Exploring Interdisciplinary Innovations in Science and Management

Volume II

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PREFACE

It is with immense pleasure and scholarly enthusiasm that we present *"Exploring Interdisciplinary Innovations in Science and Management, Volume II".* This volume reflects the spirit of collaboration across diverse domains—ranging from applied mathematics, computer science, mechanical engineering, and electronics to literary studies and management. Each chapter showcases unique, cutting-edge ideas and problem-solving approaches that hold the potential to address real-world challenges through innovative and interdisciplinary methodologies.

The compilation begins with robust contributions in the realm of mathematical modeling and computational optimization. Chapters on solid and fuzzy transportation problems, shortest-path analysis, and intuitionistic and picture fuzzy sets underline the growing relevance of advanced mathematical tools in decision-making processes—particularly in fields like healthcare, logistics, and network design. These studies not only demonstrate technical excellence but also show how mathematical abstractions can be adapted to tackle tangible human problems, such as selecting effective cancer treatments or optimizing air traffic management systems.

Parallel to the computational and analytical sciences, this volume explores the depth and application of graph theory in modern contexts. Contributions highlighting graph coloring for railway networks, cordial labeling on complex graphs, and recent advancements in theoretical techniques emphasize the pivotal role of discrete mathematics in solving infrastructure and network-related problems. Such insights bridge the gap between theoretical constructs and their real-world applications, especially in urban planning, transportation, and information systems.

The convergence of innovation and engineering is further exemplified through chapters dedicated to sustainable product design, smart vehicles, and electric mobility solutions. From the development of three-wheeled electric scooters for differently-abled individuals to advanced fuel theft detection systems using IoT, and smart battery swapping systems—these chapters underline the urgent need for accessible, green, and intelligent technologies in our rapidly urbanizing world.

In the domain of materials science and energy, the volume includes pioneering work on energy storage innovations using phase change materials (PCM), self-healing coatings for scratch-resistant automotive paint, and the exploration of tribological behavior of PVD coatings. These studies provide promising pathways for sustainability, durability, and energy efficiency—three critical elements in contemporary materials engineering.

Notably, this volume also embraces interdisciplinary studies in science and engineering. The chapter on advancements in nanotechnology for enhanced delivery of drug, bioactive and nutrient compounds in food industry explore more on biotechnology. Alongside, the chapter on business analytics provides a comprehensive overview of how data-driven decision-making continues to shape modern management practices.

The final set of contributions delves into the rapidly evolving frontier of artificial intelligence and digital transformation. With discussions on digital twins, machine learning, and deep learning, these

chapters reflect the future of intelligent systems in manufacturing, monitoring, and performance optimization—marking the seamless integration of cyber-physical systems in the digital age.

Altogether, this volume is a testament to the strength and necessity of interdisciplinary collaboration. We hope this collection will inspire researchers, academicians, and industry professionals alike to explore the intersections of their fields, push boundaries, and contribute toward a more integrated and innovative future.

We would like to extend our sincere thanks to our publisher, Scientific Research Reports, Chennai, India, for their dedicated efforts in preparing this book, which provides enriched interdisciplinary innovations in science and management.

Wishes and Regards,

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CONTENTS

Chapter 1

Row column Reduction Method for solving solid transportation problem

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Abstract

The Solid transportation problem is an extended version of Classical transportation problem. Solid transportation problem consists of three constraint such as Supply, Demand and conveyance capacity. These constraints are taken as triangular fuzzy number. A new algorithm is proposed for finding solution for solid transportation problem.

1. Introduction

The solid transportation problem is a three-dimensional problem. Nowadays there is various modes of transports available for transporting goods (example Road transport, Water transport, Air transport). Sometimes, variation occurs in transportation cost according to season, offseason, and moderate. Here, uncertainty exists in transporting goods. So fuzzy method is one of the methods to solve Problem having uncertainty. An extension of transportation problem was started by shell [1]. Haley [2] developed a solution procedure to a solid transportation problem and made comparison between solid transportation and classical transportation problem. Padian and Anuradha [3] proposed new zero point method to find

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optimum solution for solid transportation problem. Sobana and Anuradha [4] proposed heuristic algorithm to find an optimal solution to fuzzy solid transportation problem. The aim of this paper is to find an optimal solution for solid transportation problem under imprecise environment

This paper consists of 6 sections. Section 2 and 3 projects Preliminaries and proposed algorithm. In section 4 and 5 numerical examples are chosen to illustrate the proposed algorithm and comparison table. Finally, the paper is concluded in Section 6.

2. Preliminaries

2.1 Fuzzy set

Let U be a universe of discourse. A Fuzzy set $\tilde{A}$ of U is defined by a membership function $f_{\tilde{A}}: U \rightarrow [0,1]$ where $f_{\tilde{A}}(x)$ is called the membership function and is represented as $\tilde{A} = \{(x, f_{\tilde{A}}(x))/x \epsilon U\}$

2.2 Normal

A fuzzy set $\tilde{A}$ defined on the universe set U is said to be **Normal** iff

$$Sup f_{\tilde{A}}(x) = 1, x \epsilon U$$

2.3 Convex

A fuzzy set $\tilde{A}$ defined on the universe set U is said to be Convex iff

$$f_{\tilde{A}}(\lambda x + (1-\lambda)y) \geq \min\left(f_{\tilde{A}}(x), f_{\tilde{A}}(y)\right) \ \forall x, y \epsilon U and \lambda \epsilon [0,1]$$

2.4 Fuzzy number

A fuzzy number $\tilde{A}$is a fuzzy set on the real line R must satisfy the following conditions.

(i) $f_{\tilde{A}}(x_0)$ is piecewise continuous

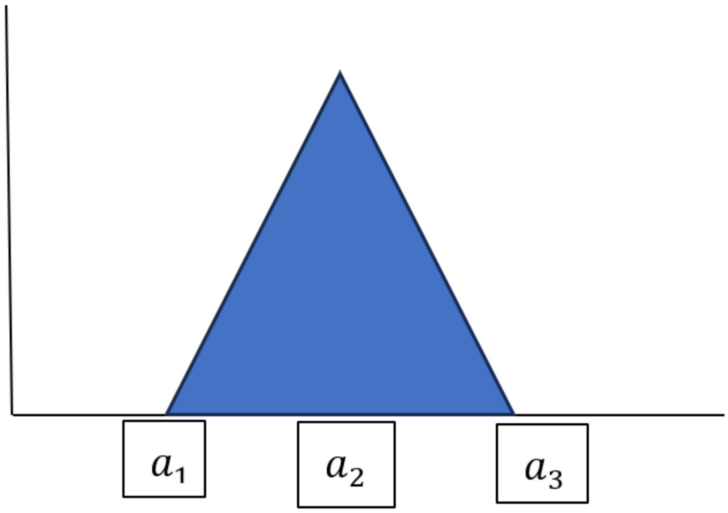
(ii) There exist at least one $x_0 \epsilon R$ with $f_{\tilde{A}}(x_0)$ =1

(iii) $\tilde{A}$ Must be normal and convex

2.5 Triangular fuzzy number

Fuzzy number represented with three points as follows A=(a_1, a_2, a_3)this representation is interpreted in membership function

$$\mu_A(x) = \begin{cases} 0 & x < a_1, x > a_3 \\ \dfrac{x - a_1}{a_2 - a_1} & a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & a_2 \le x \le a_3 \end{cases}$$



2.6 Operation of Triangular Fuzzy Number

Let $\widetilde{A_1} = (a_1, a_2, a_3)and\widetilde{A_2} = (b_1, b_2, b_3)$be two non-negative triangular fuzzy number then

i) $\widetilde{A_1} \oplus \widetilde{A_2} = (a_1, a_2, a_3) \oplus (b_1, b_2, b_3)$=$(a_1 + b_1, a_2 + b_2, a_3 + b_3)$

ii)$\widetilde{A_1} - \widetilde{A_2} = (a_1, a_2, a_3) - (b_1, b_2, b_3)$=$(a_1 - b_3, a_2 - b_2, a_3 - b_1)$

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2.7 Mathematical formation of solid transportation problem

The mathematical model of Fuzzy solid transportation problem is

$$Minimize\ \ z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} c_{ijk}x_{ijk}$$

Subject to

$$\sum_{j=1}^{n}\sum_{k=1}^{l} x_{ijk} = a_i\ i = 1,2,\dots..m$$

$$\sum_{i=1}^{m}\sum_{k=1}^{l} x_{ijk} = b_j\ j = 1,2,\dots..n$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ijk} = e_k\ k = 1,2,\dots..l$$

$$x_{ijk} \geq 0\ for\ all\ i,j,k$$

Where $c_{ijk}$the fuzzy transportation is cost from i^{th} origin to j^{th} destination by means of k^{th} conveyance and x_{ijk} is the number of units transported from i^{th} origin to j^{th} destination by means of k^{th} conveyance.a_i is the amount of material available at origin. b_j is the amount of material required at destination.e_k is the amount of material shipped by conveyance k.

2.8 Solid Transportation Problem

Consider the Fuzzy solid transportation problem whose values are triangular fuzzy numbers the solution for this problem can be obtained by the following algorithm given problem is divided into two category i) maximum problem ii) minimum problem.

Origin	Destination									
	D_1			D_2			D_3			
	$E_1(e_1)$	$E_2(e_2)$	$E_3(e_3)$	$E_1(e_1)$	$E_2(e_2)$	$E_3(e_3)$	$E_1(e_1)$	$E_2(e_2)$	$E_3(e_3)$	SUPPLY
O_1	C_{111}	C_{112}	C_{113}	C_{121}	C_{122}	C_{123}	C_{131}	C_{132}	C_{133}	a_1
O_2	C_{211}	C_{212}	C_{213}	C_{221}	C_{222}	C_{223}	C_{231}	C_{232}	C_{233}	a_2
O_3	C_{311}	C_{312}	C_{313}	C_{321}	C_{322}	C_{323}	C_{331}	C_{332}	C_{333}	a_3
Demand	b_1			b_2			b_3			

3. Proposed Algorithm

1) Construct the Upper bound problem by choosing maximum value from each entry (cost/Supply/Demand/Capacity of conveyance).
2) Check the problem is balanced. If not convert it into balanced problem.
3) The cost matrix is reduced by using Row reduction formula,

$$R_{ijk} = C_{ijk} - \min_{\substack{j=1 to 3 \\ K=1 \text{ to } 3}} \{C_{ijk}\}, \quad \text{i=1 to 3}$$

4) Again, the cost matrix is reduced by using Column reduction formula,

$$CO_{ijk} = C_{ijk} - \min_{\substack{i=1 to 3 \\ K=1 \text{ to } 3}} \{C_{ijk}\}, \quad \text{j = 1 to 3}$$

5) Choose the row /column, according to maximum value is present in supply /demand.
6) Select the cell having the minimum value (i.e. Sum of row reduction and column reduction value) from the selected row/column.

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7) Preference given to the cell with both $R_{ijk} = 0, CO_{ijk} = 0$. Otherwise, choose The Cost cell using the formula

   Cost cell = $min\{R_{ijk} + CO_{ijk}\}$

8) The minimum value of (supply, demand, capacity of conveyance) is allocated to the selected cell. It is subtracted from supply, demand and capacity then mark the remaining value. After allocation, any one the term (supply, demand, capacity) will be zero. Remove the corresponding row /column /conveyance value.

9) Repeat the step 5 to 7, until all the supply demand and capacity of conveyance will be zero.

10) Find the optimal solution using MODI method.

11) Repeat the steps from 2 to 9 to get the optimal solution for Lower bound problem.

4. Numerical Example

Origin	Destination									
	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	SUPPLY
O_1	(2,5,7)	(1,2,4)	(5,8,11)	(8,9,12)	(3,7,11)	(1,2,3)	(3,4,6)	(6,7,9)	(5,6,7)	(10,13,16)
O_2	(8,10,11)	(3,7,9)	(2,3,4)	(2,3,5)	(9,12,15)	(5,6,8)	(4,6,8)	(2,3,5)	(9,10,12)	(12,14,16)
O_3	(3,5,7)	(7,9,10)	(4,6,8)	(4,7,9)	(2,3,5)	(8,10,12)	(7,9,11)	(3,5,6)	(2,3,4)	(8,11,13)
Demand	(9,11,13)			(11,13,14)			(10,14,18)			

Consider the fuzzy solid transportation problem with three origin that is O_1, O_2, O_3, three destinations D_1, D_2, D_3 and three type of conveyance E_1, E_2, E_3. The cost of transporting one unit of goods from i^{th} source to j^{th} destination whose elements are triangular fuzzy number and shown in the following table. Find out the minimum transportation cost.

The capacity of E_1, E_2, E_3 are (9,11,13),(11,13,15),(10,14,17)

4.1 Solution

In the above problem,

$$Total\ supply = Total\ demand = Total\ capacity\ of\ conveyance$$

Therefore the transportation problem is balanced.

The Upper bound problem of triangular Fuzzy solid transportation problem is given by

	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	7	4	11	12	11	3	6	9	7	16
O_2	11	9	4	5	15	8	8	5	12	16
O_3	7	10	8	9	5	12	11	6	4	13
Demand	13			14			18			

Where the capacity of E_1, E_2, E_3 are 13,15,17

Applying the step 3 and 4 we get

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	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	7_3^4	4_0^1	11_7^8	12_9^9	11_8^8	3_0^0	6_2^3	9_5^6	7_3^4	16
O_2	11_7^7	9_5^5	4_0^0	5_2^1	15_{12}^{11}	8_5^4	8_4^4	5_1^1	12_8^8	16
O_3	7_3^3	10_6^6	8_4^4	9_6^5	5_2^1	12_9^8	11_7^7	6_2^2	4_0^0	13
Demand	13			14			18			

Applying steps 5 to step 9 we get final allocation

	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	[2] 7_3^4	[10] 4_0^1	11_7^8	12_9^9	11_8^8	[4] 3_0^0	6_2^3	9_5^6	7_3^4	16
O_2	[1] 11_7^7	9_5^5	4_0^0	[10] 5_2^1	15_{12}^{11}	8_5^4	8_4^4	[5] 5_1^1	12_8^8	16
O_3	7_3^3	10_6^6	8_4^4	9_6^5	5_2^1	12_9^8	11_7^7	6_2^2	[13] 4_0^0	13
Demand	13			14			18			

It satisfies all the constraint supply, demand and conveyance, therefore, the solution is non degenerate basic feasible solution.

The Optimal Transportation cost is = Rs.204

The lower bound problem of triangular fuzzy solid transportation problem is given by

	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	2	1	5	8	3	1	3	6	5	10
O_2	8	3	2	2	9	5	4	2	9	12
O_3	3	7	4	4	2	8	7	3	2	8
Demand	9			11			10			

Where the capacity of E_1, E_2, E_3 are 9,11,10

	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	2_1^1	1_0^0	5_4^4	8_7^7	3_2^2	1_0^0	3_1^2	6_4^5	5_3^4	10
O_2	8_7^6	3_2^1	2_1^0	2_1^0	9_8^7	5_4^3	4_2^2	2_0^0	9_7^7	12
O_3	3_2^1	7_6^5	4_3^2	4_3^2	2_1^0	8_7^6	7_5^5	3_1^1	2_0^0	8
Demand	9			11			10			

	D_1			D_2			D_3			
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	Supply
O_1	2_1^1	[∈] 1_0^0	5_4^4	8_7^7	3_2^2	[10] 1_0^0	3_1^2	6_4^5	5_3^4	10
O_2	8_7^6	[1] 3_2^1	2_1^0	[1] 2_1^0	9_8^7	5_4^3	4_2^2	[10] 2_0^0	9_7^7	12
O_3	[8] 3_2^1	7_6^5	4_3^2	4_3^2	2_1^0	8_7^6	7_5^5	3_1^1	[∈] 2_0^0	8
Demand	9			11			10			

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It satisfies all the constraints supply, demand and conveyance

Then the solution is non degenerate basic feasible solution.

The Optimal Transportation cost = Rs.59

According to proposed method the problem with three supplies, demand and conveyance transportation cost lies between Rs.59 and Rs.204.

4.2 Proposed method

Problem	Origin	Destination	Conveyance
Upper bound problem	O_1	D_1	E_1, E_2
	O_2	D_2	E_1, E_3
	O_3	D_3	E_2, E_3
Lower bound problem	O_1	D_1	E_1, E_2
	O_2	D_2	E_1, E_3
	O_3	D_3	E_2, E_3

4.3 Vogels Method

Problem	Origin	Destination	Conveyance
Upper bound problem	O_1	D_1	E_1
	O_2	D_2	E_1, E_3
	O_3	D_3	E_1, E_2, E_3
Lower bound problem	O_1	D_1	E_1, E_2
	O_2	D_2	E_1, E_3
	O_3	D_3	E_2, E_3

5. Comparison table

S.no	Problem	Transportation cost		
		Vogel's Method Approximation method	Modified Method	Proposed Method
1	Upper bound Problem	Rs.214	Rs.205	Rs.204
2	Lower bound Problem	Rs.59	Rs.59	Rs.59

6. Conclusion

In this paper the proposed algorithm reduces the complexity of finding the optimal solution for solid transportation problem. This method reduces the time convexity and converges to optimal solution quickly. In the both upper bound and lower bound problem conveyance are same in proposed method but they are different in Vogel's method.

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Chapter 2

Recent Developments in Graph Theory and Its Applications: Techniques and Practical Implementations

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Abstract

Graph theory is a sophisticated mathematical framework for studying the characteristics and connections of graphs, which are collections of nodes and edges. Significant advancements have been made in graph theory and its applications in recent years, leading to novel techniques and real-world implementations. This abstract provides an overview of these recent advances. One notable development is the emergence of Graph Neural Networks (GNNs), which enable learning graph-structured data representations. GNNs have been successfully applied in various domains, including node classification and link prediction. Community detection algorithms have also improved accuracy and efficiency, benefiting social network analysis and other related fields. Graph embedding techniques have also progressed, facilitating learning low- dimensional vector representations for nodes or subgraphs. This advancement has enhanced tasks such as link prediction and node classification. Furthermore, temporal graph analysis has gained attention for studying dynamic graphs, allowing for predicting future states and anomaly detection. The application of graph theory in social networks has yielded valuable insights into

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sentiment dynamics, influence maximization, and information diffusion. Graph theory has significantly contributed to transportation and urban planning, addressing challenges like traffic flow optimization, route planning, and public transportation design. Furthermore, the application of graph theory in bioinformatics and drug discovery has led to advancements in drug-target interaction and protein function prediction. Recent advances in graph theory have opened up new avenues for research and practical applications. The growing availability of large-scale graph data and the need to extract insights from complex interconnected systems continue to drive the evolution of this field. These advancements hold great potential for addressing real-world challenges across diverse domains.

Keywords: *Community Detection, Influence Maximization, Network Embedding, Temporal Graphs, Graph Databases*

INTRODUCTION

Applications in the field of computing make extensive use of the principles of graph theory. Data mining, picture segmentation, clustering, image capture, networking, etc., are all active areas of study in computer science. A tree-shaped data structure, for instance, would use nodes and links to organize its data. Network topologies may also be modelled using graph ideas. Resource allocation and setup both make use of graph colouring's central idea. In graph theory, excellent applications include the travelling salesperson problem, database design principles, resource networking, use of pathways, walks, and circuits. This results in creation of cutting-edge algorithms and theorems with far-reaching practical implications.

For many situations in the actual world, a diagram may be described simply by including numerous points and lines that connect many pairs of these points. The points may represent people with lines connecting them to romantic partners or close friends or contact centres with lines depicting other kinds of relationships between them and the outside world. In such diagrams, the way the lines are joined is secondary to whether or not they connect two designated locations. Graph theory provides a statistical abstraction of such situations. Graph theory concepts are widely used in many disciplines for analysis and simulation. The study of atoms, molecules, and chemical bonding all fall under this umbrella. Graph theory has many applications in the social sciences, including the study of networks and the study of how ideas spread from one place to another. The theory of graphs is used for the preservation of biodiversity, with vertices representing habitats and edges representing routes of movement between habitats. This information is crucial for studying the transmission of diseases and parasites and the impact of migration on other species. You must know this. Graph theory ideas are ubiquitous in the realm of computing [1]. “Breadth First Search, Depth First Search, Topological Sort, Bellman-Ford, the algorithm of Dijkstra, Minimum Trees, the Algorithm of Kruskal, and Prim's algorithm are all examples of algorithms used in graph theory.”

HISTORY OF GRAPH THOERY

The Koinsber bridge problem of 1735 is considered the progenitor of the graphic principle. The Eulerian Graph Theorem may be derived from this conundrum. In order to address the Koinsberg Bridge issue, Euler developed the Eulerian graph. In 1840, A.F. Mobius introduced the ideas of a total and a bi-partisan graph; later, Kuratowski proved that both graphs were planar concerning leisure-time issues. Current

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in electrical networks or circuits may be measured using the tree principle (Gustav Kirchhoff created a connected graph without cycles in 1845) and other graphical technical notions. Thomas Gutherie uncovered the four-colour printing error plaguing readers since 1852. 1856 Thomas, P. Kirkman, and William Hamilton studied polyhedral cycles. He came up with the concept of the Hamiltonian graph after seeing that some journeys went to several different sites only once. H. Dudeney addressed a riddle problem in his 1913 talk. After a century, Kenneth Appel and Wolfgang Haken tackled the problem of the four colours. The foundations of graph theory were laid [2]. Caley mastered several analytic forms from differential calculus to study the trees. Moreover, this has several ramifications for theoretical chemistry. This motivates the development of enumerative graph theory. In any case, Sylvester proposed a "Graph" in 1878, making connections between "quantum invariants" and the covariant of algebraic expressions and molecular diagrams [3]. Ramsey began his colour experiments in 1941, eventually recognising the field of study now known as severe graphic theory. The puzzle of the four primary colours was solved by Heinrich's computers in 1969. The study of asymptotic graph connection has led to the discovery of a random graphic design concept.

APPLICATIONS OF GRAPH THEORY

The ideas of graph theory are widely used to study and simulate various applications. This encompasses the study of atoms, molecules, and chemical bonding. Graph theory also has applications in the social sciences, such as studying diffusion processes and determining a performer's fame. In biology and conservation, diagrams show where different species live and where their migrations and other movements take them. This information is vital for studying migratory patterns, tracking the spread of illnesses and parasites, and understanding the impact of migration on other species [4, 5]. Principles of theoretical graphics are often used in scientific investigations. Finds the shortest path between two nodes and solves problems like the tour salesperson's conundrum and the little stretch in a weighted network. Other applications include simulating transportation systems, business networks, and game theory [6]. The finite-game approach is represented as a digraph. In this case, the vertices indicate the places and the edges of the paths taken. Graph theory has several applications in science and engineering. Given any of the following:

1. Computer Science

The theory is used in computer graphics to examine algorithms like the Dijkstra Algorithm, the Prims Algorithm, and the Kruskal Algorithm. The application domains used to define the computation flow include graphs. Communication webs may be represented using graphs. Graphs illustrate the structure of the findings. Rules-based graph manipulation is the foundation for graph transformation methods. Graph databases provide reliable, always-available storage and querying for structured graph data. The fastest path across a network may be determined with the help of graph theory. In Google Maps, locations are represented as vertices or points, while corners represent roads; this representation is used to calculate the shortest route between any two given points.

2. Electrical Engineering

In electrical engineering, graph theory is used to build circuit linkages. Topologies are used to describe these kinds of connections.

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Examples include sequence topology, bridge topology, star topology, and parallel topology.

3. Linguistics

In linguistics, graphs are often used for the parsing of language trees and grammar for language trees. Lexical semantics uses semantic networks, which are very useful for computers, and makes it easier to model the meaning of words by interpreting them in context. As a diagrammatic tool, phonological analysis (such as optimum theory) and morphological analysis (such as finite-state morphology using finite-state transducers) are widely used in the study of languages.

4. Physics and Chemistry

Chemical compounds may be represented as graphs in chemistry. To resolve inconsistencies between two sequences, statistical biochemistry permits the omission of any sequence of cell samples. This is represented as a directed graph, with the sample sequences serving as vertices. When there is a collision between the sequences, an edge is drawn between the two conflicting vertices. The plan is to get rid of all disagreements by eliminating possible vertices, which are sequences. In brief, graphic theory significantly impacts various contexts and rapidly expands throughout a wide range of periods. The following section provides an in- depth examination of how graph theory is used in computing. In physics and chemistry, molecules are analysed using chart theory. Statistics on graph-theoretic properties in connection to atom topology allow for quantitative analysis of the 3D layout of complicated artificial atomic systems. Statistical mechanics also make use of graphs. In this field, diagrams depict the local connections between the interacting parts of a system and the dynamics of the underlying physical processes. Porous media microchannels may be expressed as graphs, with the vertices representing the larger pores and the boundaries representing the smaller pores. The molecular structure and molecular grid may benefit from using a graph. It also enables us to compare the structures of different molecules and show how atoms are connected to them.

5. Computer Network

In a computer network, the connections between nodes follow the rules of graph theory. When it comes to keeping networks safe, graph theory is often used. We will use the vertex colouring technique to colour the map in four hues. It is possible to assign up to four unique frequencies to any GSM (Grouped Special Mobile) mobile network using the Vertex Colouring Algorithm.

6. Social Sciences

The field of sociology also makes use of graph theory. For instance, social network analysis methods may probe how rumours spread or how credible specific individuals are. Their friendship and knowledge graphs describe the connectivity between people. Certain people can influence the actions of others in impactful diagrams. Using the collaborative graphs approach, two people work together in a familiar setting, such as watching a movie.

7. Biology

Bimolecular entities (such as chromosomes, proteins, or metabolites) serve as the "nodes" in biological networks, while the "edges" connecting the nodes represent the interactive, physical, or chemical interactions between the nodes. Graph theory is used for transcriptional regulation networks. It is also seen in metabolic networks. Protein-protein interaction (PPI) networks are another use

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of graph theory. Partnerships that share a drug-related objective. Synergistic Effects of Drugs.

8. **Mathematics**

The cornerstone of mathematics is operational analysis. Graph theory has several applications in the field of organizational analysis. Minimum travel costs, the timetable has a problem. The lines represent the highways that connect the cities. With the help of a certain kind of graph, we may build hierarchically organized information like a family tree.

PROBLEMS IN GRAPH

Enumeration

Graphical listing, or the issue of how many graphs there are that satisfy the stated requirements, has generated a large body of research. Harary and Palmer [6] present some of the results of this study.

Sub-graphs, induced sub-graphs, and minors

A common issue has a fixed graph as a subgraph in a given graph, called the subgraph isomorphism issue. A justification for being concerned is that specific graph properties for subgraphs are inherited, implying that a graph only owns the proprietorship if other subgraphs have the value. Sadly, it is always an NP-complete question to locate maximal subgraphs of a certain kind. Examples include:

- Clique problems have the maximum complexity and are thus NP-complete.
- Graph isomorphism is a subset of the broader subgraph isomorphism issue. It raises doubts about the isomorphism of

the two diagrams. It is possible that we do not know whether this issue is NP- complete or if it can be solved in polynomial time.

- Similarly, mediated segments of a particular graph are identified. Again, some essential graph properties for induced subgraphs are inherited, implying that a map has a property only if they are all caused by all the caused subgraphs. Also, NP-complete is always the maximum mediated subgraphs of a certain kind. For instance:
- A different collection (NP-Complete) problem is the most edgeless influenced subgraph or isolated group.
- Another problem, the minor confinement issue, is having a fixed graph as a minor of a specific diagram. Every graph generated by taking a subgraph and contracting a few (or no) edges are a minor or subcontract. Most charts are passed to minors, meaning a character is only held if all minors share it. Wagner's Theorem states, for instance:
- A portion of the network is planar as it does not include the complete two-part map $K_{3,3}$ or the complete map K_5 as a minor.
- A related challenge is considering a defined diagram as a subset of a specified map, the challenge of a containment subset. Every graph generated by subdividing (or not) edges is a subset or homomorphism of a graph. The isolation of subdivisions is related to properties like planarity. For example, the theorem Kuratowski states:
- A diagram is flat because it does not contain a complete division K3,3 or a complete diagram K5 as a section.

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- The Kelmans-Seymour assumption is another problem with unit containment:
- A subset of a 5-vertex graph K5 is used with a 5-vertex graph that is not planar.
- Another type of issue is linked to how many species are defined from their point-deleted subgraphs and to generalizations of maps. For instance:
- Speculation on reconstruction

Graph colouring

Several problems of graph theory and theorems apply to different colouring strategies of graphs. In general, you are interested in painting a graph such that there are no two neighbouring vertices with identical hues. Coloured edges (possibly such that no two edges are the same colour) or other differences can also be seen.

The following are some of the famous findings and conclusions regarding graph colouring:

- The Erds-Faber-Lovász conjecture is still open, as is the Four-Color Theorem and the Strong Perfect Graph Theorem.
- Behzad's hypothesis (unresolved) on total colouring.
- The (unresolved) List Colouring Conjecture.
- The unanswered Hadwiger hypothesis in graph theory

Subsumption and unification

The theory of restricted design refers to families of graphs connected to a limited sequence. In such applications, graphs are organized so that more narrow graphs are subdivided into more general, more complex graphs, which contain more details. Machine graph integration and evaluating the route of a subsumption connection between two graphs are examples of graph operations. Effective unification methods are devised, and the most generic graph, i.e. incorporating all information in) the inputs, is defined as the result of unifying two argument graphs. Without the actual graph, just a single graph description is given.

Graph fusion adequately fulfils and combines functions for restrictive structures that are purely compositional. Automatic hypothesis checking and modelling the creation of language structure are well-known applications.

Route problems

- Problems like the Hamiltonian path issue, minimum spanning tree, and the route inspection problem (sometimes known as the "Chinese postman problem") are all examples.
- The Steiner tree, the Three-Castle Problem, the Travelling Salesman Problem, and the Seven Bridges of Königsberg are all examples of NP-hard problems.

Network flow

Systems of diverse conceptions of network flows are facing multiple difficulties, for instance:

- Maximal Flow Minimum Cut Theorem

Visibility problems

- Issues with Museum Security

Covering problems

Graphic coverage can apply to specific set coverage problems on vertical / subgraphs subsets.

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- The prevailing issue in package covers is the unique case where the collection is closed.
- The problem with the cover vertex is the case with the frame cover, where the sets are all sides.
- The initial set cover issue can be represented as a vertex cover in a hypergraph, often called a hitting set.

Decomposition problems

There is a wide variety of concerns related to decomposition, defined as partitioning a graph's edge set (the number of vertices following each part's edges, as required). This is also required when subdividing a whole diagram into smaller sub diagrams, such as Hamiltonian cycles, that are isomorphic to the original. For example, many issues require decomposing a Kn network into n1 specified trees with 1, 2, 3..., n_1 edges, where n is the number of edges in the graph.

Among the many decomposition issues that have been examined are the following:

- Arboricity, decomposition to the fewest available trees
- Double loop wrapping, decomposition into loops that are precisely two-fold on each side
- Layer painting, decomposing in the fewest practicable matches
- Factorization of the line, decomposition of an ordinary line into average graphs

CONCLUSION

This study presents a bibliometric analysis of the rapidly growing yet relatively nascent field of graph theory. Current publication trends indicate a strong and increasing interest in Graph Neural Networks (GNNs), which have gained considerable traction within the research community. Notably, conference papers emerge as the most impactful contributions in this area. Franco Scarselli, a key figure in GNN research, authored the seminal work that laid the foundation for this domain. While China hosts numerous active research institutions, the most influential academic hubs are predominantly located in Europe and the United States. A significant portion of GNN-related research has been published in the *Lecture Notes in Artificial Intelligence* and *Lecture Notes in Bioinformatics* series. Among the most frequently explored tasks are node classification, link prediction, and graph classification. Additionally, bibliometric trends reveal growing interest in the attention mechanism, underscoring its rising prominence in the field.

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Chapter 3

Advancements in Nanotechnology for Enhanced Delivery of Drug, Bioactive and Nutrient Compounds in Food Industry

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Abstract

Nanotechnology is transforming a number of fields by facilitating the accurate manipulation of materials at the atomic and molecular levels (typically below 100 nm). This paper focuses on surfacing recent advancements regarding the utilization of nanoparticles as effective delivery techniques in food science and medicine. The whole thing brings out the food industry but also to the health medicine field, providing efficiency and safety as solutions in the applications. These innovative approaches are expected to transform consumer goods and open the door for tailored solutions that sustainably and globally address changing dietary and health demands.

Keywords: Medical nanotechnology, Nutraceuticals, SAMNs, Self-assembled nanostructures, NLCs..

1. Introduction

Nanotechnology is the cutting-edge field that is involved with very novel ideas and also recent innovations towards the creation of working systems at the molecular level. The general definition of nanotechnology is the application of the principles of materials

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science, applied physics, and applied chemistry in order to manipulate matter at an atomic, sub-nanometre, and at the molecular level, generally under 100 nanometres, as well as developing tools or materials within that size range (Patel B et al., 2024). Considering the encapsulation of nutraceuticals, several delivery methods based on nanoparticles have been developed, including nanoliposomes, SLNs, NLCs, microemulsions, and biopolymer nanoparticles (Jafari, S. M., Fathi, M., & Mandala, I., 2015). The physiochemical characteristics of materials change when reduced into the nanoscale and thus form the basis for a potential benefit in the use of nanomaterials as delivery systems. In the pharmaceutical sciences, "nanoparticles" are frequently characterised as having diameters below 1000 nm (<1 μm).

2. Nanotechnology in Food Modulation

The absorption, uptake, and bioavailability of bulk molecules in comparison to nanoparticles have been extensively studied by researchers in the fields of medicine, veterinary science, and nutrition. They find that food in nanoform has a greater bioavailability and can be better digested and assimilated. Researchers are interested in creating and promoting nano-sized products, supplements, and nutraceuticals because of these aspects of nanotechnology. The whole food industry is being impacted by nanotechnology, including manufacturing, processing, distribution, storage, and transportation. Therefore, the food sector uses nanotechnology for encapsulation, structural control, and the manufacture of nutrients and other additives. The development of nanofood aims to reduce costs, increase nutrition, flavour, and food safety. By adjusting the sugar and salt level of food, this technique is also used to create low-calorie foods with improved flavour, look, and usefulness that complement nutritional supplements (Nile S.H et al., 2020). Nanotechnology can help enhance the characteristics of bioactive chemicals, including their solubility, transport capabilities, extended residence time in the gastrointestinal system, and effective cell absorption, and by decreasing their particle size (Prasad R.D et al., 2022).

3. Nanotechnology in Nutrients Delivery

Every major food company is constantly seeking ways to improve food safety, food qualities, and manufacturing efficiency. Market share and a competitive advantage are the ultimate goals of many research and development projects currently underway. In a highly competitive field where innovation is a must, nanotechnologies have emerged as a potential way to improve the production of better-quality foods with improved attributes. Nanoparticles may also be used to add vitamins, minerals, and other nutrients to food and beverages, without adding their flavour or changing their appearance. The encased nutrient is transported into the bloodstream by the nanoparticles through the stomach. The stomach and duodenum's high acidity and enzyme activity can affect bioactive substances including lipids, proteins, carbs, and vitamins.

3.1 Encapsulation of Food Components, Edible Supplements

The production of nutraceuticals that incorporate nanosized ingredients and additives like vitamins, antioxidants, preservatives, and antimicrobials, as well as the absorption, flavour, and bioavailability of functional compounds, might all be greatly enhanced by nanotechnology. Among the nutraceuticals that aid in preventing the development of cholesterol are beta-carotenes, phytosterols, and lycopene. Because it increases selenium

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consumption, green tea with nano-selenium offers several health advantages. Packaging materials to provide nanoscale functionality, including controlled core release, is known as nanoencapsulation. Food is not in its pristine natural condition; thus, functional additives enhance its stability and functionality. While preventing unfavourable interactions with other food ingredients, nanoencapsulation may increase the solubility, bioavailability, and stability of food ingredients. These two are the most promising antioxidant transporters in terms of lipids. Furthermore, nutritional supplements, enzymes, minerals, vitamins, additives, and antimicrobials can be delivered under control using nanoliposomes. It is possible to improve the nutritious content of processed meals by using nanocochelates. WPI had an opposite effect since it increased the stability of oxidative beta-carotene, while maize oil residue in a reduced amount of b-carotene in the solid lipid matrix after its addition into the SLNPs (Jagtiani E., 2022).

3.2 Medical Nanotechnology

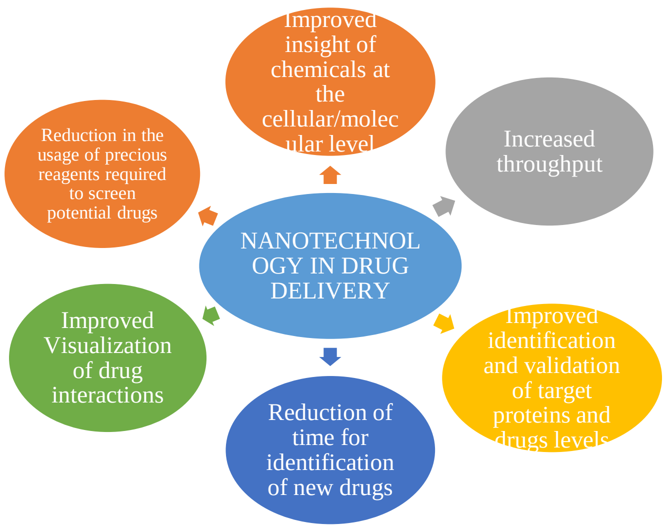

Figure 1. Nanotechnology in Drug Delivery

Medical nanotechnology has produced a number of nano-scaled structures based on these materials that can be employed as drug carriers to promote therapeutic efficacy, decrease systemic adverse effects, and improve bioavailability. Along with being bioinert, biocompatible, biodegradable, and non-toxic to the body, these carriers must shield the medication from deterioration and inactivation while being transported to the designated location, enabling a prolonged release of the medication in the intended location (Basyreva L.Y et al., 2020).

4. Nanoceuticals

Nutrients that have been transformed into nanoparticles via the use of nanotechnology are known as nanoceuticals. Manufacturers of dietary supplements make a number of claims about their products including nanoparticles, such as the conversion of fat-soluble nutrients into water-soluble ones. Nutrients that have been transformed into nanoparticles via the use of nanotechnology are known as nanoceuticals. There are commercial dairy products, foods, and the idea of "nanoceuticals" is becoming more and more popular (Arshad R et al., 2021).

4.1 Self-Assembled Nanostructures

Self-assembled supramolecular nanostructures have received great interest among the various drug delivery methods due to their drug selectivity in targeting and tunable pharmacokinetic properties (Yadav s et al., 2020). Self-assembled nanostructures based on drugs take advantage of the phenomenon of self-assembly to achieve targeted delivery as a promising approach. The word "self-assembly" is used to refer to the way molecules spontaneously come together to assume specific structures. In these systems, drug molecules, e.g., medicines or bioactive molecules, self-assemble into nanoaggregates

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or supramolecular structures that are stabilized by non-covalent interactions like hydrogen bonds, hydrophobic contacts, or electrostatic interactions. These systems reduce the requirement for additional nondrug excipients by making use of the inherent properties of the drugs themselves (where the drug serves as both payload and carrier), and thus they are an attractive and efficient means of enhanced drug delivery (El-Masry et al., 2024).

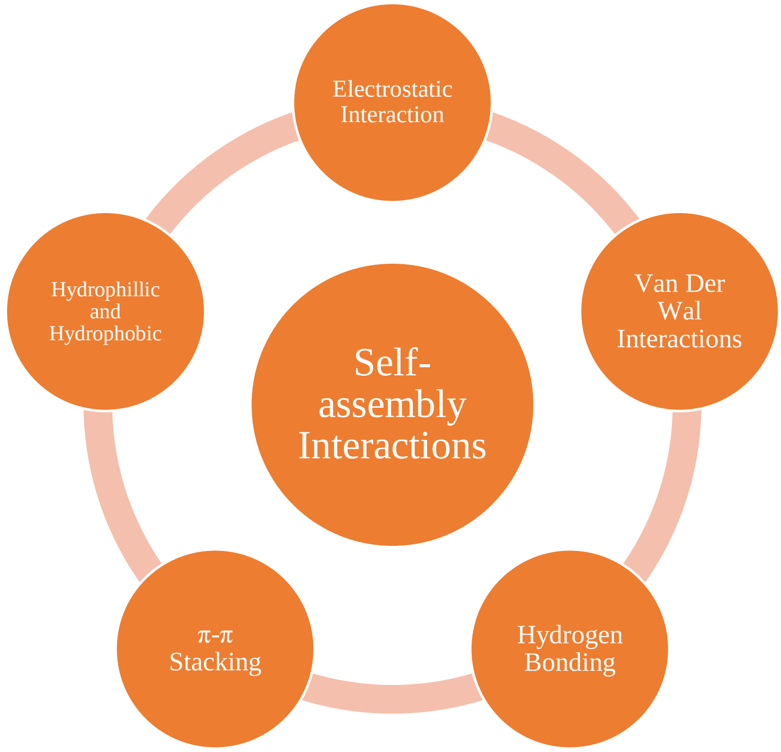

Figure 2. Types of interactions in Self-assembled Nanostructures

Self-assembly is a spontaneous process in which separate components organize into distinct structures through non-covalent interactions, such as electrostatic forces, hydrogen bonds, hydrophobic interactions, and π-π stacking. These interactions are central to natural processes, exemplified by the synthesis of phospholipids in cell membranes, and have been effectively harnessed to develop advanced drug delivery systems (Zhang A et al., 2020). Most drugs, especially those that are polymeric or amphiphilic, have the ability to self-assemble in aqueous environments.

4.2 Surface Active Maghemite Nanoparticles (SAMNs)

Surface active maghemite nanoparticles (SAMNs), one of the iron-oxide nanomaterials, have a number of intriguing characteristics, such as strong saturation magnetization, super-paramagnetism, and ease of manipulation with tiny magnetic fields (Biswas R et al., 2022). Pulses, cereals, milk, meat, eggs, marine goods (such as fish, prawns, or lobsters), and food by-products were among the dietary sources from which bioactive peptides were extracted. By offering a sustainable way to turn food waste into useful bioactive chemicals, food science research today seeks to solve the worldwide problem of food waste (Sarker A et al., 2024).

4.3 Food Safety and Nanotechnology

Foodborne illnesses cost the US economy $152 billion annually, particulary for bacterial contaminations caused by Salmonella, Escherichia coli, Listeria monocytogenes, and Camphylobacter spp (Scallan E et al., 2015). Other foodborne pathogens include Campylobacter spp., Clostridium perfringes, Cryptosporidium parvum, Cyclospora cayetanensis, E.coli O157:H7, Shiga toxin-producing E.coli non-O157 (STEC non-O157), and L.monocytogenes.

4.4 Innovations and Customer's Safety

Over the last years, there has been a great rise in the demand for healthier food products because more and more consumers have now become conscious of how nutrition influences human health. Due to this increased sense of awareness, the number of health-promoting additives added to food and beverages to create "functional foods" especially to improve human performance, health, and well-being has also risen. However, the need for food items with nutritional profiles

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tailored to the needs of the elderly is risen as the population ages. It is anticipated that there will be around 1.5 billion persons over 65 worldwide by 2050, or 16% of the overall population.

5. Social Impact

Beyond its scientific and commercial implications, the advancement of nanotechnology-based delivery systems has significant social impact, particularly in addressing global health disparities. By enabling more effective delivery of essential nutrients and therapeutic agents, nanotechnology can help combat malnutrition and nutrient deficiencies in vulnerable populations. Fortification of staple foods with nano-encapsulated vitamins and minerals ensures better absorption and efficacy, which can be life-changing in regions with limited access to diversified diets or healthcare infrastructure. This technology holds promise in supporting public health initiatives aimed at reducing disease burden and improving quality of life across socio-economic strata.

Moreover, nanotechnology opens new avenues for inclusive healthcare and nutrition solutions by lowering costs through enhanced bioavailability and reduced dosage requirements. For chronic conditions requiring long-term treatment, nano-delivery systems can improve therapeutic outcomes while minimizing side effects, enhancing patient adherence especially in underserved communities. In food systems, the incorporation of bioactive-loaded nanocarriers can lead to functional foods that support preventive health, potentially decreasing the reliance on expensive medical interventions. As awareness and accessibility to these technologies grow, nanotechnology has the potential to democratize health and nutrition, bridging the gap between advanced science and real-world social equity.

6. Future Perspectives

Targeted delivery systems represent one of the most promising frontiers of nanotechnology in both pharmaceutical and food industries. By employing nanocarriers such as liposomes, dendrimers, polymeric nanoparticles, and micelles, it is now possible to selectively deliver therapeutic agents, bioactives, or nutrients to specific tissues or cells, significantly minimizing adverse effects on healthy tissues. This advancement is particularly transformative for drug and nutrient delivery, where precision and efficiency are paramount.

Emerging innovations focus on *stimuli-responsive nanoparticles* that can intelligently release their payload in response to environmental triggers such as pH fluctuations, temperature changes, or the presence of disease-specific enzymes. Such systems provide controlled release and improved bioavailability, reducing dosage frequency and enhancing patient compliance or consumer benefit in nutraceutical applications.

Furthermore, the convergence of nanotechnology with genomics and personalized medicine is paving the way for customized therapeutic and nutritional strategies. By tailoring nanoparticle formulations based on individual genetic profiles, a new era of precision nutrition and medicine is on the horizon—offering optimized interventions for both disease prevention and health promotion.

In the context of the food industry, nanotechnology will continue to revolutionize the development of fortified foods with enhanced stability, targeted delivery, and improved sensory properties. Encapsulation of bioactives, antioxidants, and essential nutrients in

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nanosystems not only protects them from degradation during processing and storage but also ensures their optimal absorption in the gastrointestinal tract.

As research evolves, future nanodelivery systems will likely incorporate biodegradable and sustainable materials, aligning with environmental and regulatory goals. The integration of real-time monitoring through nanosensors and intelligent packaging could also synergize with delivery systems, offering responsive and adaptive food products that dynamically cater to individual health needs.

6. Conclusion

Nanotechnology is revolutionizing the pharmaceutical and food industries through enhanced stability of food, enhanced delivery of nutrition, and creating medicinal applications. The quality of customer experience is enhanced by nanotechnology-facilitated exact control of food shelf life, texture, and taste. Delivery of nutrition with nanocarriers ensures optimal uptake of essential nutrients through enhancing bioavailability and targeted delivery. Encapsulation methods protect vulnerable food constituents and bioactive substances as well as offer extended shelf life and timed release in nutrition supplements. Nanoceuticals, where nanotechnology is combined with nutraceuticals, provide additional health benefits through enhanced solubility and bioactivity of active compounds.

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Chapter 4

An Overview of Business Analytics and its Applications

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Abstract

Business analytics is a comparatively new term that is ahead popularity in both business and theoretical circles like nobody else in newantiquity. In greatestover-all terms, commercial analytics is the art and science of determiningvision – by means of sophisticated mathematical, statistical, machine learning, and network science methods lengthways with a diversity of data and skilled knowledge – to sustenanceimproved and faster/timely decision-making. Therefore, business analytics can be believed of as an enabler for decision-making and problem solving.

Keywords: Business analytics, statistical, machine learning, network science methods.

1. Introduction

Analytics is the process of transforming data into actionable insights by identifying meaningful trends, making predictions, and ultimately, working smarter to achieve better business outcomes. Analytics is the process of discovering, interpreting, and communicating significant patterns in data. Quite simply, analytics helps us see insights and meaningful data that we might not otherwise detect. Business analytics focuses on using insights derived from data to make more informed decisions that will help organizations increase sales, reduce costs, and make other business improvements

1.1. Definition

Business analytics is the process of transforming data into insights to improve business decisions. Data management, data visualization, predictive modeling, data mining, forecasting simulation, and optimization are some of the tools used to create insights from data. Yet, while business analytics leans heavily on statistical, quantitative, and operational analysis, developing data visualizations to present your findings and shape business decisions is the end result. For this reason, balancing your technical background with strong communication skills is imperative to do well in this field.

At its core, business analytics involves a combination of the following

- identifying new patterns and relationships with data mining;
- using quantitative and statistical analysis to design business models;
- conducting A/B and multi-variable testing based on findings;
- forecasting future business needs, performance, and industry trends with predictive modeling; and
- Communicating your findings in easy-to-digest reports to colleagues, management, and customers.

1.2. How Data Analytics Influences Business Decisions?

According to a 2020 NewVantage Partners report, 64.8% of Fortune 1000 companies surveyed have invested at least $50 million into their business analytics efforts, and 91.5% attempted to implement artificial intelligence (AI)-based technologies in some form. While

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these figures appear to illustrate progress, the other side of the coin is only 14.6% of all responding businesses used these technologies across their operations.

Within this general framework, the insights gleaned ultimately help optimize and streamline business processes, eliminating any estimates and grey areas in the process.

Thus, organization-wide optimization may encompass:

- shaping and evaluating future company decisions based on the performance of past initiatives or market trends;
- examining individual departments' performance within an organization and influencing their growth efforts;
- monitoring employees' performance and productivity;
- determining current and future staffing needs and the market skills needed to perform these roles effectively;
- assessing and predicting how well potential investments will perform;

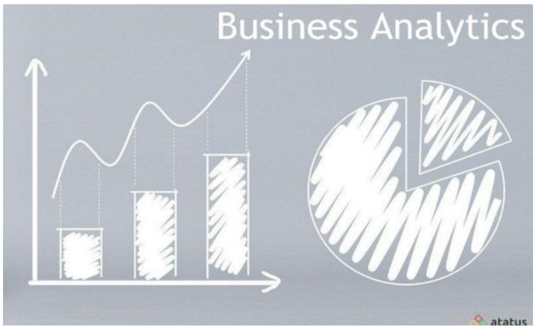

Figure. 1: Source : https://www.atatus.com/glossary/business-analytics/

- Identifying demand for a particular product or service based on market trends and consumer behavior;
- Scheduling release dates for new products and media;

- Evaluating product sales by location, and using that information to meet future customer demands;
- Creating optimal logistics routes for shipping and delivering merchandise;
- Making product recommendations based on customers' past search habits;
- Gathering data from vehicles and equipment to improve future performance; and
- Identifying potential growth opportunities for a business, and how these scenarios could play out.

2. **Business Users**

Even with these advances, business users, while expert in their particular areas, are still unlikely to be expert in data analysis and statistics. To make decisions based on the data collected by and about their organizations, they must either rely on data analysts to extract information from the data or employ analytic applications that blend data analysis technologies with task-specific knowledge. In the former, business users impart domain knowledge to the analyst, then wait for the analyst to organize and analyze it and communicate back the results. These results typically raise further questions, hence several iterations are necessary before business users can actually act on the analysis. In the latter, analytic applications incorporate not only a variety of data mining techniques but provide recommendations to business users as to how to best analyze the data and present the extracted information. Business users are expected to use it to improve performance along multiple metrics. Unfortunately, the gap between relevant analytics and users'

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strategic business needs is significant. The gap is characterized by several challenges:

- *Cycle time.* The time needed for the overall cycle of collecting, analyzing, and acting on enterprise data must be reduced. While business constraints may impose limits on reducing the overall cycle time, business users want to be empowered and rely less on other people to help with these tasks.
- *Analytic time and expertise.* Within the overall cycle, the time and analytic expertise necessary to analyze data must be reduced.
- *Business goals and metrics.* Unrealistic expectations about data mining "magic" often lead to misguided efforts lacking clear goals and metrics.
- *Goals for data collection and transformations.* Once metrics are identified, organizations must collect and transform the appropriate data. Data analysis is often an afterthought, limiting the possible value of any analysis.
- *Distributing analysis results.* Most analysis tools are designed for quantitative analysts, not the broader base of business users who need the output translated into language and visualizations appropriate for business needs.
- *Integrating data from multiple sources.* The extract-transform-load (ETL) process is typically complex, and its cost and difficulty are often underestimated.

2.1. Key Components of Business Analytics

- **Data Aggregation**

  Data must first be obtained, sorted, and filtered, either through volunteered data or transactional records before it can be analysed.

- **Data Mining**

  To detect trends and establish links, data mining for business analytics filters through enormous datasets using databases, statistics, and machine learning.

- **Association and Sequence Identification**

  The identification of predictable activities that are carried out in conjunction with other acts or in a sequential order

- **Text mining**

  For qualitative and quantitative analysis, examines and organises big, unstructured text databases.

- **Forecasting**

  Analyses historical data from a given time period in order to create educated predictions about future occurrences or behaviours.

3. Predictive Analytics

Predictive business analytics employs a number of statistical techniques to build models that

- **Predictive Analytics**

  Predictive business analytics employs a number of statistical techniques to build models that extract data from datasets,

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discover patterns, and provide a score for a variety of organisational outcomes.

- **Optimization**

  Businesses can use simulation tools to test out best-case scenarios once patterns have been discovered and predictions have been made.

- **Data Visualization**

  It provides visual representations of data, such as charts and graphs, to make data analysis simple and rapid.

3.1. Significance of Business Analytics

Business analytics is crucial because it helps organizations make data-driven decisions, optimize operations, and gain a competitive advantage.

3.2. Scope of Business Analytics

With the changing dynamics and technology today, every small, medium, and big enterprise depends on business analytics to channel their company resources in increasing revenue and cutting operational costs simultaneously.

Forecasting demand, spotting potential supply chain disruptions, risk assessment, and offering crisis support are examples of how business analytics may help.

4. Customer Experience

The key to smooth business operations is ensuring a quality customer experience. Business analytics empowers businesses to gain profound insights into their customer base, including their preferences, purchasing behaviors, and overall patterns.

By thoroughly studying and comprehending these aspects, companies can effectively customize their offerings to meet customer expectations, enhance satisfaction, and cultivate unwavering loyalty to their brand.

With the help of business analytics, organizations are granted the opportunity to personalize their products and services, ensuring that they align perfectly with their customer's unique needs and desires.

This personalized approach fosters stronger connections with customers and drives long-term success by establishing a competitive edge in the market.

4.1. Inventory Management

The overhead costs and supply chain processes will be improved using inventory management. By analyzing the data, businesses can gain insights into the frequency and timing of orders, determine which products are in high demand, and assess their readiness to meet customer needs.

With this understanding, businesses can strategically plan their supply chain operations, ensuring efficient inventory management, timely deliveries, and minimized stockouts.

Moreover, business analytics empowers businesses to scale their services sustainably by identifying opportunities for expansion, evaluating resource allocation, and making data-driven decisions to support growth.

Through analytics, businesses can streamline their supply chain operations, reduce costs, and enhance competitiveness.

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4.2. Sales and Marketing

Businesses can analyze customer responses to their marketing campaigns and product offerings to develop customized campaigns and identify optimal cross-selling and upselling opportunities.

This process entails examining various aspects, such as customers' age demographics, average income, and purchase motivations, to predict patterns and trends in their buying behavior.

By understanding these factors, companies can tailor their product messages and launch timings to align with their customer's needs and preferences, ultimately enhancing customer satisfaction and driving sales.

4.3. Finance

Big data and business analytics enable companies to manage their finances more efficiently. By gaining insights into their marketing spend and comprehensively understanding incoming and outgoing transactions, businesses can significantly improve their decision-making processes and allocate resources more effectively.

A study conducted by McKinsey & Company demonstrated that adopting an integrated analytics approach to analyze marketing expenditure can unlock up to $200 billion in savings on a global scale.

This emphasizes the significant impact that leveraging data and analytics can have on optimizing financial operations and maximizing business value.

5. Conclusion

In this chapter, the following things were discussed

- Analytics is the process of discovering, interpreting, and communicating significant patterns in data. . Quite simply, analytics helps us see insights and meaningful data that we might not otherwise detect. Business analytics focuses on using insights derived from data to make more informed decisions that will help organizations increase sales, reduce costs, and make other business improvements.
- **Analytics** refers to the systematic analysis of data to uncover patterns, insights, and trends that help in decision-making. It involves collecting, processing, and interpreting data using statistical, mathematical, and computational techniques to drive informed actions.

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9 788198 400680

Chapter 5

Three Wheeled Electric Scooter for Physically Challenged Person

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Abstract

This study focuses on the design and development of a three-wheeled electric scooter specifically tailored for physically challenged individuals. The scooter is engineered for enhanced stability, ease of use, and ergonomic comfort, ensuring safe and efficient mobility. Key features include a lightweight yet durable frame, an optimized battery-powered motor for extended range, and user-friendly controls for effortless operation. The design incorporates adaptive seating and accessibility features to accommodate users with varying mobility challenges. This innovation aims to improve independence and quality of life for individuals with physical disabilities by providing a reliable and sustainable transportation solution.

Keywords: Three-wheeled electric scooter, mobility aid, physically challenged, adaptive transport, ergonomic design.

1. Introduction

Mobility is a fundamental aspect of independent living, and for physically challenged individuals, having a reliable and accessible means of transportation is crucial. Traditional mobility aids such as manual wheelchairs and crutches can be physically demanding and limiting in terms of speed and distance. Electric mobility solutions, such as three-wheeled electric scooters, offer a practical and efficient alternative, enhancing the freedom and quality of life for individuals with disabilities. These scooters provide a comfortable and user-friendly design, allowing users to navigate urban and rural environments with minimal effort.

Figure 1. https://images.app.goo.gl/xqcAUsJy6V9fw8698

A three-wheeled electric scooter for physically challenged individuals is designed with a focus on stability, safety, and ease of use. The three-wheel configuration ensures better balance compared to two-wheeled models, reducing the risk of tipping. Additionally, the scooter is equipped with a battery-powered motor that provides smooth acceleration and sufficient range for daily commuting. The incorporation of adaptive seating, accessible controls, and durable construction further enhances usability, making it a suitable option for individuals with varying degrees of mobility impairment.

With advancements in battery technology, lightweight materials, and intelligent control systems, modern electric scooters are becoming more efficient and user-friendly. The development of such mobility solutions aligns with the global push toward inclusive transportation

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and sustainable mobility. By integrating innovative features, such as regenerative braking, smart navigation, and ergonomic seating, the three-wheeled electric scooter can serve as a practical and empowering mobility aid for physically challenged individuals, promoting independence and social inclusion.

2. Materials and Method

The development of the three-wheeled electric scooter for physically challenged individuals involves careful selection of materials and components to ensure durability, lightweight construction, and ease of operation. The frame of the scooter is primarily made from aluminum alloy, which offers a balance between strength and weight, making it easier to maneuver. The seating and support structures are designed with high-density foam and synthetic leather to provide comfort and ergonomic support. The scooter is powered by a lithium-ion battery, chosen for its high energy density, long cycle life, and fast charging capabilities. A brushless DC (BLDC) motor is used for propulsion, providing efficient power output with minimal maintenance requirements.

The design methodology follows an iterative process, beginning with conceptual modeling and 3D CAD design. Finite Element Analysis (FEA) is performed to assess the structural integrity of the frame under various load conditions. The electrical system, including the battery, motor controller, and throttle mechanism, is integrated with safety features such as automatic braking, speed limiters, and an emergency stop switch. A user-friendly control panel with a digital display is incorporated to provide real-time information on speed, battery level, and distance traveled. Additionally, the scooter is equipped with anti-tip wheels and shock-absorbing suspension to enhance stability on uneven surfaces.

For performance evaluation, prototype testing is conducted under different terrain and load conditions. Parameters such as maximum speed, battery efficiency, braking distance, and maneuverability are analyzed to ensure optimal performance. User trials are also performed to assess comfort, ease of use, and accessibility features. Based on the test results, necessary modifications and optimizations are implemented to improve the overall functionality of the scooter. The final design aims to provide a reliable and efficient mobility solution for physically challenged individuals, ensuring enhanced independence and ease of transportation.

3. Experiments

To ensure the scooter meets safety, efficiency, and usability standards, a series of experiments were conducted, categorized into the following key aspects:

3.1. Structural Integrity Test

Objective: To evaluate the strength and durability of the frame under different load conditions.

Method: Finite Element Analysis (FEA) was performed on the aluminum alloy frame to simulate stress and deformation under maximum weight capacity. Physical load testing was also conducted by placing varying weights (up to 120 kg) on the scooter and measuring structural deflections.

Expected Outcome: The frame should withstand the applied loads without excessive deformation or failure.

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3.2. Battery Performance and Range Test

Objective: To analyze battery efficiency, charge retention, and real-world range.

Method: The lithium-ion battery was fully charged and tested under different terrain conditions (flat roads, inclines, and rough surfaces). The scooter was run continuously while recording voltage drops and distance traveled.

Expected Outcome: The scooter should provide an optimal range of 30-50 km per full charge with minimal battery degradation over time.

3.3. Speed and Maneuverability Test

Objective: To measure the scooter's speed control, turning radius, and stability.

Method: The scooter was tested at different speeds (5 km/h, 10 km/h, and 15 km/h) on a test track with various obstacles. The turning radius was measured by navigating a circular path of a fixed diameter. Stability was checked on inclined surfaces.

Expected Outcome: The scooter should maintain smooth acceleration and braking, with a stable turning radius and no risk of tipping over.

3.4. Braking Efficiency Test

Objective: To evaluate the braking system's response time and stopping distance.

Method: The scooter was accelerated to 10 km/h and 15 km/h, and the brakes were applied. The stopping distance was recorded on dry and wet surfaces.

Expected Outcome: The scooter should stop within a short distance (1-2 meters) without skidding or loss of control.

3.5. User Comfort and Accessibility Test

Objective: To assess user-friendliness, seating comfort, and ease of control.

Method: A group of physically challenged individuals tested the scooter in real-world scenarios. Feedback on seat comfort, handle accessibility, and control panel usability was collected via surveys.

Expected Outcome: Users should find the scooter comfortable and easy to operate, with intuitive controls.

4. Results and Discussion

The experimental evaluation of the three-wheeled electric scooter for physically challenged individuals provided key insights into its performance, safety, and usability. Each test yielded valuable results that helped refine the final design.

4.1. Structural Integrity and Durability

The Finite Element Analysis (FEA) confirmed that the aluminum alloy frame could withstand a maximum load of 120 kg with minimal deformation. Physical load tests further validated the frame's strength, with no noticeable structural failures under real-world conditions. The use of lightweight yet durable materials contributed to the scooter's overall stability and longevity.

4.2. Battery Performance and Range

The lithium-ion battery performed efficiently, providing a range of approximately 40 km per full charge under normal load conditions. The battery retained 85% efficiency after multiple charge cycles, with minimal voltage drops even under continuous use. However, range reduction was observed on steep inclines and rough terrains, which indicated the need for optimized power management.

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9 788198 400680

4.3. Speed and Maneuverability

The scooter achieved a maximum speed of 15 km/h, which was within safe limits for urban mobility. The turning radius was measured at 1.2 meters, making it suitable for tight spaces. Stability tests on inclines (up to 10-degree slopes) showed that the scooter remained balanced, with the anti-tip mechanism effectively preventing rollovers.

4.4. Braking Efficiency

The braking distance at 10 km/h was 1.5 meters, while at 15 km/h, it was 2.3 meters on dry surfaces. On wet surfaces, the stopping distance increased by approximately 20%, but remained within safe limits. The regenerative braking system improved energy efficiency by recovering 8-10% of lost energy, extending battery life.

4.5. User Comfort and Accessibility

User trials indicated high satisfaction in terms of comfort, ease of use, and control accessibility. The ergonomic seat provided adequate lumbar support, and the control panel was easy to navigate, even for users with limited hand mobility. Some users suggested minor improvements, such as adjustable armrests and additional cushioning, which were incorporated into the final design.

4.6. Discussion

The results demonstrated that the three-wheeled electric scooter is a practical and effective mobility solution for physically challenged individuals. Its combination of lightweight materials, efficient battery performance, and ergonomic design ensures ease of use and long-term reliability. The successful integration of safety features, including regenerative braking and anti-tip mechanisms, enhances the scooter's stability and user confidence.

However, certain limitations were identified, such as reduced efficiency on steep inclines and slight increases in braking distance on wet surfaces. Future improvements could focus on enhanced motor efficiency, improved waterproofing of electrical components, and a more adaptive seating system to cater to a wider range of users.

The study highlights the potential of electric mobility solutions in enhancing independence and accessibility for physically challenged individuals, paving the way for further advancements in assistive transportation technologies.

5. Conclusion

The development and testing of the three-wheeled electric scooter for physically challenged individuals demonstrated its effectiveness as a safe, efficient, and user-friendly mobility solution. The scooter's lightweight aluminum alloy frame provided durability without compromising maneuverability, while the lithium-ion battery ensured an optimal travel range of approximately 40 km per charge. Performance tests confirmed stability on inclines, efficient braking, and smooth acceleration, making it suitable for urban and semi-urban environments.

User trials highlighted the scooter's comfort, accessibility, and ease of control, with minor recommendations incorporated into the final design. While the scooter performed well under various conditions, challenges such as range reduction on steep inclines and increased braking distance on wet surfaces indicate potential areas for future improvements. Enhancements in motor efficiency, adaptive seating, and waterproofing could further optimize the design.

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9 788198 400680

Overall, this study underscores the importance of electric mobility solutions in promoting independence and accessibility for physically challenged individuals. By integrating advanced safety features, ergonomic design, and efficient power management, this three-wheeled electric scooter represents a significant step toward inclusive and sustainable transportation.

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Chapter 6

Fuzzy Transportation Problem Helps to Choose the Appropriate Treatment for Blood Cancer

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Abstract

Organisations are under more pressure than ever to develop new methods to generate and provide value for customers in today's fiercely competitive market. It becomes increasingly difficult to specify and deliver consignments to customers that are both economical and of high quality. A strong foundation for addressing this topic is offered by transportation models. It guarantees timely availability and effective transportation of both raw materials and completed items. This work focuses on determining the optimal value of transportation problems using a novel approach to determine the lowest transportation cost. Here, supply and demand are represented as triangular fuzzy intuitionist numbers. In addition, we put up a novel solution to the imbalanced transportation issue. A numerical example is provided to show the solution process.

Keywords: Fuzzy, Triangular fuzzy Matrix, FNWCM, FLCM, FVAM.

1. Introduction

By communicating an assessment of the relationship in the fuzzy set to every possible speaker in the discourse universe, a fuzzy logic can

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be quantitatively expressed. It is impossible to completely eradicate ambiguity in any field, be it science, engineering, medicine, or administration. Numerous influences of the built environment, including both direct and indirect ones, such as physical activity, housing affordability, employment accessibility, social capital, etc., have been linked to blood cancer, according to study. Although cancer can begin anywhere in the body, certain organs are more likely to experience it than others. There are over a hundred different forms of cancer, with colorectal, lung, breast, and prostate cancers accounting for 41% [8] and 50% [9] of cases in the United States and Canada, respectively. Cancer is a disease that is difficult to diagnose and cure, which makes it a chronic condition with high incidence and fatality rates across the globe. Since the beginning of human history, cancer has been a disease [10]. An Egyptian papyrus that dates to 1600 BC contains the earliest known description of breast cancer. Later on, the term was created when blood vessels began to emerge from tumours and spread outward, resembling the legs of a crab (cancer in Latin) [11]. Celsus (25 BC–50 AD) advocated surgery as a cancer treatment until Galen (c. 2 AD) suggested laxative intake as a possible remedy, sharply criticising surgery. The dominant trend in science and engineering at the turn of the nineteenth century was the reduction of intricate real-world systems to exact mathematical models. Zadeh introduced the idea of fuzzy set theory to address this imprecision/uncertainty.

The focus of this paper is on transportation issues that have fuzzy numbers for parameter representation, sometimes known as fully fuzzy or fuzzy transportation problems. We have looked at the fuzzy transportation issue with one goal, the fuzzy and fully fuzzy multi-objective multi-commodity solid transportation problem, the fuzzy transportation problem with time minimization, and the fuzzy non-linear programming problem. Both scenarios of the single objective unbalanced completely fuzzy transportation problem have been covered. We have suggested methods to and the facility/facilities at which the deceit in supply should be increased to meet the demand at a minimum cost, or the client(s) to whom the excess supply be transported for future demand, in contrast to the existing methods of solving fully fuzzy unbalanced transportation problems.

2. Preliminaries

2.1 Definition: 2.1 (Fuzzy set)

If the fuzzy set membership function the following qualities are present in a well-defined real set: relationship occupation $\mu_A: X \to [0,1]$ is said to be fuzzy.

1. A is normal. It resources that there occurs a $x \in X$, such that $\mu_A(x) = 1$.
2. A is curved it resources that for every $p_1, p_2 \in X$
3. $\mu_A(Ap_1 + (1-\lambda)p_2) \geq min\big(\mu_A(p_1), \mu_A(p_2)\big), \lambda \in [0,1]$

is superior semi continuous.

4. Supp (A) is constrained,
5. where$max(a) = \{x \in X: \mu_A(x) > [0,1]\}$

2.2 Definition: 2.2 (Triangular Membership function)

Three parameters (a, b, c) specify this, where (a <b<c) gives the x Coordinates of the three angles. The crisp value for which the membership function must be ascertained is variable x. In the discourse universe. Figure displays the graphical

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representation. These two mathematical models can both be used to express the triangular members function numerically.

(i) Triangle (x: a,b,c) = Max (Min $\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0$

(ii) Triangle (x: a,b,c) = $\begin{cases} 0, x \leq a \\ \frac{x-a}{b-a}, a \leq x \leq b \\ \frac{c-x}{c-b}, b \leq x \leq c \\ 0, c \leq 2 \end{cases}$

2.3 Definition: 2.3 (Defuzzification)

Defuzzification is the process of producing a quantifiable result in crisp logic, given fuzzy sets and corresponding membership degrees. It is the process that maps a fuzzy set to a crisp set. It is typically needed in fuzzy control systems.

2.4 Definition: 2.4 (Trapezoidal Membership function)

There are four parameters that define this. The X coordinates of the four angles of the underlying trapezoidal MF are {a, b, c, d} with (a< b ≤c< d). The trapezoidal M. F. is represented graphically. Either one of the following mathematical models can be used to represent it.

(i) Trapezoidal (x: a,b,c,d) = Max (Min $\left(\frac{x-a}{b-a}, \frac{d-x}{d-c}\right), 0$

(ii) Trapezoidal (x: a,b,c,d) = $\begin{cases} 0, x \leq a \\ \frac{x-a}{b-a}, a \leq x \leq b \\ 1, b \leq x \leq c \\ \frac{d-x}{d-c}, c \leq x \leq d \\ 0, d \leq x \end{cases}$

A transportation problem can be expressed mathematically as follows:

Minimize

$$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} R_{ij}E_{ij} \ldots\ldots(3.1)$$

Subject to

$$Z = \sum_{j=1}^{m} E_{ij} = pi \qquad j = 1,2,3 \ldots n$$

$$Z = \sum_{i=1}^{m} E_{ij} = qi \qquad i = 1,2,3 \ldots n \qquad \ldots\ldots\ldots\ldots(3.2)$$

$$E_{ij} \geq 0 \text{ for all } i,j$$

where the amount being transferred from the ith origin to the jth end point must be either a positive integer or zero, and the cost of transferring a unit from the ith source to the jth journey's finish is supplied. It's obvious that a necessary and sufficient condition exists if the given linear programming problem in (1) has a solution.

$$\sum_{i=1}^{n} p_i = \sum_{j=1}^{m} q_j \qquad \text{------}(3.3)$$

Uncertainty in Transportation: Oftentimes, the objectives of transportation-related issues are nonsensical and inconsistent. Furthermore, cost coefficients in targets are typically nonsensical due to poor information and uncertainty in the numerous potential suppliers and settings. The majority of these numbers are ascertained by a simple forecasting procedure. Therefore, it is more efficient to use fuzzy algorithms rather than crisp ones to handle transportation issues with one or more objectives. In mathematics, a fuzzy TP can be expressed as surveys:

Minimize

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$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} r_{ij} E_{ij} \qquad \text{------(3.4)}$$

Subject to

$$\left.\begin{array}{l} \sum_{j=1}^{n} E_{ij} = \tilde{p}_i j = 1,2,\ldots,n \\ \sum_{i=1}^{m} E_{ij} = \tilde{q}_j i = 1,2,\ldots,m \\ E_{ij} \geq 0 i = 1,2,\ldots,m, j = 1,2,\ldots,n\} \end{array}\right\} \ldots\ldots..(3.5)$$

When the transit costs create uncertainty about the quantities of supply and demand. The mathematically defined fuzzy LPP problem is said to have a solution if there is an obvious sufficient and necessary condition that

$$\sum_{i=1}^{n} p_i = \sum_{j=1}^{m} q_j \qquad \text{------(3.6)}$$

3. Algorithm

Here are the steps involved in resolving the transportation problem:

Step 1:

Use the ranking function to transform fuzzy values from the provided Transportation problem into crisp values.

Step 2:

To determine the right top and bottom of the corresponding cost, subtract the minimum cell cost from each cell cost in each row and column of the transportation problem.

Step 3:

Add the costs for the right top and right bottom, and then enter the total number in the associated cell cost.

Step 4:

Find the lowest element in each row and column of the Transportation table, and then deduct it from the corresponding row and column.

Step 5:

Determine the total of the values in the column and row. Select the maximum penalty amount and place the minimum amount of supply and demand in the row and column's minimum elements. Remove by erasing the rows or columns that represent the locations of supply and demand satisfaction.

Step 6:

Keep going through steps 4 and 5 until all supply and demand are satisfied.

Step 7:

Align the initial transportation expense with the cell cost that was satisfied.

Step 8:

Determine the lowest possible price.

That is, Total Cost = $\sum\sum C_{ij} X_{ij}$

4. As an illustration

Examine the Case Study on the Fuzzy Transportation Problem. The bacterium that causes blood cancers is the source of many disorders. They are among the primary causes of sickness in many countries. Although people of all ages are impacted, children are more

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susceptible due to their exposure to nurturing surroundings. Blood cancer can be avoided depending on the steps taken at various stages of the disease's spread. Health departments can significantly contribute to the control of these diseases by putting into practice efficient administration, prevention, and control strategies.

The simplicity of doing different transactions in Trichy Section for Blood Cancer illnesses is as follows: Stem cell transplantation (K1), Chemotherapy (K2), and Radiation Therapy (K3), in that order. Furthermore, the number of patients affected by blood cancers, such as D1 for leukaemia, D2 for lymphoma, D3 for myeloma, and D4 for sarcoma, is as follows: (6,7,8,9), (2,5,7,10), (1,3,4,6), and (1,2,3,4). The following is the estimated cure time for each patient for the treatment-disease combination:

Table 1: TherapeuticTimeper Patient

Treatment	Disease	TherapeuticTimeper Patient (in days)
Stem cell transplantation	Leukemia	[1,2,3,4]
	lymphoma	[2,3,4,6]
	Myeloma	[8,10,11,12]
	Sarcoma	[5,6,7,11]
Chemotherapy	Leukemia	[0,1,3,4]
	lymphoma	[-1,0,1,3]
	Myeloma	[6,7,8,9]
	Sarcoma	[0,1,2,4]
Radiation	Leukemia	[4,5,6,7]

Therapy	lymphoma	[6,7,8,10]
	Myeloma	[11,13,15,18]
	Sarcoma	[6,8,9,10]

5. Fuzzy Transportation problem

Table 2: Balanced Table with Fuzzy TherapeuticStint and Uncertain Blood cancer Disease with Therapy treatment

Treatments/Diseases	Leukemia (D_1)	lymphoma (D_2)	Myeloma (D_3)	Sarcoma (D4)	Supply (availability of treatmentT_j)
Stem cell transplantation	[1,2,3,4]	[2,3,4,6]	[8,10,11,12]	[5,6,7,11]	[1,6,7,12]
Chemotherapy	[0,1,3,4]	[-1,0,1,3]	[6,7,8,9]	[0,1,2,4]	[0,1,2,4]
Radiation Therapy	[4,5,6,7]	[6,7,8,10]	[11,13,15,18]	[6,8,9,11]	[6,10,12,16]
Demand (no. of patients exaggerated by the disease D_i to be engaged the treatment)	[6,7,8,9]	[2,5,6,9]	[1,3,4,6]	[1,2,3,4]	

The fuzzy transportation raking problem can be expressed mathematically in the following form in order to conform to the model.

$$Min\ Z = R(1,2,3,4)x_{11} + R(2,3,4,6)x_{12} + R(8,10,11,12)x_{13} + R(5,6,7,11)x_{14} + R(0,1,3,4)x_{21} + R(-1,0,1,3)x_{22} + R(6,7,8,9)x_{23} + R(0,1,2,4)x_{24} + R(4,5,6,7)x_{31} + R(6,7,8,10)x_{32} + R(11,13,15,18)x_{33} + R(6,8,9,10)x_{34}$$

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$$R(\tilde{a}) = \int_0^1 0.5(a_\alpha^L a_\alpha^U)d\alpha$$

where $\left(a_\alpha^L a_\alpha^U\right) = \{((b-a)+a)+(d-(d-c))\}$

$$R(1,2,3,4) = \int_0^1 (0.5)((\alpha+1)+(4-\alpha))d\alpha$$

Step 1:

Table 3: **Transportation Problem-** Fuzzy Trapezoidal Ranking method

	D_1	D_2	D_3	D_4	**Supply**
C1	2.5	3.5	10.5	6.5	6.5
C2	2	0.5	7.5	1.5	1.5
C3	5.5	7.5	14	8.5	11
Demand	7.5	5.5	3.5	2.5	

As a result, (4+3-1) = 6 cells are assigned, and we have our workable solution. Next, we determine the overall days and the supply and demand values that correspond to it.

Total days= **(5.5X7.5) + (3.5X5.5) + (10.5X1) + (7.5X1.5) + (14X1) + (8.5X2.5) = 117.5**

6. Conclusion

In this study, the transportation expenses are viewed as fuzzy, more realistic, and all-encompassing values that represent imprecise numbers. Furthermore, by employing ranking indices, the fuzzy transportation problem with fuzzy numbers has been converted into a crisp transportation problem. Numerical example demonstrates that we can obtain both the crisp and fuzzy optimal cost and the optimal solution using this method. Therefore, by employing triangular fuzzy numbers for the supply, demand, time, and prescription parameters, a fuzzy multi-objective LPM has been developed in this research to distribute the various deals to the various disease populations in an effort to lower the prescription and overall healing time. Reducing the inclusive curing time and preparation may help to mitigate the loss of human output. Other difficulties, such as those involving project schedules, assignments, and network flow, can also be resolved with this method.

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Chapter 7

Innovative Energy Storage in Refrigerators Using Phase Change Material (PCM) on Condenser Coils

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Abstract

This study focuses on enhancing the energy efficiency of refrigerators by integrating PCM with the condenser coil to store excess thermal energy. The conventional refrigeration systems dissipate heat inefficiently, leading to energy losses. Hence the need for thermal energy storage solutions to optimize condenser performance the PCM layer is applied to the back-side condenser coil, enabling heat absorption and delayed release. Experimental results show a 12-15% reduction in compressor run time and a 10-12% improvement in overall COP. This approach contributes to sustainable cooling by reducing power consumption and enhancing refrigeration system performance.

Keywords: PCM, COP, condenser*, energy,* refrigeration.

1. Introduction

Refrigeration systems play a crucial role in preserving food, medical supplies, and other perishable goods. However, conventional refrigerators dissipate heat from the condenser coil into the surrounding environment without utilizing this thermal energy effectively. This heat loss leads to increased energy consumption and reduced efficiency, making refrigeration systems a significant contributor to household and industrial power usage. In recent years, researchers have explored various methods to improve refrigeration performance, and one promising approach is the integration of PCMs for thermal energy storage.

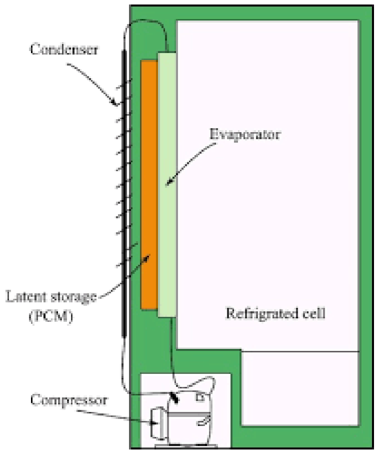

Figure.1. Side view of the Refrigerator

However, limited research has been conducted on integrating PCMs with condenser coils to enhance heat dissipation and energy efficiency. This study aims to address this research gap by covering the back-side condenser coil of a refrigerator with PCM to store excess heat and release it gradually, reducing thermal fluctuations and improving system performance.

The key objective of this research is to evaluate the impact of PCM-assisted condenser coils on energy consumption and system efficiency. An experimental setup is developed to compare the performance of a conventional refrigeration system with a PCM-integrated system. The study measures parameters such as compressor run time, temperature fluctuations, and overall energy savings. This research provides valuable insights into improving

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energy efficiency in refrigeration systems while minimizing environmental impact. By utilizing PCM for thermal energy storage in condenser coils, this study offers a novel solution for reducing power consumption and enhancing cooling system performance.

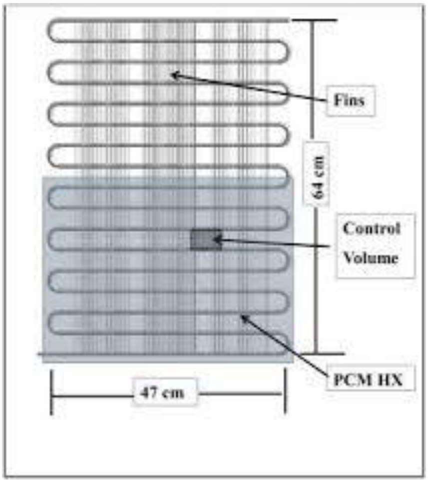

Figure.2. Condenser coil

2. Statement of Project

This project aims to enhance refrigerator energy efficiency by integrating PCM with the back-side condenser coil for thermal energy storage. The PCM absorbs excess heat during peak operation and releases it gradually, reducing compressor cycling and energy consumption. Experimental analysis will compare a conventional system with the PCM-integrated condenser to evaluate improvements in performance.

3. Literature Review

Recent research by Ashwajeet Dhanedhar et al. (2024), published in *Recent Trends in Mechanical Engineering (Springer)*, presents a comparative analysis of various phase change materials (PCMs) aimed at enhancing the efficiency of refrigeration systems. The study effectively compares different PCMs in terms of their cooling performance. However, a notable research gap exists as it does not address the long-term thermal stability and durability of these materials under continuous refrigeration cycles—an essential factor for practical and commercial applications.

The work of Subhanjan Bista and colleagues (2018) in *Applied Thermal Engineering (Science Direct)* emphasizes the potential of PCMs to improve performance and reduce energy consumption in domestic refrigerators. While the paper showcases the advantages of PCM integration, it falls short of exploring the optimal positioning and integration techniques, particularly with respect to the condenser coils. These integration strategies play a crucial role in maximizing heat transfer and ensuring the effectiveness of PCMs.

Yusufoglu et al. (2015), in their study published in the *International Journal of Refrigeration (Science Direct)*, investigate the use of PCMs to improve the efficiency of household refrigerators. The findings demonstrate performance improvements with PCM usage. Nonetheless, the research lacks a discussion on thermal conductivity limitations of PCMs and the impact of varying ambient temperatures, both of which can significantly influence the overall performance of PCM-enhanced refrigeration systems.

In a more recent study (2023) published in *Sustainable Energy Technologies and Assessments (Science Direct)*, Van Nhanh Nguyen and co-authors explore the application of PCMs in boosting refrigeration system performance. While their analysis reveals energy-saving benefits, it omits a comprehensive cost-benefit analysis and an environmental impact assessment. These aspects are critical

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when evaluating the feasibility and sustainability of PCM applications on a commercial scale.

4. Methodology

This study aims to enhance refrigerator efficiency by integrating PCM with the back-side condenser coil to store excess heat and improve energy utilization. The methodology involves multiple phases, including system design, material selection, experimental setup, data collection, and analysis.

4.1. System Design and Selection

- A conventional household refrigerator with a back-side condenser coil is selected.
- PCM with suitable thermal properties (high latent heat and thermal conductivity) is chosen.
- A casing is designed to encapsulate the condenser coil with PCM, ensuring effective heat absorption and release.

4.2. Material Selection

- The PCM is selected based on melting temperature, thermal conductivity, and stability.
- Paraffin-based PCM is considered due to its suitable phase transition temperature (30-40°C) and high heat absorption capacity.

5. Experimental Setup

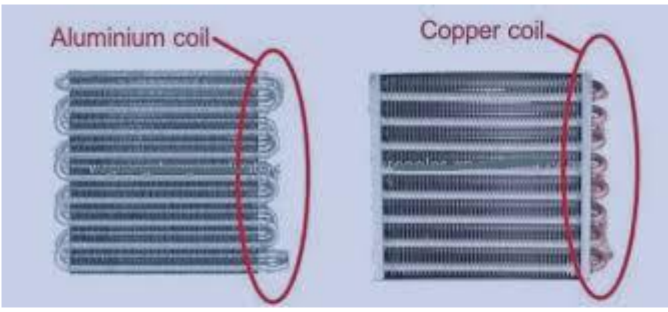

Figure.3. Condenser coil types

- Two refrigerator units are used: one conventional and one modified with PCM-covered condenser coils.
- Sensors are installed to monitor compressor run time, condenser temperature, and power consumption.
- Data acquisition systems record real-time temperature fluctuations and energy usage.

5.1. Data Collection and Analysis

- The experiment runs for a fixed duration under identical ambient conditions.
- Key parameters such as compressor run time, energy consumption, and coefficient of performance (COP) are recorded.
- A comparative analysis is conducted to evaluate the impact of PCM integration.

5.2. Flow Chart

Start

|

⍰— System Design and Selection

| ⍰— Choose a conventional refrigerator

| ⍰— Select appropriate PCM

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```
|     ├── Design casing for PCM integration
|
├── Experimental Setup
|     ├── Install sensors and monitoring devices
|     ├── Setup conventional and PCM-based systems
|     ├── Conduct test runs under controlled conditions
|
├── Data Collection
|     ├── Monitor compressor run time
|     ├── Record energy consumption
|     ├── Analyze temperature fluctuations
|
├── Performance Analysis
|     ├── Compare PCM-based system with conventional setup
|     ├── Evaluate efficiency improvement
|     ├── Assess energy savings
|
├── Conclusion and Recommendations
|     ├── Summarize findings
|     ├── Suggest improvements for PCM integration
|
└── End
```

5.3. Expected Outcome

- The PCM-coated condenser coil is expected to reduce compressor cycling by 12-15%.
- Energy consumption is projected to decrease by 10-12%, enhancing overall efficiency.

Improved thermal regulation will lead to stable cooling performance and reduced environmental impact.

6. Conclusion

Integrating Phase Change Materials (PCMs) with refrigerator condenser coils offers a promising approach to enhancing energy efficiency and sustainability in refrigeration systems. The primary advantage of PCMs lies in their ability to absorb and release latent heat during phase transitions, thus maintaining a more stable temperature within the system. By incorporating PCMs into condenser coils, excess heat can be absorbed and stored during peak operation, helping to reduce the workload on the compressor and leading to lower energy consumption. Research in this area has shown that the integration of PCMs not only improves the energy efficiency of refrigerators but also contributes to reducing their environmental impact by lowering overall energy demand and greenhouse gas emissions.

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Chapter 8

Study on Self-Healing Coatings for Scratch-Resistant Car Paint

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Abstract

This study investigates self-healing coatings for scratch-resistant car paint, focusing on their effectiveness in restoring surface integrity. Experiments were conducted using polyurethane-based coatings infused with microcapsules containing healing agents. Coated samples were subjected to controlled scratches of 100–500 µm in width, and healing efficiency was analyzed through optical microscopy and surface roughness measurements. Results showed that coatings with 10 wt% microcapsules exhibited an average healing efficiency of 85% within 24 hours, compared to 40% for those with 5 wt%. Additionally, nano indentation tests indicated a 30% improvement in hardness. These findings highlight the potential of self-healing coatings for enhancing automotive paint durability.

Keywords: Sustainable Materials, Eco-Friendly Coatings, Automotive Sustainability, Waste Reduction, Innovation in Green Technology.

1. Introduction

Automotive coatings play a pivotal role in not only enhancing the aesthetic appeal of vehicles but also providing a protective layer

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against environmental factors, such as UV radiation, moisture, chemicals, and physical abrasions. However, conventional automotive paints are inherently susceptible to scratches, chipping, and surface damage due to daily exposure to harsh conditions, including road debris, weather changes, and mechanical wear. These imperfections not only compromise the visual appeal of a vehicle but also leave the underlying layers exposed to corrosion, oxidation, and further deterioration over time.

To address these challenges, self-healing coatings have emerged as a groundbreaking innovation in automotive paint technology. These advanced coatings are engineered to autonomously repair minor scratches and surface damage, thereby extending the longevity of the paint and reducing the need for frequent touch-ups or refinishing. By incorporating self-healing mechanisms, such as microcapsules filled with healing agents, shape-memory polymers, or dynamic polymer networks, these coatings can restore their original structure after sustaining damage, often requiring little to no external intervention. This self-repairing capability significantly enhances both the functional durability and aesthetic retention of vehicle exteriors.

2. Mechanisms of Self-Healing Coatings

Self-healing coatings rely on various mechanisms to repair surface damage, including

2.1. Microcapsule-Based Healing

One of the earliest approaches involves embedding microcapsules filled with healing agents within the coating matrix. When a scratch occurs, these microcapsules rupture, releasing the healing agent, which then polymerizes and fills the damaged area. The efficiency of this mechanism depends on factors such as capsule size, healing agent composition, and the polymerization process.

2.2. Intrinsic Self-Healing Polymers

This mechanism involves the use of polymers with reversible chemical bonds, such as hydrogen bonding, Diels-Alder reactions, and disulfide linkages. These polymers can reform broken bonds upon exposure to heat, light, or other external stimuli, enabling the coating to regain its original structure and function.

2.3. Shape Memory Polymers (SMPs)

SMPs have the ability to return to their original shape upon the application of heat or other triggers. When incorporated into coatings, they can enable the self-repair of scratches by physically closing the damaged areas upon activation.

2.4. Nanotechnology-Based Healing

The effectiveness of self-healing coatings is largely determined by the materials used in their formulation. These materials play a crucial role in enabling autonomous or stimulated healing mechanisms, thereby extending the lifespan and durability of coated surfaces.

3. Nanomaterials

Nanomaterials are incorporated into self-healing coatings to improve their mechanical strength, conductivity, and responsiveness to external stimuli. Key nanomaterials include

- Graphene and Graphene Oxide These materials enhance the mechanical and barrier properties of coatings while also enabling self-healing through electrical or thermal stimuli.

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- Carbon Nanotubes (CNTs) CNTs improve toughness and facilitate healing through thermal conductivity, allowing localized heating to trigger self-repair.
- Silica Nanoparticles These nanoparticles enhance scratch resistance and can also act as carriers for healing agents, ensuring controlled release when damage occurs.

4. Additives and Catalysts

To improve efficiency, self-healing coatings often incorporate additives and catalysts that enhance the healing process. These include

- Photoresponsive Additives Light-activated materials, such as spiropyrans and diarylethenes, undergo structural changes upon UV exposure, triggering self-repair mechanisms.
- Thermoresponsive Agents Shape-memory polymers (SMPs) and thermally activated healants can trigger healing when exposed to heat, enabling crack closure and material reformation.
- Metal-Based Catalysts Ruthenium, Grubbs' catalysts, and other metal catalysts facilitate polymerization reactions in healing agents, accelerating the repair process.

By combining these materials, researchers and industries are developing innovative self-healing coatings that enhance durability, reduce maintenance costs, and improve sustainability across various applications, including aerospace, automotive, marine, and construction industries.

5. Performance Evaluation of Self-Healing Coatings

The effectiveness of self-healing coatings is assessed using a range of characterization techniques to evaluate their mechanical, chemical, and environmental performance. These techniques help determine the coating's ability to autonomously repair damage, maintain protective properties, and withstand real-world conditions. The key evaluation methods include

5.1. Scratch Tests

Scratch tests are conducted to assess the coating's ability to recover from mechanical damage

- A controlled scratch is introduced using a stylus or blade to simulate wear and tear.
- The healing process is monitored over time to observe the coating's ability to restore its original structure.
- Optical microscopy or profilometry is used to quantify the depth and width of scratches before and after healing.
- This test is crucial for evaluating coatings used in automotive, aerospace, and industrial applications where surface integrity is essential.

5.2. Scanning Electron Microscopy (SEM)

SEM provides high-resolution imaging of the coating's surface morphology and microstructural changes

- Before healing, SEM helps visualize cracks, voids, or scratches at the microscopic level.
- After the healing process, SEM imaging determines the extent of damage recovery and material reformation.
- This technique is particularly useful for coatings incorporating nanomaterials, as it can reveal nanoscale healing mechanisms.

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5.3. Fourier-Transform Infrared Spectroscopy (FTIR)

FTIR is used to analyze the chemical changes that occur during the self-healing process

- Infrared spectra are collected before and after healing to detect new chemical bonds or changes in functional groups.
- For polymer-based coatings, FTIR helps confirm the polymerization of healing agents like dicyclopentadiene (DCPD) or the oxidation of natural oils.
- This method is valuable for coatings with autonomously triggered chemical reactions.

5.4. Contact Angle Measurements

The contact angle test evaluates changes in surface wettability before and after healing

- A droplet of water is placed on the coating surface, and the contact angle is measured.
- A reduction in contact angle may indicate surface degradation, while restoration to the initial value suggests successful healing.
- This test is particularly useful for coatings with hydrophobic or self-cleaning properties, such as those used in marine and architectural applications.

6. Recent Advancements and Challenges

Recent advancements in self-healing coatings have led to the development of more sophisticated, efficient, and responsive systems. Some of the key innovations include

6.1. Multi-Trigger Self-Healing Systems

- Modern self-healing coatings are designed to respond to multiple external stimuli, such as light, heat, and mechanical stress, enabling more reliable and adaptable healing mechanisms.
- For instance, coatings incorporating photoresponsive polymers can activate self-healing under UV or visible light, while thermoresponsive materials initiate repair when exposed to elevated temperatures.
- These multi-trigger systems are particularly useful for applications in aerospace, automotive, and electronics, where environmental conditions vary widely.

6.2. Hybrid Self-Healing Coatings

- Combining microcapsule-based and intrinsic self-healing mechanisms has led to improved healing efficiency and durability.
- Microcapsules filled with healing agents provide autonomous repair when ruptured, while intrinsic polymer networks allow multiple healing cycles through reversible chemical bonds.
- Hybrid approaches offer enhanced mechanical strength, better adhesion, and the ability to heal both small cracks and large-scale damage.

6.3. Smart Coatings with Real-Time Damage Detection

- Innovations in sensing and diagnostic capabilities have led to the development of self-healing coatings that can detect and repair damage in real time.

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- Some coatings incorporate fluorescent or color-changing indicators that signal the presence of microcracks or wear, allowing for early intervention.
- Electrically conductive nanomaterials, such as graphene or carbon nanotubes, enable coatings to monitor structural integrity through resistance changes, providing valuable insights for maintenance and safety.

7. Future Outlook

Advancements in nanotechnology, AI-driven material design, and green chemistry are expected to address many of these challenges. As self-healing coatings become more affordable, durable, and environmentally friendly, their adoption in industries such as automotive, aerospace, infrastructure, and consumer electronics is likely to increase, paving the way for more sustainable and maintenance-free materials in the future.

8. Conclusion

Self-healing coatings represent a promising advancement in automotive paint technology, offering a solution to the persistent issue of surface scratches. By leveraging microcapsules, intrinsic polymers, nanomaterials, and smart coatings, researchers continue to enhance the healing efficiency and durability of these coatings. However, further advancements are needed to overcome challenges related to cost, scalability, and environmental impact. As research progresses, self-healing coatings have the potential to revolutionize the automotive industry, providing long-lasting and maintenance-free vehicle exteriors.

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Chapter 9

Determination of Shortest Path Problem in Intuitionistic Fuzzy Environment

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Abstract

In this chapter the shortest path problem was discussed with intuitionistic fuzzy environment. An algorithm was framed to solve the shortest path problem for the given numbers to find the exact path and minimal distance. Numerical example has been illustrated to represent the algorithm. This study helps to calculate the optimal path with minimum value.

Keywords: Triangular fuzzy number, Minimal value a – cuts, Euclidean distance.

1. Introduction

Among the researchers in network problem it is found that the shortest path problem is simple and often it is in the research mode. The aim of the shortest path problem is to find a path with minimum distance. Dubois and Prade [3] have introduced the shortest path problem. They applied the fuzzy minimum operator to calculate the shortest path length. Due to uncertainty it is difficult to calculate the exact estimates to overcome this Zadeh[10] introduced fuzzy set theory it plays a vital role to handle the ambiguity in project network. Atanassov [2] developed Intuitionistic fuzzy set which plays a major role in handling both belonging and non-belonging.

Sadollah Ebrahimnejad, Reza Tavakoli-Moghaddam [5] illustrated the fuzzy Shortest path problem by a different algorithm in Network. P.K. Raut, Dr.S.P.Behera, Dr.J.K.Pati [4] suggested a new Calculation of Shortest Path in Fuzzy Environment with closed Network. Gaurav kumar, Rakesh Kr Bajajand Neeraj Gandotra [14] developed" Algorithm for Shortest Path Problem in a Network with Interval-valued Intuitionistic Trapezoidal Fuzzy Number". Tarek Eljerbi and Mohamed Muamer [8] organized Fuzzy Rough Shortest Path problems.

1.1. Preliminaries

1.1.1. Intuitionistic fuzzy number

If $\tilde{A} = \{(x, \mu_{\tilde{A}}(x), \gamma_{\tilde{A}}(x)) : x \in R\}$ is a intuitionistic fuzzy number defined on the set of real numbers then

(i)There exist a real number $x_0 \in R$ such that $\mu_{\tilde{A}}(x_0) = 1$

and $\gamma_{\tilde{A}}(x_0) = 0$

(ii) $\mu_{\tilde{A}}$ of $\tilde{A}$ is fuzzy convex and upper semi-continuous.

(iii)$\gamma_{\tilde{A}}$ of A is fuzzy concave and lower semi-continuous.

1.1.2. Euclidean distance

Let $\tilde{P} = (p_1, p_2, p_3, p_4, p_5)$ and by $\tilde{Q} = (q_1, q_2, q_3, q_4, q_5)$ be any two intervals then the Euclidean distance

$$D_i = \sqrt{(p - p'_i)^2 + (q - q'_i)^2 + (r - r'_i)^2 + (s - s'_i)^2 + (t - t'_i)^2}$$

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1.1.3. Minimum value of ∝ - cuts

Let Aα= [p1, p2] and Bα = [q1, q2] be two ∝ - cuts. The minimum value of Aα and Bα is given by MV = [min (p1, q1), min (p2, q2)].

1.1.4. Triangular fuzzy number

A fuzzy number $\check{P} = (p_1^{\square}, p_2^{\square}, p_3^{\square})$ is called to be a triangular fuzzy number if it has a membership function

$\check{P}$ ={(x, $\mu_{\tilde{P}}(x)$; x∈ $X, \mu_{\tilde{P}}(x) \in [0,1]$}

$$\mu_{\tilde{P}}(x) = \begin{cases} 0 & x < p_1^{\square} \\ \frac{x - p_2^{\square}}{p_1^{\square} - p_2^{\square}} & for\ p_1^{\square} \le x \le p_2^{\square} \\ \frac{p_3^{\square} - x}{p_3^{\square} - p_2^{\square}} & for\ p_2^{\square} \le x \le p_3^{\square} \\ 0 & for\ \ x > p_3^{\square} \end{cases}$$

1.1.5. Intuitionistic triangular fuzzy number

An intuitionistic triangular fuzzy number is defined as $\check{P} = (p_1^{\square}, p_2^{\square}, p_3^{\square})(p_1^{\square\square}, p_2^{\square}, p_3^{\square\square})$ were $p_1^{\square}, p_2^{\square}, p_3^{\square}, p_1^{\square\square}, p_2^{\square}, p_3^{\square\square}$ are real numbers which has the following membership and non –membership functions

$$\mu_{\tilde{P}}(x) = \begin{cases} 1 & x < p_1^{\square} \\ \frac{p_2^{\square} - x}{p_2^{\square} - p_1^{\square}} & for\ p_1^{\square} \le x \le p_2^{\square} \\ 0 & for\ x\ =\ p_2^{\square} \\ \frac{x - p_2^{\square}}{p_3^{\square} - p_2^{\square}} & for\ p_2^{\square} \le x \le p_3^{\square} \\ 1 & for\ \ x > p_3^{\square} \end{cases}$$

$$\gamma_{\tilde{P}}(x) = \begin{cases} 1 & x < p_1^{\square\square} \\ \frac{p_2^{\square} - x}{p_2^{\square} - p_1^{\square\square}} & for\ \ p_1^{\square\square} \le x \le p_2^{\square} \\ 0 & for\ x\ =\ p_2^{\square} \\ \frac{x - p_2^{\square}}{p_3^{\square\square} - p_2^{\square}} & for\ p_2^{\square} \le x \le p_3^{\square\square} \\ 1 & for\ \ x > p_3^{\square\square} \end{cases}$$

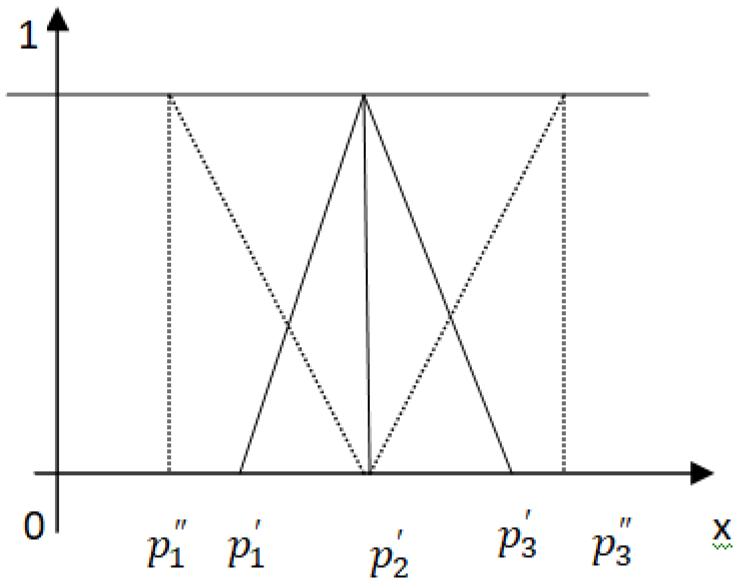

Figure.1. Graphical representation of triangular intuitionistic fuzzy number

2. Proposed Algorithm to find the shortest path

Step 1: Ranking value is calculated for membership and non-membership function.

Step 2: Using the α – cut ranking value the nodes from t = n the permanent node is finalized and it was assumed as Lmin

Step 3: The possible paths are calculated.

Step 4: The ranking technique is applied for the possible paths for membership and non-membership function.

Step 5: Now the least value of α – cuts is calculated for all the possible paths

MV = [min (p1, q1), min (p2, q2)].

Step 6: Then the Euclidean distance is calculated among MV and Lmin for all the possible paths.

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$$D_i = \sqrt{(p - p_i)^2 + (q - q_i)^2}$$

2.1. Real- time example

A food delivery service like Swiggy aims to plan its routes and times while considering factors such as conditions of the traffic, performance of service person and customer performance. In this example a delivery order is placed in Triplicane to deliver is food in Mkb nagar. When a delivery order is placed Intuitionistic fuzzy set assess multiple potential routes to utilize algorithm adapted for Intuitionistic fuzzy set to determine the optimal delivery route that minimizes expected delivery time. But some time the routes may not be efficient due to uncertainty and variability there may be delay due to traffic condition, insufficient weather etc.

Here the nodes are

Node 1: Triplicane, Node 2: Simpson, Node 3: Vallalar nagar, Node 4: Chindadripet, Node 5: Nehru Stadium, Node 6: Basin bridge, Node 7: Mkb nagar.

The planner can compare the routes not only based on shortest expected travel time but also on reliability. By applying Intuitionistic fuzzy set, Swiggy can effectively account for the uncertainties and variabilities associated with food delivery. This leads to optimized routing, reduced delivery times, enhanced customer satisfaction making the service more efficient and reliable.

Table 1. Numerical example

Activity	Duration
1 – 2	(17, 21.89, 28) (16, 25.223, 30)
1 – 3	(15,19.78, 26) (14, 21.89, 29)
2 – 4	(13, 21.11, 28) (12,18.56, 29)
4 – 5	(14, 19.78, 25) (13,19.22, 27)
2 – 5	(14, 20.22, 26) (12, 20.89, 29)
3 – 6	(15, 21.67, 28) (14, 23.78, 31)
5 – 6	(16, 21.44, 27) (15, 23, 31)
5 – 7	(12, 17.89, 24) (10, 19.67, 28)
6 – 7	(16, 23.67, 30) (15, 24.22, 33)

Table 1 showing the defuzzified value of triangular intuitionistic fuzzy number.

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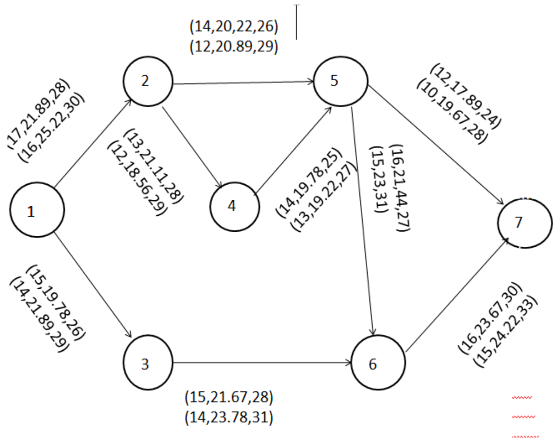

Figure.2. Network diagram of triangular intuitionistic fuzzy number

Step 1: The ranking value is calculated for membership and non-membership function

Now the ranking procedure for intuitionistic triangular fuzzy number is calculated for membership function as

$$R(p_1^{\square}, p_2^{\square}, p_3^{\square}) = \left(\frac{p_1^{\square}+2p_2^{\square}+p_3^{\square}}{4}\right)$$

and for non-membership function is

$$R(p_1^{\square\square}, p_2^{\square}, p_3^{\square\square}) = \frac{1}{4}\left(p_1^{\square\square} + 2p_2^{\square} + p_3^{\square\square}\right)$$

For the path 1 - 2 the ranking procedure for the membership function is calculated for (17, 21.89, 28) (16, 25.223, 30) as

$$R(17, 21.89, 28) = \frac{17 + 43.78 + 28}{4} = \frac{88.78}{4} = 22.195$$

The ranking procedure for the non - membership function is calculated as

$$R(16, 25.223, 30) = \frac{16 + 50.446 + 30}{4} = \frac{96.446}{4} = 24.111$$

The same ranking technique was applied for the remaining paths and the results were given in the table below.

Table 2. Ranking values

Paths	**Ranking values for Membership function**	**Ranking values for Non – membership function**
1- 2	22.195	24.111
1 - 3	20.14	21.695
2 - 4	20.805	19.53
2 - 5	20.11	20.695
4 - 5	19.64	19.61
3 - 6	21.585	23.14
5 - 6	21.47	23
5 - 7	17.945	19.335
6 - 7	23.335	24.11

Table 2 showing the ranking values of the path.

Step 2: Using the α – cut ranking value the nodes from t = n the permanent node is finalized and it was assumed as Lmin.

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From node t = 7, it has (6,7) and (5,7) were the temporary edges having [(12,15,17.67,21,24)(10,14,20,25,28); (5,7)] = [17.89,19.42] and [(16,19, 23, 29, 30) (15, 17, 24.67, 31, 33); (6,7)] = [23.5, 24.11]. The edge (5.7) is determined for ∝ - cut ranking technique-wise smallest for membership function and smallest for non-membership function. So (5, 7) is choosen as a permanent node. From node 5 the edges (2,5) and (4,5) are concluded to be as a temporary edges with [(14,16, 19.67, 25, 26) (12, 15, 20.67, 27, 29); (2, 5)] = [20.14, 20.77] and [(14, 16, 19.33, 24, 25) (13, 15, 19.67, 23, 27); (4,5)] = [19.69, 19.445] and for the edge [(13, 15, 22.33, 26, 28) (12,14, 17.67, 24, 29); (2, 4)] = [21.11, 20.028] then the ∝ - cut ranking technique-wise for the edge [(2, 4) + (4,5] is [40.8, 39.473]. The edge (2,5) is determined for ∝ - cut ranking technique-wise smallest for membership function and smallest for non-membership function. So (2, 5) is choosen as a permanent node. It is found that from permanent node 2, it has only one edge (1, 2) then it stops since it reaches source node 1. The concluded path is 1 – 2 – 5 – 7 is the fuzzy shortest path.

Step 3: The possible paths are calculated.

The possible paths are

1 – 2 – 5 – 7

1 – 2 – 4 – 5 – 7

1 – 2 – 4 – 5 – 6 – 7

1 – 3 – 6 – 7

The path length were calculated for the path 1 – 2 – 5 – 7

(17, 21.89, 28) (16, 25.223, 30) + (14, 20.22, 26) (12, 20.89, and 29) + (12, 17.89, 24) (10, 19.67, and 28)

= (43, 60, and 78) (38, 65.783, and 87)

The ranking procedure for membership function is

$R(43, 60, 78) = \frac{43+120+78}{4}$

$= \frac{241}{4} = 60.25$

The ranking procedure for non - membership function is

$R\ (38, 65.783, 87) = \frac{38+131.566+87}{4}$

$= \frac{256.566}{4} = 64.142$

The same procedure were applied for the remaining possible paths and the results were given below

Table 3. Ranking values for the possible paths

Possible paths	Ranking
1 – 2 – 5 – 7	(60.25, 64.145)
1 – 2 – 4 – 5 – 7	(80.585, 82.537)
1 – 2 – 4 – 5 – 6 – 7	(107.445, 110.25)
1 – 3 – 6 – 7	(65.06, 68.945)

Table 3 showing the ranking values for the possible paths has know that 1 – 2 – 5 – 7 is the shortest path so it is assumed as Lmin.

ISBN 978-819840068-0
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Now the Lmin = (60.25, 64.145) = L1

Step 5: Now the minimum value of α – cuts is calculated for all the possible paths

MV = [min (p1, q1), min (p2, q2)].

For i = 1

MV = min (Lmin, Li)

= min (Lmin, L1) = min ((60.25, 64.145), (60.25, 64.145)) = (60.25, 64.145)

Step 6: Then the Euclidean distance value calculated among MV and Lmin for all the possible paths.

$$D_i = \sqrt{(p - p_i)^2 + (q - q_i)^2}$$

D1 = D(MV , Lmin) = D((60.25, 64.145) (60.25, 64.145))

$$= \sqrt{(60.25 - 60.25)^2 + (64.145 - 64.145)^2} = 0$$

For i = 2

MV = min (Lmin , L2) = min ((60.25, 64.145) , (80.585,82.537)) = (60.25, 64.145)

D2 = D (MV , Lmin) = D((60.25, 64.145) (80.585,82.537))

$$= \sqrt{(60.25 - 80.585)^2 + (64.145 - 82.537)^2}$$

$$= \sqrt{(-20.335)^2 + (-18.392)^2}$$

$$= \sqrt{413.512 + 338.266} = \sqrt{751.778} = 27.42$$

For i = 3

MV = min (Lmin, L3) = min ((60.25, 64.145), (107.445, 110.25)) = (60.25, 64.145)

D3 = D (MV, Lmin) = D((60.25, 64.145) (107.445,110.25))

$$= \sqrt{(60.25 - 107.445)^2 + (64.145 - 110.25)^2}$$

$$= \sqrt{(-47.195)^2 + (-46.105)^2}$$

$$=\sqrt{2227.37 + 2125.67} = \sqrt{4353.038} = 65.977$$

For i = 4

MV = min (Lmin , L4) = min ((60.25, 64.145) , (65.06,68.945))= (60.25, 64.145)

D4 = D(MV , Lmin) = D((60.25, 64.145) (65.06,68.945))

$$= \sqrt{(60.25 - 65.06)^2 + (64.145 - 68.945)^2}$$

$$= \sqrt{(-4.81)^2 + (-4.8)^2}$$

$$=\sqrt{23.136 + 23.04} = \sqrt{46.176} = 6.795$$

3. Conclusion

In this paper by using the innovative algorithm the shortest path is obtained with minimum distance. It is illustrated with a numerical example and the real time example is compared with the result for a better understanding. The algorithm can be applied to find the shortest in further research work to yield a better result.

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Chapter 10

An Application of Picture Fuzzy Sets in Similarity Measure for Thyroid Disease Activity Relationships and its symptoms

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Abstract

A similarity measure in a picture fuzzy set plays a vital part in managerial problems with uncertainties to deal with real-life situations. Data mining and decision-making of various results have been developed in the literature, the importance of similarity measures is considered and their application is used in medical diagnosis. As this measure is used to compare the different diagnoses and their application of disease and its symptoms. Here we are going to compare thyroid disorders with two different extents, namely hyperthyroidism and hypothyroidism, how closely related. Their coexistence identifies patients at a higher risk of metabolic and reproductive complications, which will affect women's infertility. Fertile women’s physical and mental health can be influenced by hormone imbalance; they are more likely to have thyroid disorders, such as hyperthyroidism (overactive thyroid or Graves’ disease) and hypothyroidism (underactive thyroid or Hashimoto’s thyroidism). As the prevalence of these endocrine dysfunctions increases, the

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association with an autoimmune thyroid disease is increasingly being recognized. While the causality of this association is still uncertain, the two conditions are a bidirectional relationship. Both aid in hormonal imbalance.

Keywords: Fuzzy set (Fs), Picture Fuzzy set (PFs), Similarity measures (Sm), Disease Activity Relationship (DAR), Thyroid, Hyperthyroidism (H1).

1. Introduction

Positive membership functions[$\mu_A(X)$], neutral membership functions[$V_A(X)$] and negative membership functions[$\gamma_A(X)$]are the three membership functions characterized for picture fuzzy sets such that $0 \leqslant [\mu_{A1}(X)]+[V_{A1}(X)]+[\gamma_{A1}(X)] \leqslant 1$ real-life problems are needed. Techniques and methodology to compare such objects are important. There are many methods to measure the distance between objects as a general self-proof framework in order to compare fuzzy sets [1]. Numerous researchers focus on fuzzy set theory's application and generalization. Cuong et al. [2, 4] exposed various fundamental properties and operations while developing the picture fuzzy set theory. A picture fuzzy set is an idea for computational intelligence problems, which are issues in real-world applications where traditional approaches and methodologies are inadequate to execute. These problems are inspired by nature [3]. L.A. Zadeh in 1965 introduced fuzzy sets [8], and Atanassov's intuitionistic fuzzy set in 1986 was both generalized by picture fuzzy sets. Uncertain problems were handled with an intuitionistic fuzzy set and also proved to be quite valuable in addition to the non-membership degree and degree of membership in the fuzzy sets [6, 7]. In real life, there are circumstances where intuitionistic fuzzy sets fall short. Voting is a perfect instance where there are more yes, abstain, no, and refused responses, and the technique addresses the circumstance is the picture fuzzy set [15, 16,17].

1.1. Thyroid Function Test

Thyroid function tests are used to measure thyroid glands, namely T3 (triiodothyronine), which regulates a number of vital bodily processes such as body temperature, heart rate, and metabolism, as well as normal growth and development. T4 (thyroxine) is a primary thyroid hormone in the tissue of the body; it is transformed into T3. The thyroid normally produces about four times more T4 than T3, but T3 is a much more powerful hormone. Two hormones of thyroid glands, T3 and T4, help the body to produce and regulate the hormones adrenaline (also called epinephrine) and dopamine. Hormones are chemical substances that help to control certain cells and organs. Fear, excitement, and pleasure are various bodily and emotional responses that happen when stimulated. The process by which oxygen and calories are converted into energies. Calcitonin helps form bones and regulates calcium levels in the body. Iodine and tyrosine are used by these thyroids to produce these hormones present in many foods like kelp, eggs, strawberries, and dairy products. It is even added to table salt. Tyrosine is an amino acid found in soy-based foods. The pituitary gland, a peanut-sized organ in the brain, regulates the thyroid’s release of hormones into the bloodstream after it converts iodine and tyrosine (TSH, or thyroid-stimulating hormone).

1.2. Hypothyroidism (H0)

The high level of TSH indicates insufficient T4 production by the thyroid gland, and it is called hypothyroidism or underactive thyroid, and the symptoms include weight gain, lack of energy, hair loss,

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fatigue, constipation, dry skin, irregular menstrual periods, joint pain, increased blood cholesterol, and depression. The early stage of HT, which is a chronic swelling of the thyroid, is an autoimmune condition that causes the immune system to attack thyroid glands and damage the peripheral vestibular organ, a structure in an inner ear that's responsible for regulating balance. Complications of H0 include developmental issues in a baby born to a birthing parent, trouble conceiving affecting ovulation, depression, myxedema, or severe.

1.3. Hyperthyroidism (H1)

The low level of TSH indicates excess of T4, and it is called hyperthyroidism or overactive thyroid, caused by taking too much thyroid medication and the symptoms such as weight loss, high level of anxiety, insomnia, tremors, hair loss, mood swings, heart palpitations, increased hunger, sweating, and changes in menstrual periods, eye pain, and constipation. Abnormally high levels of T3 most commonly indicate a condition called GD or bulging eyes. It's an autoimmune disorder associated with hyperthyroidism. Complications of H1 include skin rashes, osteoporosis and thinning bones, increased risk of blood clots and stroke, irregular menstrual cycle and fertility issues, and heart issues.

Table 1.

Thyroid Condition	T3	T4	TSH
H1	High	High	Low
H0	Low or Normal	Low	High

2. Preliminaries

This section consists of basic definition of fuzzy set, picture fuzzy set and similarity measures between picture fuzzy sets.

2.1. Fs [5]

"In a universal set X_1,a fuzzy set $\widetilde{A1}$is a set of ordered pairs with the formation $\widetilde{A1} = \left\{\left((x_1, \mu_{\widetilde{A1}}(x_1))\middle| x_1 \in X_1\right)\right\}$.The grade of membership function or degree of truth of x_1, A1 is $\mu_{\widetilde{A1}}(x_1)$ and is defined as: $\mu_{\widetilde{A1}} : X_1 \to [0,1]$".

2.2 Pfs [9]

" APFs A1 in a finite set $X_1$the formation as follows:

$$\widetilde{A1} = \{(x_1, \mu_{\widetilde{A1}}(x_1), v_{\widetilde{A1}}(x_1), \gamma_{\widetilde{A1}}(x_1), |x_1 \in X_1)\}$$

Where $\mu_{\widetilde{A1}}(x_1), v_{\widetilde{A1}}(x_1)\, and\, \gamma_{\widetilde{A1}}(x_1)$ represent the positive-membership function, negative-membership function and neutral-membership function of $x_1$to set A1, respectively. For each point x_1 in X_1, we have $\mu_{\widetilde{A1}}(x_1), v_{\widetilde{A1}}(x_1), \gamma_{\widetilde{A1}}(x_1) \to [0,1]$.

Also, $0 \le \mu_{\widetilde{A1}}(x_1) + v_{\widetilde{A1}}(x_1) + \gamma_{\widetilde{A1}}(x_1) \le 1, also\ for\ x_1 \in X_1$

$\prod_{A1}(x_1) = 1 - \left(\mu_{\widetilde{A1}}(x_1) + v_{\widetilde{A1}}(x_1) + \gamma_{\widetilde{A1}}(x_1)\right)$ Called the refusal-membership degree of x_1 to set A1. For convenience, we can use $x = (\mu_{\widetilde{A1}}, v_{\widetilde{A1}}, \gamma_{\widetilde{A1}})$ to represent an element in PFs.

We denote PFs(X_1) is a collection of picture fuzzy set on X_1 where $X_1 = \left\{\left((x_1, 1,\ 0,\ 0)\middle| x_1 \in X_1\right)\right\}$ and $\emptyset = \left\{\left((x_1,\ 0,\ 0, 1)\middle| x_1 \in X_1\right)\right\}$.

2.3 The inclusion, union, intersection and complement of any two PFs A1 and B1 in a finite set X_1, are respectively [1] defined as follows

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1. $A1 \subseteq B1\ iff\ x_1 \in X_1, \mu_{\widetilde{A1}}(x_1) \leq \mu_{\widetilde{B1}}(x_1),\ v_{\widetilde{A1}}(x_1) \leq v_{\widetilde{B1}}(x_1),\ \gamma_{\widetilde{A1}}(x_1) \leq \gamma_{\widetilde{B1}}(x_1)$.
2. $A1 = B1\ iff\ \forall\ x_1 \in X_1, A1 \subseteq B1\ and\ A1 \supseteq B1$.
3. $A1 \cup B1 = \left\{x_1, \left(max\left(\mu_{\widetilde{A1},}\mu_{\widetilde{B1}}\right)\right),\ \left(min(v_{\widetilde{A1}}, v_{\widetilde{B1}})\right),\ \left(max\left(\gamma_{\widetilde{A1},}\gamma_{\widetilde{B1}}\right)\right)\right\}$.
4. $A1 \cap B1 = \left\{x_1, \left(min\left(\mu_{\widetilde{A1},}\mu_{\widetilde{B1}}\right)\right),\ \left(max(v_{\widetilde{A1}}, v_{\widetilde{B1}})\right),\ \left(min\left(\gamma_{\widetilde{A1},}\gamma_{\widetilde{B1}}\right)\right)\right\}$.
5. $coA1 = \widetilde{A1} = \{(x_1,\ v_{\widetilde{A1}}(x_1),\ \mu_{\widetilde{A1}}(x_1), \gamma_{\widetilde{A1}}(x_1), |x_1 \in X_1)\}$.

2.4 If an operator of $d(A1, B1)$satisfies the following, it is a similarity measure between $A1 \in PFs(X_1)\ and\ B1 \in PFs(X_1)$ [2],

a. $0 \leq d(A1, B1) \leq 1$.
b. $d(A1, B1) = 0\ iff\ A1 = B1$.
c. $d(A1, B1) = d(B1, A1)$.
d. $If\ A1 \subseteq B1 \subseteq C1, then\ d(A1, B1) + d(B1, C1) \geq d(A1, C1)$.

2.5 Be the normalized hamming distance between A1 and B1,

$$d(A1, B1) = \frac{1}{n}\sum_{i=1}^{n}\{\left|\mu_{\widetilde{A1},}(x_1) - \mu_{\widetilde{B1}}(x_1)\right| + |v_{\widetilde{A1}}(x_1) - v_{\widetilde{B1}}(x_1)| + \left|\gamma_{\widetilde{A1},}(x_1) - \gamma_{\widetilde{B1}}(x_1)\right|\}.$$

2.6 A1 and B1 is the normalized Euclidean distance,

$$d(A1, B1)\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\mu_{\widetilde{A1},}(x_1) - \mu_{\widetilde{B1}}(x_1)\right)^2 + \left(v_{\widetilde{A1}}(x_1) - v_{\widetilde{B1}}(x_1)\right)^2 + \left(\gamma_{\widetilde{A1},}(x_1) - \gamma_{\widetilde{B1}}(x_1)\right)^2}.$$

2.7 A cosine similarity measure between two PFs A1 and B1in universe X_1, is defined as,

$d_{cos}(A1, B1)$
$= \frac{1}{n}\sum_{i=1}^{n} cos\left\{\frac{\pi}{2}\left|\mu_{\widetilde{A1},}(x_1) - \mu_{\widetilde{B1}}(x_1)\right| + \left|v_{\widetilde{A1}}(x_1) - v_{\widetilde{B1}}(x_1)\right| + \left|\gamma_{\widetilde{A1},}(x_1) - \gamma_{\widetilde{B1}}(x_1)\right|\right\}.$

2.8 A cotangent similarity measure between two PFs A1 and B1in universe $X_1$is

$d_{cot}(A1, B1)$
$= \frac{1}{n}\sum_{i=1}^{n} cot\left\{\frac{\pi}{4} + \frac{\pi}{4}\left|\mu_{\widetilde{A1},}(x_1) - \mu_{\widetilde{B1}}(x_1)\right| \vee \left|v_{\widetilde{A1}}(x_1) - v_{\widetilde{B1}}(x_1)\right| \vee \left|\gamma_{\widetilde{A1},}(x_1) - \gamma_{\widetilde{B1}}(x_1)\right|\right\}.$

$\vee$ is the maximum operation.

2.9 A cosine similarity measure between two PFs A1 and B1in universe X_1

is $d_{cos}(A1, B1) = \frac{1}{n}\sum_{i=1}^{n} \frac{\mu_{\widetilde{A1},}(x_1)\mu_{\widetilde{B1}}(x_1) + v_{\widetilde{A1}}(x_1)v_{\widetilde{B1}}(x_1) + \gamma_{\widetilde{A1},}(x_1)\gamma_{\widetilde{B1}}(x_1)}{\sqrt{\mu_{\widetilde{A1}}(x_1)^2 + v_{\widetilde{A1}}(x_1)^2 + \gamma_{\widetilde{A1}}(x_1)^2}\sqrt{\mu_{\widetilde{B1}}(x_1)^2 + v_{\widetilde{B1}}(x_1)^2 + \gamma_{\widetilde{B1}}(x_1)^2}}.$

2.10 A set theoretic similarity measure between two PFs A1 and B1in universe X_1

is $d_{sts}(A1, B1) = \frac{1}{n}\sum_{i=1}^{n} \frac{\mu_{\widetilde{A1},}(x_1)\mu_{\widetilde{B1}}(x_1) + v_{\widetilde{A1}}(x_1)v_{\widetilde{B1}}(x_1) + \gamma_{\widetilde{A1},}(x_1)\gamma_{\widetilde{B1}}(x_1)}{max\left(\mu_{\widetilde{A1}}(x_1)^2 + v_{\widetilde{A1}}(x_1)^2 + \gamma_{\widetilde{A1}}(x_1)^2, \mu_{\widetilde{B1}}(x_1)^2 + v_{\widetilde{B1}}(x_1)^2 + \gamma_{\widetilde{B1}}(x_1)^2\right)}.$

2.11 Let $X_1 = \{x1, x2, x3, \dots xn\}$ be the universe of discourse and A sine similarity measure between two PFsin universe X_1 is

$A1 = \{x_1, \mu_{\widetilde{A1}}(x_1), v_{\widetilde{A1}}(x_1), \gamma_{\widetilde{A1}}(x_1) : x_1 \in X_1\}$ and

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$B1 = \{x_1, \mu_{\widetilde{B1}}(x_1), v_{\widetilde{B1}}(x_1), \gamma_{\widetilde{B1}}(x_1) : x_1 \in X_1\},$

$$d(A1, B1) = \frac{\sqrt{2}}{3n}\sum_{1}^{n} \sin\frac{\pi}{4}\{|\mu_{a1}(x_1) - \mu_{b1}(x_1)| + |v_{a1}(x_1) - v_{b1}(x_1)| + |\gamma_{a1}(x_1) - \gamma_{b1}(x_1)|\}.$$

3. Application of Proposed Method in Dar Study of Symptoms

3.1. Methodology

Let $\left\{\begin{matrix} Hashimoto's\ Thyroiditis(HT), Obesity(O), Myxedema(M), \\ Peripheral\ Neuropathy(PN), Jaundice(J) \end{matrix}\right\}$

be the set of disease corresponding to H0 and let

$$\left\{\begin{matrix} Grave's\ Disease(GD), Infertilit(I), Cancer(C), \\ Osteoporosis(OS) \end{matrix}\right\}$$

be the set of disease corresponding to H1. Also let

$$\left\{\begin{matrix} Anxiety(S1), Fatigue(S2), Hair\ loss(S3), \\ Irregular\ periods(S4), Depression(S5) \end{matrix}\right\}$$

be the set of symptoms. The proposal similarity measure can be done to evaluate similarity measure between H0 and H1 symptoms.

$$d(H1, H0) = \frac{\sqrt{2}}{3n}\sum_{1}^{n} \sin\frac{\pi}{4}\{|\mu_{a1}(x_i) - \mu_{b1}(x_i)| + |v_{a1}(x_i) - v_{b1}(x_i)| + |\gamma_{a1}(x_i) - \gamma_{b1}(x_i)|\}.$$

Where$i = 1,2,..,n$.

Moreover, the similarity between each pair of $\{HT, O, M, PD, J\}$ and $\{GD, I, C, OS\}$. The following matrix is given below:

$$\begin{pmatrix} d(GD,HT) & d(I,HT) & d(C,HT) & d(OS,HT) \\ d(GD,O) & d(I,O) & d(C,O) & d(OS,O) \\ d(GD,M) & d(I,M) & d(C,M) & d(OS,M) \\ d(GD,PN) & d(I,PN) & d(C,PN) & d(OS,PN) \\ d(GD,J) & d(I,J) & d(C,J) & d(OS,J) \end{pmatrix}$$

Now, here we use the concept of distance between picture fuzzy sets, which implies more similarity and more comparable. Each column has a minimum value, which gives the similarity of H0 and H1 with respect to different diseases.

3.2. A case study in disease

In this case study we analysis the disease activity of Thyroid low level to high level under the proposed sine similarity measure in a decision-making situation. S1, S2…S5 are the symptoms that were compared.

The relationship between Symptoms and disease of H0 in terms of picture fuzzy sets is given in table 1 and Disease of tH1 and symptoms in terms of picture fuzzy sets is given in table 2.

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Table 1. Symptoms and disease of H0 picture fuzzy relation

H0 SYMPTOM/ DISEASE	Hashimoto's Thyroiditis (HT)	Obesity (O)	Myxedema (M)	Peripheral Neuropathy (PN)	Jaundice (J)
Anxiety (S1)	(0.7, 0.5, 0.4)	(0.6, 0.4, 0.6)	(0.5, 0.5, 0.6)	(0.4, 0.6, 0.3)	(0.8, 0.3, 0.5)
Fatigue (S2)	(0.4, 0.1, 0.3)	(0.6, 0.6, 0.4)	(0.4, 0.7, 0.5)	(0.4, 0.8, 0.8)	(0.9, 0.3, 0)
Hair Loss (S3)	(0.9, 0.3, 0.2)	(0.9, 0.3, 0.4)	(0.7, 0, 0.4)	(0.6, 0.4, 0.5)	(0.4, 0.2, 0.1)
Irregular Periods (S4)	(0.7, 0.4, 0.5)	(0.9, 0.3, 0.4)	(0.8, 0.4, 0.4)	(0.3, 0.6, 0.7)	(0.9, 0.3, 0)
Depression (S5)	(0.7, 0.1, 0.4)	(0.9, 0.3, 0.3)	(0.5, 0.1, 0.8)	(0.9, 0.3, 0)	(0.9, 0, 0.3)

Table 2. Disease of H1 and symptoms picture fuzzy relation

H1 SYMPTOM/ DISEASE	Anxiety (S1)	Fatigue (S2)	Hair Loss (S3)	Irregular Periods (S4)	Depression (S5)
Grave's Disease (GD)	(0.6, 0.4, 0.3)	(0.5, 0.6, 0.3)	(0.7, 0.2, 0.3)	(0.8, 0.5, 0.3)	(0.7, 0.5, 0.3)
Infertility (I)	(0.4, 0,0.8)	(0.4, 0.3, 0.9)	(0.5, 0.2, 0.6)	(0.4, 0, 0.7)	(0.4, 0.3, 0.9)

Cancer (C)	(0.3, 0.5, 0)	(0.6, 0.6, 0)	(0.7, 0.4, 0.2)	(0.5, 0.5, 0.6)	(0.4, 0.5, 0.7)
Osteoporosis (OS)	(0.6, 0.2, 0.5)	(0.3, 0.3, 0.9)	(0.4, 0.4, 0.9)	(0.7, 0, 0)	(0.9, 0.1, 0)

We now represent H0 (HT, O, M, PN, J) as picture fuzzy sets for symptoms as follows.

$$HT = \{S1(0.7, 0.5, 0.4),\quad S2(0.4, 0.1, 0.3),\quad S3(0.9, 0.3, 0.2),\quad S4(0.7, 0.4, 0.5),\quad S5(0.7, 0.1, 0.4)\}$$

$$O = \{S1(0.6, 0.4, 0.6),\quad S2(0.6, 0.6, 0.4),\quad S3(0.9, 0.3, 0.4),\quad S4(0.9, 0.3, 0.4),\quad S5(0.9, 0.3, 0.3)\}$$

$$M = \{S1(0.5, 0.5, 0.6),\quad S2(0.4, 0.7, 0.5),\quad S3(0.7, 0, 0.4),\quad S4(0.8, 0.4, 0.4),\quad S5(0.5, 0.1, 0.8)\}$$

$$PN = \{S1(0.4, 0.6, 0.3),\quad S2(0.4, 0.8, 0.8),\quad S3(0.6, 0.4, 0.5),\quad S4(0.3, 0.6, 0.7),\quad S5(0.9, 0.3, 0)\}$$

$$J = \{S1(0.8, 0.3, 0.5),\quad S2(0.9, 0.3, 0),\quad S3(0.4, 0.2, 0.1),\quad S4(0.9, 0.3, 0),\quad S5(0.9, 0, 0.3)\}$$

Similarly, we represent H1 (GD, I, C, OS) as picture fuzzy sets for symptoms as follows.

$$GD = \{S1(0.6, 0.4, 0.3),\quad S2(0.5, 0.6, 0.3),\quad S3(0.7, 0.2, 0.3),\quad S4(0.8, 0.5, 0.3),\quad S5(0.7, 0.5, 0.3)\}$$

$$I = \{S1(0.4, 0, 0.8),\quad S2(0.4, 0.3, 0.9),\quad S3(0.5, 0.2, 0.6),\quad S4(0.4, 0, 0.7),\quad S5(0.4, 0.3, 0.9)\}$$

$$C = \{S1(0.3, 0.5, 0),\quad S2(0.6, 0.6, 0),\quad S3(0.7, 0.4, 0.2),\quad S4(0.5, 0.5, 0.6),\quad S5(0.4, 0.5, 0.7)\}$$

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$$OS = \{S1(0.6, 0.2, 0.5),\quad S2(0.3, 0.3, 0.9),\quad S3(0.4, 0.4, 0.9),\quad S4(0.7, 0, 0),\quad S5(0.9, 0.1, 0)\}$$

$$d(HT, GD) = \frac{\sqrt{2}}{3\times 5}\sin\frac{\pi}{4}[|0.7-0.6| + |0.5-0.4| + |0.4-0.3| + |0.4-0.5| + |0.1-0.6| + |0.3-0.3| + |0.9-0.7| + |0.3-0.2| + |0.2-0.3| + |0.7-0.8| + |0.4-0.5| + |0.5-0.3| + |0.7-0.7| + |0.1-0.5| + |0.4-0.3|]$$

$$d(HT, GD) = \frac{\sqrt{2}}{15}\times\frac{1}{\sqrt{2}}[0.1+0.1+0.1+0.1+0.5+0+0.2+0.1+0.1+0.1+0.1+0.2+0+0.4+0.1] = \frac{1}{15}[2.2] = 0.1466 \cong 0.147.$$

$$d(HT, I) = \frac{\sqrt{2}}{3\times 5}\sin\frac{\pi}{4}[|0.7-0.4| + |0.5-0| + |0.4-0.8| + |0.4-0.4| + |0.1-0.3| + |0.3-0.9| + |0.9-0.5| + |0.3-0.2| + |0.2-0.6| + |0.7-0.4| + |0.4-0| + |0.5-0.7| + |0.7-0.4| + |0.1-0.3| + |0.4-0.9|]$$

$$d(HT, I) = \frac{\sqrt{2}}{15}\times\frac{1}{\sqrt{2}}[0.3+0.5+0.4+0+0.2+0.6+0.4+0.1+0.4+0.3+0.4+0.2+0.3+0.2+0.5] = \frac{1}{15}[4.8] = 0.3200 \cong 0.320.$$

$$d(HT, C) = \frac{\sqrt{2}}{3\times 5}\sin\frac{\pi}{4}[|0.7-0.3| + |0.5-0.5| + |0.4-0| + |0.4-0.6| + |0.1-0.6| + |0.3-0| + |0.9-0.7| + |0.3-0.4| + |0.3-0.2| + |0.7-0.5| + |0.4-0.5| + |0.5-0.6| + |0.7-0.4| + |0.1-0.5| + |0.4-0.7|]$$

$$d(HT, C) = \frac{\sqrt{2}}{15}\times\frac{1}{\sqrt{2}}[0.4+0+0.4+0.2+0.5+0.3+0.2+0.1+0.1+0.2+0.1+0.1+0.3+0.4+0.3] = \frac{1}{15}[3.6] = 0.2400 \cong 0.240.$$

$$d(HT, OS) = \frac{\sqrt{2}}{3\times 5}\sin\frac{\pi}{4}[|0.7-0.6| + |0.5-0.2| + |0.4-0.5| + |0.4-0.3| + |0.1-0.3| + |0.3-0.9| + |0.9-0.4| + |0.3-0.4| + |0.2-0.9| + |0.7-0.7| + |0.4-0| + |0.5-0| + |0.7-0.9| + |0.1-0.1| + |0.4-0|]$$

$d(HT, OS) = \frac{\sqrt{2}}{15} \times \frac{1}{\sqrt{2}} [0.1 + 0.3 + 0.1 + 0.1 + 0.2 + 0.6 + 0.5 + 0.1 + 0.7 + 0 + 0.4 + 0.5 + 0.2 + 0 + 0.4] = \frac{1}{15}[4.2] = 0.2800 \cong 0.280.$

The matrix between set of H1 and H0 derivatives is finally as follows.

$$\begin{matrix} SIM \\ HT \\ O \\ M \\ PN \\ J \end{matrix} \begin{pmatrix} GD & I & C & OS \\ 0.147 & 0.320 & 0.240 & 0.280 \\ 0.113 & 0.313 & 0.253 & 0.260 \\ 0.167 & 0.247 & 0.227 & 0.313 \\ 0.227 & 0.280 & 0.260 & 0.267 \\ 0.220 & 0.393 & 0.333 & 0.247 \end{pmatrix}$$

From the above data it is proven. the proposed method is very useful in DAR study of diagnosis.

4. Conclusion

In this paper, a picture fuzzy set of a similarity measure is used in the decision-making problem of thyroid disease of two different extents, low to high, which is hypothyroidism and hyperthyroidism. The disease ofH1 is Hashimoto's thyroiditis, and the disease of H0 is osteoporosis. Likewise, the disease of H1 is peripheral neuropathy, and the disease of H0 is infertility. H1 is obesity and H0 is infertility, with H1 being my edema and H0 being osteoporosis. H1 is obesity with H0 is osteoporosis, and H1 is peripheral neuropathy with H0 is cancer have the similarity measure. Finally, we can conclude that a low level of thyroid hormone can interfere with the release of an egg from the ovary (ovulation), which impairs fertility. In addition, some of the underlying causes of hypothyroidism, such as certain autoimmune or pituitary disorders. A high level of thyroid hormone can disrupt the menstrual cycle and increase the risk of early-term miscarriage and also premature birth. Thus, the thyroid disorder, high or low, directly affects fertility, which leads to infertility. The

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disease of the H0 and H1 when intersecting forms a similarity, and the results were very satisfactory. The method used in comparing the symptoms of the disease is evident.

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Chapter 11

Cordial Labeling on Grotzsch Graph

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Abstract

Let f be a function from v (G) to {0, 1} and for each edge uv, assign the label | f (u) – f (v) | . f is called a cordial labeling if the number of vertices labeled with 0 and the number of vertices labeled with 1 differ by at most 1 and the number of edges labeled with 0 and the number of edges labeled with 1 differ by at most 1. A graph with a cordial labeling is called cordial graph. A graph with a cordial labeling is called cordial graph. In this paper we prove that Grotzsch Graph, fusion of any two adjacent vertices of degree 4 in a Grotzsch Graph, duplication of any vertex f degree 3 in a Grotzsch Graph, switching the central vertex in the Grotzsch Graph and path union of two copies of Grotzsch Graph are cordial labeling graphs.

Keywords: Grotzsch Graph, Cordial labeling, fusion, duplication, switching, path union.

1. Introduction

In this paper, we consider only simple finite undirected graph. For notation and standard terminology related to the graph theory we referred to Harary[3].for dynamic survey of various graph labeling , e refer to Gallian [2]. Cahit introduced the concept of cordial labeling in the year 1987 in [1]. Let f be a function from V (G) to {0, 1} and for each edge uv, assign the label | f(x)−f(y) | . f is called a cordial labeling

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if the number of vertices labeled with 0 and the number of vertices labeled with 1 differ by at most 1 and the number of edges labeled with 0 and the number of edges labeled with 1 differ by at most 1. K-Product cordial labeling [4] has been introduced by R. Ponraj, M. Sivakumar and M. Sundaram. Motivated by these works in this paper we prove Grotzsch graphs and some operations in a Grotzsch graphs are cordial graphs.

Definition.1.1: Let f be a function from v(G) to {0, 1} and for each edge uv, assign the label |f(u) − f(v)|. f is called a cordial labeling if the number of vertices labeled with 0 and the number of vertices labeled with 1 differ by at most 1 and the number of edges labeled with 0 and the number of edges labeled with 1 differ by at most 1.

Definition.1.2: Let u and v be two distinct vertices of a graph G. A new graph G1 is constructed by fusing two vertices u and v by a single vertex x in G1 such that every edge which was incident with either u or v in G now incident with x in G1.

Definition.1.3: Duplication of a vertex v_k of a graph G produces a new graph G_1 by adding a vertex v_k' with $N(v_k) = N(v_k')$. In other words. A vertex v_k' is said to be a duplication of vk if all the vertices which are adjacent to v_k are now adjacent to v_k'.

Definition.1.4: A vertex switching Gv of a graph G is obtained by taking a vertex v of G, removing the entire edges incident with v and adding edges joining v to every vertex which are non-adjacent to v in G.

Definition.1.5: Let G be a graph and let G1=G2=……=G_n=G, where n ≥ 2, then the graph obtain by adding an edge from each G_i to G_{i+1} (1 ≤ i ≤ n-1) is called the path union of G.

Definition.1.6: The Grotzsch graph G is a triangle – free graph with 11 vertices and 20 edges. It contains a star $K_{1,5}$ in which each pendant vertex of $K_{1,5}$ is connected with two rim vertices of the cycle C_5 whose vertex set , V(G) = $\{w,v_1,v_2,v_3,v_4,v_5, u_1,u_2,u_3,u_4,u_5\}$ and the edge set = $\{wv_i$, $1\leq i \leq 5\}$ U $\{u_iu_{i+1}$, $1\leq i \leq 4$, $u_5u_1\}$U $\{v_1u_2,v_1v_5,v_2u_1,v_2u_3,v_3u_2,v_3u_4,v_4u_3,v_4u_5,v_5u_4,v_5u_1\}$.

2. Main Results

Theorem 2.1. The Grotzsch Graph (G) is a cordial labeling.

Proof:

Let the Grotzsch graph G with 11(n) vertices and 20 edges.

Define the vertex label f: $\rightarrow$ V = {0,1}

f(u) = 0, $f(u_i)$ =0 , $1 \leq i \leq (n-1)/2$, $f(v_i) = 1$, $1 \leq i \leq (n-1)/2$

The edge labels are

$f^*(uu_i) = 0$, $1 \leq i \leq (n-1)/2$, $f^*(u_iv_i) = 1$, $1 \leq i \leq (n-1)/2$,

$f^*(u_iv_{i+2}) = 1$, $1 \leq i \leq (n-5)/2$, $f^*(v_iv_i+1) = 0$, $1 \leq i \leq (n-3)/2$,

$f^*(u_3v_n) = 1$, $f^*(u_4v_1) = 1$, $f^*(v_1v_n) = 0$.

Hence, we obtain $|e(0)-e(1)| \leq 1$.

Therefore G admits cordial labeling.

Theorem.2.2. The duplication of any arbitrary vertex of degree 3 in a Grotzsch Graph is a cordial graph.

Proof:

Let the Grotzsch graph with 11(n) vertices and 20 edges. Let u be the central vertex and let u_k' be the duplication of the vertex u_k in the Grotzsch Graph. Let G be the graph obtain by duplication of the

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vertex u_k' of the degree 3 in Grotzsch Graph, then number of vertices and edges in G are 12 and 23.

Define the vertex label f: V $\rightarrow$ {0, 1}

Duplication of vertex u_k, where k= 2i-1, $1 \leq i \leq (n-1)/2$,

F (u) = 0, f (u_i) =0, $1 \leq i \leq (n-1)/2$, f (v_i) = 1 , $1 \leq i \leq (n-1)/2$

For all the values of k, we obtain the absolute difference of edge label with 0 and 1 is less than or equal to one.

Theorem 2.3. The fusion of any two adjacent vertices of degree 4 in the Grotzsch graph is a cordial labeling.

Proof:

Let the graph with 11(n) vertices and 20 edges. In the Grotzch graph let u be the central vertex and it has 5 vertex of degree 3, 5 vertex of degree 4 and one vertex of degree 5. Let G be the graph obtained by fusion of any two adjacent vertices of degree 4 with vertex 10 and edges 19.

Define the vertex label f: $\rightarrow$V = {0, 1}

Case: 1 Fusion of v_1 and v_2

F (u) =0, f (u_i) =0, $1 \leq i \leq (n-2) / 2$, f(u_n/2) = 1, f(v_i) =1,$1 \leq i \leq (n-2) / 2$

The edge labels are

f*(uu_i) = 0 , $1 \leq i \leq (n-2) / 2$, f*(v_iv_i+1) = 0 , $1 \leq i \leq (n-4)/2$.

f*(uu_n/2)=1, f*(v_1v(n-2)/2)=0, f*(u_n/2v1)=0, f*(u_4v_2)=1, f*(u_5v_3)=0, f*(u_1v_4) = 1.

f*(u_iv_i) = 1, $1 \leq i \leq (n-2)/2$.

f*($u_{i+1}v_1$) = 0 , $1 \leq i \leq (n-6)/2$

From the above labeling we obtain |e (0)-e(1)| ≤ 1.

Case: 2 Fusion of v_2 and v_3

$f(u) = 0$, $f(u_i) = 0$, $1 \le i \le (n-2)/2$, $f(v_i) = 1$, $1 \le i \le (n-2)/2$, $f(u_n/2)=1$.

The edge labels are

$f^*(uu_i) = 0$, $1 \le i \le (n-2)/2$, $f^*(v_iv_i+1) = 0$, $1 \le i \le (n-4)/2$,

$f^*(u_n/2_v2_{i-1}) = 0$, $1 \le i \le (n-6)/2$, $f^*(u_iv_i)= 1$, $1 \le i \le (n-2)/2$,

$f^*(u_{2i}v_i)= 1$, $1 \le i \le (n-6)/2$, $f^*(v_1v_{(n-2)/2}) = 0$,

$f^*(u_3v_1) = 1$,$f^*(uu_n/2) = 1$,$f^*(u_1v_{(n-2)/2}) = 1$.

From the above labeling we obtain the $|e(0)-e(1)| \le 1$.

Case: 3 Fusion of v_3 and v_4

$f(u) = 0$, $f(u_{i+1}) = 0$, $1 \le i \le (n-2)/2$, $f(v_i) = 1$, $1 \le i \le (n-2)/2$.

The edge labels are

$f^*(uu_{i+1}) = 0$, $1 \le i \le (n-2)/2$, $f^*(v_iv_{i+1}) = 0$, $1 \le i \le (n-4)/2$,

$f^*(v_1v_{(n-2)/2}) = 0$, $f^*(u_1v_{(n-2)/2}) = 0$, $f^*(u_1v_2) = 0$, $f^*(uu_1) = 1$.

$f^*(u_{i+1}v_{i+1}) = 1$, $1 \le i \le (n-4)/2$, $f^*(u_{i+1}v_i) = 1$, $1 \le i \le (n-6)/2$,

$f^*(u_{i+3}v_{i+1}) = 1$, $1 \le i \le (n-6)/2$, $f^*(u_{n/2}v_1) = 1$.

From the above labeling we obtain $|e(0)-e(1)| \le 1$.

Case: 4 Fusion of v_4 and v_5

$f(u)=0$, $f(u_1)=0$, $f(u_{i+2})=0$,$1\le i \le (n-4)/2$, $f(u_2)=1$, $f(v_i)=1$,$1 \le i \le (n-2)/2$.

The edge labels are

$f^*(uu_1) = 0$, $f^*(uu_{i+2}) = 0$, $1 \le i \le (n-4)/2$, $f^*(v_iv_{i+1}) = 0$, $1 \le i \le (n-4)/2$,

$f^*(u_2v_{2i-1}) = 0$, $1 \le i \le (n-6)/2$, $f^*(v_1v_{(n-2)/2}) = 0$, $f^*(uu2) = 1$,

$f^*(u_{i+2}v_{i+2}) = 1$, $1 \le i \le (n-6)/2$, $f^*(ui+2v_{i+1}) = 1$, $1 \le i \le (n-6)/2$,

$f^*(u_1v_{2i}) = 1$, $1 \le i \le (n-6)/2$,$f^*(u_{n/2}v_{2i-2}) = 1$, $1 \le i \le (n-6)/2$.

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From the above labeling we obtain |e (0)-e(1)| ≤ 1.

Case: 5 Fusion of v_5 and v_1

$f(u) = 0$, $f(u_3) = 1$, $f(u_i) = 0$, $1 \le i \le (n-6)/2$, $f(u_{i+3}) = 0$, $1 \le i \le (n-6)/2$, $f(v_i) = 1$, $1 \le i \le (n-2)/2$.

The edge labels are

$f^*(uu_i) = 0$, $1 \le i \le (n-6)/2$, $f^*(uu_{i+3}) = 0$, $1 \le i \le (n-6)/2$,

$f^*(u_3v_{2i}) = 0$, $1 \le i \le (n-6)/2$, $f^*(v_iv_{i+1}) = 0$, $1 \le i \le (n-4)/2$,

$f^*(v_1v_{(n-2)/2}) = 0$, $f^*(uu_3) = 1$, $f^*(u_iui+1) = 1$, $1 \le i \le (n-6)/2$,

$f^*(u_i+3v_{i+2}) = 1$, $1 \le i \le (n-6)/2$, $f^*(v_1u_{n/2}) = 1$, $f^*(u_2v_1) = 1$,

$f^*(u_1v_{(n-2)/2}) = 1$, $f^*(u_{(n-2)}/2v_{(n-2)/2}) = 1$,

From the above labeling we obtain |e (0)-e(1)| ≤ 1.

Theorem 2.4. The union of two copies of Grotzsch graph is a sum divisor cordial labeling.

Proof:

Let the Grotzsch graph G with 11(n) vertices and 20 edges. Consider two copies of Grotzsch graph. Let the vertex set be V= {ui, $1 \le i \le n$ U v_i, $1 \le i \le n$} and the total number of edges are 41.

Define the vertex label f: ➔ V = {0, 1}

$f(u) = 0$, $f(u_i) = 0$, $1 \le i \le (n-1)/2$, $f(u_{(n-1)/2+i}) = 1$, $1 \le i \le (n-1)/2$, $f(v) = 1$,

$f(v_i) = 1$, $1 \le i \le (n-1)/2$, $f(u_{(n-1)/2+i}) = 0$, $1 \le i \le (n-1)/2$.

The edge labels are

$f^*(uu_{i+1})=0$, $1 \le i \le (n-1)/2$, $f^*(u_{(n-1+2i)}/2u_{(n+1+2i)/2}) = 0$, $1 \le i \le (n-3)/2$,

$f^*(u_{n-1}u_{(n+1)/2}) = 0$, $f^*(u_iu_{(n+1+2i)/2})=1$, $1 \le i \le (n-3)/2$, $f^*(u_{(n-1)/2u(n+1)/2}) = 1$,

$f^*(u_{i+1}u_{(n-1+2i)/2})=1$, $1 \le i \le (n-3)/2$, $f^*(u_1u_{n-1})=1$, $f^*(vv_{i+1})=0$, $1 \le i \le (n-1)/2$,

$f^*(v_{(n-1+2i)/2}u_{(n+1+2i)/2}) = 0$, $1 \le i \le (n-3)/2$, $f^*(v_{n-1}v_{(n+1)/2}) = 0$,

$f^*(v_iv_{(n+1+2i)/2}) = 1$, $1 \le i \le (n-3)/2$, $f^*(u_{(n-1)/2}v_{(n+1)/2}) = 1$,

$f^*(v_{i+1}v_{(n-1+2i)/2})=1, 1\le i\le(n-3)/2$, $f^*(v_1v_{n-1})=1$, $f^*(u_{(n+1)/2}v_{(n+1)/2}) = 1$.

From the above labeling we obtain $|e(0)-e(1)| \le 1$.

Theorem 2.5. The switching of a central vertex u in the Grotzsch graph is a cordial graph.

Proof:

Let the Grotzsch graph G with 11(n) vertices and 20 edges. In the Grotzsch graph, Let u be the central vertex and G be the new graph obtained by switching the central vertex u with 11 vertices and 20 edges.

Define the vertex label f: →V = {0, 1}

$f(u) = 0$, $f(u_i) = 0$, $1 \le i \le (n-1)/2$, $f(v_i) = 1$, $1 \le i \le (n-1)/2$.

The edge labels are

$f^*(uv_i) =0, 1\le i\le(n-1)/2$, $f^*(v_iv_{i+1})=0$, $1 \le i \le (n-3)/2$, $f^*(v_1v_{(n-1)/2}) = 0$,

$f^*(u_iv_{i+1})=1, 1\le i\le(n-3)/2$, $f^*(u_1v_{(n-1)/2})=1$, $f^*(u_i+1v_i)=1, 1\le i \le (n-3)/2$,

$f^*(u_1v_{(n-1)/2}) = 1$.

From the above labeling we obtain $|e(0)-e(1)| \le 1$.

3. Conclusion

In this paper we proved that the Grotzsch graph fusion of any two adjacent vertices of degree 4 in a Grotzsch Graph, duplication of any vertex f degree 3 in a Grotzsch Graph, switching the central vertex in the Grotzsch Graph and path union of two copies of Grotzsch Graph are admits Cordial Labeling.

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Chapter 12

Performance Evaluation of Ramie-Sisal Fiber Reinforced Epoxy Composites for Sustainable Particle Board Applications

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Abstract

This research examines the mechanical, absorption, and thermal behavior of hybrid composites reinforced with short ramie and sisal fibers in an epoxy resin matrix. Different fiber lengths (10, 15, 20, and 25 mm) and weight fractions (20%, 25%, 30%, and 35%) were evaluated. The optimal combination of 20 mm fiber length and 30% fiber content yielded the highest tensile and flexural strength. Scanning Electron Microscopy (SEM) illustrated fiber pullout and fracture characteristics, while Fourier Transform Infrared Spectroscopy (FTIR) and X-ray diffraction (XRD) provided insights into chemical structure and crystallinity. Thermogravimetric analysis (TGA) confirmed high thermal stability, with a decomposition temperature of 378°C. The results suggest that these composites hold promise for lightweight and eco-friendly particle board applications, providing enhanced strength, reduced water absorption, and improved thermal resistance.

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Keywords: Ramie fiber; Sisal fiber; Epoxy resin; Mechanical properties; Particle board applications;

1. Introduction

The rising demand for sustainable and biodegradable materials has driven increased interest in natural fiber composites, particularly in the automotive and construction industries. Ramie (Boehmeria nivea) and sisal (Agave Sisalana) fibers possess remarkable mechanical properties, making them effective reinforcements in polymer-based materials. In previous studies the fiber are mats or long fibers, but in this research the use of short fibers enhanced the mechanical properties and material uniformity in epoxy composites. Short fibers provide better dispersion and stress transfer, improving interfacial adhesion and reducing void content in the final composite structure. The use of hybrid fiber composites can lead to materials with optimized mechanical and physical properties, making them suitable for structural applications. This study aims to analyze how different fiber lengths and weight fractions affect mechanical performance, absorption characteristics, and thermal stability to assess their suitability for particle board applications.

2. Materials and Methods

Ramie and sisal fibers were obtained from local areas in Chennai, Tamil Nadu, and India. Epoxy resin (LY556) and hardener (HY951) were mixed in a 10:1 ratio. Density measurements revealed values of 1.68 g/cm^3 for ramie and 1.32 g/cm^3 for sisal. The fibers were extracted and cut into lengths of 10, 15, 20 and 25 mm and then it is treated with 5% NaOH to enhance fiber-matrix adhesion by removing surface impurities. This treatment increases fiber roughness and facilitates better chemical bonding with the epoxy matrix. The fibers were then air-dried for 48 hours before composite fabrication. Short fiber-reinforced epoxy composites were manufactured using compression molding at 100°C and subjected to an 8-hour curing process. This method ensures uniform fiber dispersion and enhances matrix impregnation. Fiber weight fractions of 20%, 25%, 30%, and 35% were incorporated to evaluate the effect of increasing reinforcement content on material performance. Graphical representation of the ramie and sisal hybrid fibre composite plate preparation are as shown in figure 1.

Mechanical properties were assessed according to ASTM standards, including tensile (D3039), flexural (D790), and impact strength (D256). Tensile and flexural testing was performed using a universal testing machine at a constant crosshead speed, ensuring accurate load-deflection curves. Impact testing was conducted using the Charpy impact test method. Absorption properties were evaluated following ASTM D570 standards by immersing composite samples in water and sodium hydroxide (NaOH) solutions. The percentage of weight gain was recorded at hourly intervals up to 50 hours to assess the hydrophobicity and chemical resistance of the composites. Characterization techniques included XRD, FTIR, SEM, and TGA to analyze crystallinity, chemical composition, microstructural integrity, and thermal degradation behavior. SEM images were captured to examine fracture morphology, fiber pullout, and interfacial adhesion between fibers and the epoxy matrix. TGA was conducted under a nitrogen atmosphere to determine the thermal degradation temperature and residual weight of the composites.

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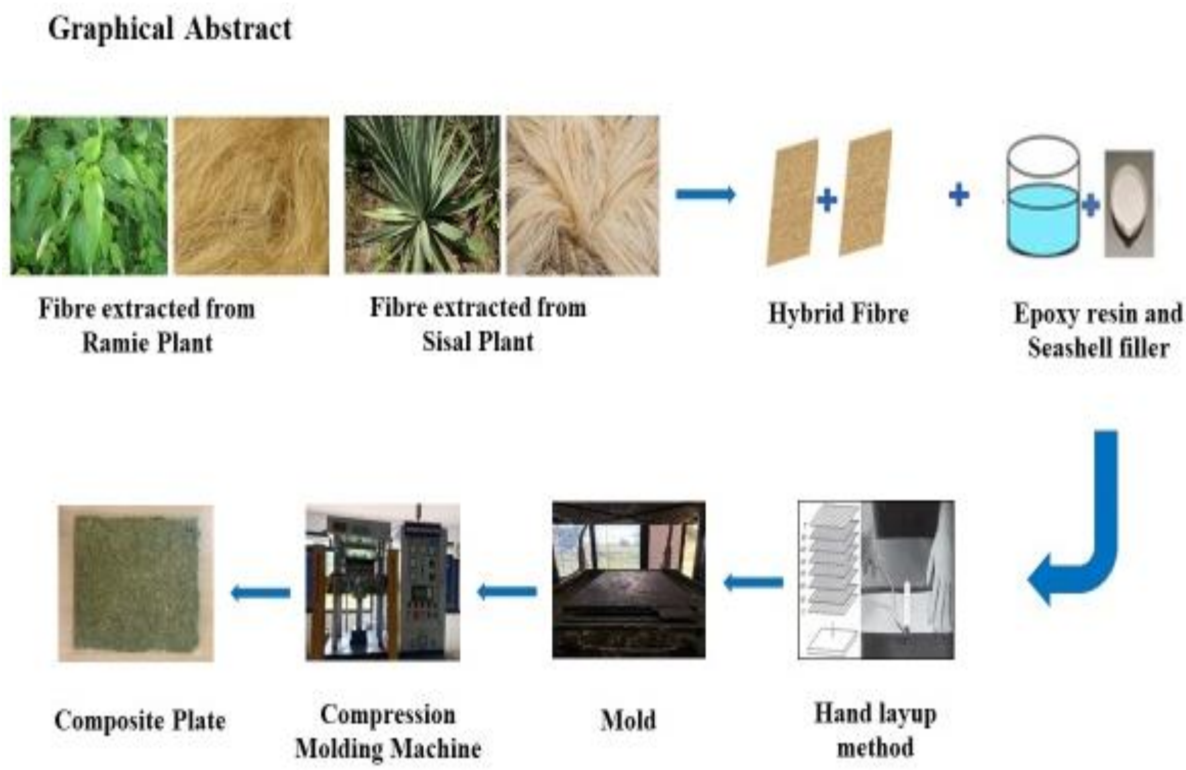

Figure. 1: Graphical representation of the ramie and sisal hybrid fibre composite plate preparation

3. Results and Discussion

3.1. Mechanical Properties

The highest tensile (37.46 MPa) and flexural (52.16 MPa) strengths were observed in composites incorporating 20 mm fibers at 30% fiber content using the equipment's as shown in the figure 2. Increased fiber loading up to 30% led to improved stress distribution and matrix-fiber bonding, enhancing composite strength. However, at 35% fiber content, mechanical properties declined due to fiber clustering and increased void formation, which negatively affected load-bearing capacity. The impact strength of the composites also increased with fiber content up to 30%, demonstrating improved energy absorption under dynamic loads.

Tensile Strength:

Flexural strength:

Impact strength:

Figure. 2: Experimental setup for the ramie and sisal hybrid composite for the Tensile, Flexural and Impact Strength testing's.

3.2. Absorption Studies

Water and chemical absorption tests demonstrated minimal moisture uptake, indicating strong resistance to environmental degradation. The 20 mm, 30% fiber composite exhibited superior hydrophobic properties, absorbing only 5.4% water over a 50-hour period. Comparatively, coir-based composites exhibited absorption rates of up to 8.6%, demonstrating that the hybrid ramie-sisal composites offer better moisture resistance. Reduced water absorption enhances the composites' suitability for applications in humid environments, such as construction and marine industries.

3.3. Thermal Properties

Thermal analysis revealed that the 30% fiber composite had the highest stability, with a peak decomposition temperature of 378°C.

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This indicates that the hybrid composites can maintain their structural integrity at elevated temperatures. The initial weight loss at 100-150°C was attributed to moisture evaporation, while major degradation occurred above 300°C due to cellulose and hemicellulose breakdown. XRD characterization confirmed a crystallinity index of 60.25%, which correlates with enhanced mechanical strength and improved thermal resistance. The FTIR spectra identified key functional groups responsible for fiber-matrix adhesion, confirming effective chemical bonding post-alkaline treatment.

3.4. Microstructural Analysis

SEM images highlighted fiber pullout and brittle fracture mechanisms at higher fiber content levels, particularly in samples exceeding 30% fiber weight fraction as shown in the figure 3 and figure 4. At optimized fiber content, the fiber-matrix interface displayed improved adhesion, reducing the likelihood of premature composite failure. Fiber dispersion within the epoxy matrix was more uniform at 30% fiber loading, supporting the mechanical test results.

a) **b)**

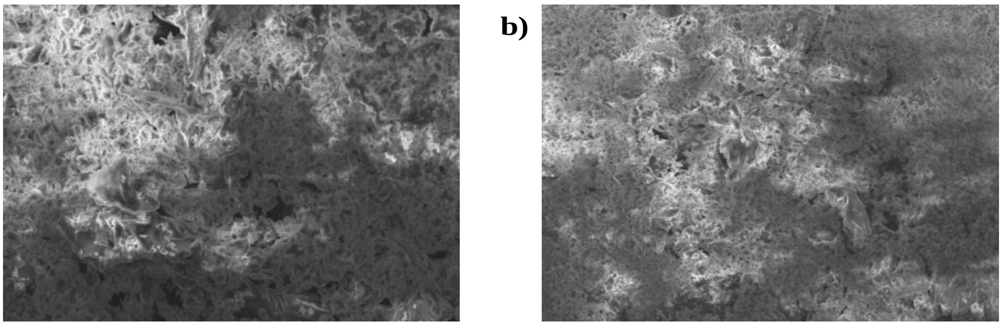

Figure. 3: a) and b) Surface morphological images of hybrid polymer composite

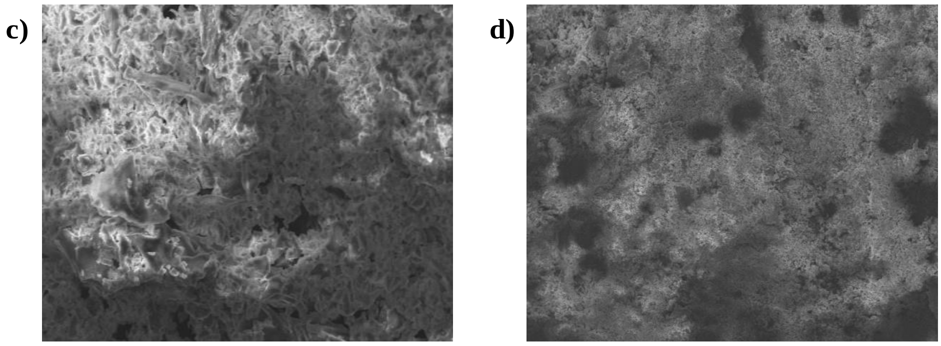

Figure. 4: c) and d) Surface morphological images of hybrid polymer composite

4. Conclusion

This study confirms that hybrid epoxy composites reinforced with 20 mm ramie and sisal fibers at 30% content offer improved mechanical strength, thermal stability, and moisture resistance. The results suggest that these composites are suitable for applications requiring high strength-to-weight ratios, such as particle board and medium-density fiberboards. Additionally, the composites' hydrophobic nature and thermal resistance make them viable for humid environments and temperature-sensitive applications. Future research may focus on optimizing fiber-matrix compatibility using different surface treatments, evaluating alternative resin formulations, and investigating the long-term durability of these composites under real-world environmental conditions. The potential for industrial-scale production should also be explored to assess the economic viability of these eco-friendly materials.

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Chapter 13

Application of Graph Coloring in Railway Junction Design and Capacity Analysis

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Abstract

In order to provide sustainable freight and passenger transportation services, railways are an essential component of modern society. In instance, railways not only contribute to the expansion of regional development and the economy, but they also help to reduce the negative environmental impacts that are caused by the transportation industry. When it comes to transporting goods over long distances and huge volumes, rail freight transport is the preferred mode of transportation due to the obvious benefits that come with economies of scale. Additionally, passenger services that operate over medium and long distances are considered to offer comparable advantages. Rail transit systems are an essential component of public transportation in urban areas, contributing to the transportation of millions of commuters on a daily basis.

Keywords: Graph coloring, railway junction, capacity analysis, scheduling, conflict resolution.

1. Introduction

Efficient railway junction design is critical for maximizing network capacity and ensuring operational safety. Traditional railway planning often faces challenges involving complex track layouts, overlapping schedules, and the necessity for conflict-free routing. As railway networks grow denser, modern approaches increasingly incorporate mathematical modeling techniques to enhance system performance.

One such technique is graph coloring, a well-established method in combinatorial optimization. By modeling railway junctions as graphs—where tracks, routes, or trains correspond to vertices and their interactions represent edges—graph coloring provides a structured method for conflict management and capacity planning. This chapter explores the application of graph coloring in railway junction design, offering insights into its effectiveness in analyzing operational capacity and optimizing track usage.

2. Graph Theory Fundamentals

Graph theory, a branch of discrete mathematics, offers powerful tools for representing relationships between objects. In the context of railway systems:

- Vertices (Nodes) represent individual routes, track sections, or movements.

- Edges (Links) signify potential conflicts between these elements, such as track crossing or merging.

Graph coloring refers to the assignment of colors to vertices such that no two adjacent vertices share the same color. In railway junctions, this translates to ensuring that conflicting movements do not occur

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simultaneously. A minimal coloring—the fewest colors used without conflict—often corresponds to optimal junction capacity or scheduling efficiency.

Chromatic Number: The minimum number of colors needed to achieve a proper coloring is called the chromatic number of the graph, denoted as χ (G).

3. Modeling Railway Junctions Using Graphs

Modeling railway junctions as graphs involves:

- Defining Movements: Each possible train movement through a junction is represented as a vertex.

- Identifying Conflicts: Movements that cannot occur simultaneously (due to track crossing, merging, or safety regulations) are connected by an edge.

Thus, a railway junction's operation can be abstracted into a conflict graph. Proper coloring of this graph ensures safe scheduling: two movements linked by an edge (i.e., in conflict) must occur at different times.

Example: Simple Junction Model

Consider a basic junction where three tracks converge. Movements between different tracks may conflict depending on their paths. Representing these movements as vertices and their conflicts as edges creates a small graph. Applying graph coloring yields a minimal conflict-free movement schedule.

4. Application in Capacity Analysis

Graph coloring directly supports capacity analysis in several ways:

4.1 Determining Movement Slots

Each color assigned in the graph represents a time slot or movement window. A junction with chromatic number $\chi(G)$ requires at least $\chi(G)$ distinct slots to accommodate all movements without conflict. Minimizing $\chi(G)$ maximizes throughput.

4.2 Identifying Bottlenecks

High chromatic numbers often indicate areas where the physical design or scheduling creates excessive conflicts, signaling the need for redesign or capacity enhancement.

4.3 Evaluating Alternative Designs

Comparing the chromatic numbers of different junction designs allows planners to quantitatively assess the operational efficiency of each layout.

4.4 Real-Time Scheduling

In dynamic operations, real-time graph coloring algorithms can assist in adaptive train control systems, quickly recalculating movement orders to resolve emergent conflicts.

5. Case Study Overview

In practice, a study was conducted applying graph coloring techniques to a mid-sized railway junction. Key findings included:

- Conflict Graph Construction: Movements were systematically identified and conflicts mapped to build the corresponding graph.

- Coloring Algorithms Applied: Greedy coloring algorithms, along with optimization techniques, determined the chromatic number.

5.1 Results

- A significant reduction in the number of required movement slots was achieved.

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- Identification of critical conflicting movements allowed targeted infrastructure improvements.

- Enhanced scheduling flexibility improved junction throughput by an estimated 15–20%.

6. Conclusion

Graph coloring offers a structured and efficient method for addressing complex scheduling and capacity challenges in railway junction design. By abstracting movements and conflicts into a mathematical model, railway engineers and planners can quantitatively assess junction efficiency, identify operational bottlenecks, and devise effective improvement strategies.

As railway systems continue to evolve toward higher-density, higher-frequency operations, the integration of graph theory techniques like coloring will become increasingly essential. Future research may focus on integrating graph coloring with AI-based predictive models, enabling even more dynamic and resilient railway operations.

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Chapter 14

Investigation of Microstruture and Tribological Properties of PVD CRN Coatings on Stainless Steel for Automobile applications

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Abstract

Surface modification by means of thin film deposition is an important industrial process used to protect base materials against wear, fatigue, corrosion and many other surface related damage phenomena. Thin hard coatings such as TiN, CrN, and TiAlN have been accepted particularly in the cutting and forming tool industries. TiN and TiAlN coating widely used for dry cutting operations due to its high hardness, CrN coatings have been used to form tool dies for its hardness and corrosion resistance. Tool steels are supplied with heat treated state, generally hardened and tempered to provide for particular application. Tool dies are precision products whose final shape and dimensions are important in micron level accuracy for production of parts. The tool steels have different machinability which varies with the chemical composition and microstructure of steels. The objective of this project is to coat CrN on 6959 steel die components. It is very essential to substantiate the role of different sputtering conditions for achieve desired microstructural properties. The microstructural characteristics of thin film are effectively governed by sputtering parameters. The present work is to evaluate the effect of process parameters on properties of coated surface and to optimize the CrN thin film coating on plastic mould tool steels using RSM. The characterization of coating is to be examined by using - XRD, scratch tester, pin on disc and micro hardness tester.

Keywords: TiN, CrN, and TiAlN, XRD, scratch tester, pin on disc and micro hardness tester.

1. Introduction

The rapid advancement of the automotive industry has driven the need for high-performance materials that offer enhanced durability, wear resistance, and efficiency. Among various surface engineering techniques, Physical Vapor Deposition (PVD) coatings have emerged as a promising solution to improve the surface properties of components subjected to severe mechanical and thermal stresses. Chromium Nitride (CrN) coatings, in particular, have garnered significant attention due to their excellent hardness, corrosion resistance, and superior tribological behavior.

Stainless steel, widely used in automotive applications for its corrosion resistance and strength, often faces challenges such as wear and friction when exposed to dynamic loading and harsh environmental conditions. To address these limitations, applying CrN coatings via PVD techniques has become a strategic approach to enhance the performance and longevity of stainless steel components.

This study focuses on the investigation of the microstructure and tribological properties of PVD-deposited CrN coatings on stainless steel substrates. By examining the coating's morphology, crystallinity, and wear characteristics, the research aims to provide

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insights into the suitability of CrN coatings for critical automotive parts such as engine components, valve trains, and exhaust systems. The findings of this investigation will contribute to the development of more efficient and reliable automotive materials, supporting the ongoing pursuit of performance optimization and sustainability in vehicle manufacturing.

Surface engineering is an economic method for the production of material, tools and machine parts with required surface properties, such as wear and corrosion resistance when two surface contact wear occurs on both surfaces. Individuals and industry tend to focus on the wearing surface that has the greatest impact on their own economic situation, and consider the other surface to be abrasive. Plasma assisted coatings have proved themselves excellent for economical, reliable surface modification processes.

2. Product Placement

Alain d'Astous and Francis Chartier (2000) have communicated that there are fundamentally three purposes behind the course of action by advertisers. Right off the bat, watching movies is an uncommonly thought activity. In light of open to seating blueprints and least external uproar decibels and it will without a doubt have irregular condition of purchaser thought. Moreover powerful movies have a broad number of watchers who may be a planned intrigue bunch effectively and adequacy. It is progressively reasonable similarly to the extent costs per watcher. Finally, placing a thing in movies is a non - assaulting, typical and inconspicuous strategy for going into displaying things. It has been observed that publicists, previously, focused on the position of the thing anyway disregarded the buyer's response towards it.

This fails to recognize whether the social affair of an individual's reaction is of fulfillment/wretchedness/weakness or enthusiasm. Prior research has revealed that the sort of plan (honest or prominent) and emphasis (low or direct) impacts the judgment of thing purchase. Straightforward circumstance has a positive effect whereas emphasis of prominent things has a negative effect as communicated by Homer, Pamela Miles (2009).

3. Purpose of the Study

The inspiration driving this investigation is to vary differentiating alternatives to improve courses of action in various mediums. The maker furthermore expects to watch purchase and resulting repeat purchase of brands set in the midst of various undertakings and to evaluate the thin class which gets the most outrageous responses through thong plans. The assessment also attempts to assess whether the thin circumstance prompts a prevalent survey. Finally, it hopes to assess whether this prompts an extended customer steadfastness.

4. Research Methodology

The examination included setting up an overview for watchers which had various parameters to pass judgment on the effect of brand survey and purchase directly through the situation of things. The audit was done over watchers featuring a collection of statistical and socialization characteristics across over Mumbai, India. The examination is exploratory in nature and the example picked was using the convenience testing method. The examination was finished using SPSS 14.0. Both Univariate and Multivariate bits of knowledge were performed and the makers have in like manner endeavored to think about the model using the Confirmatory Factor examination.

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The examination was driven in excess of 104 respondents including 38 folks and 66 females. The survey contained 39 inquiries on brand audit through thing plans.

5. Results and Discussion

5.1 Microstructural Analysis

The surface morphology of the CrN coatings deposited on stainless steel substrates was examined using Scanning Electron Microscopy (SEM). The images revealed a dense and columnar microstructure, which is characteristic of PVD CrN coatings. The columnar grains were uniform and tightly packed, indicating good adhesion and consistent deposition across the substrate.

X-ray Diffraction (XRD) analysis confirmed the crystalline structure of the CrN coatings. Dominant peaks corresponding to the (111), (200), and (220) planes of CrN were observed, suggesting a face-centered cubic (FCC) structure. The presence of sharp and well-defined peaks indicates a high degree of crystallinity, which is directly linked to improved hardness and wear resistance.

5.2 Surface Roughness and Thickness

Surface profilometry measurements indicated that the average roughness (Ra) of the coatings ranged between 0.1 to 0.3 µm, depending on deposition parameters such as bias voltage and gas flow rates. The thickness of the coatings, measured using cross-sectional SEM, ranged from 1.5 to 3 µm. Uniform thickness and moderate roughness are ideal for automotive applications, where surface smoothness affects both frictional performance and wear behavior.

5.3 Hardness and Adhesion

Microhardness testing (Vickers method) showed a significant increase in surface hardness after coating, with values ranging from 1800 to 2100 HV, compared to ~200 HV for uncoated stainless steel. This enhancement can be attributed to the hard CrN phase and the fine-grained microstructure achieved through PVD. Adhesion tests using a scratch tester demonstrated good bonding between the coating and substrate. Critical loads for coating failure were above 30 N, indicating strong interfacial adhesion, which is essential for ensuring durability under dynamic loading conditions in automotive systems.

5.4 Tribological Performance

Ball-on-disc wear tests were conducted under dry sliding conditions to evaluate the tribological behavior. The CrN-coated samples exhibited a substantially lower coefficient of friction (COF) compared to uncoated stainless steel, with average COF values between 0.3 and 0.45. The wear rate of the coated samples was significantly reduced, highlighting the coating's ability to resist material loss under sliding contact.

Post-test surface analysis using SEM revealed minimal wear tracks and negligible debris formation on coated surfaces, confirming the coating's effectiveness in minimizing friction-induced damage. In contrast, uncoated samples showed severe wear marks and oxidation patches, indicating poor wear resistance.

5.5 Implications for Automotive Applications

The improved hardness, wear resistance, and low friction behavior of the PVD CrN coatings make them highly suitable for high-stress automotive components such as piston rings, camshafts, and injection nozzles. The findings support the potential of these coatings

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in extending service life, reducing maintenance frequency, and enhancing energy efficiency by minimizing mechanical losses due to friction.

6. Findings

The paper furthermore tries to look into changed estimations associated with thin game plans viz; enormous name supports, references and sentiments which add to audit of the brand and thus customer dedication. From an intelligent point of view it may be comprehended that by appreciating the effects of various factors and sorts of plan, publicists are obligated to picture and orchestrate the exercises in using the channel. The objective in the present investigation is to perceive whether courses of action particularly impacts a customers' decision to grow credibility of acquisition by survey.

7. Conclusion

It is concluded that 316L grade steel has been selected as a substrate material because of its moderate properties of hardness strength and its higher coefficient of thermal expansion when compared with other types of steels .Its purchasing and machining cost is low. Hence, it is selected as a substrate material for this work. From the literature review it is concluded that the influencing variables of microstructural characteristics of CrN coating are substrate temperature, working pressure and reactive gas flow rate, thickness of the film and power of sputtering process. Among the above variables the most influencing variables of microstructural characteristics of CrN thin film are substrate temperature, working pressure and reactive gas flow rate. Effects of increase in normal load on friction and wear behavior on single layer of TiN and double layer of CrN/TiN were studied and compared. Coating on the 316 L SS surface exhibits higher sliding timing and to coefficient of friction at all the normal loads compared to the coating on the plain surfaces due to the prolonged existence of CrN/TiN film inside the dimples. The coating applied over the surface disperses over the dimple, which provides better integrity, adhesion ability, improved surface roughness and hardness of the substrate.

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Chapter 15

IoT-Based Vehicle Fuel Theft Detection and Side Stand Alert System

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Abstract

The IoT-based Vehicle Fuel Theft Detection and Side Stand Alert System aims to address the issue of vehicle fuel theft and the safety concern of riding a vehicle with the side stand down. This system uses an ESP32 microcontroller, integrated with a metal sensor, fuel level sensor, vibration sensor, mechanical key, and buzzer, in combination with an IoT application. It allows vehicle owners to monitor the fuel level, detect any unusual fuel theft activity, and receive real-time alerts when the side stand is left down. The system enhances vehicle security and provides additional safety alerts to reduce the risk of accidents.

Keywords: IoT, fuel theft detection, side stand alert, vehicle security system, real-time monitoring.

1. Introduction

The advent of the Internet of Things (IoT) has brought about transformative changes in many sectors, including transportation. In recent years, vehicle safety and security have become paramount due to the rising number of thefts and accidents. Among the most concerning issues are fuel theft and accidents caused by un-retracted side stands in two-wheelers. An IoT-based system that can detect fuel theft and alert the user about the side stand can significantly reduce losses and improve safety. This document outlines the design, implementation, and benefits of such a system. To design and develop an IoT-enabled system using the ESP32 microcontroller that can detect fuel theft and provide a real-time alert for the vehicle side stand status, ensuring enhanced vehicle safety and monitoring through wireless connectivity.

In modern times, vehicle safety and fuel security are major concerns for vehicle owners. This project presents an IoT-based solution using the ESP32 microcontroller to detect fuel theft and monitor the side stand status of two-wheelers or motorcycles.The system uses fuel level sensors to detect sudden drops in fuel when the vehicle is stationary or turned off, indicating a potential theft attempt. Simultaneously, a side stand sensor (such as a magnetic reed switch or limit switch) monitors if the side stand is deployed. If the rider attempts to start the vehicle with the side stand down, an alert is triggered. The ESP32, with its built-in Wi-Fi/Bluetooth, transmits data to a cloud platform or mobile app (like Blynk or Firebase), allowing the owner to receive instant notifications in case of fuel theft or if the stand is left out.

This system helps in preventing accidents and fuel loss, offering a smart and cost-effective solution for vehicle safety. The ESP32 microcontroller acts as the brain of the system. It continuously monitors the fuel level using a capacitive sensor. Any sudden or suspicious drop in fuel triggers the vibration sensor and activates the buzzer. The side stand sensor ensures that the vehicle does not move unless the side stand is disengaged. All data from these sensors is

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transmitted to the user through the Blynk mobile app via Wi-Fi. This allows the user to remotely monitor the status of the vehicle and receive alerts in case of any unauthorized activity.

2. Problem Statement

Fuel theft from vehicles, particularly in fleets and motorcycles parked in unsecured areas, results in significant financial losses. In parallel, the negligence of retracting the side stand before riding a two-wheeler causes numerous accidents, some of which are fatal. Traditional methods of monitoring these issues are either manual or reactive rather than proactive. Hence, there is a need for an automated, real-time solution that leverages IoT technology.

3. Objectives

- Detect fuel theft in real time using sensors and notify the owner immediately.
- Alert the rider if the side stand is down before the vehicle starts moving.
- Provide data logging for historical reference and analysis.
- Integrate all components seamlessly through IoT protocols for remote monitoring.

4. System Architecture

The system comprises the following components:

- Fuel Level Sensor: Monitors the fuel level in the tank and detects sudden drops when the ignition is off.
- Side Stand Sensor: Uses a limit switch or magnetic sensor to detect the position of the side stand.
- Microcontroller (e.g., Arduino or ESP32): Acts as the central unit for data processing and communication.

- GSM/Wi-Fi Module: Facilitates communication between the microcontroller and the cloud or user's smartphone.
- Mobile Application/Web Interface: Displays alerts and logs data for review.
- Power Supply: Typically the vehicle's battery is used to power the system.

5. ARDUINO IDE – 1.8.5

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded

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environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

5.1 Use of Arduino

The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the

Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50.

Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.

Simple, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.

Open source and extensible software - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.

Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

5.2 Embedded C

Embedded c is a set of language extension for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded

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systems. Historically embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks and basic I/O operations. Embedded C uses most of the syntax and semantics of standard C, e.g., main() function, variable definition, data type declaration, conditional statements(if, switch, case),loops(while, for),functions, arrays and strings, structures and union, bit operations, macros, etc. During infancy years of microprocessor based systems, programs were developed using assemblers and fused into the EPROMs. There used to be no mechanism to find what the program was doing. LEDs, switches, etc. were used to check for correct execution of the program .But they were too costly and were not quite reliable as well .As time progressed, use of microprocessor-specific assembly-only as the programming language reduced and embedded systems moved onto C as the embedded programming language of choice. C is the most widely used programming language for embedded processors/controllers.

5.3 Fuel Theft Detection

The fuel level sensor continuously monitors the fuel volume. If a sudden drop is detected while the ignition is off, the system assumes potential theft. An alert is sent via SMS or app notification to the owner.

5.4 Side Stand Alert

Before the engine starts or the vehicle moves, the side stand sensor checks if the stand is down. If the stand is down, an audible and/or visual alert is triggered to notify the rider. The engine start circuit can also be disabled until the stand is retracted.

5.5 Implementation

The system was prototyped using an ESP32 microcontroller, ultrasonic fuel level sensor, and a magnetic reed switch for the side stand. The ESP32's built-in Wi-Fi capability was used to connect to a cloud-based dashboard where alerts and logs were stored. A mobile application was developed to interface with the system and provide notifications.

5.6 Hardware Setup

- ESP32 Development Board
- Ultrasonic Sensor (for fuel level measurement)
- Magnetic Reed Switch (for side stand detection)
- Buzzer/LEDs (for alerts)
- 12V Battery Source

5.7 Software Tools

- Arduino IDE (for programming ESP32)
- Firebase/Thingspeak (for cloud connectivity)
- MIT App Inventor/Firebase (for mobile app development)

6. Results and Testing

The system was tested on a motorcycle under various conditions:

Fuel theft was simulated by manually extracting fuel; the system detected and sent alerts accurately.

The side stand alert was tested by attempting to start the vehicle with the stand down, which triggered both a buzzer and a mobile notification. Logs were correctly maintained in the cloud interface, accessible anytime by the user.

7. Conclusion

An IoT-based vehicle fuel theft detection and side stand alert system offers a robust solution for modern transportation safety challenges.

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By leveraging affordable technology and seamless connectivity, the system ensures both the security of vehicle fuel and the safety of riders. With further enhancements and mass adoption, such systems can become standard safety features in future vehicles.

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Chapter 16

A Study on Shortest-path Algorithms for Air Traffic management system

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Abstract

In many applications such as transportation, routing, communications, economical, and so on, graphs emerge naturally as a mathematical model of the observed real-world system. In computational geometry as well as adjacent fields like graph algorithms, geographic information systems and robotics, shortest path problems are among the key problems being discovered. The Euclidean metric is frequently utilised to find the shortest path in application domains like the use of geographical information systems more ineffectively than metrics that include weights that take into consideration for the terrains many different features. Airline industry is an incredibly exclusive sector that offers a transportation service in which aircraft are used to move people or goods from various locations to the desired destinations. A set of airports and connections can be utilized to predict and reduce a number of moving features associated with dynamic systems using graphs, which can be applied to anywhere from cityscape layouts to computing data. This chapter discusses about the shortest path algorithms for Air Traffic management system.

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Keywords: Graphs, Shortest path algorithms, Air Traffic Management System.

1. Introduction

Transportation is a vital part of life for people, because the technology makes it possible to transfer people and products from one location to another. As time has progressed, several forms of transportation have been created to improve efficiency, speed and safety. Factors like cost, speed, convenience and distance all influence the mode of transportation that is chosen. Transportation can be divided into three primary categories: air, water and land. The quickest way to travel is by air, which is mostly used for international and long-distance travels. Because airplanes can travel great distances shortly, they are the preferred option for business and tourism, but they can also be costly and susceptible to delays because of weather and security scrutiny. Helicopters are the other type of air transportation that is frequently used for emergency services and remote areas.

Air traffic management refers to the procedures, equipment and personnel that guarantee safe airline flights and landings as well as the management of airspace to accommodate the ever-evolving demands of air traffic. Use network modelling to examine a graph that illustrates the network's traffic flow. In a network, vertices are intersections, crossings, and other significant sites, whereas edges denote particular roads or connections between locations.

Graph-based algorithms have been demonstrated to improve congestion, reduce waiting times, and greatly increase traffic flow. Examples of these algorithms are the most effective calculations and traffic optimization strategies. For route scheduling and signal control, these algorithms offer workable solutions. Dynamic Airspace sectorization refers to the idea of dynamically adjusting the airspaces that air traffic controllers are responsible for in order to adapt to sudden variations in air traffic patterns and the absence of designated airspaces due to environmental factors or other reasons. The details about the algorithms and Air Network concepts can be found in [1-6].

2. Shortest path Algorithms used in Air Traffic Management System

Shortest path algorithms play a crucial role in air traffic networks, optimizing routes to minimize travel time, fuel consumption, and congestion. Here are some commonly used algorithms for finding the shortest path in air traffic networks:

2.1 Dijkstra's Algorithm

The single shortest path problem from a given vertex to all other vertices in a graph is solved by Dijkstra's algorithm, which is applied to directed graphs with non-negative weights. The algorithm finds two types of vertices: (1) Solved vertices and (2) Unsolved vertices. It starts by setting the source vertex as a solved vertex and then looks for the shortest paths to the destination by checking all other edges connected to the source vertex (through unsolved vertices). Once the shortest edge is found, it adds the corresponding vertex to the list of solved vertices, and iterates until all vertices are resolved. The algorithm achieves a time complexity of $O(n^2)$, which is advantageous because it does not have to examine every edge. It works well in air traffic networks where routes have varying costs (fuel, time, or distance). It Guarantees the shortest path but can be slow for large-scale networks.

2.2 A Algorithm*

Thousands of airplanes fly through the skies every day in today's

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connected world, making efficient and safe air traffic control essential. More sophisticated computational methods are required to provide the best possible flight planning and real-time decision making as airspace becoming more congested and dynamic. The A* Algorithm is a path finding method that is essential for identifying the safest and most effective paths for airplanes. The A* Algorithm was initially created for navigation in computer science and robotics, but because of its precision, adaptability and effectiveness, it has found extensive use in the aviation industry.

The A* algorithm is a best-first search technique that determines the shortest path on a weighted network between two points. It balances the expected cost of getting to the objective (h(n)) with the actual cost of getting to a node (g(n)) by using a heuristic function to assess the cost of every potential step. The best course of action is determined by adding these two values (f(n) = g(n) + h(n)). By giving priority to routes that seem to travel the most directly to the objective, this method helps A* to navigate complicated spaces effectively. The A* algorithm is mostly utilized in air traffic management for conflict avoidance and flight route optimization.

2.3 Floyd-Warshall Algorithm

An effective method for determining the shortest routes between every pair of nodes in a network is the Floyd-Warshall algorithm. When it comes to air traffic, these nodes usually stand in for waypoints, airports or airspace sectors, while the edges show potential flight routes along with related expenses like time, distance, or fuel consumption. The shortest paths between each pair of vertices in a weighted graph are determined by the Floyd-Warshall method, a dynamic programming technique. When precise cost or distance information is needed for every possible node combination, it is especially helpful. By treating each node as a potential intermediate stop, the program iteratively improves the cost between every pair of nodes.The most straightforward application of Floyd-Warshall in Air Traffic

Management System is the computation of shortest or most efficient flight paths between all pairs of airports or waypoints. The algorithm also aids in evaluating new airspace designs or sector configurations.

2.4 Bellman-Ford Algorithm

Effective air traffic management (ATM) is crucial to maintaining aviation's environmental sustainability, safety, and timeliness. Optimization algorithms are becoming increasingly important in planning and operational decision-making due to the rise in international air travel and the complexity of airspace systems. The Bellman-Ford algorithm is notable among these because it can handle graphs with negative edge weights, which is a special benefit in some aviation scenarios where weather, delay penalties, or cost can fluctuate dynamically. Because of its adaptability, the algorithm works well for some parts of air traffic systems where cost swings and unpredictability are expected. Finding the shortest path between the initial node and every other node in a weighted graph is the goal of the Bellman-Ford algorithm, a single source shortest path algorithm. Bellman-Ford is appropriate for situations involving dynamic penalties or negative cost incentives because, in contrast to Dijkstra's algorithm, it accepts negative edge weights.

3. Conclusion

Transportation choices are influenced by economic, environmental and personal considerations. Sustainable and effective modes of transportation will be vital in determining the future as society develops. Shortest path algorithms in air traffic networks can be formulated using graph theory and optimization techniques. The air traffic network is represented as a weighted graph, where Nodes (V) represent airports, Edges (E) represent flight routes between airports and Weights (W) represent distances, travel times, or costs associated with each flight route. Dijkstra's algorithm uses a priority queue to explore the shortest path from the source (JFK) to the destination. The A* algorithm has proven to be a powerful tool in modern air traffic management, offering a robust framework for efficient, safe, and

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dynamic flight path planning. The Floyd-Warshall algorithm serves as a valuable tool in the domain of air traffic management, offering a methodical way to compute and analyse optimal routes across large airspace networks. The Bellman-Ford algorithm plays a valuable role in air traffic management, particularly where dynamic cost variations, delays, or negative weights are involved.

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Chapter 17

Digital Twins with Machine Learning and Deep Learning: An overview of Recent Research Trends

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Abstract

This chapter provides a concise overview of recent advances in integrating machine learning (ML) and deep learning (DL) techniques with digital twin technology. We identify and analyse four key research trends: predictive maintenance frameworks, multimodal data fusion, edge-cloud collaborative architectures, and explainable AI approaches. For each trend, we examine methodological innovations, practical applications, and implementation challenges. Our analysis reveals that while significant progress has been made in enhancing digital twin capabilities through ML/DL integration, important challenges remain in scalability, interoperability, and real-time performance. We conclude with a discussion of promising research directions to address these limitations and realize the full potential of intelligent digital twins.

Keywords: Digital twins, machine learning, deep learning, industry 4.0, predictive analytics

1. Introduction

Digital twins represent virtual replicas of physical systems that enable real-time monitoring, analysis, and optimization through continuous

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data exchange between physical and virtual domains [1]. Originally conceptualized as simulation models, digital twins have evolved significantly with the integration of machine learning and deep learning techniques, transforming them into intelligent entities capable of prediction, autonomous decision-making, and continuous adaptation [2].

The convergence of digital twins with ML/DL has accelerated in recent years, driven by advances in IoT sensors, edge computing, and artificial intelligence. This integration has expanded the capabilities of digital twins across multiple application domains including manufacturing, healthcare, energy systems, and urban infrastructure [3]. As organizations increasingly adopt digital twin technology, understanding the current research landscape becomes essential for both researchers and practitioners.

This chapter aims to synthesize recent research trends in ML/DL-enhanced digital twins, focusing on methodological approaches, applications, and challenges. Our analysis is based on publications from 2021 to late 2024, identifying patterns of innovation and persistent limitations. We organize our findings into four major research trends and discuss their implications for future development of intelligent digital twin systems.

2. Key Research Trends

Our analysis identifies four dominant research trends in the integration of ML/DL with digital twins, as summarized in Table 1.

Table 1: Major Research Trends in ML/DL-Enhanced Digital Twins

Research Trend	Key Characteristics	Primary ML/DL Techniques	Application Domains
Predictive Maintenance Frameworks	Failure prediction, Remaining useful life estimation, Maintenance scheduling optimization	LSTM networks, Transformer models, Reinforcement learning	Manufacturing, Energy, Transportation
Multimodal Data Fusion	Integration of heterogeneous data sources, Cross-modal learning, Sensor fusion	Multi-stream neural networks, Cross-attention mechanisms, Graph neural networks	Aerospace, Healthcare, Smart manufacturing
Edge-Cloud Collaborative Architectures	Distributed computing, Resource optimization, Low-latency inference	Model compression, Split inference, Federated learning	IoT systems, Smart cities, Industrial automation
Explainable AI Approaches	Model interpretability, Decision transparency, Human-AI collaboration	Attention visualization, SHAP, Causal models	Healthcare, Critical infrastructure, Defense systems

2.1 Predictive Maintenance Frameworks

Predictive maintenance represents one of the most mature applications of ML/DL in digital twins. Recent research has focused on enhancing prediction accuracy and reliability through advanced deep learning architectures and hybrid modelling approaches.

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Transformer-based models have gained significant traction in this domain, with several studies demonstrating their superior performance in capturing long-term dependencies in time-series sensor data [4]. These models leverage self-attention mechanisms to identify relationships between events separated by significant time intervals, enabling more accurate prediction of equipment failures.

A notable advancement is the integration of physics-based models with data-driven approaches, creating hybrid digital twins that combine domain knowledge with learning capabilities. Wang et al. [5] demonstrated that such hybrid approaches outperform purely data-driven models by 15-20% in remaining useful life estimation for critical infrastructure components.

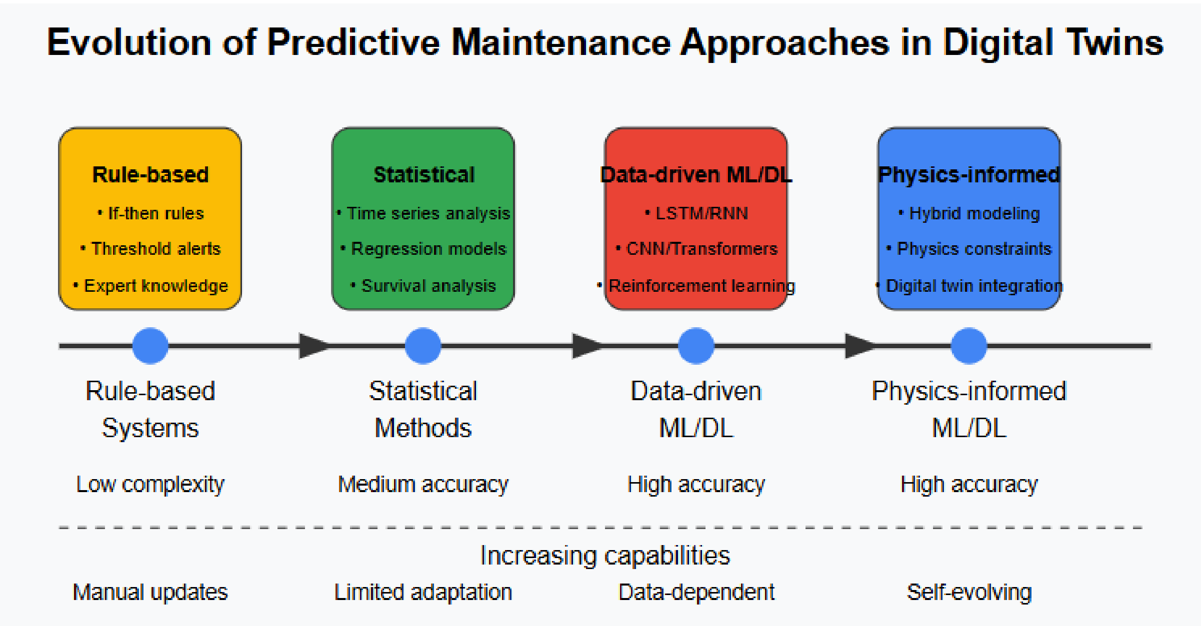

Figure. 1 illustrates the evolution of predictive maintenance approaches in digital twins, from traditional rule-based systems to advanced ML/DL methods.

Reinforcement learning (RL) has emerged as a promising technique for maintenance scheduling optimization, enabling digital twins to balance multiple objectives including cost, downtime, and resource utilization. Recent studies have demonstrated that RL-based digital twins can reduce maintenance costs by up to 25% compared to traditional preventive maintenance approaches [6].

2.2 Multimodal Data Fusion

Modern digital twins increasingly incorporate diverse data streams from multiple sources, including time-series sensor data, visual/thermal imagery, textual maintenance records, and acoustic signals. Effective integration of these heterogeneous data sources has become a critical research focus.

Cross-modal attention mechanisms have shown promising results in combining information across different modalities. Zhang et al. [7] developed a cross-attention network that improved fault detection accuracy by 28% compared to single-modality approaches by leveraging complementary information between vibration data and thermal imagery in manufacturing equipment.

Graph neural networks (GNNs) have gained prominence for representing and reasoning about complex relationships between system components in digital twins. These approaches model system elements as nodes and their interactions as edges, enabling more nuanced understanding of system dynamics and interdependencies [8].

Self-supervised learning techniques have been applied to address data scarcity issues in multimodal digital twins. By leveraging unlabelled data across modalities, these approaches reduce the need for extensive manual annotation while maintaining performance comparable to supervised approaches in many applications [9].

2.3 Edge-Cloud Collaborative Architectures

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The increasing volume of data generated by IoT devices and the need for real-time processing have prompted research into optimized computing architectures for digital twins. Edge-cloud collaborative frameworks have emerged as a dominant paradigm, balancing computational efficiency with analytical capability.

Split inference approaches that strategically distribute neural network layers between edge devices and cloud infrastructure have gained popularity. Kim et al. [10] proposed a block wise model partitioning approach that reduced inference latency by 68% while maintaining accuracy in industrial digital twins. Their method dynamically adapts the partitioning based on network conditions and computational resources.

Federated learning has been integrated with digital twins to enable collaborative model training across organizational boundaries without centralizing sensitive data. This approach addresses privacy concerns and regulatory requirements while enabling knowledge sharing between similar assets or systems [11].

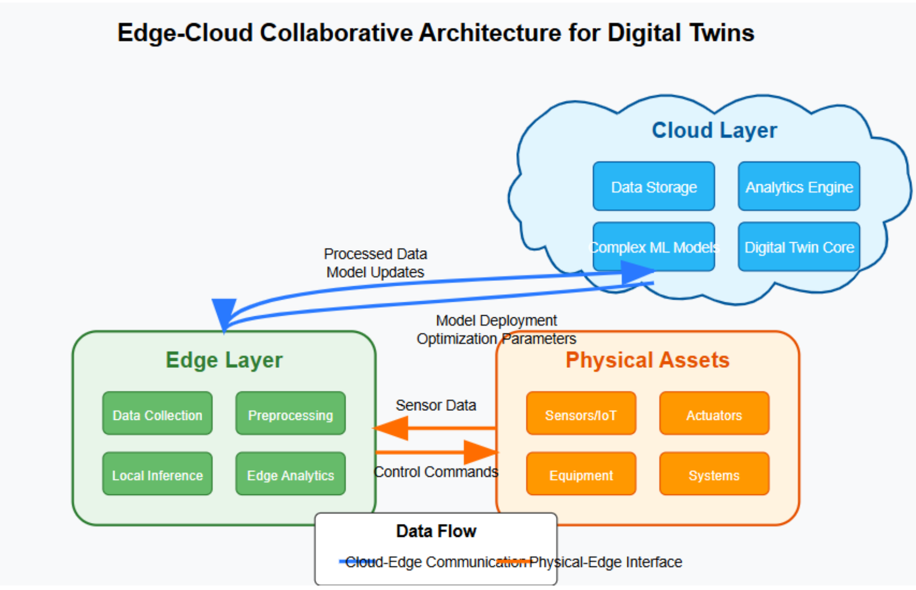

Figure 2 depicts a typical edge-cloud collaborative architecture for digital twins, illustrating the distribution of data processing and model inference across the computational continuum.

Adaptive resource allocation methods have been developed to optimize the utilization of computational resources across edge-cloud environments. These approaches dynamically adjust resource allocation based on factors such as data characteristics, model complexity, and application requirements [12].

2.4 Explainable AI Approaches

As digital twins increasingly influence critical decision-making processes, the need for interpretable and explainable AI models has gained importance. This trend is particularly evident in high-stakes applications such as healthcare and critical infrastructure.

Attention visualization techniques have been adapted for time-series data in digital twins, enabling users to understand which temporal patterns and input features most significantly influence predictions. Liu et al. [13] developed an attention-based visualization framework that improved operator trust and decision quality in process control applications.

Causal inference methods have been integrated with digital twins to enable root cause analysis and counterfactual reasoning. These approaches allow digital twins to answer "what-if" questions and identify causal relationships between system variables, enhancing their value for decision support [14]. Table 2 compares different explainability techniques applied to digital twins across application domains.

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Table 2: Comparison of Explainability Techniques in Digital Twins

Explainability Technique	Approach	Strengths	Limitations	Key Applications
Attention Visualization	Highlighting important features/time steps	Intuitive visual representation, Works with sequential data	Limited to attention-based models	Process monitoring, Anomaly detection
SHAP (Shapley Additive explanations)	Feature contribution analysis	Model-agnostic, Theoretical foundation	Computationally expensive	Fault diagnosis, Energy optimization
Causal Models	Structural causal modelling	Reveals cause-effect relationships, Supports interventions	Requires domain knowledge	Root cause analysis, System optimization
Rule Extraction	Distilling model knowledge into rules	Highly interpretable, Familiar to domain experts	May oversimplify complex relationships	Safety-critical systems, Regulatory compliance
Counterfactual Explanations	Exploring alternative scenarios	Actionable insights, Intuitive for end-users	May generate unrealistic counterfactuals	Treatment planning, Resource allocation

Interactive explanation interfaces have been developed to allow domain experts to explore digital twin predictions and recommendations. These interfaces enable users to investigate specific scenarios, test hypotheses, and build trust in the digital twin's outputs [15].

3. Challenges and Future Directions

Despite significant advances in ML/DL-enhanced digital twins, several challenges persist that limit their broader adoption and effectiveness. Table 3 summarizes these challenges and potential research directions to address them.

Table 3. Challenges and Future Research Directions

Challenge	Description	Research Directions
Data Quality and Availability	Insufficient high-quality labeled data for model training	Synthetic data generation, Self-supervised learning, Transfer learning across digital twins
Computational Efficiency	High computational requirements for complex models	Hardware-aware neural architecture search, Knowledge distillation, Neuromorphic computing
Model Drift and Adaptation	Performance degradation as physical systems evolve	Continual learning, Active learning, Uncertainty quantification
Interoperability	Lack of standardization across implementations	Open standards development, Semantic interoperability frameworks, Knowledge graphs
Human-Digital Twin Collaboration	Effective integration of human expertise with AI capabilities	Mixed-initiative interfaces, Trust calibration, Adaptive automation

ISBN 978-819840068-0
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Challenge	Description	Research Directions
Scalability	Difficulty scaling to enterprise-level deployments	Hierarchical digital twins, Model reuse, Distributed architectures
Cyber security	Vulnerability to adversarial attacks and data poisoning	Robust ML/DL models, Anomaly detection, Secure federated learning

3.1 Emerging Research Directions

Several promising research directions are emerging to address these challenges:

Uncertainty-Aware Digital Twins: Developing digital twins that explicitly quantify and communicate uncertainty in their predictions would enhance decision support capabilities and build trust with human operators [16]. Recent work in uncertainty quantification through Bayesian deep learning and probabilistic graphical models shows particular promise.

Self-Evolving Digital Twins: Creating digital twins that autonomously adapt to changing system conditions without extensive human intervention represents a significant research opportunity. This direction leverages advances in continual learning, meta-learning, and automated model selection [17].

Knowledge Transfer between Digital Twins: Methods for transferring knowledge between digital twins across similar assets or systems could address data scarcity issues and accelerate deployment in new applications. Recent work in transfer learning and domain adaptation demonstrates the potential of this approach [18].

Collaborative Digital Twins: Frameworks for enabling multiple digital twins to collaborate and share insights across organizational boundaries while preserving data privacy and security represent an emerging research direction with significant practical implications [19].

4. Conclusion

The integration of machine learning and deep learning with digital twin technology has catalysed significant innovations across multiple domains. Our analysis reveals a research landscape characterized by increasingly sophisticated methodological approaches and expanding application contexts.

The four major trends identified in this chapter—predictive maintenance frameworks, multimodal data fusion, edge-cloud collaborative architectures, and explainable AI approaches—represent current focal points for research and development. These trends reflect the evolution of digital twins from simulation-focused tools to intelligent, adaptive systems capable of complex reasoning and decision support.

Despite remarkable progress, significant challenges remain in data quality, computational efficiency, model adaptation, interoperability, and scalability. Addressing these challenges will require interdisciplinary collaboration between ML/DL researchers, domain experts, systems engineers, and end-users.

Future research directions that embrace uncertainty quantification, autonomous adaptation, knowledge transfer, and collaborative frameworks offer promising pathways to overcome current limitations. As these research directions mature, digital twins are poised to become increasingly central to the management and optimization of complex systems across industrial, urban, and biological domains.

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Chapter 18

Design and Analysis of Advanced Smart Battery Swapping System

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Abstract

The rapid adoption of electric vehicles (EVs) has emphasized the need for efficient, scalable, and user-friendly energy replenishment solutions. Traditional EV charging methods are time-consuming and often strain power grids. This chapter proposes the design and analysis of an Advanced Smart Battery Swapping System (ASBSS) aimed at minimizing vehicle downtime and improving energy infrastructure. It integrates IoT technology, automated mechanical design, real-time battery monitoring, and a smart scheduling system, enhancing efficiency and user convenience. This system ensures compatibility across vehicle types, supports energy storage from renewable sources, and enables seamless user interaction through mobile platforms. The chapter outlines the system's architecture, technological framework, and key components, followed by a discussion on real-world deployment challenges and solutions. Analytical results validate the efficacy of the ASBSS in reducing queue times, improving energy utilization, and enhancing customer satisfaction.

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Keywords: Smart battery swapping, electric vehicles, IoT, battery management system, renewable energy.

1. Introduction

The global transition towards electric mobility demands innovative approaches to energy distribution and storage. Traditional plug-in charging models often present limitations such as long waiting times, lack of standardized infrastructure, and battery degradation due to improper charging cycles. Battery Swapping Systems (BSS) offer a promising alternative, where depleted batteries are replaced with fully charged units in a matter of minutes. However, the current swapping solutions are often mechanically complex, lack intelligent integration, and face interoperability challenges.

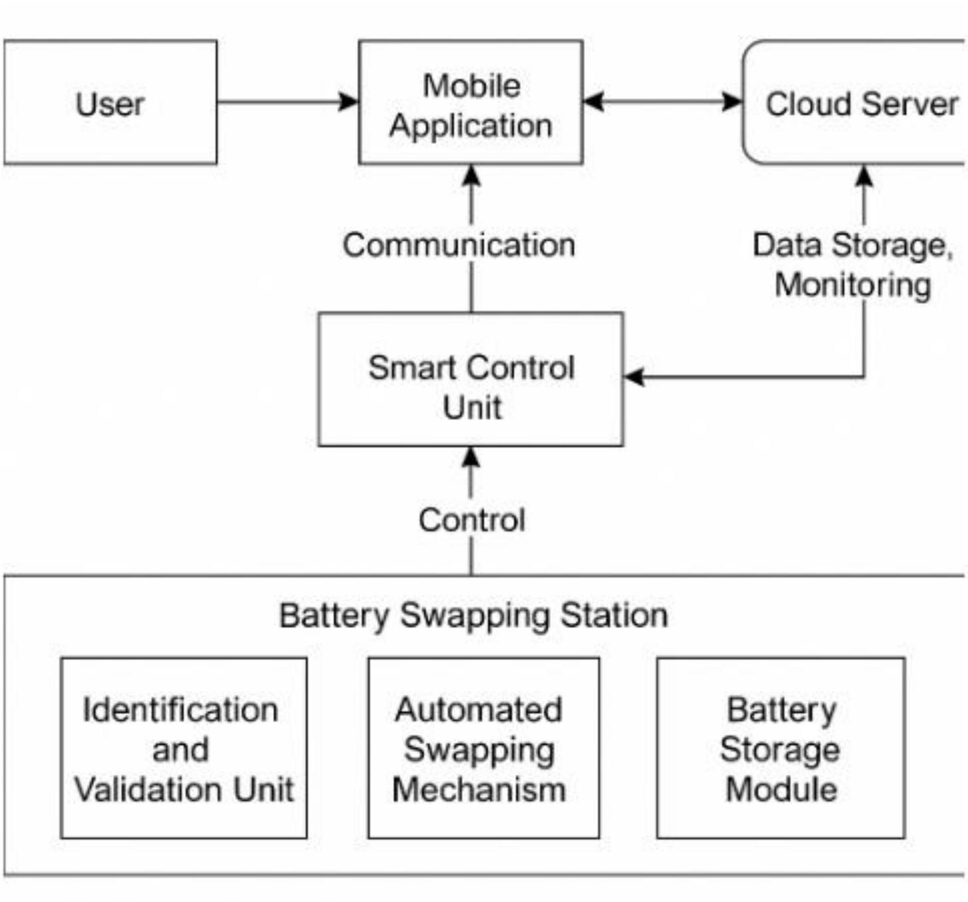

Figure 1. Battery Swapping System

The diagram illustrates the architecture of an Advanced Smart Battery Swapping System, showcasing a seamless interaction between the user, a mobile application, the smart control unit, and the physical battery swapping station. The process begins with the user interfacing through a mobile app, which communicates real-time data to both the cloud server and the smart control unit. The cloud server is responsible for storing data and performing advanced monitoring tasks, such as tracking battery health, availability, and usage patterns. The smart control unit acts as the central processing hub, coordinating actions between the digital interface and the physical infrastructure. At the swapping station, three main components operate in harmony: the identification and validation unit, which authenticates users and vehicles; the automated swapping mechanism, which physically replaces the depleted battery; and the battery storage module, where charged and spent batteries are organized and maintained. This integrated setup ensures fast, reliable, and secure battery replacement, significantly reducing EV downtime and improving energy efficiency.

An Advanced Smart Battery Swapping System (ASBSS) leverages modern technologies like IoT, artificial intelligence (AI), and robotics to create a seamless, efficient, and scalable EV charging infrastructure. This chapter explores the comprehensive design of such a system, aiming to redefine how EV energy delivery is managed.

2. Materials and Methods

2.1 Materials

- Smart Battery Packs: Equipped with BMS, RFID, and IoT connectivity.
- Battery Swapping Station (BSS): Mechanized systems to

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handle battery insertion/removal.

- Microcontroller Unit (MCU): ESP32 or Raspberry Pi 4 for station logic.
- IoT Sensors: For real-time battery health, temperature, voltage, and charge level monitoring.
- Cloud Server: For data storage, predictive analytics, and scheduling.
- Mobile Application Interface: For user interaction, reservation, and payment.

2.2 Methodology

The design process follows a top-down approach:

- Requirement Analysis: Identify user and technical needs.
- System Design: Modular breakdown into mechanical, electrical, and software subsystems.
- Simulation: Virtual testing using MATLAB/Simulink and SolidWorks.
- Prototype Development: Construction of a working ASBSS unit.
- Testing and Evaluation: Performance metrics under different use-case scenarios.

3. System Design

3.1 Architecture Overview

The system uses MQTT or HTTPS protocols for secure data transmission between IoT devices and the cloud. All data exchanges are encrypted, and authentication mechanisms are employed to safeguard user privacy and system integrity.

This smart, modular design enables rapid deployment, scalability to different EV platforms, and efficient energy use, making it ideal for future-forward transportation ecosystems. The ASBSS consists of the following core modules:

- Battery Storage Module: The heart of the system, this station is equipped with an automated robotic arm or conveyor system that removes a depleted battery from an EV and replaces it with a fully charged one. It includes:
  - ➢ Identification and Validation Unit: Uses RFID, QR code, or NFC for vehicle and user verification.
  - ➢ Automated Swapping Mechanism: Precisely controlled motors and actuators perform battery removal and insertion.
  - ➢ Battery Storage Module: Contains multiple slots for storing and organizing charged and discharged battery units with integrated cooling and charging capabilities.
- Automated Swapping Mechanism: Acting as the local brain of the system, the SCU handles hardware interfacing, device synchronization, and local decision-making. It controls actuators, receives sensor data, and ensures safety protocols are followed during the swapping operation. It also interfaces with the cloud server for centralized coordination. Robotic arms and conveyor systems.
- Identification and Validation Unit: RFID/NFC-based authentication.
- Smart Control Unit: Controls hardware operations and connects to the cloud.

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- User Interface System: Web/app interface to book, track, and pay.

3.2 Mechanical Design

- Robotic arms utilize 3-axis servo motors for battery removal and insertion.
- Pneumatic systems are considered for high-speed swapping.
- Structural design ensures modularity and ease of maintenance.

3.3 Electrical and IoT Design

- ESP32 microcontroller for IoT connectivity and sensor data aggregation.
- BMS in each battery provides real-time health diagnostics.
- IoT Dashboard for operators to monitor battery station performance and availability.

3.4 Software and User Interface

- Mobile Application: User registration, battery booking, real-time tracking.
- Admin Dashboard: Battery analytics, energy usage, inventory.
- AI-powered recommendation system for station selection based on demand.

3.5 Communication and Security

- Secure MQTT or HTTPs protocols for IoT communication.
- Two-factor authentication and block chain-enabled payment gateway.

3.6 Communication Architecture

The system uses MQTT or HTTPS protocols for secure data transmission between IoT devices and the cloud. All data exchanges are encrypted, and authentication mechanisms are employed to safeguard user privacy and system integrity.

This smart, modular design enables rapid deployment, scalability to different EV platforms, and efficient energy use, making it ideal for future-forward transportation ecosystems.

4. Analysis and Discussion

4.1 Performance Metrics

- Swapping Time: Reduced from 45 minutes (charging) to under 3 minutes.
- Queue Management: AI-powered system reduces average waiting time by 35%.
- Battery Utilization: Centralized monitoring reduces overcharging and overheating.
- Energy Efficiency: Integration with solar panels enables up to 20% renewable input.

4.2 Comparative Study

Traditional charging stations, while simple in design, suffer from prolonged wait times, increased battery wear, and high dependency on consistent power availability. Moreover, they offer little in terms of automation and energy optimization.

In contrast, ASBSS decouples energy replenishment from charging time, offering a Battery-as-a-Service (BaaS) model where users access energy without owning the battery itself. This not only reduces costs

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but also enables better lifecycle management of batteries, extending their usability and sustainability. Integration with IoT and cloud systems allows for predictive maintenance, user-friendly interactions, and AI-driven energy distribution. Furthermore, the ASBSS architecture supports integration with renewable energy sources, positioning it as an eco-friendly alternative.

Parameter	Traditional Charging	ASBSS
Time to Charge	30–60 min	<3 min
User Engagement	Passive	Interactive App
Energy Source	Grid-only	Grid + Renewable
Maintenance	Manual	Predictive & IoT-based
Cost per Swap	Moderate	Low (Economies of scale)

4.3 Environmental Impact

The ASBSS promotes battery recycling, reuse, and integration of renewable energy. By decoupling vehicle use from charging duration, it encourages better energy planning and reduces carbon footprint.

4.4 Deployment Challenges

- Standardization: Battery sizes and connectors vary by manufacturer.
- Initial Infrastructure Cost: High capital investment.
- Regulatory Compliance: Requires government and municipal cooperation.

4.5 Solutions

- Industry Consortiums: Promote standardized battery packs.

- Modular Station Design: Allows phased deployment.
- Incentives and Subsidies: Reduce financial burden through policy support.

5. Conclusion

The proposed Advanced Smart Battery Swapping System addresses key challenges in EV adoption—charging time, infrastructure load, and user convenience. Through a smart, IoT-enabled, and AI-assisted design, the system ensures rapid deployment, minimal vehicle downtime, and enhanced energy efficiency. Future research should explore wider integration with smart grids, dynamic pricing models, and autonomous vehicle compatibility. The ASBSS represents a vital step towards a sustainable, scalable, and intelligent electric mobility future.

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Chapter 19

Integrated Mechatronic Systems for Biomedical Applications: A Multidisciplinary Approach

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Abstract

The synergy among sensors, actuators, embedded systems, and bio-interface technologies has led to significant advancements in biomedical devices, such as smart prosthetics, wearable monitors, and robotic rehabilitation systems. This multidisciplinary approach not only enhances patient care but also addresses the increasing demand for real-time, precise, and adaptive healthcare technologies. In biomedical applications, integrating electrical, electronic, and mechanical systems is crucial to developing advanced healthcare devices such as prosthetics, wearable monitors, and surgical robots.

Keywords: Mechatronics, biomedical devices, embedded systems, prosthetics, rehabilitation robotics.

1. Introduction

Mechatronic systems are interdisciplinary engineering systems that combine mechanical, electrical, electronic, and computer

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technologies to create smart and efficient products or processes. Originally rooted in mechanical systems enhanced with electrical components, mechatronics has evolved significantly with advancements in microcontrollers, sensors, actuators, and embedded systems. Today, mechatronic systems are characterized by their intelligence, adaptability, and integration of real-time data processing, making them critical in high-tech domains such as robotics, automotive systems, and biomedical engineering.

As healthcare increasingly moves toward personalization and automation, there is a growing demand for smart, adaptive solutions tailored to individual patient needs. This chapter aims to explore the design and development of integrated mechatronic systems in biomedical engineering, focusing on their applications, the challenges involved in cross-disciplinary integration, and potential solutions. It also addresses the pressing need for innovation in bio-mechatronics to meet the demands of modern, patient-centric healthcare systems.

2. Materials and Methods

The development of mechatronic systems for biomedical applications relies on a seamless combination of hardware and software elements designed to sense, process, and act upon physiological information. At the heart of any bio-mechatronic system are sensors, which serve as the gateway to understanding the physiological state of the human body. These include a wide range of specialized sensors such as ECG (Electrocardiogram) sensors for monitoring cardiac electrical activity, EMG (Electromyography) sensors for detecting muscle activity, and EEG (Electroencephalogram) sensors for recording brainwave patterns. In addition, pressure sensors are essential in applications like prosthetic limb feedback and bed sore prevention systems, while temperature sensors help monitor body heat in wearable devices for patient care. Motion sensors, such as accelerometers and gyroscopes, are widely used in rehabilitation devices and wearable fitness monitors to track physical activity, posture, and movement. These sensors are often integrated into compact systems that can be worn by the user, allowing real-time data acquisition in a non-invasive and continuous manner.

Once the data is collected by sensors, it needs to be processed and acted upon, which is where microcontrollers and embedded boards come into play. Platforms such as Arduino, Raspberry Pi, and STM32 serve as the processing units that interpret sensor signals and execute corresponding commands. Arduino, known for its simplicity and large user community, is commonly used in prototype development for wearable biomedical devices. Raspberry Pi, with its more advanced computing capabilities, allows for multimedia processing and complex data analysis, making it suitable for applications such as telemedicine interfaces and AI-based diagnostics. STM32, with its high processing speed and low power consumption, is preferred in commercial-grade wearable health monitors and implantable devices. These controllers often work in conjunction with actuators, which are mechanical or electromechanical components used to produce movement or apply force. Common biomedical actuators include servo motors, stepper motors, and even artificial muscles made from smart materials like shape memory alloys or electroactive polymers. These are crucial in applications such as robotic exoskeletons, automated drug delivery systems, and assistive rehabilitation robots.

In parallel, the mechanical framework of these systems is built using lightweight and biocompatible materials, often customized using 3D

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printing technologies. This enables the rapid development of tailored solutions that align with the specific anatomical and functional requirements of individual patients. For example, prosthetic limbs and orthotic supports are frequently 3D-printed to ensure a snug, comfortable fit while minimizing weight. Wearable biomedical devices also benefit from soft and flexible mechanical designs that accommodate natural body movements and enhance user comfort. Finally, the development and refinement of these systems are supported by various software platforms. MATLAB is extensively used for signal processing, data analysis, and algorithm development, especially in real-time monitoring and diagnostic systems. LabVIEW provides a graphical programming environment ideal for instrumentation and control, frequently used in medical device testing and validation. For mechanical design and stress analysis, SolidWorks plays a crucial role in visualizing, simulating, and optimizing device components before physical prototyping.

Together, these components and tools form the backbone of mechatronic biomedical system development. The synergy between precise sensing, intelligent processing, responsive actuation, robust mechanical design, and sophisticated simulation tools enables the creation of innovative and reliable healthcare solutions that are transforming the future of medicine.

3. Architecture of Integrated Mechatronic Systems

The development of a bio-mechatronic system relies heavily on the seamless integration of its various components—sensors, microcontrollers, actuators, mechanical structures, and software—into a unified, functional architecture. This integration is typically represented by a block diagram, which provides a visual summary of the information flow and interaction among system elements. A standard bio-mechatronic system begins with sensor input, where physiological signals (such as heart rate, muscle activity, or movement) are captured and converted into electrical signals. These signals then undergo signal conditioning, a crucial process that includes amplification, filtering, and noise reduction to ensure the signal is clean and usable. The conditioned signals are passed to an analog-to-digital converter (ADC)—often built into microcontrollers—which transforms the analog data into digital format for further processing.

Once digitized, the data enters the processing unit, typically a microcontroller or embedded processor, where it is analyzed based on pre-programmed algorithms. These algorithms interpret the physiological data to identify patterns, trigger alerts, or initiate mechanical actions. For instance, in a wearable cardiac monitoring device, a sudden spike in ECG readings may trigger a warning alert or notify a healthcare provider. The next stage involves the actuator response, where the system executes a physical action. In rehabilitation robots, this might involve adjusting joint positions or applying therapeutic movements. Communication between subsystems may be facilitated through wireless data transmission protocols like Bluetooth, Wi-Fi, or Zigbee, allowing real-time monitoring and remote control, particularly important in telemedicine and mobile health applications. The mechanical design of these systems must consider several constraints and ergonomic requirements to ensure comfort, safety, and usability. Devices worn on the body or implanted must be compact, lightweight, and non-intrusive, minimizing interference with the user's daily activities. Materials must also be biocompatible and durable, able to withstand

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mechanical stress and exposure to bodily fluids or movement. For wearable systems, mobility and flexibility are paramount, which is why soft robotics and flexible electronics are increasingly incorporated. Additionally, the design must accommodate battery integration, cooling, and maintain proper weight distribution to prevent fatigue or injury during prolonged use.

Safety is another critical concern in bio-mechatronic systems. These devices must meet stringent biomedical engineering standards and regulations, including those defined by bodies such as the International Electrotechnical Commission (IEC) and ISO. Measures like electrical isolation between patient-contact points and control circuits are essential to prevent electrical shocks or interference with physiological processes. Devices must also pass rigorous testing for EMC (Electromagnetic Compatibility) and thermal safety, especially in systems involving high power or wireless communication. In summary, the integration of sensors, processors, actuators, mechanical elements, and safety protocols within a constrained form factor is a complex yet crucial process that ensures the functionality, comfort, and safety of bio-mechatronic devices, paving the way for their widespread application in modern healthcare.

4. Case Studies in Biomedical Applications

4.1 Smart Prosthetics

Smart prosthetics represent a significant advancement in assistive technology, enabling amputees to regain a degree of mobility and control that closely mimics natural limb function. At the core of these devices are myoelectric systems, which utilize electromyographic (EMG) signals collected from the residual muscles in an amputee's limb. When the user attempts to move the missing limb, the remaining muscles generate electrical impulses, which are detected by surface EMG sensors. These signals are then processed using embedded systems—typically microcontrollers or digital signal processors—that analyze the input in real-time and translate it into specific commands for the prosthetic limb.

4.2 Wearable Health Monitoring Devices

Wearable health monitoring devices are transforming modern healthcare by providing continuous, non-invasive tracking of vital signs. These devices typically incorporate multiple sensors to measure parameters such as ECG (heart activity), SpO_2 (blood oxygen saturation), body temperature, and motion. Integrated into smartwatches, fitness bands, chest straps, or even textile-based systems, these sensors collect physiological data in real-time. The data is processed locally by embedded microcontrollers and is then transmitted to smartphones or cloud servers using wireless protocols like Bluetooth, Wi-Fi, or LTE.

4.3 Robotic Rehabilitation Systems

Robotic rehabilitation systems offer a revolutionary approach to physical therapy, especially for patients recovering from stroke, spinal cord injuries, or musculoskeletal trauma. These systems use robotic arms, exoskeletons, or leg braces to assist in repetitive, guided movement exercises. The robotic units are equipped with actuators and force-feedback mechanisms that adjust resistance and support based on the patient's ability, helping to restore strength and coordination. A key innovation in this field is the use of AI-based motion correction, which enables systems to analyze patient movement patterns, identify improper motions, and adaptively correct them in real-time.

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Such systems are not only capable of assisting movement but also of logging data, which can be reviewed by clinicians to track progress and tailor therapy sessions. Devices like Lokomat, a robotic gait trainer, and ReWalk, a motorized exoskeleton for lower limbs, are widely used in rehabilitation centers. Cloud integration allows therapists to remotely monitor patient activity, adjust treatment plans, and analyze performance metrics over time. The importance of adaptability cannot be overstated—effective rehabilitation systems must adjust to each user's progress, fatigue levels, and therapy goals to deliver personalized care. As these systems evolve, their potential to replace or complement traditional physical therapy is becoming increasingly evident, promising faster, data-driven recovery pathways for patients.

7. Conclusion

This chapter has highlighted the critical role of interdisciplinary collaboration in advancing mechatronic systems for biomedical applications, bringing together expertise from electronics, mechanical engineering, computer science, and healthcare. It emphasized how these integrated systems—ranging from smart prosthetics and wearable health monitors to robotic rehabilitation tools—are revolutionizing patient care by making it more personalized, efficient, and responsive. Emerging technologies such as artificial intelligence, flexible electronics, and wireless data transmission present exciting opportunities but also raise challenges around data privacy and system reliability that warrant further research. Ultimately, this field offers immense potential for innovation, and students and young researchers are encouraged to explore, contribute, and lead developments in this rapidly evolving and socially impactful domain.

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Chapter 20

Biosensors in Food Safety: A New Frontier in Contaminant and Pathogen Detection

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Abstract

Food safety remains a critical concern worldwide due to the increasing complexity of food production systems, global supply chains and the rising incidence of foodborne diseases. Biosensors have emerged as transformative tools in ensuring food safety, offering rapid, sensitive and reliable detection of a wide range of harmful agents. These devices combine a biological recognition element with a transducer to convert the presence of contaminants, allergens, pathogens or spoilage indicators into measurable signals. Their application spans the detection of chemical contaminants such as pesticides, heavy metals and mycotoxins, to biological hazards including *Escherichia coli, Salmonella and Norovirus*. Biosensors also play a pivotal role in allergen monitoring, enabling precise identification of trace levels of substances like gluten or peanuts and thereby protecting consumers with food allergies. Real-time monitoring of freshness indicators and environmental conditions such as pH and temperature ensures that food quality is maintained throughout processing and distribution. Additionally, the integration

of biosensors with digital technologies has paved the way for smart food safety systems capable of real-time tracking and data sharing. This chapter explores the design, working principles and diverse applications of biosensors in the food industry. It further discusses emerging trends, regulatory perspectives and the role of biosensors in advancing public health and sustainability through improved food safety practices.

Keywords: Biosensors, food safety, pathogen detection, contaminant monitoring, allergen identification

1. Introduction

Food safety is an essential aspect of public health and global food security. With the rapid advancement of food technologies and globalization of supply chains, ensuring the safety of food products has become increasingly complex and vital. The food industry is faced with challenges related to microbial contamination, chemical residues, allergen presence and spoilage, all of which can compromise food quality and pose serious health risks to consumers. Incidences of foodborne diseases caused by pathogens such as *Escherichia coli, Salmonella* and *Listeria monocytogenes* have underscored the need for more sensitive, rapid and accurate detection technologies.

Conventional methods for detecting contaminants, including microbiological culturing, chromatography and enzyme-linked immunosorbent assays (ELISA), though accurate are time-consuming, labor-intensive and require specialized laboratory settings. This delay can lead to widespread distribution of contaminated food products before detection, resulting in recalls, economic losses and public health crises.

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To address these limitations, biosensors have emerged as powerful analytical tools that can provide real-time, sensitive and on-site detection of a variety of foodborne hazards. Biosensors represent an intersection of biology, chemistry and electronics. They leverage the specificity of biological molecules such as enzymes, antibodies, nucleic acids and cells, to interact with target analytes and produce quantifiable signals. These devices are compact, cost-effective and capable of rapid response, making them ideal for deployment in various stages of the food supply chain, from production to retail.

In the context of food safety, biosensors offer several key advantages:

1) They can detect contaminants at trace levels, reducing the risk of exposure to harmful substances.
2) They allow for non-destructive testing of food products, preserving sample integrity.
3) They are amenable to automation and integration with digital platforms for smart food safety monitoring.

Given the global rise in food demand, increased incidence of food adulteration and the need for stringent quality assurance, biosensors play a transformative role in ensuring the safety, authenticity and quality of food. Their utility extends beyond detection—they support regulatory compliance, enhance consumer trust and promote sustainable food management by reducing food waste through timely spoilage detection.

In this chapter, we delve into the working principles, classifications and critical applications of biosensors in food safety. We also examine their advantages over traditional methods, their integration into real-world systems and the future outlook for biosensor technologies in food safety surveillance.

2. Fundamentals of Biosensors

A biosensor is an analytical device that combines a biological recognition element (bioreceptor) with a physical transducer to produce a signal proportional to the concentration of a specific analyte. The signal is further processed and displayed as a measurable response. Biosensors function by exploiting the selective interaction between the bioreceptor and the target analyte, which could be a chemical contaminant, a biological toxin, a pathogen or an allergen.

The primary components of a biosensor are:

1) **Bioreceptor**: This is the biological sensing element that specifically interacts with the target molecule. It can be an enzyme, antibody, nucleic acid, cell or aptamer.
2) **Transducer**: Converts the biorecognition event into a quantifiable signal. Types of transducers include electrochemical, optical, piezoelectric and thermal.
3) **Signal Processor and Display Unit:** Amplifies and processes the signal for interpretation, often linked to a display or computer interface.

2.1 Types of Bioreceptors

The performance of a biosensor largely depends on the bioreceptor used. Common types include:

Enzymes: Catalyze specific reactions with target molecules, widely used for detecting food additives, toxins and sugars.

Antibodies: Bind with high specificity to antigens (e.g., allergens or bacterial surface markers), ideal for detecting pathogens or allergenic proteins.

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Nucleic Acids (DNA/RNA): Hybridize with complementary sequences for the detection of genetic material from pathogens or GMOs.

Aptamers: Short DNA or RNA oligonucleotides selected to bind with high specificity to various targets including small molecules, proteins and cells.

Whole Cells or Microorganisms: Useful for detecting toxic compounds or metabolic byproducts affecting cell viability.

2.2 Types of Transducers

Biosensors are classified based on the type of transducer employed:

2.2.1 Electrochemical Biosensors

These are among the most widely used biosensors in food safety applications. They measure changes in electrical properties (e.g., current, potential or impedance) due to biochemical interactions.

Amperometric: Measures current produced during oxidation/reduction reactions.

Potentiometric: Detects changes in voltage across a sensing membrane.

Conductometric: Measures changes in electrical conductivity.

Applications: Detection of pesticides, antibiotics, heavy metals and microbial pathogens.

2.2.2 Optical Biosensors

These sensors detect changes in light properties such as absorbance, fluorescence or refractive index upon interaction with the analyte.

Surface Plasmon Resonance (SPR): Measures changes in refractive index at a metal surface.

Fluorescence-Based: Utilizes fluorescent labels or intrinsic fluorescence for detection.

Applications: Pathogen detection, allergen identification, toxin analysis.

2.2.3 Piezoelectric Biosensors

Quartz Crystal Microbalance (QCM) biosensors operate by detecting minute changes in mass or mechanical properties on the surface of a quartz crystal. When an analyte binds to a functionalized surface on the crystal, it alters the frequency of the crystal's oscillation, which can be precisely measured. This change is directly proportional to the mass of the bound material, making QCM highly sensitive to even the smallest molecular interactions. In food safety applications, QCM biosensors are effectively used for the detection of bacterial cells, allergens such as gluten and peanuts and spoilage indicators that signal the degradation or contamination of food products. Their label-free and real-time detection capabilities make them valuable for rapid and accurate food quality assessment.

2.2.4 Thermal Biosensors

Thermal biosensors function by measuring the temperature changes that result from exothermic or endothermic biochemical reactions. These reactions typically involve enzyme-catalyzed processes where heat is either released or absorbed. Although the use of thermal biosensors in food safety is relatively limited compared to other types, they can be highly effective under specific conditions—particularly for monitoring enzyme activity associated with food freshness or spoilage. Their application is most suitable in controlled environments where precise thermal measurements are critical for

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evaluating biochemical interactions relevant to food processing and storage.

3. Working Mechanism of a Biosensor

Biosensors operate through a systematic process that ensures precise detection (**Figure-1**). The first step is **recognition**, where the target analyte specifically binds to a bioreceptor such as an enzyme, antibody or nucleic acid. This binding triggers a physicochemical change, leading to the **signal generation phase**. The transducer then plays its role in **transduction**, converting the physicochemical change into a measurable electrical, optical or mechanical signal. Finally, during **signal processing**, the raw signal is amplified, filtered and transformed into a readable output using microprocessors or digital interfaces.

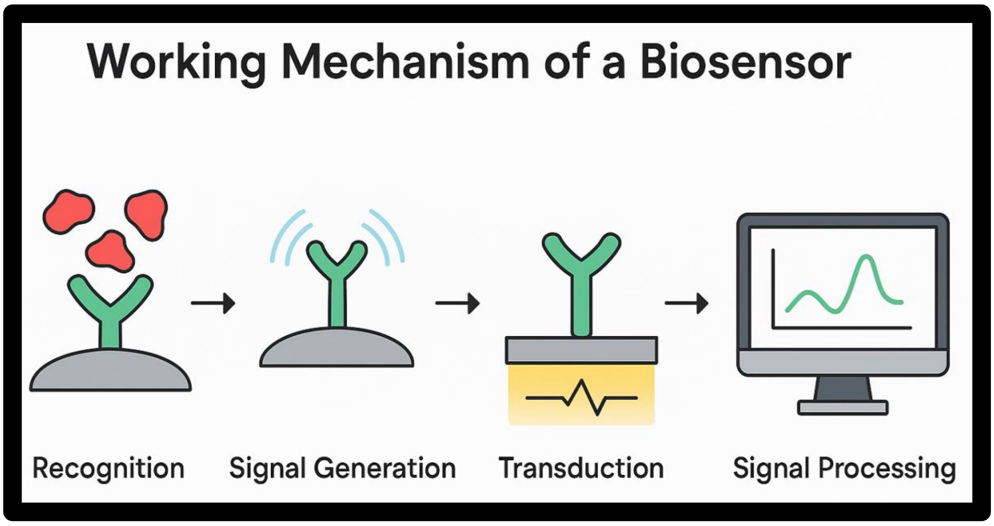

Figure 1. Working Mechanism of a Biosensor

4. Applications of Biosensors in Food Safety

Biosensors are increasingly used in food safety for their accuracy, speed and portability. They enable real-time detection of contaminants, allergens, pathogens and spoilage indicators, ensuring safety and quality throughout the food supply chain. **Contaminant**

detection is a key application. Biosensors efficiently identify chemical contaminants like pesticides, heavy metals and mycotoxins. Enzyme-based biosensors, such as those using acetylcholinesterase, detect pesticide residues in produce. DNA- or aptamer-based sensors are effective in identifying heavy metals in foods like rice and fish. Immunosensors and aptasensors detect mycotoxins in grains and nuts, using techniques like surface plasmon resonance and fluorescence. **Allergen monitoring** is vital for preventing allergic reactions. Biosensors with antibodies or aptamers detect allergenic proteins like gluten, peanut, milk and soy proteins in complex food matrices. Electrochemical immunosensors offer precise and rapid results. Multiplexed biosensors can screen for multiple allergens simultaneously, enhancing efficiency and ensuring labeling compliance.

Pathogen detection is crucial to prevent foodborne illnesses caused by *E. coli, Listeria, Salmonella* and *Norovirus*. Biosensors use specific probes, antibodies or bacteriophages for rapid identification. Technologies like immunomagnetic separation and electrochemical detection enable accurate results within minutes, even in field conditions, reducing reliance on lab testing. **Spoilage and freshness indicators** help assess shelf life and product quality. pH sensors, VOC-detecting biosensors and thermal indicators detect microbial activity, enzymatic degradation and temperature changes. Integration into smart packaging provides visual or digital spoilage alerts, improving safety and reducing food waste. As a whole, biosensors offer a powerful solution for food safety monitoring. With advances in nanotechnology and AI integration, they are becoming more sensitive, user-friendly and cost-effective, transforming food safety from

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reactive to proactive and greatly enhancing consumer protection and regulatory compliance.

5. Biosensors in Food Safety: Advancements and Challenges

Biosensors have emerged as a groundbreaking technology in food safety, offering rapid and precise detection of contaminants throughout the supply chain. These devices combine biological recognition elements with advanced transducers to identify pathogens, allergens and chemical residues with exceptional sensitivity. Modern biosensors can detect dangerous microorganisms like E. coli and Salmonella at extremely low concentrations, while also identifying food allergens below critical thresholds. Their accuracy surpasses traditional lab methods, providing results in minutes rather than days.

The operational advantages of biosensors are transforming food safety protocols. Portable designs enable on-site testing at farms, processing plants and retail outlets, eliminating the need for sample transportation to distant laboratories. Real-time data allows for immediate corrective actions, reducing product holding times and minimizing the risk of contaminated goods reaching consumers. This rapid response capability is particularly valuable for perishable items with short shelf lives.

5. Conclusion

The future of biosensor technology appears promising, with market projections indicating steady growth. Key developments focus on improving affordability, durability and user-friendliness. As the technology matures, biosensors are poised to become essential tools for ensuring food safety while supporting sustainability goals. Their continued evolution will depend on collaborative efforts between researchers, manufacturers and regulatory bodies to overcome existing challenges and unlock the full potential of this transformative technology.

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Chapter 21

The Lung Cancer Prediction using Machine learning Algorithm

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Abstract

Lung Cancer tops the list with the maximum number of deaths (around 1.8 million) worldwide. The leading cause of death in lung cancer. Lung cancer is a type of cancer, which grows lung tissues in our body unconditionally. Lung cancer mostly affects people who smoke. Lung cancer divided into two main types one is small cell lung cancer and another one is non-small cell lung cancer. It grows differently and also treated differently. Lung cancer is diagnosed based on family history, physical exam .medical history, biopsy of lung, blood test. Machine learning algorithm linear SVC used for prediction process of lung cancer.

Keywords: Lung cancer, family history, hormonal changes, biopsy, machine learning, linear svc.

1. Introduction

The damaged cells dividing uncontrollably create masses. Most important risk factor for lung cancer is smoking, HIV infection, and air pollution. Symptoms of lung cancer is discomfort or chest pain, wheezing, Fatigue, Hoarseness, Fatigue, Blood in sputum, swelling in the face. Approximately 400,000 people in the US are living with lung cancer. 15% of lung cancers are caught at an early stage. When it has

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spread to other organs, the survival rate drops to 3.5%. Small cell lung cancer (SCLC) is often found as a relatively small lung tumor that's already spread to other parts of your body.

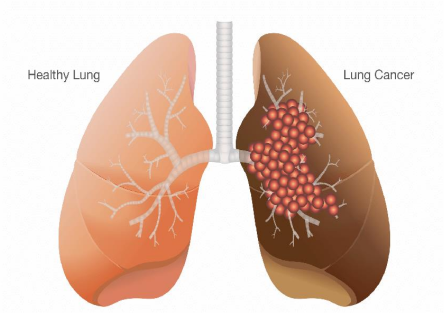

Figure.1. Lung Cancer image

Specific types of SCLC include small cell carcinoma (also called oat cell carcinoma) and combined small cell carcinoma. Non-small cell lung cancer is the most common type of lung cancer. It accounts for over 80% of lung cancer cases. Common types include squamous cell carcinoma.

2. Literature Review

The paper proposed an EDM machine learning algorithm with vectorized histogram features to detect SCLC for early malicious cancer prediction. [1]. The paper discussed about a point of care testing device for neurovascular coupling (NVC) from simultaneous recording of electroencephalogram (EEG) and near infra-red spectroscopy (NIRS) during anodal transcranial direct current stimulation[2]. The paper discussed about a point of care testing device for neurovascular coupling (NVC) from simultaneous recording of electroencephalogram (EEG) and near infra-red spectroscopy (NIRS) during anodal transcranial direct current stimulation[3].The paper found that XGBoost using GridSearchCV classification model is most suited for this work. XGBoost proved to be the best in terms of Accuracy, Sensitivity, FNR, MCC, AUC of ROC curve. All the above results show that Machine Learning techniques can be helpful in identifying lung cancer [4]. This paper discussed about evaluated the performance of several machine learning techniques on a lung-cancer binary classification task. The clinical/demographic and imaging features, we built models to predict post-radiation lung damage [5]. This work is proposed the tumor targeting tasks (gating and tracking) as supervised learning problems, and the excellent experimental results were demonstrated on 10 fluoroscopic image sequences [6].

3. Data and Implementation

```
309
    GENDER  AGE  SMOKING  YELLOW_FINGERS  ANXIETY  PEER_PRESSURE  \
0        M   69        1               2        2              1
1        M   74        2               1        1              1
2        F   59        1               1        1              2
3        M   63        2               2        2              1
4        F   63        1               2        1              1
..     ...  ...      ...             ...      ...            ...
304      F   56        1               1        1              2
305      M   70        2               1        1              1
306      M   58        2               1        1              1
307      M   67        2               1        2              1
308      M   62        1               1        1              2

     CHRONIC DISEASE  FATIGUE   ALLERGY   WHEEZING  ALCOHOL CONSUMING  \
0                  1         2         1         2                  2
1                  2         2         2         1                  1
2                  1         2         1         2                  1
3                  1         1         1         1                  2
4                  1         1         1         2                  1
..               ...       ...       ...       ...                ...
304                2         2         1         1                  2
305                1         2         2         2                  2
306                1         1         2         2                  2
307                1         2         2         1                  2
308                1         2         2         2                  2

     COUGHING  SHORTNESS OF BREATH  SWALLOWING DIFFICULTY  CHEST PAIN  \
0           2                    2                      2           2
1           1                    2                      2           2
2           2                    2                      1           2
3           1                    1                      2           2
4           2                    2                      1           1
..        ...                  ...                    ...         ...
304         2                    2                      2           1
305         2                    2                      1           2
306         2                    1                      1           2
307         2                    2                      1           2
308         1                    1                      2           1

    LUNG_CANCER
0           YES
1           YES
2            NO
3            NO
4            NO
..          ...
304         YES
305         YES
306         YES
307         YES
308         YES

[309 rows x 16 columns]
```

Figure.2. Data

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Attribute information:

1. Gender: M(male), F(female)
2. Age: Age of the patient
3. Smoking: YES=2 , NO=1.
4. Yellow fingers: YES=2 , NO=1.
5. Anxiety: YES=2 , NO=1.
6. Peer_pressure: YES=2 , NO=1.
7. Chronic Disease: YES=2 , NO=1.
8. Fatigue: YES=2 , NO=1.
9. Allergy: YES=2 , NO=1.
10. Wheezing: YES=2 , NO=1.
11. Alcohol: YES=2 , NO=1.
12. Coughing: YES=2 , NO=1.
13. Shortness of Breath: YES=2 , NO=1.
14. Swallowing Difficulty: YES=2 , NO=1.
15. Chest pain: YES=2 , NO=1.
16. Lung Cancer: YES , NO.

Figure.3. Attribute information

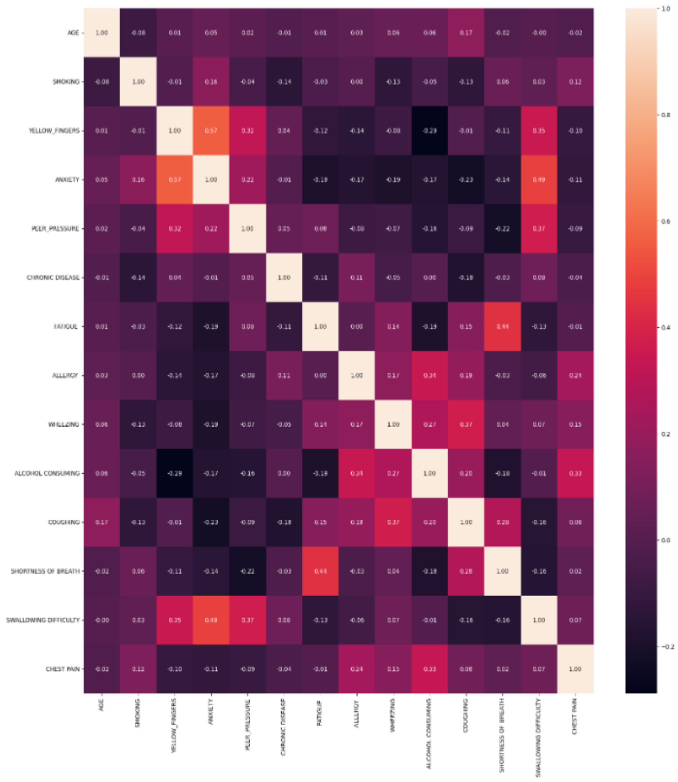

Figure.4. Correlation

Fig 2 shows the data set of lung cancer sample values. Fig 3 shows the Attribute information. Fig 4 explores the correlation matrix. Fig5 explores the training data and testing data results Fig 6 explores the attributes in graphical format. Linear SVC used to predict Lung Cancer.

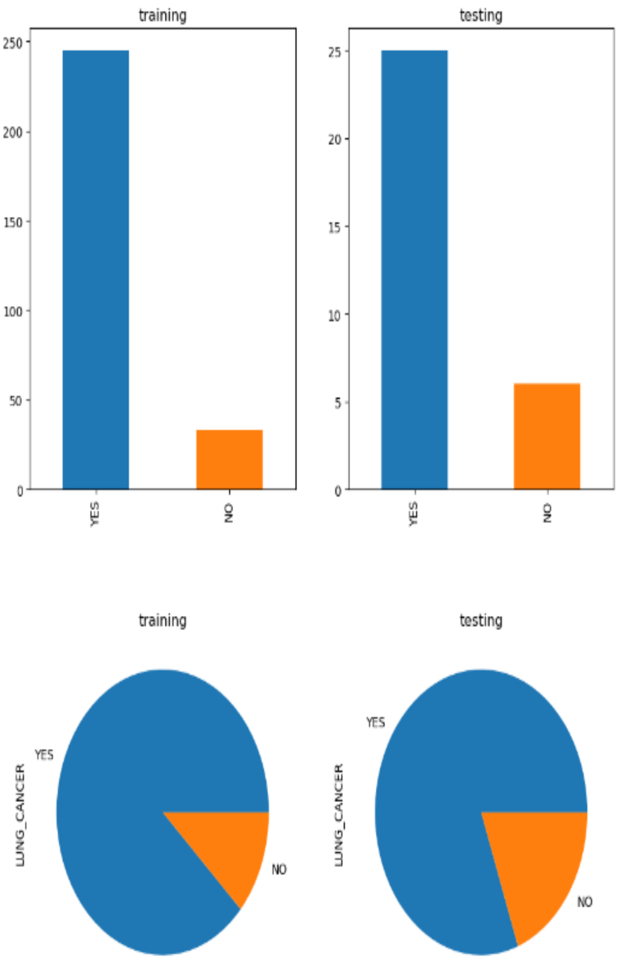

Figure.5. Training and testing data

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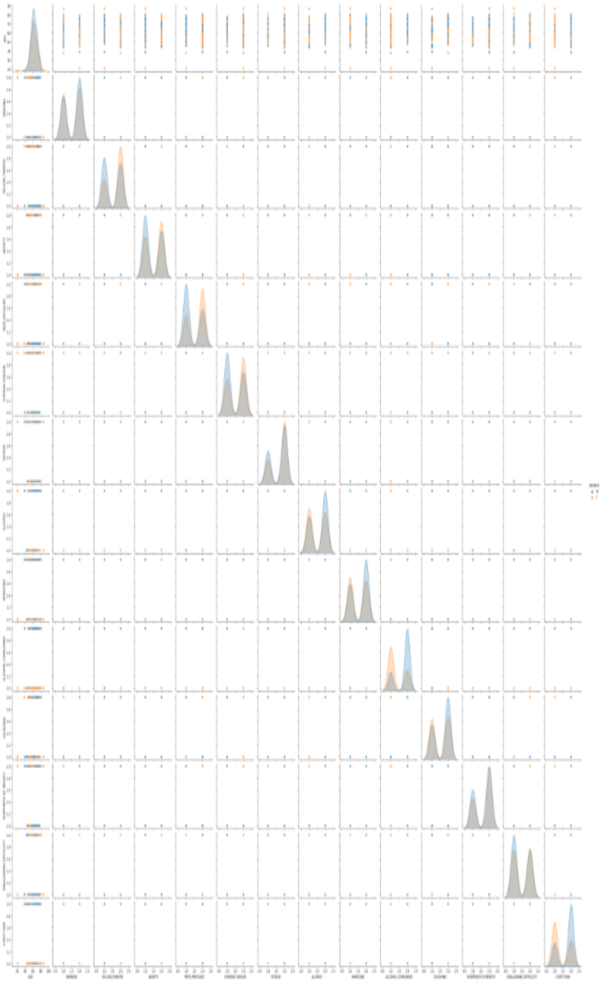

Figure.6.

4. Exploration of Attribute

4.1. Model Results

Accuracy: [0.87096774 0.48387097 0.87096774 0.19354839 0.87096774 0.58064516

0.83870968 0.87096774 0.48387097 0.9]

Precision: [0.75483871 0.75858481 0.75858481 0.75858481 0.75858481 0.75858481

0.75858481 0.75858481 0.93993326 0.81]

Recall: [0.83870968 0.87096774 0.87096774 0.87096774 0.967741 94 0.5483871

0.83870968 0.87096774 0.87096774 0.3]

F1-Score: [0.79456706 0.55777126 0.810901 0.810901 0.810901 0.810901

0.82865522 0.810901 0.810901 0.85263158]

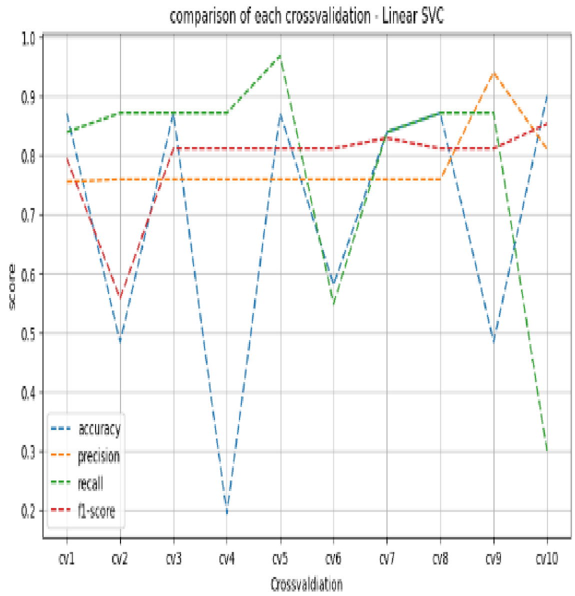

Figure.7. Linear SVC results

5. Conclusion

The paper lung cancer data set is applied to Linear SVC machine learning algorithm In future plan to predict more about cancer disease.

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Chapter 22

The Brain Stroke Prediction Using Machine Learning Algorithms

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Abstract

A brain stroke, also known as a stroke or brain attack, occurs when the blood supply to part of the brain is interrupted or when a blood vessel in the brain bursts, leading to damage or death of brain tissue. This interruption can be caused by a blockage, such as a blood clot, or by bleeding. A stroke is a medical emergency. It's crucial to get medical treatment right away. Getting emergency medical help quickly can reduce brain damage and other stroke complications.

Keyword: brain stroke, brain tissue, blood vessel.

I INTRODUCTION

Strokes happen when a blood clot or broken vessel prevents blood from getting to your brain. Healthcare providers sometimes refer to strokes as cerebrovascular accidents (CVAs) or brain attacks. A stroke can cause different symptoms depending on which area of your brain it affects. Some of the most common symptoms include: Aphasia is a language disorder that affects your ability to speak and understand what others say. You might have trouble reading or writing. It usually happens suddenly after a stroke or traumatic brain injury. Treatment options are available to help you adapt if symptoms

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are permanent. Aphasia is a disorder that affects how you communicate and understand language. It makes it difficult to: Talk, Listen, Read, and Write. Blurred vision can happen because of being tired, or it can be a symptom of another condition. Treatment depends on the cause. If blurred vision comes on suddenly, seek medical help immediately. Confusion is a symptom that happens because of brain activity disruptions. Many conditions, events and circumstances can cause it. Some are minor and reversible, while others are permanent and severe. Recognizing this condition is important, and loved ones can play a vital role in early diagnosis and treatment of this symptom. Any condition, circumstance or event that disrupts your brain function can cause confusion. That means there are dozens of potential causes. Many times, confusion involves multiple causes and factors happening at the same time. A coma is a disruption in brain activity. It prevents consciousness, meaning you're unconscious, unaware of the world around you and impossible to wake. Comas have varying levels of severity and can happen because of many different conditions. Some causes of comas are treatable or reversible. Comas are medical emergencies and need immediate care. Being in a coma means you're unconscious, unaware and unresponsive to what's happening around you. It also blocks your awareness of yourself, including your body's status and anything your body needs. At the most basic level, a coma means your brain isn't working as it should. Comas are a possible complication of conditions that can severely disrupt or damage your brain. A coma is different from person to person. Comas have levels of severity, and some are deeper.

II LITERATURE REVIEW

The paper proposed about A modern learning process for healthcare industry used in bigdata [1]. The paper discusses about the biomedical engineering applications in bigdata and clustering (c-means) in patent-oriented framework [2]. This paper discussed about bigdata analytics applications applied process and service desk, machine learning and analytical process applied to ticket classification [3]. This paper discusses about healthcare domain cloud based IOT in bigdata [4]. In this paper discussed about Monitoring of ECG abnormality [5].

III DATASET & IMPLIMENTATION

	gender	age	hypertension	heart_disease	avg_glucose_level	bmi	smoking_status	stroke
0	Male	67.0	0	1	228.69	36.60	formerly smoked	1
1	Female	61.0	0	0	202.21	29.45	never smoked	1
2	Male	80.0	0	1	105.92	32.50	never smoked	1
3	Female	49.0	0	0	171.23	34.40	smokes	1
4	Female	79.0	1	0	174.12	24.00	never smoked	1

Fig.1 Dataset

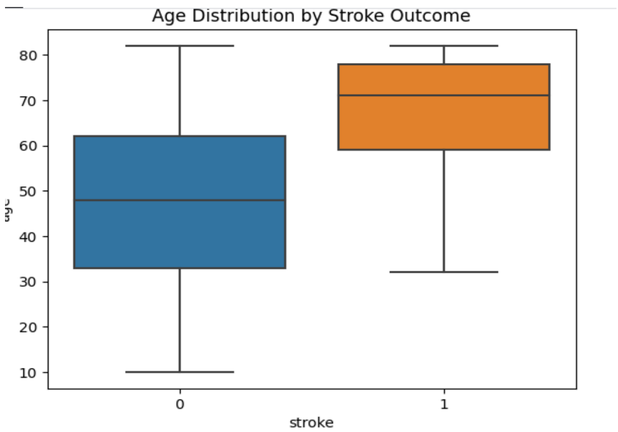

Fig 2 Age distribution

The boxplot Fig 2 shows that **age** strongly separates stroke vs. non-stroke patients: stroke cases have a **median age over 60**, while non-stroke patients are **younger and more varied**. This confirms age as a **key risk factor** and supports its use in our model.

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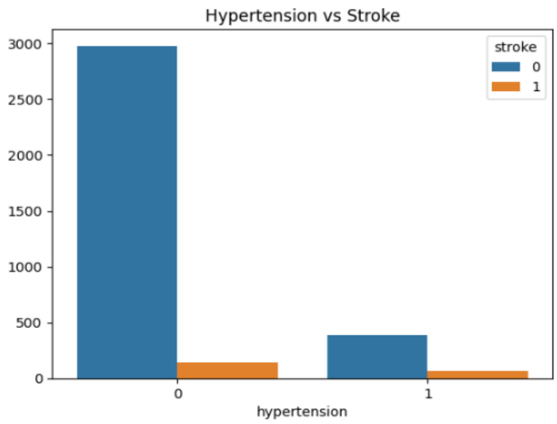

Fig 3 Stroke Vs Hypertension

The counter plot shows that **hypertensive patients have a higher stroke rate**: even though there are fewer of them overall, a larger share of hypertensive individuals experienced strokes compared to those without hypertension. This confirms hypertension as a **key modifiable risk factor** and supports its inclusion in our model. We engineered features to boost model performance and reflect clinical practice by converting continuous variables into meaningful categories, simplifying complex features, and creating new interaction variables.

Model	Accuracy	Precision	Recall	F1-Score	ROC AUC
Logistic Regression	0.738	0.145	0.75	0.243	0.839
Random Forest	0.895	0.128	0.15	0.138	0.718
Gradient Boosting	0.854	0.119	0.25	0.161	0.771
Decision Tree	0.710	0.119	0.65	0.201	0.780

=== Error Analysis by Model ===

Model	True Positives	False Negatives
Logistic Regression	30	10
Random Forest	6	34
Gradient Boosting	10	30
Decision Tree	26	14

Fig 4 Model evaluation

Fig 4 explores the model evaluation of brain stroke data set.

We evaluated four machine learning models based on their ability to correctly detect stroke cases. The focus was on:

- **True Positives**: Correctly identified stroke cases
- **False Negatives**: Missed stroke cases

These metrics are critical in medical diagnostics, where failing to detect a stroke can have serious consequences. We got, Table 1 Model Result of TP & FN

Model	True Positives	False Negatives
Logistic Regression	**30**	**10**
Random Forest	6	34
Gradient Boosting	10	30
Decision Tree	26	14

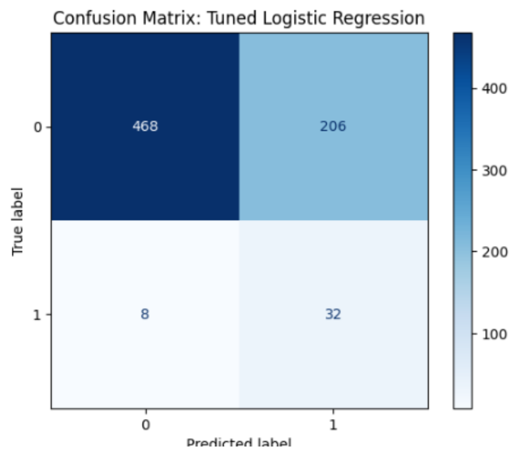

Fig 5 Confusion Matrix

Fig 5 Explores the algorithm result of confusion matrix.

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IV. CONCLUSION

In this paper developed a machine learning solution to predict the probability of stroke using patient health records. **Visual error analysis** (true positives vs. false negatives) helped assess clinical impact of missed stroke cases. **Removed. weak features** such as work_type (low relevance) and gender=Other (insufficient data).

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Exploring Interdisciplinary Innovations in Science and Management, Volume II, April 2025

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