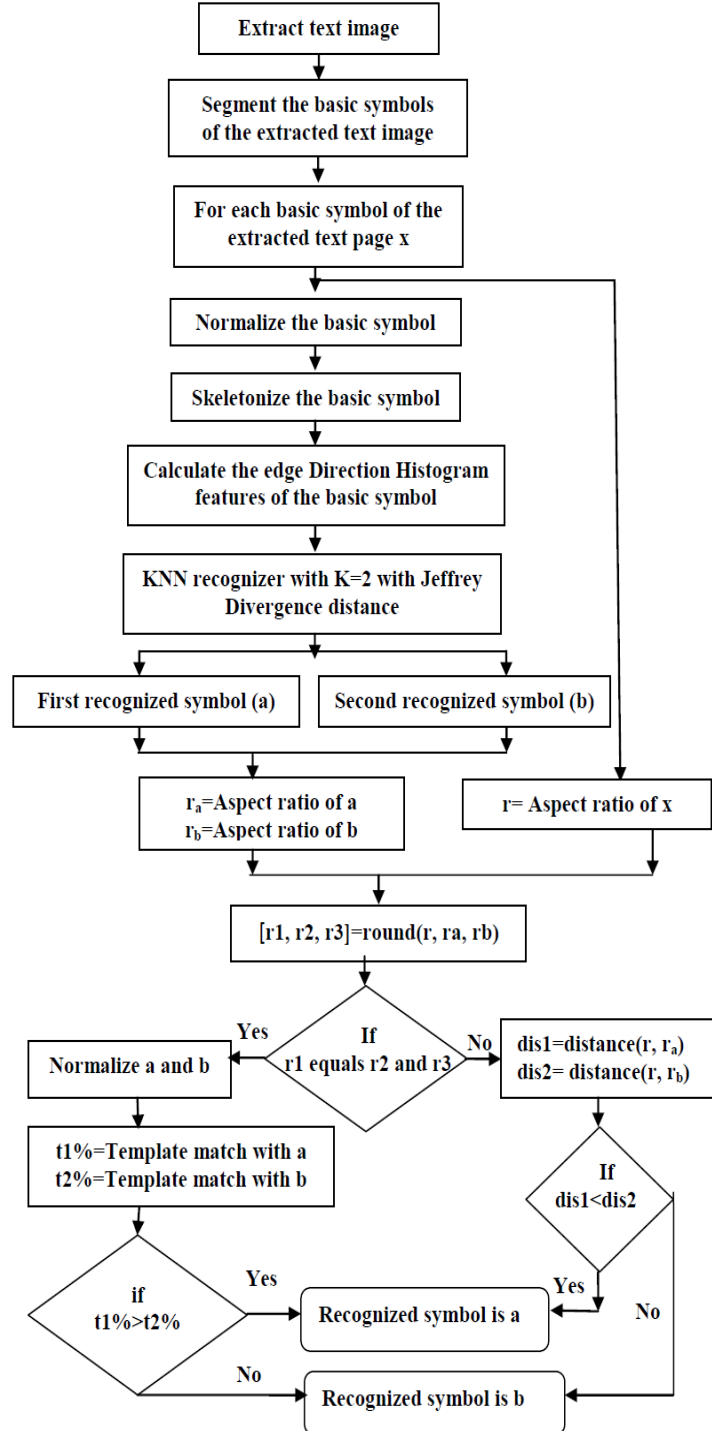


Fig. 7. Flow chart of the proposed Telugu OCR system

TABLE 1. CONFUSION TABLE

S. No.	Confusion Symbols			
	<i>Phonetic 1</i>	<i>Phonetic 2</i>	<i>Confused Basic Symbol 1</i>	<i>Confused Basic Symbol 2</i>
1.	pa	sa	ప	స
2.	va	na	వ	న
3.	ma	nu	మ	ను
4.	la	ra	ల	ర
5.	Ta	la	ట	ల
6.	vA	ha	వా	హ
7.	da	u	ద	ఉ
8.	va	cha	వ	చ
9.	gha	su	ఘ	సు

V. EXPERIMENTAL RESULTS AND DISCUSSION

Some samples images are taken from different newspaper clips and old books for testing the algorithm proposed. A sample text is prepared in each of the four fonts present in the database embedded on same textured background as given in Fig. 8. Another sample text is prepared in seven fonts i.e. Mandali, Suranna, Amma, Peddana, TenaliRamaKrishna, Timmana and Krishna which are not in database on different textured backgrounds. They are given in Fig. 9. In another experiment, another sample text image is prepared for different sizes of four fonts present in the database.

Text extraction algorithm is performed on above images. The extracted text image is given in Fig. 10, 11 and 12. Extracted text image is ready for recognition. Recognition process is performed on extracted text images and the results are given in Tables 2, 3 and 4. The recognition accuracy obtained for various database fonts is 100%. The recognition accuracy for seven fonts which are not in database is still as high as 98% even though there are large variations in the writing styles of the fonts. These results provide confidence in the veracity and effectiveness of the proposed approach.



Fig. 8. Sample text image of fonts present in the database

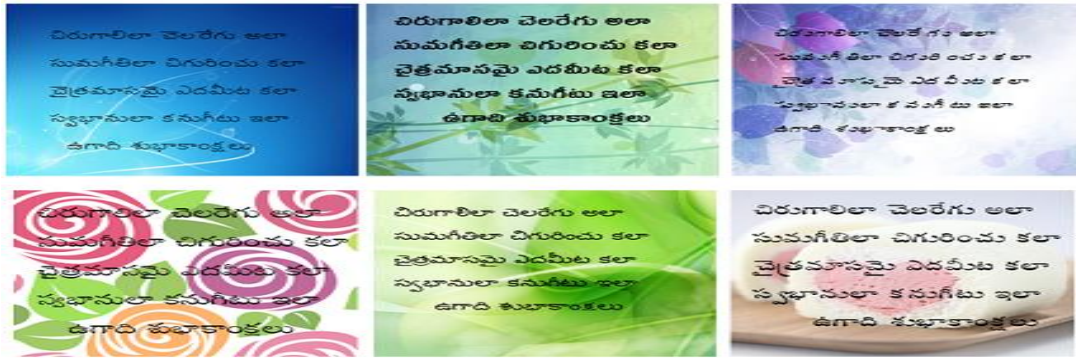


Fig. 9. Sample text image of which are not in database on different backgrounds.

మహావైద్యుడి మందుచీటీ

కార్లసన్ వ్యక్తిగత
వైద్యుడు క్లినిక్

[illegible]

ఎత్తుకు పైఎత్తు: ఆనంద్, కార్ల్స్సన్

రాష్ట్రంలో నాయకత్వాన్ని మార్చే పక్షంలో
ముఖ్యమంత్రి పదవికి దళిత నాయకుడి
పేరును కూడా పరిశీలించాలని
ఉపముఖ్యమంత్రి దామోదర్ రాజనరసింహ
కాంగ్రెస్ అధినాయకత్వానికి సూచిస్తున్నట్లు
తెలిసింది. ఎన్.సి.ఎస్.టి ఉపప్రణాళిక గురించి
అధినాయకత్వానికి వివరించేందుకు గత
రెండు రోజుల నుండి ఢిల్లీలో మకాం వేసిన

(a)

‘మాస్ట్ ఆర్టిటర్’ కక్షను పెంచే
ప్రయోగం విజయవంతం

[illegible]

విష్ణు నాలుగో సారి ఉమ్మడినాం కష్టమ


పాపే నమమూరే చంద్రాగ్రే (40) పొద్దుమీద కట్టిపెట్టి ఆసనం కూర్చుంటుంది. అతని అండ్ల ప్రావీణ్యం, పాపే శక్తిని ప్రదర్శించుకున్నప్పుడు కామ్యూనిటీలో పెరిగిపోయే దీనిని దీక్షితులు అంటే శక్తివంతుల రుద్రమణి వ్యాఖ్య. బట్టి న్యాయం అంటేనే వివేకానివారందరికీ అది ముఖ్యమైనా. మన జీవితంలో కనీసం నాలుగైదు, షుభముగా మారుతున్నప్పుడు తమకు అది షుభం అనిపిస్తుంది. ఈ సందర్భం జ్వరంతో కూడినదిగా అనే గ్రామం అపోకే అనుకున్న వివేకాని వల్ల కేరళలోని గ్రామ ప్రజల 78, 78% అంతా అందుకున్నప్పుడు పెరిగిపోయింది. మొదట నాల్గవంటి మునుగు ముత్యమాయా దీక్షితులవలన అయిన వివేకం తెలిసింది. ఈ సందర్భంలో దీక్షితులవలన అప్పుడు జీవితంలో భారత ఉపసంస్కృతి అలాగనే భారత ప్రజలకు ప్రసాదించే అత్యంత బాధ్యమైన సమస్యగా దీనిని పాపే కల్పించినామోమీ 1242 గిలబతుల అయిన పాపేమూర్తి తెలిసింది.

Fig. 10. Extracted text image of Fig. 1(a).

Fig. 11. Extracted text image of Fig. 1(b).

బంకించంద్ర చటర్జీ

మూలం:
సుబోధకంధ్ర సేవోగ్రంథ
అనువాదం:
దేవులకర్ణి రామానుజరావు


ಸಾಹಿತ್ಯ ಲಲಿತಾ

(b)

Fig. 12. Extracted text image of Fig. 1 (c) and (d).

TABLE 2. RECOGNITION RATES FOR IMAGES WITH FONTS BOTH IN DATABASE AND NOT IN DATABASE

S No.	Fonts	Recognition Rate
	<i>In Database</i>	
1.	Harshapriya	100%
2.	Godavari	
3.	Hemalatha	
4.	Gautami	
	<i>Not in Database</i>	
1.	Mandali	98%
2.	Suranna	
3.	Peddana	
4.	Amma	
5.	TenaliRamaKrishna	
6.	Timmana	100%
7.	Krishna	

TABLE 3. RECOGNITION RATES FOR IMAGES WITH TEXT IN VARIOUS SIZES

S. No.	Type of FonTS	Recognition Rate for Different Sizes (%)						
		15	18	20	25	30	32	35
1.	Harshapriya	98	98	99	100	100	100	100
2.	Hemlatha	96	98	98	99	100	100	100
3.	Godavari	94	96	97	97	98	99	100
4.	Gautami	98	99	99	100	100	100	100

TABLE 4. RECOGNITION RATES OF NEWSPAPER IMAGES AND OLD BOOKS

S. No.	Images of Fig.	Image Taken from	FonTS	Recognition Rate
1.	10	'Sakshi' newspaper	Unknown	95%
2.	11	'Andhra Bhoomi' newspaper		96%
3.	12 (a)	ppt slide		99 %
4.	12 (b)	old book		98%

The performance of the text extraction algorithm and proposed OCR system compared with other algorithms as given in table 5. Text extraction method performs well for textured background and news paper images.

TABLE 5. COMPARISION TABLE

S. No.	Authors	Accuracy of Text Extraction	Accuracy of OCR
1	Garg [8]	86% for newspaper	-
2	Negi [9]	100% only for newspaper layouts	97-98%

3	Rao [10]	73.5% for ancient script	-
4	Kaur [11]	70.50% for caption text images, 70.43% for document text images and 50.40% for scene text images.	-
5	Proposed	100% for newspaper layouts and textured backgrounds including old books	95-100%

VI. CONCLUSIONS

The text extraction method does not affect the image containing characters much. This is confirmed by the high recognition accuracies obtained on the various test images from newspapers and books. The proposed system has been tested on a variety of images taken from different newspapers, old books and synthetic images on textured backgrounds. It works on several unknown fonts even in the presence of complicated backgrounds although the database consists of only four fonts. The recognition accuracies obtained are 98-100% in most cases. Thus, the proposed approach for Telugu OCR performs well for extracted text images from a larger variety of sources than the previous attempts which were more restrictive and domain specific.

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